MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

A Whole New World - From Local to Global

Annual Conference 2022

29 Nov–1 Dec

Massey University, Palmerston North

GSNZ 2022

Programme & Abstracts

Geoscience Society of New Zealand

Geoscience Society of New Zealand Miscellaneous Publication 161A
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GEOSCIENCES 2022, Palmerston North

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GEOSCIENCE SOCIETY OF NEW ZEALAND

Annual Conference
29th November – 1st December 2022
Massey University
Palmerston North

PROGRAMME AND ABSTRACTS

Local Organising Committee

Anke Zernack (Lead Convenor)
Julie Palmer (Co-Convenor)

Anke Zernack, Julie Palmer, Jon Procter, Melody Whitehead, Stuart Mead,
Georg Zellmer & Gabor Kereszturi (Science Programme)
Shannen Mills, Sarah Tapscott, Stuart Mead & Anke Zernack
(Social Programme)
Gabor Kereszturi & Anke Zernack (Field Trip coordinators)
Georg Zellmer (Student Presentation Judging coordinator)
Shannen Mills & Sarah Tapscott (Social Media)
Matt Irwin (IT)
Nicki Sayers (Sponsorship)

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SESSION CONVENORS

We would like to thank the session convenors for their time and effort in developing the scientific programme and reviewing the abstract submissions.

Libby Abbott (Te Pū Ao)
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Peter Almond (Lincoln University)
David Barrell (GNS Science)
Mark Bebbington (Massey University)
Mac Beggs (University of Canterbury)
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Kyle Bland (GNS Science)
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Sally Watson (NIWA)
Alana Weir (University of Canterbury)
Melody Whitehead (Massey University)
Jack Williams (University of Otago)
James Williams (University of Canterbury)
Tom Wilson (University of Canterbury)
Andrea Wolter (GNS Science)
Georg Zellmer (Massey University)

FIELD TRIP LEADERS

A big thank you also to the field trip leaders for offering such a great selection of field trips for the conference.

Ben Dixon (Te Ahu A Turanga Alliance)
Terry Hapi (Rangitāne o Manawatu)
Gabor Kereszturi (Massey University)
Stuart Mead (Massey University)
Anja Moebis (Massey University)
Alan Palmer (Massey University)
Julie Palmer (Massey University)
Jon Procter (Massey University)
Callum Rees (Massey University)
Malcolm Todd (Horizons Regional Council)

CONFERENCE PROGRAMME OVERVIEW

Date		Day Event	Evening Event
Monday 28 November	***Pre-Conference***	Pre-Conference Workshops	Icebreaker Function ECR Mixer
Tuesday 29 November	***Day 1***	First Day of Scientific Programme	Public Lecture Fun Games & BBQ Night
Wednesday 30 November	***Day 2***	Second Day of Scientific Programme	GSNZ AGM Conference Gala Dinner
Thursday 01 December	***Day 3***	Last Day of Scientific Programme	
Friday 02 December/ Saturday 03 December	***Post-Conference***	Post-Conference Field Trips	

LUNCHTIME MEETINGS AND EVENTS

DAY 1 – 29 November

LAVA NZ SIG Updates (SSLB1)
Geoff Kilgour

GeOID SIG Updates (GLB2.03)
Jenny Stein

WOMEESA - Women in Earth and Environmental Sciences in Australasia (GLB2.05)
Jess Hillman

DAY 2 – 30 November

Scientific drilling idea – CALDERA:
Connections Among Life, geo-Dynamics and Eruptions in a Rifting Arc caldera (SSLB1)
Cécile Massiot

Geochemistry SIG Updates (GLB2.03)
Sebastian Naeher

Sedimentology SIG IAS Updates (GLB2.05)
Mark Lawrence

Oil & Gas SIG (GLB3.01)
Mac Beggs

Paleontology SIG (GLB3.02)
Daniel Thomas

DAY 3 – 01 December

GEONET – PART OF THE FABRIC OF NEW ZEALAND (20^{th} Anniversary lecture, SSLB1)
Catherine Ross, GeoNet Programme Leader

SOCIAL PROGRAMME

Icebreaker Function

Date: Monday 28 November
Location: Wharerata, Massey University
Time: 5.00pm - 7.00pm

Icebreaker sponsored by

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Fun Games and BBQ Night

Date: Tuesday 29 November
Location: Sports & Rugby Institute, Massey University
Time: 7.00pm – late

Local craft brews sponsored by

VOLCANIC RISK SOLUTIONS

Conference Gala Dinner

"Dream Big: Opening the Door to a Whole New World"

Date: Wednesday 30 November
Location: Awapuni Function Centre and Racecourse
Time: 7.00pm - late

Band sponsored by

VOLCANIC RISK SOLUTIONS

Bus departures

Main Massey Bus Stop Columbo Rd: 6.30 & 6.40pm, Fitzherbert Ave opposite Harrington's Motel and at Distinction Coachman Hotel: 6.35 and 6.45pm

Departure Racecourse to Massey with 2 stops along Fitzherbert Ave: 10.15, 10.30, 11.15 pm & 12.15am

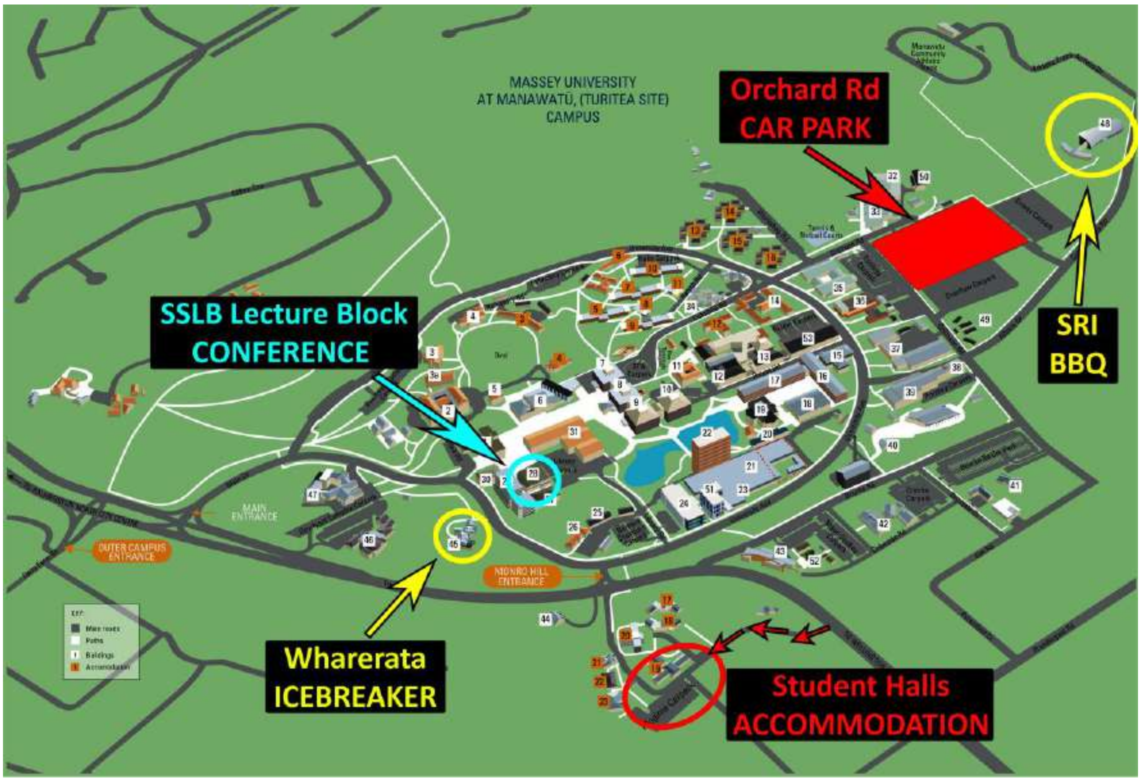
ECR EVENTS

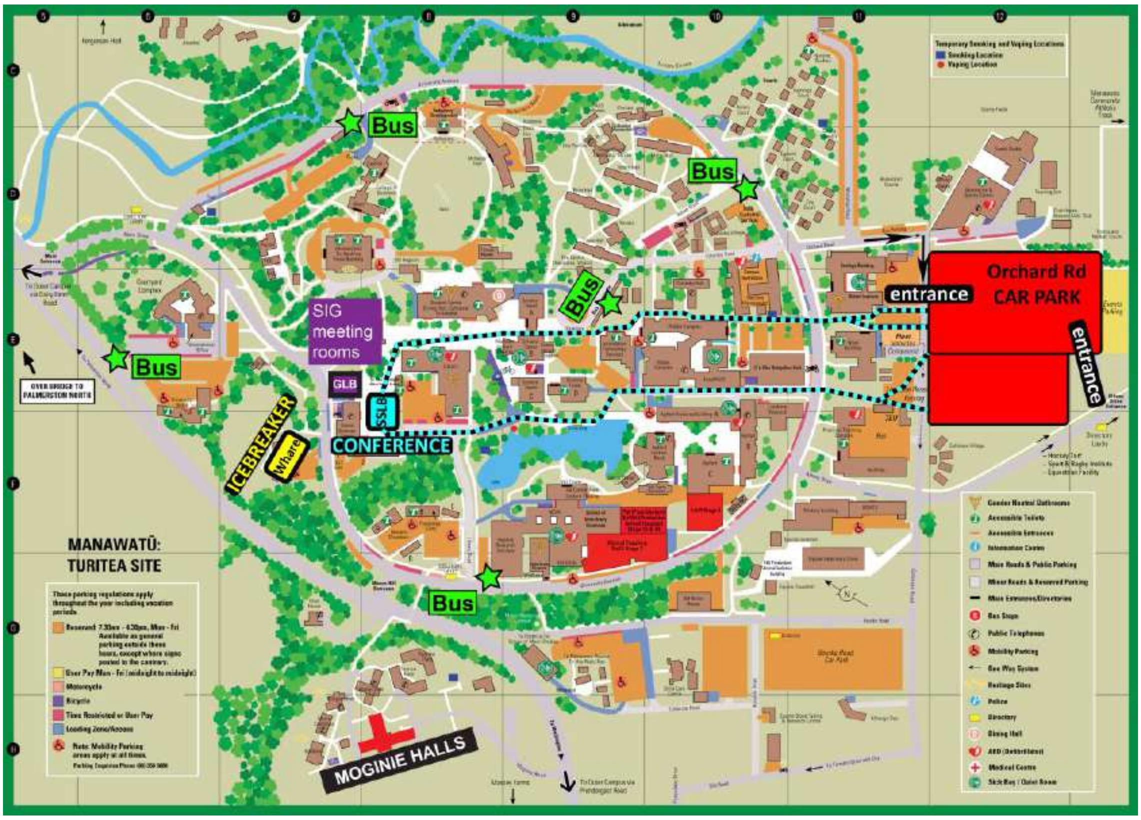
Early Career Researchers (ECR) Mixer

Date: Monday 30 November
Location: Rosie O'Grady's Irish Pub, 96 Fitzherbert Ave, Palmerston North
Time: from 7.30 pm / after the Icebreaker
Organiser: *Shannen Mills*

Main entrance Social Science Lecture Block (SSLB)

MASSEY UNIVERSITY CAMPUS - OVERVIEW





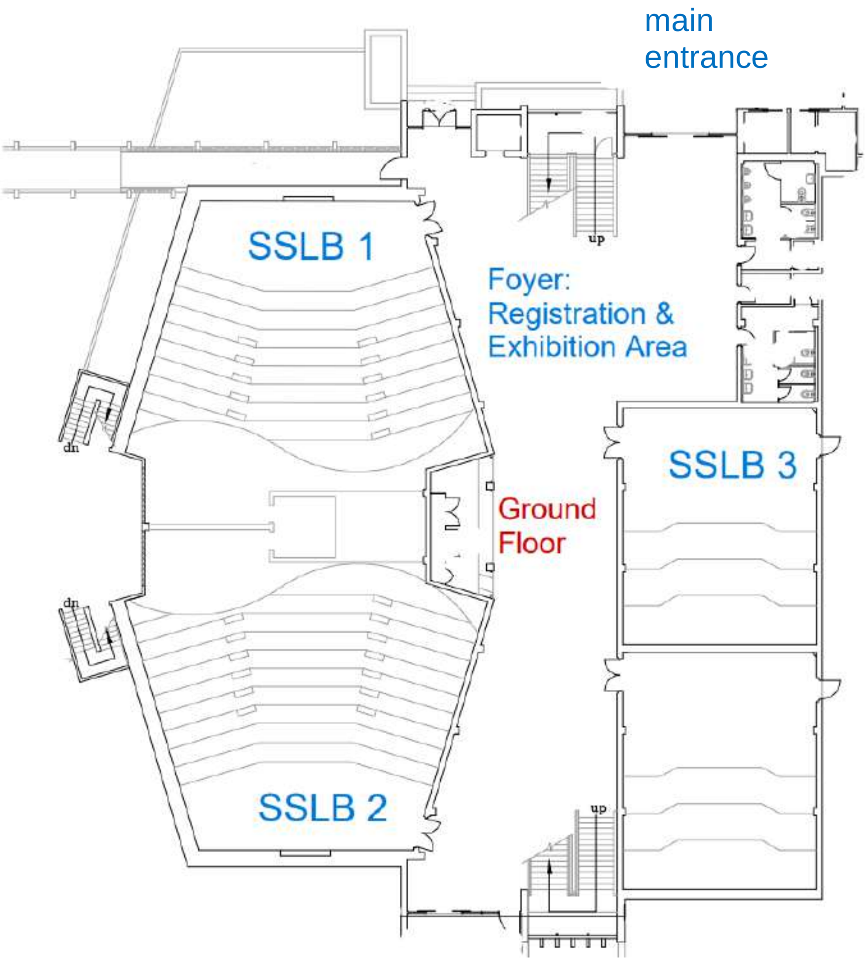
CONFERENCE VENUE

Social Science Lecture Block (ground floor)

Access to SSLB1, 2, 3 Lecture Theatres

Registration & Exhibition Area

Catering and Tea & Coffee stations

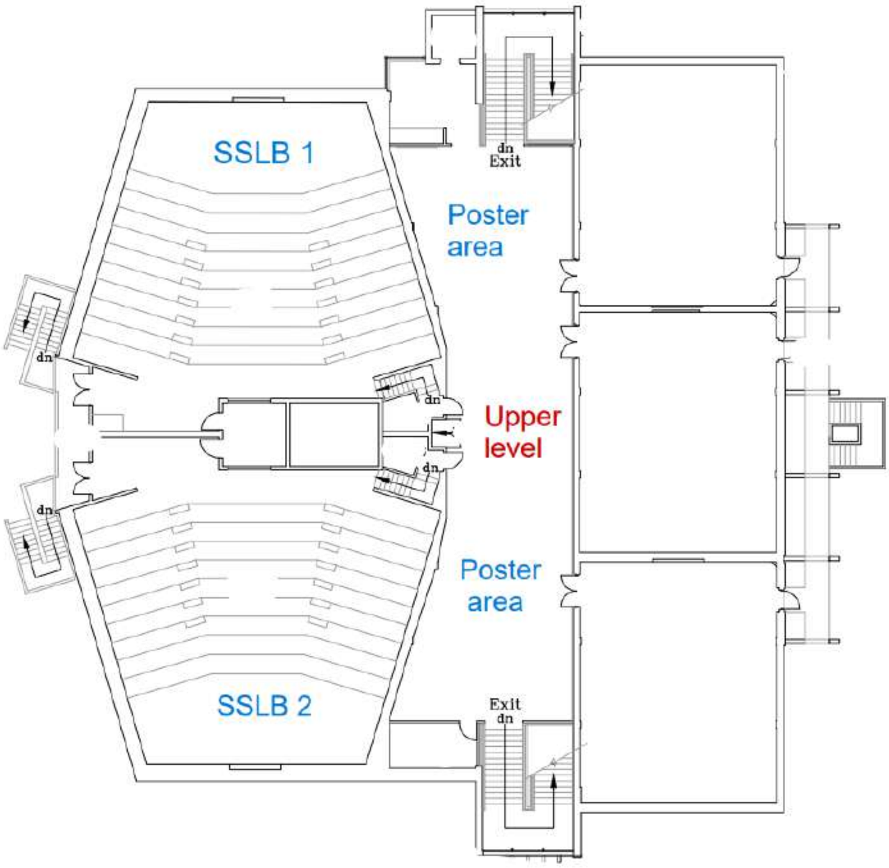


Social Science Lecture Block (upper floor)

Access to SSLB1 & 2 Lecture Theatres

Poster Display Area

Craft Beer Bar (poster sessions only)



PRE-CONFERENCE WORKSHOPS

Microanalysis in the Earth Sciences (max 45 participants)

Leader: Ery Hughes, Te Pū Ao, (GNS Science)
Date: Monday 28 November 2022, 08.30am to 5.30pm
Cost: $20 for conference attendees
$40 for non-conference attendees

The aim of the workshop is for participants to get an overview of the microanalytical techniques available for analysing samples in the Earth Sciences (e.g., geochemistry, paleobiology, volcanology, petrology, tephra chronology, structural geology, etc.). Individual sessions would focus on a specific technique and cover sample preparation, fundamentals of how the technique works, possible problems with the analysis, and examples of applications in the Earth Sciences. Participants would be expected to have a background in Earth Sciences but not specialised knowledge of the techniques covered. Techniques covered would include a selection of Electron Probe MicroAnalysis (EPMA), Scanning Electron Microscopy (SEM), Electron Back Scatter Diffraction (EBSD), Fourier Transform InfraRed (FTIR) spectroscopy, Raman spectroscopy, Secondary Ion Mass Spectrometry (SIMS), and X-ray Absorption Spectroscopy (XAS).

Additional Information: Pizza lunch, tea, coffee and snacks provided. Please let us know about your dietary requirements when registering for the workshop. And don't forget to bring your Keep Cup!

For any queries relating to this workshop please contact: e.hughes@gns.cri.nz

Modelling Synthetic Earthquakes and Tsunami

Leaders: Andy Nicol (University of Canterbury), Bill Fry (Te Pū Ao/GNS Science)
Date: Monday 28 November 2022, 9.30am to 4.30pm
Cost: Free for conference attendees, Workshop Only fee $20

Synthetic earthquakes offer the prospect of improving resilence to a range of co-seismic hazards. Physics-based models of earthquakes have been used to assess and forecast fault rupture, ground shaking, tsunami and landslides. The aim of this workshop is to present the results of earthquake simulations for New Zealand faults. Consideration will be given to the impact of fault geometries on model outputs, while simulated earthquakes will be compared to existing datasets to test and evaluate their ability to replicate real earthquakes. We will discuss the utility of the model outputs and their application to tsunami and landslide hazards together with earthquake and tsunami early warning systems. The workshop is intended to promote collaboration and discussion of future research using simulated earthquakes for improved resilience to earthquake, tsunami and landslide hazards.

Additional Information: Catering provided. Presentations by invitation.

For any queries relating to this workshop please contact:
andy.nicol@canterbury.ac.nz **&** *B.Fry@gns.cri.nz*

FIELD TRIP OFFERS

FIELD TRIP 1 (CANCELLED)

Te Ahu a Turanga:
Manawatū Tararua Highway and Cultural Sites of importance

Leaders:	Ben Dixon (Te Ahu A Turanga Alliance)
	Terry Hapi (Rangitāne o Manawatu)
Date:	1-Day trip, 2 December 2022
Cost:	$60/person

The new 11.2 km long Manawatū Tararua Highway is being constructed across the Ruahine Ranges from Ashurst to Woodville to replace the existing Manawatū Gorge Road which closed in 2017. Currently under construction by the Te Ahu A Turanga Alliance, this project has facilitated extensive borehole investigation, geological and landslide mapping and groundwater monitoring to further the geological understanding of the area.

Te Ao Māori is actively integrated into the design and construction of the project in a way that celebrates this unique area and its rich cultural heritage. You can expect to see Māori culture expressed in many places on this project, from plant species selection to the design of highway structures and celebration of areas with specific cultural significance.

This field trip will start at the site office with a welcome and introduction to the project from the Alliance, then we will review the project geological model and some of core recovered from the boreholes. Following this, we will travel to key sites along the highway to look at geological outcrops that informed the design, large exposures in 70 m high cuts currently under construction, the construction of the 300 m long bridges crossing the Manawatū River and QEII area, and areas of cultural significance including the recent discovery of moa bones.

In association with

aurecon

Bringing ideas to life

Photo credit to, and in memory of, Stefanie von Bueren

FIELD TRIP 2

Land use and stratigraphy within the eastern Whanganui Basin, lower North Island, New Zealand

Leaders:	Callum Rees (Massey University) Alan Palmer (Massey University) Julie Palmer (Massey University) Malcolm Todd (Horizons Regional Council)
Date:	1-Day trip, 2 December 2022
Cost:	$60/person

Keen to explore one of the best records of Quaternary climate change exposed onland anywhere in the world? Say no more, our journey will begin at the Manawatu Saddle, eastern Whanganui Basin, where we can see the sedimentary response to ignimbrite emplacement involving inundation of river and coastal settings, valley aggradation, infilling and loading of the Whanganui coastal embayment and formation of a hydraulically active seafloor. As we move west, towards the Rangitīkei, we will pause on the Pohangina Anticline to explore c. 1.2 –1 Ma basin fill that is exposed by some of the most severe gully erosion within the region, presenting questions around land use management and sustainability. The journey will end with stunning exposures through cyclothymic strata (c. 0.9 Ma) at Waitapu Stream and evidence of past volcanism. Lunch and good fossil picking may be enjoyed during a leisurely stroll up the deeply incised stream valley.

Additional Information: Transport will be supplied via minibuses departing from outside the conference venue at Massey University by 8:00 am. Please bring tramping boots, rain jacket, backpack, water and sunscreen.

Moderate level of fitness required.

In association with

TODD ENERGY

Photo credit: Callum Rees

FIELD TRIP 3

Mt Ruapehu –
Tephra stratigraphy, mass flow deposits & volcanic hazards

Leaders:	Gabor Kereszturi (Massey University)
	Anja Moebis (Massey University)
	Jonathan Procter (Massey University)
	Stuart Mead (Massey University)
Date:	2-Day trip, 2-3 December 2022
Cost:	$250/person

Mt Ruapehu is an andesitic composite volcano, located in the Central Volcanic Plateau. Besides producing many small to large-scale hydrothermal, magmatic, and phreatomagmatic eruptions, Mt Ruapehu has produced many small to large-scale flank collapses, and crater rim collapses that have resulted in debris avalanches, landslides, and lahars. Mt. Ruapehu is therefore an excellent natural laboratory to study stratigraphy and sedimentology of tephra and mass-flow deposits. The 2-day field trip showcases some of the sedimentary and volcanic processes by visiting key outcrops on the ring plan and lower flank of Mt Ruapehu. The field trip will introduce new research findings on the tephra stratigraphy, mass-flow hazards and landscape evolution response to major tephra forming eruptions and mass-flow events.

Additional Information: This trip includes a moderately long hike (ca. 6 km) on uneven grounds. Breakfast (Day 2), Prepacked lunch (x2) and BBQ dinner, ground transportation by utes and overnight accommodation in Tukino Ski Lodge will be provided.

Photo credit: Anke Zernack

PUBLIC LECTURE SPEAKERS

Dr Sally Potter

Biography

Sally has been researching how to best communicate forecasts and warnings for natural hazards for over 10 years.

She has helped write GeoNet's earthquake forecasts and eruption forecasts following the Whakaari/White Island 2019 eruption, as well as emergency mobile alerts. She reviewed New Zealand's volcanic alert level system and investigated how often Taupo supervolcano has had unrest. She co-leads international and domestic research programmes on severe weather, looking at how to improve warnings.

Talk: **Warning! Natural hazard forecasts and why people respond in different ways**

Where can you find out more about the natural hazards that might affect you? Why do people respond in different ways to warnings, and what makes them more effective? How can you contribute to our understanding of hazards and their impacts? What will forecasts and warnings look like in the future?

This interactive presentation will show you how we can use the best science available to support our decisions and get ourselves ready for impending natural hazards.

Dr Kate Clark

Biography

Dr Kate Clark has been researching past large earthquakes and tsunamis in Aotearoa/New Zealand for over 15 years. Kate's studies started at Massey University where she used tiny microfossils to look at changes in ocean temperature, and she ended up captivated by how fossils record sudden changes in sea level caused by large earthquakes. Her research has made major contributions to understanding the hazard posed to Aotearoa/New Zealand by our largest fault lines: the Alpine fault and the Hikurangi Subduction Zone.

Talk: **Past coastal earthquakes and tsunamis of Aotearoa/New Zealand, and preparing for our shaky future**

Much of the Aotearoa/New Zealand coastline has been shaped by past earthquakes. The coastal landscape bears the imprint of dramatic uplift, sudden subsidence, and tsunami impact. Earthquake geologists use these landscape clues to piece together the history of earthquakes and tsunamis over thousands of years. Kate will explore how the coastal landscape of the lower North Island and upper South Island contains the story of past earthquakes, and how this information helps us prepare for future seismic events.

PLENARY LECTURES

PLENARY 1 – 29 November

Dr Charlotte Severne

Once a Geologist, always a Geologist - 25 years on

What happens when you leave University armed with a Doctorate in Geology and no place to go? There are number of routes open to science graduates other than post-doctoral paths and academic roles but these are obvious and graduates are prepared. Dr Severne will discuss her journey, the opportunities and near misses that colour her career. She will also take a glance at what the workforce of the future will offer for science graduates.

Biography

Dr Charlotte Severne is the Māori Trustee and leads Te Tumu Paeroa - the Office of the Māori Trustee.

Charlotte holds a PhD in Geology from the University of Auckland. In 2016, she was made an Officer of the New Zealand Order of Merit, in recognition of her contribution as an advocate and mentor for Māori Development and Science.

Charlotte also has a wealth of experience in working with Māori business as a science advisor and in governance roles in energy, fisheries and farming entities. Prior to being appointed the Māori Trustee in September 2018, her governance leadership roles were primary and energy sector based.

PLENARY 2 – 30 November

Dr Kim Martelli

A Career in the Geosciences:
A world of opportunities from exploration to engineering!

Kim has led an interesting and varied career since graduating with a BSc in earth science from Massey University including standing on active volcanoes, riding in helicopters, blowing up rocks, avoiding terrorist attacks and land mines, hoping not to need her kidnapping insurance, and developing the liquefaction hazard map for Tauranga City.

She will talk about what led her to study earth science, what pathways she took and how she has ended up back in the Bay of Plenty. Kim will discuss the importance of taking opportunities and creating your own, and how she navigated Geoscience professions where women are a minority.

Biography

Kim is a Chartered Geologist with a PhD in volcanology from the University Clermont Auvergne (France) and has over 12 years' experience in field geology conducting geological, geomorphological and hazard mapping in challenging terrain both in New Zealand and around the world (Peru, Turkey, Armenia, Georgia...). After 7 years in Engineering Geology, she has recently taken up a role as the Natural Hazards and Infrastructure Resilience Specialist for Tauranga City Council.

Kim has a deep passion for STEM education and development, volunteering in Engineering New Zealand's The Wonder Project and Tauranga's STEM festival. She has completed leadership programmes for high potential women and future leaders, and is the chair for GSNZ Bay of Plenty Branch.

PLENARY 3 – 01 December

Hollei Gabrielsen

Herenga tangata, hononga ki te whenua.

Mai i te pae tapu o Tongariro
Ko Matua te Toa
Tae iho ki Pīhanga te uwha whakaaroha
Ko Matua te Hine
E ruku ana ahau i tōku wai kōrero
Ko Te Kōpū a Kānapanapa te wai whakahono
E ko Te Arawa!
E ko Tūwharetoa!
E ko Kurauia, Turumakina, Hikairo te mihi atu nei.

Biography

Hollei is of Ngāti Tūwharetoa and Ngāti Whitikaupeka descent and the Technical Advisor Volcanology for Te Papa Atawhai, the Department of Conservation. A māmā to three tamariki, an uri of Te Kāhui Maunga, a mokopuna of te taiao, a student of life and in pursuit of consistent growth.

Much of Hollei's career was dedicated to providing a platform for tangata whenua to assert their rangatiratanga on matters concerning their cultural, spiritual and natural landscape. More recently she made the transition to the public sector to provide technical advice on volcanic matters, unrest, risk and eruptions.

Scientific Sessions

I. Our Dynamic Planet: Magmatism and Tectonics

1a. Maunga Puia - Volcanoes and their eruptive products (LAVA NZ and Sedimentology SIGs endorsed)

*Session Convenors: **Jon Procter** (Massey University)*

Aotearoa and Zealandia's evolution has been moulded by volcanism. Volcanic products and processes have shaped our landscape and contributed to the development of our indigenous culture. Present-day volcanism threatens the resilience of communities with many complex and potentially hazardous processes impacting communities, infrastructure and economy. This session will be seeking contributions from a wide range of topics that relate to volcanism in the South Pacific, factors driving volcanism, eruptive/effusive products and hazards, past and potential future impacts, simulation of volcanic processes and volcanic geomorphology.

1b. Igneous Petrology and Geochemistry (LAVA NZ and Geochemistry SIGs endorsed)

*Session Convenors: **Georg Zellmer**, Carlos Corella Santa Cruz (Massey University)*

This session focusses on magmatism in New Zealand and globally. We welcome petrological (including experimental petrology) and geochemical studies on materials ranging from mantle rocks through plutonic intrusions to volcanic eruption products, to improve our understanding of the petrogenetic processes that govern the different tectonomagmatic systems present on Earth. Further, we are hoping to see a wide range of analytical techniques, from whole-rock to microscopic scale, and from elemental to isotopic investigations, to gain insights into (i) sources and processes of magma genesis; (ii) processes and rates of magma ascent through the crust; (iii) magma-crust interactions; (iv) links between subvolcanic magmatism and volcanic eruptions; (v) syn- and post-eruptive processes as evident from the materials investigated; (vi) intensive parameters such as pressure, temperature, and compositional changes that may be derived; and (vii) the rates and timescales of all of the above, as constrained through a range of both absolute and relative dating methods.

1c. Zealandia through space and time

*Session Convenors: **Dominic Strogen** (GNS Science), James Crampton (Victoria University of Wellington)*

All aspects of the evolution of Zealandia, including, but not limited to:

- basement terrane evolution in eastern Gondwana
- the 'basement to cover' transition - from Gondwana subduction to Zealandia rifting
- tectonic evolution and reconstructions of Zealandia and surrounding regions
- paleogeography, paleoenvironments and paleobiology
- rifting and evolution of Zealandia basins
- Paleogene–Neogene plate boundary development through Zealandia
- provenance and uplift studies
- Cretaceous and younger magmatism across Zealandia

1d. Seismotectonics of Aotearoa/ New Zealand and beyond

This session will explore the active and Quaternary seismotectonics of Aotearoa/New Zealand and the southwest Pacific through local examples, and studies that put this region in a global context. Approaches from multiple techniques and disciplines are critical to unravelling active tectonic processes, and this session aims to provide a space for studies from across the spectrum of geophysics and geology which can elucidate the kinematics and driving forces of inter- and intra-plate deformation. We welcome contributions from disciplines including, but not limited to: seismology, geodesy, tectonic geomorphology, paleoseismology, structural geology, marine geology, as well as multi-disciplinary studies related to understanding active lithospheric deformation.

*Session Convenors: **Camilla Penney** (University of Canterbury), Genevieve Coffey (GNS Science), Jack Williams (University of Otago)*

Special Session 1e. Evolution of an Active Caldera System: The Okataina Volcanic Centre

In the northern part of the Taupo Volcanic Zone (TVZ) lies the Okataina Volcanic Centre (OVC), one of the most productive and active volcanic centres in the TVZ with several geothermal fields located around the margins. The occurrence of volcanism, geothermal systems and complex caldera structure, coincident with a shift in rift-axis and a change in active fault-strike have made the OVC a focus of numerous studies (and potentially future ICDP scientific drilling) on caldera processes, their evolution and interaction with tectonic structure.

This session welcomes contributions from recent studies of the OVC across a broad range of methods (e.g. geophysical, geological, geochemical, petrological, numerical modelling, etc.). We seek contributions that explore magmatic, volcanic, tectonic, geothermal and groundwater processes occurring within, or around, the OVC. Together, this session aims to showcase our modern understanding of the OVC and feedbacks between melt and rift structure that control caldera evolution.

*Session Convenors: **Ted Bertrand**, Cécile Massiot, Cornel de Ronde (GNS Science)*

II. Lessons from Active Earth Systems: Messages from the Past for the Future

2a. Natural hazards – from the geological record to forecasting

*Session Convenors: **Melody Whitehead**, Stuart Mead, Mark Bebbington (Massey University)*

This session aims to present a comprehensive overview of current research surrounding the what, how, when, where, and why of natural hazards in New Zealand, based primarily (but not exclusively) on previous activity, models and current observations. Topics may include:

1. Geological interpretations: what does the geological record tell us about current and future hazardous events
2. System dynamics: what can physical or chemical models tell us about system evolution and event triggers, precursors, and hazard parameters
3. Physical hazard: from modelling phenomena to observations that improve understanding of hazard dynamics, cascades, zonation and communication
4. Statistical/uncertainty forecasts: from hazard forecasting to data uncertainties including where the geological record may, and may not, be valid and the limits of what the past may tell us about the future

In association with
Session Sponsor

National SCIENCE Challenges
RESILIENCE TO NATURE'S CHALLENGES
Kia manawaroa – Ngā Ākina o Te Ao Tūroa

2b. Our changing landscapes; surface process dynamics, evolution, and hazards (Sedimentology SIG endorsed)

*Session Convenors: **Sam McColl**, David Barrell (GNS Science), Kevin Norton (VUW), Karoly Nemeth*

This session brings together contributions that broaden the understanding of surface processes and their dynamics, evolution, and hazards as relevant to Earth and beyond. In particular, we welcome contributions that address topical issues in geomorphology and surface process sciences using innovative, cross-disciplinary approaches and technologies including remote-sensing, quantitative terrain analysis, numerical modelling, and geochronology. Timescales of interest may extend from that of landscape evolution over millions of years, through to the dynamics of Quaternary climate cycles, or contemporary observations and forward-looking future scenarios. Priority will be given to those contributions whose cross-disciplinary approaches enhance and draw linkages to other branches of the geosciences.

2c. Understanding climate and environmental change (Friends of the Pleistocene SIG endorsed)

*Session Convenors: **Peter Almond** (Lincoln University), Shaun Eaves (VUW), Olivia Truax, David Barrell (GNS Science)*

Global climate and environmental changes present significant challenges for current and future generations. In this session we encourage submissions from the full spectrum of climate and environmental research, with presentations having a key focus on (but not limited to): (i) analyses of present climate trends/impacts; (ii) climate/environmental reconstruction from geological archives (recent to deep time); (iii) interactions between humans, climate and environment; and iv) computer modelling of past/present climate and environmental change. This session is a 'Friends of the Pleistocene' GSNZ Special Interest Group

2d. Integrated Coastal Dynamics: Our Changing Coastline

*Session Convenors: **Kyle Bland** (GNS Science), Phaedra Upton (GNS Science)*

Coastal environments are complex and dynamic with morphodynamics that are influenced by autogenic processes, natural external forcings, climate change, and direct anthropogenic interactions. These processes act on and are recorded in the landscape and the sedimentary record over a wide range of spatial and temporal scales, from long-term and broad-scale to short-term and fine-scale processes and deposits. How will changing climate and sea level impact New Zealand's natural and built environments, and how can the nation adapt to these changes socially, economically, and environmentally? In this session we invite presentations that address all aspects of coastal dynamics. We are particularly interested in studies that cross disciplinary boundaries, address the integration of social science and Mātauranga Māori into research programmes, and use modelling to explore the impacts of changing coastal environments on people, society, and infrastructure.

2e. Marine geological processes and human impacts in the ocean

*Session Convenors: **Jess Hillman** (GNS Science), Sally Watson (NIWA), Karsten Kroeger (GNS Science), Sarah Seabrook (NIWA)*

With the majority of Te Riu-a-Māui/Zealandia and large areas offshore Australia lying underwater, marine geology is an essential field of research in Australasia. Advances in technology and the growing volume of marine data mean that we are poised on the threshold of a digital ocean. Recent and ongoing research including seafloor sampling surveys, sub-bottom surveys, seafloor mapping programmes, ROV and AUV dives have acquired a wealth of new data, allowing us to further explore offshore geology and active processes beneath the seafloor. Furthermore, we are increasingly aware of anthropogenic impacts from the coastal waters to the abyssal plains. This session seeks contributions from studies across the disciplines of marine geology and biogeosciences, ranging from the depths of the continental slopes to the shallow coasts.

III. Living in A Dynamic GeoCultural Landscape: Geosciences and Society

3a. Advances in Communication, Education, and Disaster Risk Science

*Session Convenors: **Sally Potter** (GNS Science), **Alana Weir***

Global efforts to reduce the impacts of disasters over the last decade have failed to keep up with growing exposure of people and assets to hazards, which is generating new risks and a steady rise in disaster-related losses. The United Nations Sendai Framework for Disaster Risk Reduction (2015) aims to reverse this trend, by calling for a more holistic, people-centric approach to disaster risk reduction, in which communities, government, private sectors and research institutions work together to build resilience and develop collaborative disaster risk reduction (DRR) practices. The geosciences are an essential discipline within the DRR mission, particularly through multi- and inter-disciplinary studies.

This session provides the opportunity for contributions on topics relating to geological risk and resilience studies and initiatives, co-produced knowledge across the science-policy-practice interface, and the study of dynamic, cascading properties of disaster risk. This session will also explore recent, current, and planned initiatives relating to communicating about geohazards. We encourage updates and activities from major research programmes, engagement methods and user needs assessments, communicating forecasts and risk, visualisation tools and maps, crowdsource or citizen science activities, outreach, and education programmes. Social science research on risk perceptions, behavioural response, and communication are welcome. We especially encourage contributions from practitioner and policy experts, early-career scientists, and participants from diverse backgrounds and communities.

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3b. GeoEducation, Outreach & International Development

Session Convenor: ***Jenny Stein*** *(GSNZ)*

The world is facing many challenges related to climate change, natural hazards, and resource equity & security. To face these challenges, people from across all aspects of society need to work effectively together, toward a range of common goals. To do this, non-geoscientists need to be 'on board' with geoscientific and related information, while scientists in turn need have a better understanding of the contextual realities of implementing their research. Barriers to achieving such effective communication and collaboration often include the increasingly complex nature of scientific language and research, differences in cultural values and protocols, and limitations on time and resources dedicated to 'outreach'. This session is dedicated to all those who have managed to overcome these and other challenges to meaningfully engage non-experts with geoscience. From pre-schoolers to policy makers, whether you’ve worked with local government to develop strategic plans for an uncertain future, communicated critical information in preparation for or in response to a hazardous natural event, helped build public awareness and understanding of basic geological phenomena, or inspired future generations of young geoscientists, we want to hear from you! This session is a chance to celebrate your successes, share lessons learned from any 'failures', and inspire future progress and discussion with any other insights you may have gained along the way.

3c. Science in response and recovery

Session Convenors: ***Bill Fry****, Anna Kaiser, Jen Andrews, Libby Abbott (Te Pū Ao)*

In the immediate aftermath of large earthquakes and tsunamis, science underpins response and recovery decisions. Rapid information about the event can be used to generate coseismic impact estimates, such as estimations of the spatial extent of strong ground shaking (e.g. shakemaps), landslides, or liquefaction. Estimates of postseismic impacts of event evolution include tsunami forecasts that underpin early warning, and aftershock forecasts that provide likelihood estimates of further damaging earthquakes. The coseismic and postseismic forecasts can subsequently be used to create risk products that underpin risk-based decision making, and for public messaging and advisories. In this session, we invite submissions addressing any novel aspect of response and recovery science and engineering, including but not limited to characterisation of the earthquake and its impacts, early warning, risk analysis, and information communication and distribution.

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IV. Facing the Future: Innovative Applications and Technologies in Geosciences

4a. Computational advances in Geosciences

*Session Convenors: **Stuart Mead** (Massey University), David Dempsey (University of Canterbury)*

The increasing availability of computational power, numerical platforms and machine learning techniques has created significant opportunities for geoscience. This session aims to showcase the development, use and application of computational techniques in geosciences. We invite contributions from all aspects of geoscience utilising these computational advances including, but not limited to:

- model development, improvement, application, and validation
- machine learning techniques applied to geosciences
- database development and data analysis
- techniques leveraging high performance computing (HPC)
- geoscientific data visualisation

4b. Remote Sensing and Geospatial Data Analysis for Geological Applications

*Session Convenors: **Gabor Kereszturi** (Massey University), Ian Hamling (GNS Science)*

This session highlights new research using remote sensing and geospatial data to probe geological processes. The topics can cover from the lab- and field-based to satellite remote sensing with optical, thermal, RADAR, LiDAR sensors, or combinations. The session aims to present a good blend of research from both methodology and application aspects. The methodological contributions can include validation/calibration, sensor fusion, GIS applications, image classification and regression, and sensitivity analysis. Contributions exploring geological applications are welcome from any part of geoscience, including but not limited to digital terrain analysis, landslides, suspended sediment mapping, surface deformation, mineral exploration, natural hazards, geothermal and volcano research, geological mapping, among others.

4c. Engineering Geology/Geomorphology: Advances and Applications in a Dynamic World

Session Convenors: ***Sam McColl****, Saskia de Vilder, Andrea Wolter, Kerry Leith (GNS Science)*

This session aims to highlight innovation and advances in the field of Engineering Geology/Geomorphology and the practical application of this knowledge to inform decision makers and increase resilience to natural hazards. We welcome a broad range of abstracts including advances in our understanding of slope stability mechanics and processes, the properties and behaviour soil and rock, engineering geological ground models, and innovative technologies used for monitoring and modelling ground conditions and unstable slopes.

4d. Geochemical tools and applications to reconstruct environmental and climate change, human impact and Earth history in New Zealand, Australia and Antarctica (Geochemistry SIG endorsed)

Session Convenors: ***Sebastian Naeher*** *(GNS Science), James Scott (University of Otago)*

This session highlights innovative research of the New Zealand and overseas geochemistry community about environmental and climate change. It discusses technological developments and applications of new indicators on topics such as reconstructing productivity, nutrient cycling and water quality in aquatic environments, and metal tracers and non-traditional isotope systems to quantify processes on land and at sea. Selected topics discuss pollution and human impact or new research into global geochemical cycles across time that link the earth, ocean and atmosphere. Multiproxy reconstructions of life evolution and bioheritage, high-resolution paleorecords and dating of environmental archives are also presented.

4e. Geoscience for Future Energy Systems

Session Convenors: ***Mac Beggs*** *(University of Canterbury), Miko Fohrmann (OMV)*

This session will canvass papers showcasing the roles of geoscience in enabling a sustainable, reliable and affordable future energy system for New Zealand. This may include new applications of expertise and technology from existing energy industries to the evaluation and development of new possibilities including more challenging classes of geothermal energy, offshore wind and marine energy, and geostorage for hydrogen, CO2 sequestration. Potential mineral resources for battery technology may also be addressed.

4f. Mineral Deposits: Geology, Exploration and Resources

Session Convenors: ***Michael Gazley*** *(AusIMM and RSC Mining and Mineral Exploration)*

This session is intended to be broad to capture all aspects of research on mineral deposits, exploration for mineral deposits, and examination of mineral systems and their resources, both in New Zealand and globally. This session welcomes papers that examine the structural controls on the location, architecture, depositional processes, and post-mineralisation modification of mineral deposits, through the implementation of traditional and innovative techniques at micro- to crustal-scale; through papers that examine exploration techniques or approaches to find mineral deposits; and papers that explore resource modelling, responsible development of resources and post-mining processes like mine-closure, remediation and acid-mine drainage.

New Zealand is well-endowed with mineral wealth that ranges from iron sands on the west coast of the North Island, and garnet sands of the West Coast of the South Island to hard-rock and alluvial gold of the Otago region and Coromandel Volcanic Zone. These minerals and more novel elements besides (such as REE placer deposits and Li in geothermal systems) could be extracted to support New Zealand' transition to a low-carbon economy. Minerals play a key role in this transition and New Zealand must understand its own resources, where they are and how to utilise them in an efficient and responsible manner to support this transition.

	CONFERENCE PROGRAMME for TUESDAY, 29 November		
07.00	**REGISTRATION**		
08.30	**OPENING CEREMONY SSLB1 (live-streamed to SSLB 2 overflow room)** Mihi Whakatau (Terry Hapi) Conference opening address (Simon Hills) Conference Opening Welcome (convenors) Turitea Kapa Haka rōpū *Bus transport for Kapa Haka rōpū sponsored by* tranzit coachlines		
09.15	*Sponsored by* GNS Science **PLENARY 1 SSLB1 (live-streamed to SSLB 2 overflow room)** **Charlotte Severne *"Once a Geologist, always a Geologist - 25 years on"***		
	SSLB1	***SSLB2***	***SSLB3***
9.45-10.45	**1a. Maunga Puia** *Jon Procter (Massey University)* *Sarah Tapscott (Massey University)*	**3a. Communication, Education & Disaster Risk** *Sally Potter (GNS Science); Alana Weir (University of Canterbury)* EQC	**2d. Integrated Coastal Dynamics** *Kyle Bland, Phaedra Upton (GNS Science)*
9.45-10.00	**Jarvis PA** et al. - Interaction between vortices and settling-driven gravitational instabilities at the base of volcanic clouds	**Hudson-Doyle EEH** et al. - Uncertainty: Where do individuals think it comes from? Understanding mental models of natural hazards science and advice.	**Lawrence MJF** et al. - Sedimentation Patterns in a Small Modern Anthropogenically-Influenced Estuary, Otuwhero Inlet, Abel Tasman
10.00-10.15	**Kereszturi G** et al. - Porosity, strength, and alteration – Volcano stability assessment using VNIR-SWIR reflectance spectroscopy	Das M, **Becker JS** et al. - Understanding communication processes and decision making during different stages of volcanic activity in Aotearoa New Zealand	**Bloom C** et al. - Earthquakes and Coastal Cliff Retreat in New Zealand
10.15-10.30	**Mills S** et al. - Textural characteristics of tephra formations as a proxy for understanding the impacts of a collapse cycle on the eruptive products at stratovolcanoes.	**Charlton D** et al. - Co creating a volcanic hazard mapping framework for Aotearoa New Zealand	**Keller ED** et al. - Modelling the probability of inundation with Bayesian Networks: A pilot study in the Hauraki Plains
10.30-10.45	Rooyakkers SM, **Chambefort I** et al. - Tracking Magma-Crust-Fluid Interactions at High Temporal Resolution: Magmatic Oxygen Isotopes in the Central Taupō Volcanic Zone	**Lake-Hammond A** & Orchiston C - Sharing the Science Beneath Our Feet: Preparing for the next Alpine Fault earthquake	**Bland KJ** et al. - Co-designing research for environmental, social, and cultural benefit: Tātaihia te Parataiao o te Wahapū – Hokianga Harbour Sedimentation Project
10.45-11.15	**Morning Tea**		

	SSLB1	*SSLB2*	*SSLB3*
11.15-13.00	**1a. Maunga Puia** *Jon Procter (Massey University)* *Shannen Mills (Massey University)*	**1d. Seismotectonics of Aotearoa/NZ and beyond** *Camilla Penney (University of Canterbury); Genevieve Coffey (GNS Science); Jack Williams (University of Otago)*	**2e. Marine geological processes** *Jess Hillman (GNS Science); Sally Watson (NIWA); Karsten Kroeger (GNS Science); Sarah Seabrook (NIWA)*
11.15-11.30	**Heise W** et al. - Mesh Design for inversion model resolution of the magmatic system beneath Mount Tongariro, New Zealand	**Ellis S** et al. - Transient fluctuations in stress and slip caused by geometric irregularities in shear zones: Field examples and numerical model analogues for active subduction interface deformation	**Maier KL** et al. - Dynamic seafloor environments – High-resolution measurements from Kaikōura Submarine Canyon
11.30-11.45	Otway P, **Illsley-Kemp F** & Mestel ERH - Taupō volcano's restless nature revealed by 42 years of deformation surveys, 1979–2021	**Perez-Silva A** et al. - Properties of slow slip events explained by numerical model of rate-strengthening faults subject to periodic pore fluid pressure perturbations	**Orpin AR** et al. - Using the 2016 Kaikōura earthquake to test hypotheses that underpin turbidite paleoseismology
11.45-12.00	**Kósik S** et al. - New constraints on the age and timescale of activity of the Puketerata maar-lava dome complex, Taupō Volcanic Zone, New Zealand	**Pita Sllim O** et al. - Spatiotemporal analysis of repeating earthquakes near Pōrangahau, Hikurangi Margin, New Zealand.	**Tickle S** et al. - 2016 Kaikōura earthquake turbidite shows that a single core could be representative of the seismic history of a submarine distributary system
12.00-12.15	**Mestel ERH** et al. - Three years of earthquake activity at Taupō volcano investigated with an enhanced seismic network	**Seebeck H** et al. - Geologic, earthquake and tsunami modelling of the active Cape Egmont Fault Zone	**Kroeger KF** et al. - Microbial gas generation and gas hydrate formation at the New Zealand Hikurangi Margin
12.15-12.30	**Piva S** et al. - Resolving past eruptive impacts from Taupō supervolcano using novel high resolution sampling techniques	**Stern T** et al. - Crustal structure, mantle melt zones and processes beneath the Taupo Volcanic Zone, New Zealand: evidence from active-source seismic exploration and GPS data	**Hillman JIT** et al. - Redefining the southern extent of the Hikurangi Margin Gas Hydrate Province
12.30-12.45	**Thrasher G** et al. - Interaction of Taranaki Maunga and the Cape Egmont Fault Zone	Eberhart-Phillips D, **Stirling M** et al. - The influence of basement terranes on tectonic deformation: joint earthquake travel-time and ambient noise tomography of the southern South Island, New Zealand	**Davy B** et al. - Sub-bottom profiler dating of glacial horizons and the timing of carbonate mound formation on the Southern Hikurangi Margin
12..45-13.00	**Davidson A** et al. - Challenging the paradigm of ^{238}U-excesses dominating arc settings: A Uranium-series isotopic investigation of Mt Taranaki, New Zealand	**Stirling M** et al. - Earthquake source characterisation in southern New Zealand: an update	**Black JA** et al. - 100% of the World Ocean floor mapped by 2030 - The Nippon Foundation/GEBCO Seabed 2030 project
13.00-14.30	**Lunch, meetings, and poster viewing**		
13.30-14.30	LAVANZ SIG *Geoff Kilgour* *SSLB1*	GeOID SIG *Jenny Stein* *GLB2.03*	WOMEESA *Jess Hillman* *GLB2.05*

	SSLB1	*SSLB2*	*SSLB3*
14.30-16.00	**1a. Maunga Puia** *Jon Procter (Massey University)* *Marlena Prentice (University of Waikato)*	**1d. Seismotectonics of Aotearoa/NZ and beyond** *Camilla Penney (University of Canterbury); Genevieve Coffey (GNS Science); Jack Williams (University of Otago)*	**2e. Marine geological processes** *Jess Hillman (GNS Science); Sally Watson (NIWA); Karsten Kroeger (GNS Science); Sarah Seabrook (NIWA)*
14.30-14.45	**Bann G** et al. - Newly identified tuffs from the early - mid Permian southern Sydney Basin: explosive volcanism and associated ecological mortality derived from northwest Zealandia.	**Matheson A** et al. - Modelling Earthquake Sources in Aotearoa using Joint Analysis of Seismological and Geodetic Data	**Beagley JE** et al. - Paleoenvironment and sediment basins in Dusky Sound, New Zealand characterised through seismic stratigraphy and sediment cores
14.45-15.00	**Huebsch M** et al. - Using 3D textures to assess magma-water interaction dynamics across varying conditions at Hunga volcano	**Hirschberg H** & Sutherland R - A Kinematic Model of New Zealand Fault Slip Rates and Distributed Deformation	**Isson TT** & Rauzi S - Do silica secreting organisms regulate climate on Earth?
15.00-15.15	**Krippner J** et al. - Geomorphological evolution of the Ngāuruhoe summit from the 1800s to the present day	**Warren-Smith E** et al. - Using Microearthquakes to Probe the Structure and Mechanics of Alpine Fault Segment Boundaries and Quantify Implications for Future Rupture	**Nodder SD** et al. - Importance of near-bed lateral processes in biogenic fluxes to the seafloor in deep-water environments, Aotearoa New Zealand
15.15-15.30	**Stern S** et al. - New insights into one of the largest submarine caldera eruptions of the last 2000 years in the South Pacific, the ~AD1450 Kuwae eruption, Vanuatu	**Bourguignon S** et al. - 3D image of seismic attenuation along the central Alpine Fault, New Zealand, from dense temporary seismic array data	**Ribó M** et al. - Microplastics in marine sediments: Findings from the first study around Aotearoa/New Zealand
15.30-15.45	**Zernack AV** et al. - The origin, preservation and prehistoric human use of ocean-rafted pumice found in raised beach ridges and archaeological sites in Northern Norway	**Sintenie J** et al. - Slip rates on the eastern Hope Fault, New Zealand	**Warnke F** et al. - High-resolution images of paleo-pockmarks on the Chatham Rise using densely spaced echosounder profiles
15.45-16.00	**O'Brien L** et al. - Providing a tephrochronological framework for 10myrs of deposition in the Southern Wairarapa	**Townend J** et al. - The Southern Alps Long Skinny Array (SALSA): Virtual Earthquake Analysis of Future Alpine Fault Earthquakes and Ground-Shaking	**Watson SJ** et al. - The footprint of ship anchoring on the seafloor
16.00-17.30	**Poster session/afternoon tea: SSLB Upper Foyer**		
Sponsored by NIWA Taihoro Nukurangi	1a. Maunga Puia: A1-21 1b. Igneous Petrology: A22-32 1d. Seismotectonics: A33-48	3a. Communication, Education, Disaster Risk: A49-51 2d. Integrated Coastal Dynamics: A52-53 2e. Marine geological processes: A54-59	2b. Our Changing landscapes: A60-69 4c. Engineering Geology/Geomorphology: A70-72 4b. Remote Sensing & Geospatial Data: A73-81

17.30-19.00	**PUBLIC LECTURE SSLB1 (live-streamed to SSLB 2 overflow room)** **Sally Potter *"Warning! Natural hazard forecasts and why people respond in different ways"*** **Kate Clark *"Past coastal earthquakes and tsunamis of Aotearoa/New Zealand, and preparing for our shaky future"***
19.00-late	**FUN AND GAMES BBQ DINNER Sports and Rugby Institute**

POSTERS (Tuesday, 29 November) *Sponsored by*

NIWA Taihoro Nukurangi

1a. Maunga Puia

A1	**Barker S** et al. - The climatic and environmental impacts of New Zealand supereruptions
A2	**Tapscott S** et al. - A Quantitative Investigation into Pyroclast Properties Across the Transitional Stratigraphy of the Taupo 232 CE Y4/Y5 Eruption Phases
A3	**Corna L** et al. - Runout and hazard characteristics of pyroclastic density currents after encountering obstacles
A4	**Watson L** & Cannata A - Tracking a pyroclastic density current with seismic signals at Mt. Etna (Italy)
A5	**Schuler J** et al. - Changes in Seismic Velocity Accompanying Geodetically Detected Deformation at Taupō Volcano
A6	**Hoult H** et al. - Growth of complex volcanic ash aggregates in the Tierra Blanca Joven eruption of Ilopango Caldera, El Salvador
A7	**Clarke M** et al. - Hide and seek: Cryptotephra studies applied to a deep marine core
A8	**Paredes-Mariño J** et al. - A tale of extreme fragmentation: the volcanic ash from Hunga Eruption
A9	**Jarvis PA** et al. - Constraints on the Hunga Tonga-Hunga Ha'apai eruption processes from remote magnetic field measurements of volcanic lightning
A10	**Rebecchi M** et al. - Mafic recharge in the lead-up to the world's youngest basaltic Plinian eruption: Ulawun volcano, Papua New Guinea
A11	**Kilgour G** et al. - Quantifying ballistic ejecta in volcanic deposits: a case study of the 1886 Tarawera eruption
A12	**Kilgour G** et al. - An overall assessment of volcanic unrest at Ruapehu in early 2022
A13	**Li B** et al. - The most recent fissure feed and lava-producing eruptions of the Arxan-Chaihe Volcanic Field (ACVF), NE China
A14	**Ruz-Ginouves J** et al. - Understanding flow localization using waxy fissures
A15	Marshall AJ et al. (presented by **Kennedy B/Doll P**) - Flow Units of the Rangataua Lava Flows
A16	**Doll P** et al. - Paleomagnetic constraints in Holocene lava flows eruption ages at Ruapehu, Aotearoa New Zealand
A17	**Mazumdar A** & Turner G - Palaeomagnetic records of the Laschamp and Mono Lake geomagnetic excursions from Tongariro, New Zealand
A18	Poojary S & **Turner G**. - Using Palaeomagnetic Techniques to Uncover the History of an Archaeological Site in Napier/Ahuriri, Hawkes Bay
A19	Reid H, Mead S & **Procter J** - Developing indicators of volcanic induced coastal aggradation from lahars using satellite remotely sensed imagery; A case study from the 2018 Ambae Eruption, Vanuatu.
A20	**Overwater G** et al. - Extreme facies variation and pyroxene megacrysts: a magmatic to volcanic approach to unravel the emplacement mechanisms of the Te Onepoto flank system, Lyttelton Volcanic Complex.
A21	**Zhang R** & Brenna M - Volcanology, geochemistry and age of Pigroot Hill Volcanic Complex, Waipiata Volcanic Field, New Zealand

1b. Igneous Petrology and Geochemistry

A22	**Vicente J** et al. - Modelling outgassing through channelling in vulcanian eruption.
A23	**Hamilton K** et al. - Insights into the 15 January 2022 Hunga eruption (Kingdom of Tonga) through non-juvenile pyroclasts
A24	**Hughes E** et al. - Using a multi-volatile thermodynamic model to understand the effects of sulphur on silicate magmas
A25	**Georgatou A** et al. - Petrogenesis of Brothers submarine volcano and associated hybrid seafloor massive sulfide deposit

A26	**Prentice M** et al. - Silicic volcanism at the dawn of the TVZ: Trends in geochemistry, mineralogy and magma storage, of the Tauranga Volcanic Centre, New Zealand
A27	**Baxter RJM** & Maclennan JC - Magma flux is primary control on distribution of stored magma along the slow-spreading Reykjanes Ridge
A28	**Coulter R** et al. - H_2O and CO_2 contents of volcanic glass from the offshore TVZ – southern Havre Trough
A29	**Gruender K** et al. - Deep magma sources feeding eruptions from Red Crater, Tongariro
A30	**Swann JA** et al. - Mineral Recorders of Ascent Processes in Explosive Eruptions at Mt. Taranaki, New Zealand
A31	**Stenning A** et al. - Refining the Early Geochronological Record for the Dunedin Volcano, New Zealand
A32	**Wilson LJE** et al. - Characterisation of the anomalous sub-alkaline Maniototo Basalts in the alkaline Dunedin Volcanic Group; Sources and Mechanisms

1d. Seismotectonics

A33	**Taylor-Offord S** et al. - GeoNet Sensor Network Capability; Estimates of Minimum Detectable Earthquake Magnitude in Aotearoa New Zealand
A34	**Chamberlain CJ** et al. - A Repeating Earthquake Catalogue for New Zealand
A35	**Buffett W** et al. - Investigating the lithospheric structure of New Zealand using S-to-P Receiver functions
A36	**Williams J** et al. - Along-strike extent of ruptures on geometrically complex reverse faults; insights from paleoseismic investigations and physics-based earthquake simulations of the Nevis-Cardrona Fault system
A37	**Coffey G** et al. - Slip Rate study of the Te Puninga Fault, Hauraki Rift, New Zealand
A38	**Muirhead J** - Mesozoic to Present Day Structural Fabric of the Auckland Region
A39	**Mark O** et al. - Intermediate-Depth Earthquakes Beneath the Central Taupō Volcanic Zone: Where, Why and How?
A40	**Van Wijk K** et al. - Seismic methods for three-dimensional imaging to depth of the crust under the Auckland Volcanic Field
A41	**Tateiwa K** et al. - Seismicity and its implications for fluid movement in the northern and central Hikurangi subduction zone
A42	Chua TJ, **Ellis S** et al. - Estimating fault rupture depths in the Wellington Region: constraints from laboratory experiments, seismic relocation of earthquake depths and thermal modelling
A43	**Barnes P** et al. - Compactive deformation of incoming calcareous pelagic sediments, northern Hikurangi subduction margin, New Zealand: Implications for subduction processes
A44	**Warren-Smith E** - Evidence for Spatially Heterogeneous Megathrust Fluid Valving in the Northern Hikurangi Subduction System
A45	**Tagami A** et al. - Stress field in the northwestern part of the South Island, New Zealand, and its relationship with faults of recent earthquakes
A46	**Kwong S** et al. - The PULSE Network: Building an Earthquake Catalogue to Understand SSE-Earthquake interaction on the Hikurangi Subduction Zone
A47	**Whitehead N** - How and when earthquakes create light
A48	**Glowacki T -** True Plate Tectonics Mechanisms

3a. Communication, Education, and Disaster Risk Science

A49	**Dhungana A** et al. - Model Uncertainty - What Needs to be Communicated in Hazard and Risk Models
A50	**Vinnell L** et al. - Influences on lahar preparedness in Mount Rainier, USA, communities
A51	**Wavelet E** et al. - Tsunami Early Warning System: a study case of the North of New Zealand

d. Integrated Coastal Dynamics

A23	**Craig H** et al. - Dairy farming exposure and impacts from extreme coastal flooding and sea level rise

A53	**Evans J** et al. - Recent Sedimentation History and Foraminifera Distribution in Governors Bay, New Zealand

2e. Marine geological processes

A54	**Henrys S** et al. - GeoDiscoveryNZ and ANZIC: A Decadal Strategic Vision
A55	**Hillman JIT** et al. - The human footprint on the seabed: Case studies from the Southern Hikurangi
A56	**Ribó M** et al. - Repeat seabed mapping: Understanding complex morphological changes in seafloor bedforms
A57	**Spain E** et al. - Geomorphic time series reveals the constructive and destructive history of Havre volcano, Kermadec Arc
A58	**Warren G** et al. - Is this the real life? Is this just fantasea? Caught in a landslide: Megablocks from the Deepwater Taranaki Basin.
A59	**Watson SJ** et al. - The underwater landslide archives of Aotearoa/New Zealand: Documenting occurrence or preservation bias?

2b. Our Changing landscapes

A60	**Österle J** et al. - Assessing the Pliocene–Recent erosion history of the eastern Southern Alps using cosmogenic radionuclides, tracer techniques and grain size analyses
A61	**Kosik S** et al. - Landscape evolution and quantification of long-term erosion rates in the Hautapu River catchment, New Zealand
A62	**Doyle I** et al. - Developing floodplain sediment archives to understand erosion and flood histories in contrasting catchments
A63	**Nisbet E** et al. - Palaeo-activity of large, deep-seated landslides in the Rangitikei Catchment, New Zealand
A64	**Singeisen C** et al. - Fault zone contributions to the evolution of the Half Moon Bay landslide complex, Kaikōura
A65	**Bland KJ** et al. - New insights into the geology of the Pukekohe area (Southern Auckland-Northern Waikato)
A66	**Coursey S** et al. - Subaqueous Geomorphology of Lake Whakatipu and Implications for Shoreline Hazards
A67	**Hanson JB** et al. - The New Zealand Deep-ocean and Reporting on Tsunamis (DART) Network: Update and Data Access Steps Forward
A68	**Madley M** et al. - Signals from the deep – Triggers observed on the New Zealand Deep-ocean and Reporting on Tsunamis (DART) Network
A69	**Stern T** et al. - Do tide gauge records from New Zealand provide a reliable picture of relative sea level change over the past 100 years?

4c. Engineering Geology/Geomorphology

A70	**Barrell D** & Lee J - Urban geological mapping at GNS Science
A71	**Cave M** - Deja vu all over again Bola Scale Landsliding from the March 2022 Gisborne/Tairawhiti-Wairoa Storm
A72	Wolter A, **Morgenstern** R et al. - A National Landslide Dam Database for New Zealand

4b. Remote Sensing & Geospatial Data Analysis

A73	**Asher C** - A low cost semi-autonomous aquatic rover for low pH, high temperature geothermal and volcanic waterways
A74	**Barretto J** & Caratori Tontini F - Total magnetic intensity grid of the upper North Island, New Zealand

A75	**Hamling I** et al. - Towards the development of a routine, hi-resolution, InSAR derived deformation dataset for Aotearoa
A76	Kearse J, **Stern T** et al. - Using InSAR and GNSS to characterise present-day vertical deformation at New Zealand coastal strips
A77	**Morgenstern R** et al. - High-resolution surveying of landslides using UAV-mounted LiDAR
A78	**Spesivtev A** et al. - GeoNet's GNSS Data and Products: current state and future opportunities
A79	**Stevenson T** & Brenna M - A synthesis of volcanic edifice evolution based on a 3D lithological reconstruction of Heyward Promontory, East Otago, New Zealand
A80	**Oliver WJ** et al. - Seismic and gravity surveys characterise Discovery Deep, Antarctica
A81	**Pratscher K** et al. - Induction Responses from Magnetotelluric Transfer Functions in Southland, New Zealand

	CONFERENCE PROGRAMME for WEDNESDAY, 30 November		
07.00	**REGISTRATION**		
08.00-08.30	**PLENARY 2 SSLB1 (live-streamed to SSLB 2 overflow room)** **Kim Martelli *"A Career in the Geosciences: A world of opportunities from exploration to engineering!"***		
	SSLB1	***SSLB2***	***SSLB3***
08.30-10.00	**Special Session 1e. Okataina Volcanic Centre** *Ted Bertrand, Cécile Massiot, Cornel de Ronde (GNS Science)*	**1c. Zealandia through space & time** *Dominic Strogen (GNS Science); James Crampton (VUW)*	**3c. Science in response and recovery** *Sponsored by* EQC *Bill Fry, Anna Kaiser, Jen Andrews, Libby Abbott (Te Pū Ao)*
08.30-08.45	**Bertrand T** et al. - Inferring the roots of volcano-geothermal systems in the Rotorua and Okataina calderas with Magnetotelluric models	**Strogen D** et al. - Palaeogeographic evolution of Zealandia: mid-Cretaceous to present	**Kaiser A** et al. - Rapid characterisation of earthquakes & tsunami (R-CET programme) - The local earthquake challenge
08.45-09.00	**Hamling I** et al. - Estimating the distribution of melt beneath the Okataina Caldera, New Zealand: An integrated approach using geodesy, seismology and magnetotellurics	**Palmer M** et al. - The timing of Dun Mountain Ophiolite emplacement via Rb-Sr isotope dating of metasomatic reactions along the Livingstone Fault	**Andrews J** et al. - Rapid rupture characterisation for New Zealand using the Finite-fault Rupture Detector (FinDer) Algorithm
09.00-09.15	**Carson L** et al. - 3D Visualisation model of the basement geology and caldera structure at Ōkataina Volcanic Centre	**MacFarlan D** - Zealandian Brachiopod faunas and the Jurassic Crises	Horspool N, …, **Kaiser A** et al. - GeoNet's Shaking Layer Tool: Automatic generation of maps of near-real time ground shaking for post-event response
09.15-09.30	**Villamor P** et al. - Fault Ruptures Triggered by Large Rhyolitic Eruptions at the Boundary Between Tectonic and Magmatic Rift Segments: The Manawahe Fault, Taupō Rift, New Zealand	**Powell NG** - Continental glaciation in New Zealand and West Antarctica during the Plenus Cold Event: relevance for modelling geoengineered CO_2 drawdown via ocean fertilisation	**Holden C** et al. - Engaging with End-users Towards an Earthquake Early Warning System for New Zealand
09.30-09.45	Berryman K, **Villamor P** et al. - Volcano-tectonic interactions at the southern margin of the Okataina Volcanic Centre, Taupō Volcanic Zone	**Young G** et al. - A Cretaceous Ichthyosaur from North Canterbury	**Gledhill K** & Fry B - RCET Contribution to Rapid Tsunami Threat Characterization
09.45-10.00	**Hughes E** et al. - SO_2 emissions from explosive basaltic eruptions at Okataina	**Hollis CJ** et al. - Making sense of Paleocene Zealandia	**Taylor-Offord S** & McDougall T - The Story of a Seismic Network: the R-CET Te Tai Tokerau Northland Array
10.00-10.30	**Morning Tea**		

	SSLB1	*SSLB2*	*SSLB3*
10.30-12.00	**Special Session 1e. Okataina Volcanic Centre** *Ted Bertrand, Cécile Massiot, Cornel de Ronde (GNS Science)*	**1c. Zealandia through space & time** *Dominic Strogen (GNS Science); James Crampton (VUW)*	**4e. Geoscience for Future Energy Systems** *Mac Beggs (University of Canterbury); Julie Palmer (Massey University)*
10.30-10.45	**White P** & Leonard G - Evolution of geology and groundwater-geothermal systems in the Okataina caldera groundwater catchment	**De Pietri VL** et al. - Marine Avian Diversity in the Paleocene of New Zealand	**Bennett D** - The Last Frontier (for now)
10.45-11.00	**Pearson-Grant S** et al. - Fluid and heat flow in the Ōkataina Volcanic Centre and at Lake Rotomahana, New Zealand	**Thomas DB** et al. - Largest-known fossil penguin moves peak body size closer to first appearance of Sphenisciformes in Zealandia	**Beggs M** et al. - Hikurangi Margin Gas Hydrate Deposits: Might they ever have been developed as an energy resource?
11.00-11.15	**Stucker V** et al. - Comparison of hydrothermal fluids and fields of the northern Okataina Volcanic Centre: fifty years ago to present time	**Parker M** et al. - Provenance of Miocene–Pleistocene conglomerates in the northern Canterbury Basin: implications for exhumation along the Pacific–Australian plate boundary	**Chambefort I** et al. - Geothermal: The next generation - Advancing the understanding of New Zealand's supercritical resources (**Keynote**)
11.15-11.30	**De Ronde CEJ** et al. - The geology and geophysics of Lake Rotoiti, New Zealand: Implications for sublacustrine geothermal activity	**Sagar M** et al. - An age model for the Tongaporutuan (Late Miocene) reference section, northern Taranaki	**Nicol A** et al. - Underground Storage of Green hydrogen in Aotearoa-New Zealand
11.30-11.45	**Yang J** et al. - Understanding caldera degassing from a detailed investigation at Lake Rotoiti, Okataina Volcanic Centre, New Zealand	**Shalla Y** et al. - Active faults identified between the Taupō Rift and the North Island Dextral Fault Belt: kinematics and links with volcanism from the Taupō Volcanic Centre	Adam L, **Dempsey D** et al. - Opportunities for CO_2 Sequestration in New Zealand Rocks
11.45-12.00	**Massiot C** et al. - CALDERA: a scientific drilling idea to unravel Connections Among Life, geo-Dynamics and Eruptions in a Rifting Arc caldera	**Upton P** et al. - Plate boundary intracontinental transfer across the developing Marlborough Fault System, New Zealand	**Yates E** et al. - Petrophysical properties and reservoir potential of rhyolitic lava domes

12.00-13.30	**Lunch, meetings, and poster viewing**				
12.30-13.30	Scientific drilling - CALDERA *Cécile Massiot* *SSLB1*	Geochemistry SIG *Sebastian Naeher* *GLB2.03*	Sedimentology *Mark Lawrence* *GLB2.05*	Oil & Gas SIG *Mac Beggs* *GLB3.01*	Paleontology SIG *Daniel Thomas* *GLB3.02*

	SSLB1	*SSLB2*	*SSLB3*
13.30-15.30	**Special Symposium NZNSHM 2022** *Matt Gerstenberger, Russ Van Dissen (GNS Science)*	**2c. Climate and environmental change** *Peter Almond (Lincoln University); Shaun Eaves (VUW); Olivia Truax, David Barrell (GNS Science)*	**4a. Computational Advances in Geosciences** *Stuart Mead (Massey University); David Dempsey (University of Canterbury)*
13.30-13.45	**Gerstenberger M** et al. - The 2022 Aotearoa New Zealand National Seismic Hazard Model	**Wheeler C** et al. - Do cyanobacterial blooms occur naturally in dune lakes?	**Fry B** et al. - Physics to resilience: Next generation earthquake and tsunami response (**Keynote**)
13.45-14.00	**Bora S** et al. - The 2022 revision of National Seismic Hazard Model (NSHM) for New Zealand: candidate Ground-Motion Models (GMMs) and associated hazard sensitivities	Ryan M, **Holt K** et al. - Source-to-sink archives of vegetation change since the Last Glacial Maximum, Waipaoa Sedimentary System, New Zealand.	**Wang X** et al. - COMCOT tsunami simulation model – features and recent applications
14.00-14.15	**Seebeck H** et al. - The New Zealand Community Fault Model version 1.0	**Shorrock A** et al. - Sedimentary response to glacio-eustatic changes in the Northern Hikurangi subduction margin, New Zealand	**Steinke B** et al. - Automatic recognition of pre- and syn-eruptive seismic patterns at andesitic, dome-building stratovolcanoes
14.15-14.30	**DiCaprio C** et al. - Computational Infrastructure of the NZ-NSHM: how to calculate REALLY BIG seismic hazard models	**Gorman AR** et al. - Seismic and gravity constraints on the stratigraphy of the Siple Coast region underlying the Kamb Ice Stream, Antarctica	Ardid A, **Dempsey D** et al.- Discovering eruption precursors and identifying fluid release events from correlations of feature time series engineered from seismic records: Applications to Whakaari & Ruapehu volcanoes
14.30-14.45	**Coffey G** et al. - Derivation of paleo-earthquake recurrence intervals and probabilities of detection for NZ NSHM 2022, and impact on hazard	**Grant G** et al. - Regional amplified warming in the Southwest Pacific during the mid–Pliocene (3.3–3.0 Ma)	**Hernandez BC** et al. - Geochemistry: What can it tell us about eruption explosivity?
14.45-15.00	Manea E, **Kaiser A** et al. - Evaluation of site parameters to inform seismic site characterization in New Zealand	**Rauzi S** & Isson TT - Marine clay formation across the end-Permian mass extinction event.	**Huijser D** et al. - BIROC-H_20: A new way to process FTIR spectra of olivine hosted basaltic melt inclusions
15.00-15.15	**Litchfield N** et al - New Zealand Paleoseismic Site Database	**Verleijsdonk B** et al. - Novel techniques for reconstructing relative changes in past UV-B flux	**Morice S** et al. - The Taranaki 3D Cluster Buster: A Regional Scale Seismic Dataset enabled by High-Performance Computing
15.15-15.30	**Wallace L** et al. - Geodetic deformation model for the 2022 New Zealand National Seismic Hazard Model	**Griffin AG** et al. - GNS Science's journey to be carbon neutral by 2025	Mavroeidi M & **Rattenbury M** - Fair principles applied to high-value geoscience datasets
15.30-17.00	**Poster session/afternoon tea: SSLB Upper Foyer**		
	1e. Okataina Volcanic Centre: B1-4 2a. Natural Hazards: B5-19 Special Symposium NZNSHM 2022: B20-24 3c. Science in response & recovery: B25-30	3b. GeoEducation, Outreach, Int Development B31-36 1c. Zealandia through space & time: B37-43 2c. Climate & environmental change: B44-53 4d. Geochemical Tools & Applications: B54-60	4a. Computational Advances: B61-66 4e. Future Energy Systems: B67-70 4f. Mineral Deposits: B71-73
17.00-18.00	**GSNZ AGM**		
18.30-18.40	*Buses depart Massey University*		
19.00 – 0.00	**Conference Gala Dinner "Dream Big: Opening the Door to a Whole New World", Awapuni Racecourse**		

POSTERS (Wednesday, 30 November)

1e. Okataina Volcanic Centre

B1	**De Ronde CEJ** et al. - New bathymetric map of Lake Rotoiti, New Zealand
B2	Elms HC, **Wilson C** et al. - Timescales of Magmatic Processes at Ōkataina Volcanic Centre from Fe-Mg Diffusion in Orthopyroxenes
B3	**Hall A** & Cronin S - Geological Insights into the Eruptive History of the World's Largest "Dirty" Geyser: Waimangu Geyser 1900-1904, Waimangu Volcanic Valley, New Zealand.
B4	**Miller C** et al. - The integrated history of repeated caldera formation and infill at the Okataina Volcanic Centre: Insights from 3D gravity and magnetic models

2a. Natural hazards

B5	**Gomez A** et al. - After the big event: Aftershock analysis and the Mw 7.2 March 2021 East Cape Sequence
B6	**Juarez-Garfias IdC** et al. - Mapping Stress Drop Variations Along the Alpine Fault to Investigate Conditional Rupture Segmentation
B7	Christophersen A, **Bourguignon S** et al. - Revising the magnitudes in the New Zealand earthquake catalogue to be consistent with moment magnitude
B8	**Delano J** et al. - 'Slipping' into the sea: can upper plate faults produce coastal subsidence along the Hikurangi margin?
B9	**Holden C** et al. - High-frequency Ground-shaking Simulations for Alpine Fault Earthquake Scenarios
B10	**Matheson A** et al. - Identifying rupture cascades on the Alpine-Marlborough Fault System using lacustrine paleoseismology
B11	**Newsham S** et al. - Using tree-ring growth anomalies to date earthquakes
B12	**Hughes JW** et al. - Stratigraphy and age of volcano-fluvial and tephra deposits associated with the Te Puninga Fault, Morrinsville, Hauraki Basin
B13	**Mead S** et al. - Probabilistic volcanic mass flow hazard assessment using statistical surrogates of deterministic simulations
B14	**Mengesha D** et al. - Crustal anisotropy monitoring at Whakaari/White Island Volcano
B15	**Whitehead M** et al. - Short-Term Eruption Forecasting in New Zealand
B16	**Alves LFN** et al. - Geochemical Monitoring of Volcanic Activities in New Zealand
B17	**Perttu B** et al. - Mt. Ruapehu lahars: past deposits, present modelling, and future hazards
B18	**Scott E** et al. - Development of a Bayesian Event Tree for Short-term Eruption Onset Forecasting at Taupō Volcano
B19	**Sork A** & Kennedy B - A compiled historical volcanic hazards database for Tongariro National Park, New Zealand

Special Symposium NZNSHM 2022

B20	**DiCaprio C** et al. - Kororā: a Public Portal for the NZ NSHM
B21	Iturrieta P, **Gerstenberger M** et al. - Accounting for earthquake rates' temporal and spatial variability through least-information Uniform Rate Zone forecasts.
B22	**Rollins C** et al. - The rates of moderate and large earthquakes in the New Zealand region, and their uncertainties
B23	**Thinbaijam K** et al. - The 2022 NZ-NSHM workflow for the Distributed Seismicity and Slab Source Models
B24	**Van Dissen R** et al. - NZ NSHM 2022: Geologic and Subduction Interface Deformation Models

3c. Science in response & recovery

B25	Naguit M, **Salichon J** et al. - GeoNet's Strong Motion Network: 21 Years of Products & Services
B26	**Charlton D** et al. - GeoNet's Shaking Layer Tool: understanding and incorporating user needs into new earthquake shaking products for Aotearoa, New Zealand.
B27	**Fry B** et al. - New near real-time automated beachballs for earthquakes in New Zealand and the southwest Pacific
B28	**Chamberlain CJ** & Warren-Smith E - Operational template-matching for rapid aftershock analysis
B29	**Fensom J, Nicholls DN** et al. - The NGMC in Response Mode: Examples from the March 5th East Cape Earthquake
B30	**Chin S-J** et al. - Earthquakes and Seismic Hazard in Southern New Caledonia, Southwest Pacific

3b. GeoEducation, Outreach & Int Development

B31	**Wood M** et al. - New windows on the world: Applications of extended reality in the geoscience classroom
B32	**Young J** et al. - From Picks to Pixels: Developing eXtended Reality Tools for Geoscience Education and Outreach
B33	**Boothroyd M** et al. - Fireballs Aotearoa: Establishing a network of meteor-tracking cameras around Otago and Southland
B34	**Bull S** et al. - Who's using GeoTrips.org.nz? A user-based approach to optimizing web-based geoscience communication
B35	**Banerjee D** et al. - Student surveys inform digital device practices in field teaching
B36	**Wall K** et al. - Run for the Hills! - Co-Design of Games for Geological Disaster Risk Communication

1c. Zealandia through space & time

B37	**Williams CA** et al. - Slow Slip Events at the Hikurangi Subduction Margin, New Zealand, from 2006 to 2017
B38	**Stratford W** et al. - Crust and subduction architecture in Southland and northern Solander Basin.
B39	**Hill MP** et al. - Mapping and analysis of the structure and topology of a brittle-ductile fault swarm at Crawford Knob, Franz Josef, New Zealand.
B40	Sahoo TR, …, **Strogen D** - Evolution of Cretaceous Normal Faulting in the Great South Basin
B41	**Wu Y** et al. - Geological setting and Early Oligocene invertebrate fauna at McDonald's Quarry, Kakanui, New Zealand
B42	**Whitten C** et al. - Nature vs nurture – Quantifying evolutionary rate and ecophenotypic variation in pelicaria vermis
B43	**Strogen DP** et al. - Palaeogeographic evolution of Zealandia: mid-Cretaceous to present- Part 2

2c. Climate & environmental change

B44	**Barrell D** - The Zealandia switch – Hypothesising the Southern hemisphere in the driving seat of global climate
B45	Deuss K, **Almond P** et al. - Characterisation of the vertical and lateral subsurface heterogeneity in loess soils using qualitative (morphological) and quantitative (k-means) techniques
B46	**Al-hafid S** et al. - Modelling the Response of the SPCZ to Rapid Climate Perturbations under Contrasting Orbital Boundary Conditions
B47	**Casidy J** et al. - Disentangling climate and tectonic records in Plio-Pleistocene sediments in Southern Wairarapa
B48	**Eschenroeder J** et al. - Deciphering the impact of climate variability on the remote alpine lake ecosystem of Lake Bright, New Zealand

B49	**Gordon A** et al. - Development of a Chemotaxonomic Classification of New Zealand Plants – Implications for Using Biomarkers to Reconstruct Our Bioheritage
B50	**Hanson J** et al. - A preliminary study of late Holocene sedimentary records from Te Whakaraupō | Lyttelton Harbour, New Zealand
B51	**Kelly S** et al. - Fossil seabirds from the Pliocene of Taranaki, New Zealand
B52	**McDonald L** et al. - Understanding the variability of pollen in Hikurangi Subduction Margin deep marine turbidites for paleoclimate reconstruction
B53	**Penafiel Bermudez S** & Cooper T - Re-defining the J hyperthermal event via paleoenvironmental analysis of early Eocene marl and limestone alternations from Mead Stream, New Zealand

4d. Geochemical tools and applications

B54	**Turnbull JC** et al. - Comprehensive update of marine reservoir values for New Zealand coastal waters to inform coastal hazard research
B55	**Höpker SN** et al. - Hydrological monitoring and speleothem analysis to trace modern and historic climate extremes in Hawke's Bay, New Zealand
B56	**Holden G** & Sinclair D - A High-Resolution Precipitation Record from a Cook Islands Speleothem: Evidence for a Teleconnection with Northern Hemisphere Climate During MIS 3
B57	**Naeher S** et al. - Investigating bacterial 3-hydroxy fatty acids as new indicators of past air temperature in lake sediments from New Zealand
B58	**Davis AN** et al. - Decadal Scale Variability in Marine Primary Productivity Inferred from Stable Nitrogen Isotopes in Deep-Sea Corals
B59	**Sinclair D** et al. - Trace Elements in Black Corals – Investigating Potential New Palaeoceanographic Proxies
B60	**Kollsgård CT** et al. - Integrating XRF-ratios for Arctic paleoenvironmental reconstructions

4a. Computational advances in Geosciences

B61	**Yousef Zadeh E** & Peters K - Australian Granite Database: a case study for large scale database development.
B62	**D'Anastasio E** et al. - Making GeoNet data more accessible for big data projects – GeoNet, the cloud and the AWS Open Data program
B63	**Burton C** et al. - Defining "good" in pursuit of "better": a collective effort to define "good" seismic data quality using New Zealand ambient noise models
B64	**Lacoua L** et al. - Improving large earthquake magnitudes in New Zealand
B65	**Benson T** et al. - Testing the Validity of Shear Wave Splitting Measurements in the Presence of Scattering Using Synthetic Waveform Modelling.
B66	**Foundotos L** et al. - Validation of ground-motion simulation approaches on the 2011 Mw6.2 Christchurch earthquake, New Zealand

4e. Geoscience for Future Energy Systems

B67	**O'Sullivan-Moffat H** et al. - Urban methane emissions in Auckland, New Zealand
B68	**Yang J** et al. - CO_2 Emissions of the Tauhara Geothermal Systems, Taupo Volcanic Zone, New Zealand.
B69	**Jylhänkangas S** et al. - Comparing forward models with observations of fracture-induced shear wave anisotropy in the Taupō Volcanic Zone.
B70	**Macnaughtan M** et al. - Preliminary results of an AVO analysis in the southern HSM: Insights into fluid and pressure regimes

4f. Mineral Deposits: Geology, Exploration and Resources

B71	**Hill MP** - Aggregate opportunity modelling for New Zealand

B72	**Ireland M** et al. - Radiometric Sm-Nd dating of Orogenic Scheelite, Central Otago, New Zealand
B73	**Whitehead N** & Aharon P - The Ghost Uranium Deposit of Niue Island

	CONFERENCE PROGRAMME for THURSDAY, 01 December		
07.00	**REGISTRATION**		
08.00-08.30	**PLENARY 3 SSLB1 (live-streamed to SSLB 2 overflow room)** **Hollei Gabrielsen *"Herenga tangata, hononga ki te whenua."***		
	SSLB1	***SSLB2***	***SSLB3***
08.30-09.30	**2a. Natural Hazards** *Melody Whitehead, Stuart Mead, Mark Bebbington (Massey University)*	**1b. Igneous Petrology & Geochemistry** *Georg Zellmer (Massey University); Carlos Santa Cruz (Massey University)*	**2b. Our Changing landscapes** *Sam McColl, David Barrell (GNS Science); Kevin Norton (VUW); Karoly Nemeth*
08.30-08.45	**Roger J** et al. - The global tsunami triggered by the Mw 8.1 South Sandwich Islands earthquake of the 12 August 2021: records and consequences in NZ	**Burgin D** et al. - Deciphering the Martian mantle from in-situ $^{87}Sr/^{86}Sr$ measurements on shock melted plagioclase in Martian meteorites	**Rees C** et al. - Following the Waitapu Shell Conglomerate (0.9 Ma) across the Whanganui Basin
08.45-09.00	**Bull S** et al. - Landslides as tsunami sources in the Tasman Sea/ Te Tai-o-Rēhua	**Baxter RJM** et al. - Magma-flux regulated final depths of magma storage under Iceland	**McEwan E** et al. - Investigating coseismic avulsion hazards: A new approach for earthquake and flood hazard assessment
09.00-09.15	**Williams S** et al. - From Geological evidence to tsunami impact forecasting in the Southwest Pacific Islands	**Rattenbury M** et al. - Pluton Map characterisation of Aotearoa New Zealand's intrusive rocks	**Wilson-Harding I** et al. - Reconstructing Landscape Change from Earthquakes and Storm Events in Lake Gunn, Fiordland
09.15-09.30	**Hughes L** et al. - Assessing Tsunami Hazard in New Zealand using a Long Time Scale Synthetic Earthquake Catalogue	**Seelig LK** et al. - Using trace element and isotope geochemistry of central Taupō Volcanic Zone (New Zealand) granitoids to understand the processes contributing to silicic magmatism	**Watson L** et al. - Using local infrasound arrays to detect plunging snow avalanches along the Milford Road, New Zealand | Aotearoa
9.30-10.30 *Sponsored by*	National Science Challenges – RESILIENCE TO NATURE'S CHALLENGES – Kia manawaroa – Ngā Ākina o Te Ao Tūroa	**1b. Igneous Petrology & Geochemistry** *Continued*	**4c. Engineering Geology/Geomorphology** *Sam McColl, Saskia de Vilder, Andrea Wolter, Kerry Leith (GNS Science)*
9.30-9.45	**Cronin S** et al. - A "Big Boom" – a multi-perspective view of what drove the 15 January 2022 Hunga eruption, Tonga	**Corella Santa Cruz C** et al. - New comprehensive Pb isotopic data elucidate novel petrogenetic processes across the Taupo Volcanic Zone	**De Vilder S** et al. - Disaggregating Landslide Risk: What drives landslide risk in Franz Josef and Fox Glacier Valleys?
9.45-10.00	Borrero JC, **Cronin S** et al. - Tsunami in Tonga from the January 2022 eruption of Hunga Volcano	Coulthard et al. (**Zellmer G**) - Plutonic nature of transcrustal magmatic systems revealed by sub-micron Sr-disequilibria in plagioclase	**Singeisen C** et al. - Mechanisms of rock slope failures triggered by the 2016 Kaikōura earthquake
10.00-10.15	**Cave M** - Impact of cascading severe weather events on vulnerable communities	**Lewis KR** et al. - Experimental Constraints on Homogenization of Plagioclase-Hosted Melt Inclusions from Plagioclase Ultraphyric Basalts	**Stronach A** & Stern T - A New Basin-Depth Map of the Fault-Bound Wellington CBD Based on Residual Gravity Anomalies
10.15-10.30	**Johns B** & Cave M - New Zealand National Lidar and Regional Applications	**Werner C** et al. - Is Taranaki Exhaling? Detecting Volatile Emissions from a Dormant Volcano	Kirk P**, Dixon B** et al. - An evolving story of the geology of the Manawatū Saddle: Evidence from the Manawatū-Tararua highway
10.30-11.00	**Morning Tea**		

	SSLB1	*SSLB2*	*SSLB3*
11.00-13.00	**2a. Natural Hazards** *Melody Whitehead, Stuart Mead, Mark Bebbington (Massey University)*	**4d. Geochemical Tools & Applications** *Sebastian Naeher (GNS Science); James Scott (University of Otago)*	**4b. Remote Sensing & Geospatial Data Analysis** *Gabor Kereszturi (Massey University); Ian Hamling (GNS Science)*
11.00-11.15	**Lang J** et al. - Earthquake-controlled episodic growth of a Holocene stalagmite, eastern North Island, New Zealand.	**Bird M** - Abundance and isotope (^{13}C, ^{14}C) composition of pyrogenic carbon **(Keynote)**	**Lamb O** et al. - Listening to a basaltic fissure eruption: Key findings from the 2021 Fagradalsfjall eruption, Iceland
11.15-11.30	**Viskovic P** et al. - Digitising and vectorising paper seismograms in the national earthquake information database		**Perttu A** - An automated approach to plume height estimation using infrasound from local to remote
11.30-11.45	**Penney C** et al. - In good shape? The impacts of variable fault geometries on synthetic earthquake catalogues from physics-based earthquake simulators	**Webster-Brown J** et al. - Wild Fire Geochemistry: Lessons for Managing Future Impacts on Water Quality	Haneef S, **Van Wijk K** et al. - Distributed Acoustic Sensing (DAS) for geophysical applications in Aotearoa, New Zealand
11.45-12.00	**Liao Y-W M** et al. - The role of frictional heterogeneities in the earthquake cycle	**Naeher S** et al. - Tracing organic matter derived from Australian dust and bushfires in New Zealand using lipid biomarkers	**Kellett R** et al. - Integration of Airborne Electromagnetic models with ground geophysics and detailed borehole data: Heretaunga Plains
12.00-12.15	**Humphrey J** et al. - Earthquake timings and fault interactions in Central New Zealand	**Balfoort L** et al. - Environmental conditions of the West Antarctic Ice Sheet during the Miocene: insights from organic biomarker distributions	**Nersezova EE** et al. - Composition and structure of hot spring digitate sinter: preparation for remote sampling on Mars
12.15-12.30	**Howarth J** et al. - Quantitative lacustrine paleoseismology may reveal the rupture direction of the 1717 CE Alpine Fault earthquake		**Chakraborty R** et al. - Arsenic zonation for mineral prospecting at Rise and Shine Shear Zone, New Zealand, using hyperspectral remote sensing
12.30-12.45	**Langridge R** et al. - The fault in our horizons: Regional active fault mapping updates	**Frontin-Rollet GE** et al. - Geochemical Mapping of Aotearoa's Marine Sediments: an update for Bay of Islands area	**Thwaites M** et al. - A multidisciplinary source to sink approach in mapping erosion 'hot-spots' and sediment pathways in a harbour subcatchment of Te Whakaraupō/Lyttelton, Banks Peninsula.
12..45-13.00		Dietrich Z, **C Reid** et al. - Geochemical fingerprinting of sediment sources infilling Whakaraupō / Lyttelton Harbour, New Zealand	**Jones K** et al. - A new approach to quantify sediment conveyance following the 2016 Kaikōura earthquake, New Zealand
13.00-14.30	**Lunch**		
13.30-14.00	**Catherine Ross (GeoNet Programme Leader) "GEONET – PART OF THE FABRIC OF NEW ZEALAND"** (in SSLB1 & streamed to SSLB2)		

	SSLB1	*SSLB2*	
14.30-15.30	**2a. Natural Hazards** *Melody Whitehead, Stuart Mead, Mark Bebbington (Massey University)*	**4d. Geochemical Tools & Applications** *Sebastian Naeher (GNS Science); James Scott (University of Otago)*	**3b. GeoEducation, Outreach & International Development** *Jenny Stein (GSNZ)*
14.30-14.45	**Robert G** & Carazzo G - Study of the formation and dynamics of secondary plumes through 2D experiments and models	**Stirling C** - Biogeochemical cycling of trace metals and their isotopes: Links to past and present climate change **(Keynote)**	**Kennedy B** et al. - Virtual fieldtrips to volcanoes- 10-year perspective
14.45-15.00	**Wild A** et al. - Short-term eruption forecasting for the Auckland Volcanic Field using a Bayesian Event Tree		**Boyes A** et al. - A Portal for Geoscience Webmaps and Information on the Te Riu-a-māui / Zealandia Region
15.00-15.15	**Dempsey D** et al. - Evaluation of short-term eruption forecasting at Whakaari, New Zealand	**Rowe MC** et al. - Strontium Isotope Ratios of New Zealand Kauri: An Indicator of Climate Conditions?	**Zakharovskyi V** & Nemeth K - The influence of geomorphological models on geosite recognition utilizing qualitative-quantitative assessment of geodiversity
15.15-15.30	**Bebbington M** et al. - Multiphase Eruption Forecasting Using Analogue Volcano, Eruption and Hazard Sets	**Hilton TW** et al. - Auckland's Fossil Fuel CO_2 Emissions: A Bottom-up Inventory Informed by Atmospheric Radiocarbon Observations	**Stevenson T** et al. - Finding New Zealand's next meteorite with the Fireballs Aotearoa meteor-tracking camera network: conception, results, outreach
15.30-16.30	*Prize for Best Student Talk sponsored by* Royal Society Te Apārangi; Taylor & Francis	**CLOSING CEREMONY SSLB1 (live-streamed to SSLB2)** Conference Convenors, 2021/22 Committee and GSNZ NZJGG speech and Best Student Talks Best Student Posters 2023 Convenors	*Prize for Best Student Poster sponsored by* Volcanic Risk Solutions

ABSTRACTS

In alphabetic order by first author

Opportunities for CO_2 Sequestration in New Zealand Rocks

Ludmila Adam[1], David Dempsey[2], Kasper van Wijk[3], Michael C Rowe[1], Karen Higgs[4], Edward Yates[5] and Darren Gravley[5]

[1] School of Environment, The University of Auckland, Auckland, New Zealand.
[2] Civil and Natural Resources Engineering, University of Canterbury, Christchurch, New Zealand
[3] Physics Department, The University of Auckland, Auckland, New Zealand
[4]The Old Church Rooms, Bryn-y-maen, Conwy, LL28 5EN, United Kingdom
[5] School of Earth and Environment, University of Canterbury, Christchurch, New Zealand

l.adam@auckland.ac.nz

The ambitious plan to transition Aotearoa New Zealand to a carbon neutral economy by 2050 will require all available technologies to play a role. As we transition toward a green energy mix, we will need to mitigate our existing emissions in the short term or even consider atmospheric CO_2 removal. Geosequestration of carbon dioxide (CO_2) involves the collection of greenhouse gases at source points so it can be injected into subsurface rock formations. Carbon capture and sequestration is not new. Sleipner field in Norway is the first successful example of geosequestration of CO_2 which started in 1996. In New Zealand, geothermal operators are starting to sequester their carbon emissions by dissolving the gas in reinjected brine.

The chemical reactivity of storage rocks is a key uncertainty in both sedimentary and geothermal systems. The timescales and pathways of reactions become key inputs to reservoir-scale models whose goal is to predict the rate and fate of injected CO_2. A major challenge in this regard is the vast array of rock mineralogies, host fluid compositions, and pressure-temperature conditions, all of which can potentially affect reaction rates.

Our team has advanced research on geosequestration of CO_2 in sandstones (Pohokura field-Taranaki) and volcanic (Auckland Volcanic Field, AVF and Taupō Volcanic Zone) rocks. Laboratory experiments and numerical modelling on variable carbonate cemented rocks show how cement-carbonic acid reactions influence the rock's physical and geophysical properties. We show the feasibility of monitoring for such changes with seismic methods.

In contrast, volcanic rocks with high magnesium and iron minerals can react with CO_2, precipitating carbonate minerals. This reaction is welcomed, as the liquid or dissolved CO_2 is permanently locked up in mineral form. Laboratory measurements of AVF basalts show that there is a trade-off between mineral dissolution and precipitation of carbonate minerals.

ORAL
Session 4e.

Modelling the Response of the SPCZ to Rapid Climate Perturbations under Contrasting Orbital Boundary Conditions

Susan Al-hafid[1], Daniel Sinclair[1], Steven Phipps[2] and Josephine Brown[3]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand.*
[2] *Ikigai Research, Hobart, Tasmania, Australia.*
[3] *Department of Geography, Earth and Atmospheric Sciences, University of Melbourne, Victoria, Australia.*

susan.alhafid@vuw.ac.nz

The South Pacific is the main region where persistent deep atmospheric convection of tropical origin merges with the highly fluctuating mid-latitude storm track. These interactions result in a band of heavy rainfall and convection known as the South Pacific Convergence Zone (SPCZ). It is the most extensive rain band in the southern hemisphere and is a major source of water vapour to the entire Hemisphere. A shift in the SPCZ would dramatically impact people and agriculture in all the Pacific nations and could disrupt global moisture supply. Despite the importance of the SPCZ to global climate, very little is known about its dynamics, especially how it responds to rapid climate perturbation.

The last glacial period (110-12 thousand years ago) was characterized by rapid climate changes e.g. the Dansgaard-Oeschger (D-O) events where temperatures in Greenland warmed by up to 8 °C in a few decades. This makes it a 'natural laboratory' for studying the global effects of rapid climate change. Preliminary palaeoclimate reconstructions using speleothems show that D-O events disrupted the SPCZ, but suggest that its response may have been different under different configurations of orbital boundary conditions (specifically precession and obliquity).

Here we present results from palaeoclimate model simulations examining the response of the SPCZ to rapid climate perturbations under differing orbital boundary conditions using the CSIRO MK3L coupled climate model.

POSTER
Session 2c.

Geochemical Monitoring of Volcanic Activities in New Zealand

Luana F.N. Alves[1], **Bruce Christenson**[1] **and Ery Hughes**[1]

[1]*GNS Science, Wellington, New Zealand.*

l.alves@gns.cri.co.nz

GeoNet was founded in 2001 as a collaboration between the Earthquake Commission (EQC), GNS Science and Toitū Te Whenua Land Information New Zealand (LINZ). Originally GeoNet started as a provider of high quality and timely data, supporting emergency management and scientific research. Since then it has grown into a household name with more than a quarter of a million Kiwis using the GeoNet App to access data from our geohazard monitoring. That's two decades of growing the network, building data sets, increasing monitoring capabilities and improving awareness of the geohazards we live with here in Aotearoa New Zealand.

There are eight active volcanic areas in New Zealand with several active and potentially active volcanoes located in these areas. Although the probability of an eruption affecting a large area is relatively low in any given year, New Zealand needs to be prepared for a range of volcanic eruptions.

The Geonet monitoring programme aims to maintain an up-to-date understanding of the current status of activity or volcanic unrest at New Zealand's volcanoes – this is communicated as the Volcanic Alert Level (VAL) for each volcano and make this information available to stakeholders and researchers to inform research into volcanoes and to inform disaster management and evacuation plans.

Monitoring efforts for these volcanoes include Visual observation, Chemical analysis, Seismic and acoustic monitoring, and Ground Deformation.

The chemical analysis is undertaken by the Volcanic Gas and Crustal Fluids Laboratory, located within the National Isotope Centre (NIC) in Gracefield, Wellington. We routinely sample and analyse high temperature fumaroles and hydrothermal fluids.

We analyse gases principally via gas chromatography with thermal conductivity, flame ionisation and mass spectrometric detection. We are also equipped with a quadrupole mass analyser integrated with a He-cryogenic system, which caters for ultra-trace gas phase analysis. Wet chemistry is conducted via ion chromatography, titrimetric, gravimetric and ion selective methods on gas condensates.

POSTER
Session 2a.

Rapid rupture characterisation for New Zealand using the Finite-fault Rupture Detector (FinDer) Algorithm

Jen Andrews[1], Yannik Behr[1], Maren Böse[2], Frédérick Massin[2], Anna Kaiser[1] and Bill Fry[1]

[1] GNS Science, Avalon, Lower Hutt 5010, New Zealand.
[2] Swiss Seismological Service (SED), ETH Zürich, Zürich, Switzerland.

jen.andrews@gns.cri.nz

Immediately after a significant earthquake, rapid scientific information is critical for response decision-making and estimating secondary hazards and is a key component of advisories and public communication. Characterisation of the rupture extent is especially valuable, as it strongly controls ground motion estimates, or, in offshore settings, tsunami forecasts. The Finite-fault Rupture Detector (FinDer) is designed to rapidly estimate the location, extent and orientation of the earthquake fault rupture by matching spatial distributions of high-frequency seismic amplitudes with pre-computed templates. Originally developed for earthquake early warning (EEW), it is part of the ShakeAlert system for the west coast of the US. It is also running real-time in Central America and Switzerland and has been run offline in central Italy, Japan, and China, and at global scale using EMSC felt reports. Under a large public initiative to better prepare for and respond to natural disasters (https://www.rcet.science), FinDer is now being implemented in New Zealand both as a real-time (utilizing SeisComP) and offline tool for rapid characterisation. Here we report status and performance. We have modified configurations for the New Zealand setting, including creating new template sets. We carry out a range of offline tests using historic and synthetic earthquake sources, allowing us to systematically evaluate FinDer behaviour. We will also present results from the real-time system. We analyse rupture parameter recovery as well as resultant ground motion estimates, providing performance data that can guide real-time usage and interpretation.

ORAL
Session 3c.

Discovering eruption precursors and identifying fluid release events from correlations of feature time series engineered from seismic records: Applications to Whakaari and Ruapehu volcanoes

Alberto Ardid[1], David Dempsey[1], Corentin Caudron[4], Craig Miller[3], Ben Kennedy[1], and Shane Cronin[2]

[1] University of Canterbury, New Zealand
[2] University of Auckland, New Zealand
[3] GNS Science, New Zealand
[4] Free University of Brussels, Belgium

alberto.ardid@canterbury.ac.nz

Understanding eruption precursors help interpretations of sub-surface volcanic activity, and forecasting sudden and explosive eruptions, a task that has proved exceptionally challenging due to the lack of recognizable common precursors. We developed an approach that seeks to track fluid migrations and permeability changes in volcanic conduits by exploring seismic precursors in phreatic eruptions in New Zealand volcanos Whakaari (2011-2021) and Ruapehu (2004-2021). The research addressed critical gaps in eruption triggering and risk assessment by understanding volcano dynamics and instability in magma-hydrothermal systems.

We analysed seismic data prior to numerous eruptions in New Zealand, and by a correlation analysis of time series features engineered from seismic data, we located patterns in the signals that anticipated eruptions. Numerous short-term seismic eruption precursors were found that recurred in the weeks prior to eruptions at several volcanoes. Some of the precursors found helped us to construct a data-constraint timeline of the 2019 Whakaari eruption, where we identified how vent permeability changes promoted pressurization and created the conditions for the phreatic explosion (Ardid et al., 2022, https://doi.org/10.1038/s41467-022-29681-y).

In addition, we analysed Ruapehu seismic data along with crater lake temperature and level data. We seek to improve volcanic event catalogues by locating signatures of rapid hydrothermal seal consolidations. Events are located temporally within the seismic record using an empirical model of sealing/pressurization/eruption proposed from the 2019 Whakaari eruption. Our observations are consistent with a conceptual model of pressure cycling in an edifice below the active crater lake. Shallow mineralogical sealing of the hydrothermal system by a range of physio-chemical hydrothermal processes causes pressure to build if rising magmatic fluids are trapped. Seal formation is sometimes followed by abrupt seal disruption, and depressurization of the edifice though a sudden hydrothermal-fluid release event.

ORAL
Session 4a.

A low cost semi-autonomous aquatic rover for low pH, high temperature geothermal and volcanic waterways

Cameron Asher[1]

[1] *GNS Science, Taupo, New Zealand*

c.asher@gns.cri.nz

With increasing focus on risk mitigation in volcanic and geothermal monitoring, innovative techniques and equipment to change the way we conduct field work are strongly desired. One aspect that has ample room for improvement is work on and around volcanic and geothermal lakes These pose a risk due to their high temperatures, acidic waters, and potential for eruptive activity. Typical field activities around these bodies of water are conducted in-person and focused at the water-edge or, in some cases, in small occupied boats.

This study develops a semi-autonomous aquatic rover, primarily designed for bathymetry mapping, but scalable for other scientific monitoring equipment, such as water sampling and gas measurements. The rover is required to be low cost, rapidly and remotely deployable, easily replaceable, and ultimately reduce risk to field staff by reducing exposure. Case studies of field applications are presented, showing reproducibility of results, simplicity of surveys, and quantification of risk reduction to field staff.

POSTER
Session 4b.

Environmental conditions of the West Antarctic Ice Sheet during the Miocene: insights from organic biomarker distributions.

Linda Balfoort[1,2], Gavin Dunbar[1], Sebastian Naeher[3], Huw Horgan[1]

[1]*Antarctic Research Centre, Victoria University of Wellington, Wellington, New Zealand.*
[2]*School of Geography, Environment and Earth Sciences, Victoria University of Wellington, New Zealand.*
[3]*GNS Science, Lower Hutt, Wellington, New Zealand.*

Linda.balfoort@vuw.ac.nz

The West Antarctic Ice Sheet (WAIS) is thought to be particularly vulnerable to collapse with sustained atmospheric and oceanic warming. Its past sensitivity to periods of enhanced warmth can inform us about how it may respond to future warming. During the 2021/22 field season a hot-water access hole was melted through the Ross Ice Shelf (RIS) which enabled the collection of several short (< 0.6 m) gravity cores from a channel underneath the Kamb Ice Stream Site 2 (KIS-2; -152.2919; -82.4705), ~5 km landwards of the grounding line in the southeast quadrant of the RIS. The cores contain a series of decimetre-thick graded beds that contain common reworked Miocene diatoms. These graded beds are consistent with the occurrence of episodic high-velocity flow events down the KIS channel from the interior of WAIS.

Organic biomarker distributions from core sediments are dominated by phytoplankton biomarkers. Some are specifically derived from diatoms, in particular dinosterol and its derivatives. A contribution from terrestrial plants is possibly indicated by abundant high-molecular weight *n*-alkanes and C_{29} sterols. Comparing biomarker distributions with Miocene diatom occurrence reveals organic matter preservation is poorest and *n*-alkane abundance greatest at the base of the core where there are common reworked diatoms. In contrast, surface samples are dominated by intact sterol distributions and high phytol abundance which indicate a higher degree of organic matter preservation. Biomarker distributions from other locations around the Ross Sea; KIS-1 (~50 km south of KIS-2) and Coulman High (~ 60 km east of Ross Island) show similar 'mixed' signatures of contemporary and reworked organic material.

A seaway between RIS and the Ronne Ice Shelf was present during the Miocene. The presence of terrestrial plant indicators is consistent with forested islands within this seaway. Palynological studies will further refine the environmental conditions of West Antarctica during this time.

ORAL
Session 4d.

Student surveys inform digital device practices in field teaching

Dona Banerjee[1], Tim Stahl[1], Heather Purdie[1], Sam Hampton[1,3,4], Kate Pedley[1], Ben Kennedy[1], Jonathan Davidson[1], Erik Brogt[2]

[1] *School of Earth and Environment, University of Canterbury, New Zealand*
[2] *Academic Development, University of Canterbury, New Zealand*
[3] *Frontiers Abroad, Christchurch, New Zealand*
[4] *VolcanicKED, Christchurch, New Zealand*

A substantial rise in the use of digital devices has been observed over the past two decades across all disciplines in tertiary education. Relatively few studies have documented the many variables that influence student experience and perceptions of learning in field settings. We surveyed c. 100 students and staff using devices in one-day, multi-day, and research-based field trip courses at the University of Canterbury over two years. Pre- and post-trip questionnaires, as well as thematic analysis of open-ended responses, were evaluated to determine (i) differences between trip setting and duration, (ii) advantages and disadvantages of Bring-Your-Own-Device (BYOD) vs. We-Bring-A-Device (WeBAD), and (iii) how students perceived the devices assisted their navigation and communication skills. In general, students on multi-day and research trips found devices more useful than on one-day trips, particularly when the use of the device was specific and its role clearly distinguished from that of traditional methods for navigation and data collection. Students variably preferred BYOD (for familiarity and ownership of data) or WeBAD (for memory, durability, and overall performance). Based on our data, digital device use in the field can be best adapted to two end-member scenarios: basic GPS and geotagged photos as a supplement to traditional field mapping, and custom data collection (e.g., for research projects). We developed a teaching framework that outlines best practices when incorporating devices in field-based geoscience courses and provide a case study of how we used the framework to facilitate a self-guided field trip during COVID restrictions in Christchurch. The work adds to a growing body of evidence that technology can be useful in education so long as educators carefully consider pedagogy and put evidence-informed practice ahead of novelty (e.g., Sutcliffe, 2021).

POSTER
Session 3b.

Newly identified tuffs from the early - mid Permian southern Sydney Basin: explosive volcanism and associated ecological mortality derived from northwest Zealandia.

Glen Bann[1], Brian Jones[1] and Ian Graham[2]

[1] *School of Earth, Atmospheric and Life Sciences, University of Wollongong, Wollongong, NSW, 2522, Australia*
[2] *School of Biology, Earth and Environmental Sciences, University of NSW, Kensington, NSW, Australia*

The Sydney Basin forms the most southern exposed area of the Permo-Triassic East Australian Rift System which extended along the eastern margin of Gondwana. A suite of newly identified mafic and felsic tuffs are described from all formations from the early – mid Permian Shoalhaven and Talaterang Groups of the southern Sydney Basin.

The mafic tuffs commonly comprise abundant biotite and muscovite grains, which are often deformed, K feldspar, plagioclase, volcanic quartz, with embayments, quartz shards, and zircons. The felsic tuffs contain abundant volcanic and metamorphic quartz, plagioclase, more common pumiceous material, less micas, and rare or absent, shards. Trachytic microclasts and rhyolitic material are common in both tuff types, as is carbonaceous material. Most are commonly reworked, although a lack of abrasion on the phenocrysts particularly in the mafic tuffs suggests a proximal source. Many tuffs are associated with bioturbation and marine body fossils, including death assemblages of many animal types of various life stages. Numerous dropstones of the same tuff material, in addition to dacite and rhyolite clasts and large granitic dropstones are common throughout the sequence, with volcanic clasts usually dominating in the east and metamorphic cratonic clasts in the west. The presence of *Cruziana* ichnogenera and glendonites throughout the succession, in addition to wavy contact surfaces beneath coarser sands and clasts suggest deposition was dominated by episodic storm activity in cold climate marine conditions with periodic coastal ice sheets depositing the clasts, or dropstones. Crossbedding in the sandstone units indicate a predominantly northerly palaeocurrent direction.

The felsic tuffs likely represent small or distal components of much larger volcaniclastic aprons surrounding vents to the southeast, within the northwest Zealandia craton, possibly associated with the Western Eastern Province Terranes, such as the Brook Street Terrane, or the more felsic Median Batholith and associated volcanism, or, is yet to be discovered. The source for the mafic tuffs is more proximal, from island volcanoes to the south and east of the exposed Sydney Basin. Detritus from these volcanoes periodically inundated the cratonic sediments predominantly derived from the west.

Volcanism was therefore influencing the earliest stages of the evolution of the southern Sydney Basin and the ecosystems, much earlier than previously recognized.

ORAL
Session 1a.

The climatic and environmental impacts of New Zealand supereruptions

Simon Barker[1], Stephen Piva[1], Holly Winton[1], Alex Mattin[1], Hannah Grachen[1], Nels Iverson[2], Colin Wilson[1], Rewi Newnham[1], Lionel Carter[1], Alexa Van Eaton[3], Larry Mastin[3], Matthew Ryan[4], Katherine Holt[5], Michael Sigl[6] and Kirstin Kruger[7]

[1] *Victoria University of Wellington, Wellington, New Zealand*
[2] *New Mexico Institute of Mining and Technology, Socorro, New Mexico, USA*
[3] *Cascades Volcano Observatory, United States Geological Survey, Vancouver, Washington, USA*
[4] *PDP Wellington, New Zealand*
[5] *Massey University, Palmerston North, New Zealand*
[6] *University of Bern, Bern, Switzerland*
[7] *University of Oslo, Norway*

simon.barker@vuw.ac.nz

Rapid changes in Earth's climate have been documented after historic explosive volcanic eruptions. However, the magnitude of explosive eruptions in the geological record far exceeds those witnessed in modern history, by up to one hundred times. Through simply scaling the measured impacts of historic volcanic eruptions, it has been proposed that high-magnitude volcanic "supereruptions" may have caused major shifts in Earth's past climate and severely impacted the environment. We are investigating three NZ supereruptions that spread ash across most of NZ and are exceptionally well preserved in several high-resolution palaeoenvironmental records including marine cores, terrestrial sediment and lake records and Antarctic ice cores: the 25.5 ka Oruanui (1150 km^3 ash), 350 ka Whakamaru (~3000 km^3 ash) and ~1 Ma Kidnappers (~2000 km^3 ash) supereruptions. Using multiple climate and environmental proxies in these records this Marsden-funded research will assess the impact of past NZ supereruptions across a range of climate conditions and geographical scales. First, we will model ash plumes and deposition from past supereruptions to assess eruptive conditions and the total release of volatiles. Second, we will investigate regional impacts on NZ vegetation and landscapes by looking at mm-scale changes in pollen records from lakes and bogs around NZ. Third, we will assess multiple Antarctic ice cores records that preserve vital insights into the climactic impacts of a supereruption over short, medium and long time intervals. In this presentation we will highlight our novel methodologies, preliminary findings and future research.

POSTER
Session 1a.

Compactive deformation of incoming calcareous pelagic sediments, northern Hikurangi subduction margin, New Zealand: Implications for subduction processes.

Philip Barnes[1], Maomao Wang[2], Julia Morgan[3], Rebecca Bell[4], Gregory Moore[5], Min Wang[2], Åke Fagereng[6], Heather Savage[7], Davide Gamboa[8, 9], Robert Harris[10], Stuart Henrys[11], Joshu Mountjoy[1], Anne Trehu[10], Demian Saffer[12], Laura Wallace[11,12], and Katerina Petronotis[13]

[1]National Institute of Water and Atmospheric Research (NIWA), New Zealand.
[2]College of Oceanography, Hohai University, Nanjing, Jiangsu, China.
[3]Department of Earth Science, Rice University, Houston, USA.
[4]Department of Earth Science & Engineering, Imperial College London, UK.
[5]Department of Earth Sciences, University of Hawaii, USA.
[6]School of Earth and Ocean Sciences, Cardiff University, UK.
[7]Department of Earth and Planetary Sciences, University of California, Santa Cruz,USA.
[8]Instituto Português do Mar e da Atmosfera, I.P. (IPMA), Lisboa, Portugal.
[9]Instituto Dom Luiz (IDL), Faculty of Sciences, University of Lisbon, Portugal.
[10]College of Earth, Ocean and Atmospheric Sciences, Oregon State University, USA.
[11]GNS Science, Lower Hutt, New Zealand.
[12]University of Texas Institute for Geophysics, Austin, USA.
[13]International Ocean Discovery Program, Texas A&M University, USA.

philip.barnes@niwa.co.nz

Calcareous rocks are commonly found in subduction zones, but few studies have investigated the consolidation and compactive deformation of these rocks prior to subduction, and their potential effects on subduction and accretionary processes are poorly understood. Using 2D and 3D seismic reflection data together with drilling data obtained during International Ocean Discovery Program (IODP) Expeditions 372 and 375, we evaluate the structure, growth history, and slip rates of polygonal faults identified in the incoming pelagic sedimentary sequences of the Hikurangi Margin. Such faults have rarely been documented at subduction margins. These faults are layer-bound within sequences dominated by pelagic carbonate and calcareous mudstone of Paleocene-Pliocene age. Kinematic modelling and 2D displacement analysis reveal that fault throws decrease toward the upper and lower tipline, and two groups of throw profiles are recognised that possibly reflect lateral variations in physical properties. The polygonal fault system (PFS) likely formed by syneresis processes that involve diagenetically induced shear failure and volumetric contraction of the pelagic unit in association with dewatering. Fault growth sequences reveal multiple, weakly correlated intervals of contemporaneous seafloor deformation and sedimentation and allow estimates of fault slip rates. We find evidence for a significant increase in typical slip rates from 0.5-3 m/Ma during pelagic sedimentation to > 20 m/Ma following the onset of trench-floor terrigenous sedimentation. These observations suggest that rapid loading of the incoming pelagic sediments by the trench-wedge facies was associated with renewed and faster growth of the polygonal faults. These faults will eventually be transported into the base of the accretionary wedge, enhancing geometric roughness and heterogeneity of materials along the outer megathrust. They may also provide inherited zones of weakness in the lower frontal wedge which upon selective reactivation may facilitate deformation and episodic vertical fluid migration in associated with microearthquakes, tremor, and slow slip events.

POSTER
Session 1d.

The Zealandia Switch – Hypothesising the Southern Hemisphere in the driving seat of global climate

David Barrell[1]

[1] GNS Science, Dunedin, New Zealand.

d.barrell@gns.cri.nz

Rhythmic alignment of Quaternary-age glacial cycles and Earth's orbital variation pattern points to orbital control of climate, but the linking operational mechanisms are less clear cut. Vast bodies of terrestrial and marine proxy paleoclimate data demonstrate global synchrony of glacial cycle climate shifts, despite opposing orbital forcing parameters in the Northern and Southern hemispheres. The Milankovitch model invokes orbitally-controlled extents of Northern Hemisphere continental ice sheets via summer solar radiation intensity, and synchronous globalization of the climatic signature through oceanic/atmospheric processes. An alternative view emphasizes orbital controls affecting the highly energetic atmospheric and oceanic circulation systems of the Southern Hemisphere. The Zealandia Switch hypothesis posits that the Zealandia continental massif was a key factor in the interplay of exchange between tropical and polar water masses, linked to latitudinal positions of the austral westerly winds (Denton et al. 2021).

An often-overlooked observation is that ice-age millennial-scale climate patterns had global uniformity ~50% of the time, interspersed with climatic episodes apparently anti-phased between the hemispheres and described as a bipolar seesaw. Denton et al. (2022) hypothesize that the apparently anti-phased episodes occurred under globally synchronous climatic conditions, with each episode initiated by an interhemispheric shift to warmer-than-usual summers. Dubbed 'Heinrich' summers, enhanced seasonal melt of northern continental ice sheets formed meltwater floods into the North Atlantic Ocean, resulting in unusually extensive winter sea ice that created an extreme seasonality in adjacent regions, with mild summers but ultra-cold winters. A southern driver is suggested for orbital-scale as well as millennial-scale ice-age climate shifts.

POSTER
Session 2c.

Urban Geological Mapping at GNS Science

David Barrell[1] **and Julie Lee**[2]

[1] *GNS Science, Dunedin, New Zealand.*
[2] *GNS Science, Lower Hutt, New Zealand.*

d.barrell@gns.cri.nz

GNS Science's Urban Geological Mapping project, supported through the Government's Strategic Science Investment Fund, is compiling geoscientific datasets for selected New Zealand urban centres. These datasets provide foundational information on the geological materials and structure of the target areas, geared towards practitioners in geotechnics, hazard assessment and risk reduction, and sustainable resource utilization, development and planning. Various factors are considered for selecting target areas. These include where there is a need for improved geological maps, where there are notable geological or geotechnical issues or where significant urban expansion is in progress or planned. Current target areas are Dunedin, Napier-Hastings, Auckland, and Queenstown.

The urban geology data products are tailored to the nature of each urban area, for example Queenstown's setting in a glacier-scoured basin in schist terrain compared to Auckland's highly varied Mesozoic-Cenozoic geology with capping Quaternary volcanics. Typical component datasets are a geological map, a geomorphological map, and representations of the subsurface geology in the form of cross sections, structural contours and/or digital 3D geological models. Available borehole data are compiled to assist in geological interpretation and subsurface modelling. Explanatory texts accompany these datasets. The data products are published as part of the GNS Science Geological Map series in digital-only formats that can be accessed from GNS Science servers or downloaded from the GNS Science website,

The data products will be completed and issued for each urban area, and any future updates will be done as a date-versioned new edition.

Rather than focusing on detailed geological maps at a specific scale, the project aims to provide a geological, stratigraphic and geomorphological framework for each urban area and convey 2D, 3D and 4D understanding of the geology. This is intended to give the products greater utility, and we hope longevity, in providing bigger-picture geological context for more detailed, site-specific, investigations.

POSTER
Session 4c.

Total magnetic intensity grid of the upper North Island, New Zealand

<u>Jenny Barretto</u>[1] and Fabio Caratori Tontini[2]

[1] GNS Science, 1 Fairway Drive, Avalon 5010, Lower Hutt, New Zealand
[2] Department of Earth Sciences, Environment and Life (DISTAV), University of Genova, viale Bendetto XV 5, 16132 Genova, Italy

J.Barretto@gns.cri.nz

The first integrated total magnetic intensity (TMI) grid of the upper North Island with 100 m cell size has been produced using a semi-automated procedure in Oasis montaj that merges processed airborne and shipborne magnetic data. It has been published early this year together with a master database in a publicly available GNS Science report (https://shop.gns.cri.nz/sr_2021-47-pdf/). Three regional datasets over North Island make up a regional drape grid to which 37 survey datasets have been merged. All magnetic datasets are stored in the master database.

The integrated TMI grid and master database can be updated as new magnetic data become available by following the steps outlined in the report. The processing steps are divided into groups that address discrete actions, enabling only relevant subsets of the processing sequence to be run when grid updates are made. The resulting TMI grid and master database can be exported into other formats and projections for use in other software packages. The processing sequence can be applied to create magnetic grids from any geographic area and is also adaptable for other potential field datasets.

The Geothermal Next Generation programme will use the integrated TMI grid to model for the Curie point depth in the Taupo Volcanic Zone. Work is also underway to produce an integrated TMI grid of Zealandia.

POSTER
Session 4c.

Magma flux is primary control on distribution of stored magma along the slow-spreading Reykjanes Ridge

R. J. M. Baxter[1,2] and J. C. Maclennan[2]

[1] Department of Geology, University of Otago, Dunedin, New Zealand
[2] Department of Earth Sciences, University of Cambridge, Cambridge, UK,

rjmb3@cam.ac.uk

Mid-ocean ridge (MOR) systems are the largest magmatic systems on Earth, extending over 56,000 km across the globe and producing more than 2/3 of the annual volcanic output. The balance between their spreading rate, crustal thickness and distribution of stored magma influences key characteristics such as thermal gradient and structure. Previous models of magma storage along mid-ocean ridges rely on spreading rate variations as the control. The Reykjanes Ridge (RR), a slow-spreading portion of the Mid Atlantic Ridge, has a nearly consistent spreading rate but substantially variable crustal thickness, which indicates variable magma supply despite consistent spreading rates.

Using PyOPAM, an open-source Python script written to carry out Olivine-Plagioclase-Augite-Melt (OPAM) geothermobarometry, samples between 64 N and 52.5 N and 21 W to 35.5 W are investigated and compared with calculated magma flux to assess the role of magma flux on storage depths along mid-ocean ridges.

Storage depths vary, decreasing overall southwards while magma temperature increases, along the RR despite negligible changes in the spreading rate of this ultra-slow MOR segment. The north RR has a median OPAM pressure of 3.66 kbar, and estimated magma flux of 8.82 x 10^{-6} $km^3/km^2/yr$. The southern RR has a median storage pressure of 4.8 kbar, and magma flux of 4.58 x 10^{-6} $km^3/km^2/yr$. South of the RR, the Charlie-Gibbs Fracture Zone has a median OPAM estimate of 6.32 kbar and magma flux of 2.71 x 10^{-6} $km^3/km^2/yr$. This challenges the classical concept that magma storage depths are controlled by spreading rates at mid-ocean ridges, instead indicating that magma storage depths are a function of the magma flux. Increasing magma flux drives the shallowing of final magma storage depths and decreasing magma flux increases magma storage depths.

POSTER
Session 1b.

Magma-flux regulated final depths of magma storage under Iceland

R. J. M. Baxter[1,2], J. C. Maclennan[2], D. Neave[3], T. Thordarson[4]

[1] Department of Geology, University of Otago, Dunedin, New Zealand,
[2] Department of Earth Sciences, University of Cambridge, Cambridge, UK,
[3] Department of Earth Sciences, University of Manchester, Manchester, UK,
[4] Institute of Earth Sciences, University of Iceland, Reykjavik, Iceland,

rjmb3@cam.ac.uk

An essential component of continuing to advance volcano-monitoring efforts, is to further improve understanding of volcanic system processes, architecture, and timescales for magma storage, extraction, and ascent. One important variable is constraining magma storage depths prior to imminent eruption. While some individual volcanoes have been scrutinised in detail, there is no well-consolidated understanding of magma storage-depth distribution across volcanic systems. There is some speculation of a relationship between plumbing architecture and magma-flux, but no focused effort to investigate the extent of this relationship. We investigate final magma storage depths across Iceland, for which suspected controls on magma-flux (spreading rates, mantle potential temperature) and resulting magma productivity are well constrained.

We created PyOPAM, an open-source software that runs in Python, to estimate final storage depths of basaltic melt. This streamlined, reinvigorated Olivine-Plagioclase-Augite-Melt barometer estimates the position of the eutectic of the melt, the depth where basaltic melt was three-phase-saturated. Using 366 experimental glass compositions compiled from literature, we calibrate this barometer and constrain 1 σ to 1.26 kbar. We apply PyOPAM to a dataset of ~13,400 compositional analyses compiled from Iceland. Of these, 3809 analyses generate robust pressure estimates, elucidating final storage depths for 23 of the 30 volcanic systems across Iceland.

Modal magma storage pressures increase with decreasing crustal thickness and spreading rates. Inversely, modal storage pressures decrease with increasing crust thickness and spreading rates, indicators of increasing magma flux. The thermal structure of the crust adds a secondary control on the depth of storage for basaltic magmas. High magma flux in cold crust results in deep storage of basaltic magma, while high magma-flux in warm crust results in shallow magma storage. This demonstrates that magma flux is the primary control of the final storage depths for basaltic magma, with some modulation by crust thermal structure.

ORAL
Session 1b.

Paleoenvironment and sediment basins in Dusky Sound, New Zealand characterised through seismic stratigraphy and sediment cores

Jackson Beagley[1], **Andrew Gorman**[1], **Chris Moy**[1] **and Gary Wilson**[1,2]

[1] *Department of Geology, University of Otago, Dunedin, New Zealand*
[2] *GNS Science, Lower Hutt, New Zealand*

jackson.beagley@postgrad.otago.ac.nz

Fjords are recognised hotspots for carbon accumulation and globally are thought to account for 11% of annual marine carbon burial. Dusky Sound in Fiordland National Park is a ~40 km long fjord containing multiple sub-basins functioning as carbon-rich sediment traps. The sediment architectures and depositional histories of these basins are poorly constrained, limiting our ability to calculate carbon stocks and assess key carbon delivery processes. Obtaining long sediment cores (>100m) from New Zealand fjord basins has been proposed to understand how climate change impacts carbon burial. A pre-requisite for this work, however, is understanding the thickness and geometry of sediment in mid- and inner-fjord basins.

Multi-channel seismic data, multibeam bathymetry and downcore measurements from 5 piston cores have been compiled from Dusky Sound. Seismic stratigraphy reveals a marine unit present in all basins, overlying a lacustrine unit. Deeper units are interpreted as marine given reflection characteristics and local uplift rates. Downcore XRF measurements highlight differences in late Holocene benthic redox conditions between basins, a finding that helps identify where the largest proportion of carbon is sequestered. Bathymetric data reveal varying amounts of subaqueous mass failures and fans in different basins, guiding selection of sites with better record integrities. Gastropod shells sampled from an abandoned marine proglacial delta were radiocarbon dated, indicating larger late glacial extent than currently understood and providing an indication of concurrent relative sea level in Fiordland.

From this work, two drill sites are suggested for obtaining carbon burial and climate records in Dusky Sound. The first is an intermittently hypoxic basin with ~140 m of sediment and evidence of several stages of glacial delta building and the second contains the thickest sediments identified at ~280 m. Records obtained will help constrain glacial extent, relative sea level and carbon burial processes into the last glacial.

ORAL
Session 2e.

Multiphase Eruption Forecasting Using Analogue Volcano, Eruption and Hazard Sets

Mark Bebbington[1], Susanna Jenkins[2] and Stuart Mead[1]

[1] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*
[2] *Earth Observatory of Singapore, Nanyang Technological University, Singapore*

m.bebbington@massey.ac.nz

Eruption forecasting consists of the where, the when: how likely is the occurrence of an eruption, and the what: the form/magnitude the eruption takes, the hazardous phenomena produced, and the sequence, timing and size of all the individual phenomena. Bebbington and Jenkins (2019, 2022) have created a multiphase model based on the chronology of distinct styles of activity within a volcanic eruption informed by 2670 eruptions from 353 volcanoes. The 6871 eruptive phases in this dataset carry 'marks' recording the occurrence, and in some cases, the number or magnitude of hazards of various types that occur in each phase. This size of this dataset enables us to use subsets of the data corresponding to different volcanic analogues, for example according to the type (e.g., stratovolcano, shield, …) and/or dominant composition (andesite, basalt, …) of the source volcano, or the VEI of an eruption. We explore how the multiphase model can be coupled with models for individual hazards such as tephra deposition, to produce a simulation model for probabilistic eruption chronology, hazards, and areas affected over a lengthy eruption sequence.

ORAL
Session 2a.

Hikurangi Margin Gas Hydrate Deposits: Might they ever have been developed as an energy resource?

Mac Beggs[1], Brett Rogers[1], Gareth Crutchley[2], and Francesco Turco[3]

[1] Elemental Group, [2]Geomar, [3]University of Otago.

mac@beggs.nz

The widespread occurrence of gas hydrate in the Hikurangi margin was first recognized in seismic reflection data 40 years ago (Katz, 1981), and the possibility that development of those resources might eventually be of economic significance has been a significant driver for subsequent research.

Early provisional estimates of gas volumes in place in Hikurangi margin deposits (eg Pecher and Henrys, 2003), although sometimes characterized as "conservative", were very large in comparison to eg discovered gas reserves in Taranaki Basin. It was however recognized that most of the Hikurangi margin gas hydrate province would probably host very low hydrate saturations, while concentrated accumulations would more likely occur in regions of focused fluid flow.

Interpretation of both high resolution (TAN1808) and industry seismic data over structures containing hydrate deposits offshore Wairarapa (Turco et al, 2021; Crutchley et al, in review) has revealed important details of the occurrence of both gas hydrate and free gas, allowing for more refined, but still very provisional, assessment of gas volumes in place. Notably, it appears that concentrated hydrate domains are mainly coincident within dipping strata beneath anticlines and, in some cases, vertical conduits that link sub-hydrate gas accumulations to sites of seabed gas seepage.

The scope for commercial production of gas from hydrate remains under investigation internationally, but numerical simulations of production through depressurization indicate low flow rates, therefore requiring unrealistically large numbers of wells to produce commercially meaningful daily volumes. However, where concentrated hydrate deposits are associated with sizeable underlying (and possibly laterally adjacent) free gas volumes, dissociation of gas hydrate could contribute to ultimate resource recovery. The work outlines the assessment of free gas, undersaturated hydrates and saturated hydrates across selected Hikurangi margin sites.

Any possibility of gas development from the Hikurangi margin province was foreclosed by the exploration ban in 2018 and the relinquishment of petroleum exploration permits then in place.

ORAL
Session 4e.

GeoNet – part of the fabric of New Zealand

Interim CEO GNS Science Peter Benfell (or their delegate)*

[1] *GNS Science, Lower Hutt, New Zealand*

Two decades ago, experts from GNS Science, Toitū Te Whenua Land Information New Zealand and Toka Tū Ake EQC came together to create GeoNet.

What started as a way to generate data for research has grown into a critical piece of national infrastructure – providing not just real-time monitoring, but backing the science response during emergencies and offering a social platform to inform and reassure New Zealanders.

The next two decades will offer many new opportunities, but how can we ensure a sustainable future for GeoNet? This talk will look at how GeoNet has grown and adapted – and how people remain at the heart of everything GeoNet does.

Lunchtime lecture

The last frontier (for now)

Dave Bennett

Most of Taranaki's onshore producing oil and gas fields are sourced fairly directly from the Eastern Foredeep Sub-Basin (EFSB), west of the Taranaki Boundary Fault. These fields have contributed significantly to NZ's energy supply over the last 40 years. Oil and gas 'shows and flows' have also been recorded in most of the exploration wells within and adjacent to the EFSB.

Deep wells such as Waihapa-1 and Toko-1 intersect the (Eocene) Mangahewa Coal Measures, allow estimates of hydrocarbon generation parameters. Deeper coals and carbonaceous shales within the Paleocene and Late Cretaceous will augment this potential.

A generation/expulsion depth can be extrapolated across the EFSB. Existing seismic mapping demonstrates that reserves in existing conventional fields represent a very minor percentage of the free hydrocarbons within the system. Play potential is present throughout the Tertiary section, in the form of structural and stratigraphic traps associated with the Taranaki Boundary Fault, as well as unconventional trapping potential. Gas discoveries in the 100+ BCF range could be achieved.

Despite these factors, the EFSB is still only lightly explored, due to the difficult terrain, which makes seismic exploration expensive and of generally poor quality. This is a deterrent for major and minor companies alike (for differing reasons).

As electricity demand grows, so does the price. The average wholesale price has tripled in the last five years. Renewables cannot meet this demand by themselves– they merely extend the life of more reliable generation sources such as hydro, geothermal, gas and coal. There is a need to find more gas for when the wind blows too much or not enough, and to restructure the electricity market to improve resilience and enable more energy efficient generation.

ORAL
Session 4e.

Testing the Validity of Shear Wave Splitting Measurements in the Presence of Scattering Using Synthetic Waveform Modelling.

Thomas Benson[1], Martha Savage[1] and Kenny Graham[2]

[1] School of Geography, Environment, and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand
[2] GNS Science, Lower Hutt, New Zealand

thomas.benson@vuw.ac.nz

Shear-wave splitting (SWS) measurements are a useful tool for studying temporal variation of seismic anisotropy, which in turn can be used as a proxy for changes in stress around volcanoes, magma movements, and eruptive activity. Seismic scattering has been identified in several cases as a source of uncertainty in SWS, whereby multiple arrivals from the scattering of seismic waves off of heterogeneous bodies can alter the SWS caused by anisotropy. Additionally, changes in the properties of seismic scatterers, or small variations in wave path can mimic or obscure temporal changes in anisotropy.

In this project we are trying to quantitatively measure the effects of scatterers and related sources of error on SWS measurements by using computer simulations of seismic wave propagation through the crust. The main objectives of this research are to determine how SWS measurements are affected by scatterers and how small differences in path or source affect measurements. Additionally, we want to determine whether we can use averaging techniques over the results from multiple stations to improving the results in the presence of scattering. We would also like to investigate how the depth of the scatterer, and P-wave conversion or reflection from topographical features impact the measurements.

The computer simulations are done using the program Specfem3D, which uses the spectral-element method to simulate seismic wave propagation. This software allows us to create synthetic waveforms with precisely controlled source mechanisms, wave paths and anisotropy. Scattering is introduced by including heterogenous bodies modelled from a large variety of sources. These synthetic seismograms are processed with the MFAST software package to generate splitting measurements for each set of seismograms. These datasets of splitting measurements are used to study how the splitting properties vary with small changes in model parameters, and to examine the effectiveness of different averaging techniques.

POSTER
Session 4a.

Volcano-tectonic interactions at the southern margin of the Okataina Volcanic Centre, Taupō Volcanic Zone

Kelvin Berryman[1], Pilar Villamor[2], Ian Nairn[3], John Begg[4], Brent V. Alloway[5], Julie Rowland[6], Julie Lee[2], and Ramon Capote[7]

[1] *Berryman Research & Consulting Ltd, Porirua 5026, New Zealand.*
[2] *GNS Science, PO Box 30-368, Lower Hutt 5040, New Zealand.*
[3] *Geological Investigations, RD5, Rotorua, New Zealand.*
[4] *J Begg Geo Ltd, West Rd, RD2 Masterton, New Zealand.*
[5] *Instituto de Geografía, Pontificia Universidad Católica de Chile, Santiago, Chile,*
[6] *School of Environment, University of Auckland, Private Bag 92019, Auckland 1142, New Zealand.*
[7] *Complutense University of Madrid, Madrid, Spain.*

Kelvin@brc.nz

The c. 15 km-long Ngapouri-Rotomahana Fault (NRF) is a major splay of the Paeroa Fault at the eastern margin of the modern Taupo Rift, the active tectonic structure embedded within the Taupo Volcanic Zone of North Island, New Zealand. The NRF and Paeroa Fault extend to the southern margin of the Okataina Volcanic Centre (OVC) and lie southwest of the Tarawera vent lineation, which is the source of approximately half of the eruptions of the OVC in the past 25 cal. ka BP. Here, we explore volcano-tectonic relationships between the OVC and the NRF and Paeroa Fault. Eight surface fault rupture episodes since 15.6 cal. ka BP are correlated across twelve trenches excavated across the two faults. Most fault rupture events are closely paired with volcanic activity, providing a first-order indication of probable causality. Three principal modes of interaction are identified. Firstly, large displacement events on the Paeroa fault, arguably immediately prior to the Mamaku and Rotoma rhyolite eruptions (~7.9 & ~9.4. cal. ka BP, respectively) and on the NRF immediately prior to the ~1314 CE Kaharoa eruption are candidates for earthquake static or dynamic stress triggers for those explosive eruptive events. Secondly, basalt dyke intrusion was also involved in the initiation of the Kaharoa eruption, so the spatial and temporal relationships between dyke intrusion, smaller displacement fault ruptures and initiation of the Kaharoa eruption appear closely connected. Thirdly, faulting events that are interpreted as co- or post-eruption may be the result of stress triggers associated with magma chamber deflation.

ORAL
Session 1e.

Inferring the roots of volcano-geothermal systems in the Rotorua and Okataina calderas with Magnetotelluric models

Ted Bertrand[1], Peter Kannberg[2], Grant Caldwell[1], Wiebke Heise[1], Steve Constable[2], Stephen Bannister[1], Geoff Kilgour[3], and Brad Scott[3]

[1] GNS Science, 1 Fairway Drive, Avalon, Lower Hutt, New Zealand
[2] Scripps Institute of Oceanography, 8800 Biological Grade, La Jolla, California, USA
[3] GNS Science, 114 Karetoto Road, RD4, Taupo, New Zealand.

t.bertrand@gns.cri.nz

A combination of 365 land and 34 lake-bottom magnetotelluric (MT) measurements at ~2 km spacing are used to investigate the structure of magmatic systems that drive high-temperature geothermal fields and volcanism in the northern part of the Taupo Volcanic Zone, New Zealand. These data encompass the Rotorua Caldera and Okataina Volcanic Centre, covering an area of 2,800 km^2, and were inverted to create an image of the 3-D electrical resistivity structure of the crust to a depth of 20 km. Below shallow layers of quaternary volcanic deposits the model is everywhere resistive in the greywacke basement, except for a singular conductive zone (~500 km^2) below ~8 km depth, and four additional conductive 'fingers' that rise towards the surface from locations around the margin of the deeper conductor. Consistent with other geophysical and geological data, this model resistivity structure is interpreted as a large magmatic system with intrusions of silicic melt ascending into the brittle crust. Using petrologic data and MT model resistivity, melt fraction estimates of these fingers supports their interpretation as magmatic intrusions with an overlying lens of exsolved hypersaline fluid. These fingers therefore mark the pathways of fluid and heat transport from the underlying magmatic system into the overlying brittle crust, localising the upward convective transport of heat that forms the geothermal fields.

While three of the conductive fingers connect directly with the Rotorua, Taheke-Tikitere and Waimangu geothermal fields, the fourth rises beneath the Haroharo Dome complex within the Okataina Volcanic Centre where 39 km^3 of silicic magma has been extruded in the last 9,000 years. These recent domes, which are electrically resistive, appear to cap and arrest this conductor at ~2 km depth, with surface geothermal activity displaced to the northeast, and along lake shorelines at the margin of the dome complex.

ORAL
Session 1e.

Abundance and isotope (^{13}C, ^{14}C) composition of Pyrogenic carbon

Michael Bird[1,2]

[1] *College of Science and Engineering, James Cook University, Cairns Qld, Australia*
[2] *Australian Research Council Centre of Excellence for Australian Biodiversity and Heritage*

michael.bird@jcu.edu.au

Pyrogenic carbon (PyC) is produced during the incomplete combustion of organic matter. It is pervasive in the environment, distributed throughout the atmosphere as well as soils, sediments and water in both the marine and terrestrial environment. PyC in the form of biochar has been suggested as a tool for terrestrial carbon sequestration and soil amelioration because a variable component of PyC is highly recalcitrant and persists for millennia. PyC is derived ultimately from plant material and therefore retains information on the vegetation that was burnt, encoded in its stable carbon isotope composition. PyC preserves well in sedimentary archives because it is relatively resistant to degradation, and microcharcoal particle counting has long been used to generate proxy records of fire incidence in the past. In some circumstances, PyC is relatively easy to isolate but in many others, PyC is very small, ancient, and dispersed in a matrix. Hydrogen pyrolysis (HyPy) is a technique that we have optimized for the quantification and isolation of PyC from a variety of matrices for determination of abundance, stable isotope composition and radiocarbon age.

Ecosystem δ13C values vary widely across the tropics as a result of changes in the balance of vegetation using C4 versus C3 photosynthesis and information on changes in ecosystem C3:C4 balance can be obtained from the development of δ13C time series from PyC in sedimentary archives. Stable isotope analysis of PyC in sedimentary archives by HyPy therefore enables the development a more nuanced understanding of the interplay between fire regime and vegetation structure/function (and climate) in the tropics, in the past. This talk will provide an introduction to HyPy as an analytical tool, present results from modern ground-truthing studies and from case studies where the technique has been used to develop proxy records of biomass burning, fire intensity and vegetation dynamics.

KEYNOTE
Session 4d.

100% of the World Ocean floor mapped by 2030 - The Nippon Foundation/GEBCO Seabed 2030 project

Jenny A. Black[1], **Kevin Mackay and Belen Baron**[2]

[1] GNS Science, Lower Hutt, Wellington, New Zealand
[2] National Institute of Water and Atmospheric Research (NIWA), Wellington, New Zealand

j.black@gns.cri.nz

The Seabed 2030 South and West Pacific Ocean Regional Data Centre (SaWPaC) has been formed to generate new high-resolution ocean floor maps of the western and southern Pacific Ocean. The centre is part of the joint The Nippon Foundation and the General Bathymetric Chart of the Oceans (GEBCO) initiative to produce a definitive map of the World Ocean floor by 2030 to empower the world to make policy decisions, use the ocean sustainability and undertake scientific research based on detailed bathymetric information of the Earth's seabed. The Nippon Foundation-GEBCO Seabed 2030 Project is formally endorsed as a Decade Action of the UN Decade of Ocean Science for Sustainable Development.

The SaWPaC Centre is based at NIWA Wellington and includes a collaborative partnership with GNS Science and Land Information New Zealand. It is responsible for the region from South America to Australia, north of latitude 50°S to 10° north of the Equator and the western part of the Northern Pacific Ocean to Russia. The region includes the world's deepest trenches and covers some of the remotest oceans where bathymetric data form existing ship tracks is spaced up to 100 km apart. The challenge for the SaWPaC will be to collate and combine all the available bathymetric data from the numerous nations that have surveyed in the region. The centre will also promote efforts to collect new data and contribute to map products generated by the Seabed 2030 global mapping project.

ORAL
Session 2e.

Co-designing research for environmental, social, and cultural benefit: Tātaihia te Paratajao o Te Wahapū – Hokianga Harbour sedimentation project

Kyle J. Bland[1], Wendy Henwood[2], Georgia R. Grant[1], Christopher D. Clowes[1], Shontelle Nahona[1,3], Callum Whitten[3], and Marcus J. Vandergoes[1]

[1] GNS Science, PO Box 30368, Lower Hutt 5040, New Zealand
[2] Te Rarawa Anga Mua, PO Box 361, Kaitaia 0441, New Zealand
[3] School of Geography, Environment and Earth Sciences, Victoria University of Wellington, PO Box 600, Wellington 6140, New Zealand

k.bland@gns.cri.nz

Hokianga-Nui-a-Kupe is an extensive natural harbour of great significance to Te Rarawa and other iwi with whakapapa connections to the area. Land-use changes are believed by many to have resulted in reduced species diversity and abundance, poor water quality, and increased siltation. Hokianga communities want to restore the mauri of their waterways utilising culturally connected, transdisciplinary science that engages with mātauranga Māori and local histories.

In partnership, GNS Science and Te Rarawa collected >20 sedimentary cores from the harbour between Rangi Point and The Narrows. Analyses included hyperspectral scanning, grainsize, mollusc, foraminifera and pollen diversity and abundance, XRF, stable isotope, and C-14 dating. Interviews with locals involved with the harbour throughout their lives provided a rich social history that complemented the coring aspects. They shared experiences and observations of developments and practices that had likely contributed to the current state of the harbour, including reclamations, plantation forestry, erosion, roading and causeways, and changing weather patterns. Fishermen also noted changes in fish stocks, species (including invasive species), and their distribution.

Palynology has provided a detailed record of past flora surrounding Hokianga Harbour, including the presence of tree species not (presently) widely distributed in the surrounding ngahere. *Pinus radiata* pollen spikes, typically ~30–40 cm below seabed, indicate a stratigraphic position of post-early 1970s. The Lowest Occurrence of a non-native invasive bivalve species, *Theo lubrica*, which arrived in Northland waters in the early to mid-1970s, provides further chronological constraints. Changes in sediment composition, stable isotopes, and diversity/abundances of mud-sensitive molluscan species reflect changes in sediment input. Study of benthic foraminifera reveals two primary faunal associations (*Ammonia* and *Ammonia-Haynesina*), representing intertidal and subtidal environments, respectively.

The project has assisted the project team and other partners in growing and implementing marae-based environmental education kaupapa to the next generation of kaitiaki, across Te Hiku.

ORAL
Session 2d.

New insights into the geology of the Pukekohe area (southern Auckland-northern Waikato)

Kyle J. Bland[1], Dougal B. Townsend[1], Matthew P Hill[1], Katie E. Jones[1], Julie M. Lee[1], Dominic P. Strogen[1], David J. A. Barrell[2], Biljana Lukovic[1], David W. Heron[1], and Luke Easterbrook-Clarke[2]

[1]*GNS Science, PO Box 30368, Lower Hutt 5040, New Zealand*
[2]*GNS Science, 764 Cumberland Street, Dunedin 9016*

k.bland@gns.cri.nz

‘Geology of the Pukekohe area’ is part of the first concerted geological mapping campaign led by GNS Science for more than a decade within the Auckland-Waikato area. Undertaken as part of the Urban Geology Mapping Project, its focus is providing detailed geological information for planning and other purposes in towns and cities where urban, business, or industrial land use is intensive and infrastructural investment substantial and likely to increase. This new 1:50,000 geological map, covering 829 km^2 between the southern shoreline of Manukau Harbour and the lower Waikato River, encompasses an area undergoing significant development and land-use pressure.

Geological mapping has been undertaken in close partnership with geomorphological mapping of the area, and in association with development of a 3D sub-surface geological model. Extensive use has been made of LiDAR surveys, as well as other digital data such as orthorectified aerial photograph mosaics and borehole databases.

The main features of this geological map include:

- A significantly more detailed depiction of the area’s geological units.
- Implementation of a revised lithostratigraphic framework for the Auckland region.
- Much-improved integration of geophysical, geomorphological and sub-surface (borehole) datasets.
- A mapped distribution of geological units that is significantly more consistent with landscape features.
- Recognition of several hundred landslides, and landslide deposits, mostly within the hill country east of the Drury Fault.
- Identification of many surface fault scarps, some of which delineate ‘active’ and ‘possibly active’ faults.
- Differentiation between landscape-mantling ‘tephra’ and constructional ‘lithic tuff’ deposits, which may form tuff rings.
- Recognition of several eruptive landscape-forming volcanic features (cones and flows).
- Recognition of more extensive landscape-mantling aeolian (dune) deposits.

POSTER
Session 2b.

Earthquakes and Coastal Cliff Retreat in New Zealand

Colin Bloom[1], Corinne Singeisen[1], Tim Stahl[1], Andy Howell[1,2], and Chris Massey[2]

[1] School of Earth and Environment, University of Canterbury, Christchurch, New Zealand
[2] GNS Science, Lower Hutt, New Zealand.

colin.bloom@pg.canterbury.ac.nz

New Zealand's coastline is susceptible to increasingly rapid erosion related to climate change induced sea level rise. To date, few forecasts have been made for coastal cliff retreat but predictive models will become increasingly important for mitigating future risk. To develop robust models for New Zealand, we must account for earthquakes which can cause geologically-instantaneous and widespread coastal cliff retreat in addition to background coastal erosion and retreat rate. Following the November 14th 2016, Mw 7.8 Kaikōura earthquake, we measured up to 19 m of coastal cliff-top retreat at Conway Flat, an 8 km stretch of coastal cliffs south of Kaikōura. These slopes are primarily composed of weak fan delta deposits. Based on repeat mapping of historical imagery, we have estimated the rate of historical retreat at Conway Flat since 1950 and the relative influence of the 2016 earthquake. On average the Kaikōura earthquake resulted in 4 m of cliff-top retreat, nearly 25% of average retreat over the last 72 years. High variability in average retreat over the historical record suggests that large events, like storms and earthquakes, disproportionately contribute to coastal retreat at Conway Flat. Retreat between 1950 and 1966 was likely the result of the 1951 Mw 5.9 Cheviot earthquake. Together, the Kaikōura and Cheviot earthquakes account for more than half of cliff-top retreat at Conway Flat since 1950. We also used digital surface models derived from aerial imagery and lidar to estimate the change in debris volume present at the base of the Conway Flat cliffs. On average, failed debris has been rapidly eroded by wave action since the Kaikōura earthquake with only 75% of debris remaining in early 2022. In areas with less frequent earthquakes, this rapid return to pre-event conditions makes it possible for failures to go unnoticed in long-term retreat rate estimates.

ORAL
Session 2d.

Fireballs Aotearoa: Establishing a network of meteor-tracking cameras around Otago and Southland

Mia Boothroyd[1], Thomas Stevenson[1], Marshall Palmer[1], Nadine Cooper[1] and James Scott[1]

[1] *Department of Geology, University of Otago, Dunedin, New Zealand*

boomi751@student.otago.ac.nz

An estimated 40,000 tons of extra-terrestrial material, primarily dust and rocks, enters Earth's atmosphere each year. A small proportion of this material is represented by meteorites, which provide insight into the formation and evolution of the Solar System. An estimated four meteorites land within the surface area of New Zealand every year; however, only nine confirmed meteorites have ever been found here.

Fireballs Aotearoa aims to recover meteorites and track meteor showers over New Zealand by establishing a network of night-sky cameras across the country. These cameras are part of the Global Meteor Network (GMN), a worldwide project aimed at observing meteors and tracking down any fallen debris. The NZ network, which is in its infancy, consists of a series of inexpensive cameras assembled at the University of Otago. Each camera is connected to a Raspberry Pi computer that records meteor paths, calculates probable radiants, makes time lapses and records still images triggered by meteors. Data are then automatically uploaded and are freely available at http://istrastream.com/rms-gmn/?country=NZ. If multiple cameras capture a low meteor, then the trajectory and possible strewn field can be estimated.

In order to improve coverage and raise the probability of finding the next meteorite, and with support from a Curious Minds Participatory Science Platform grant, we have built 20 cameras following relatively straightforward instructions on www.fireballs.nz for approximately $500 per camera. These have been deployed freely at schools and home observatories around Otago and Southland and are now capturing the night-sky from Stewart Island to Oamaru. The data are available for teachers to utilise in classrooms, the cameras providing a unique learning opportunity for students interested in Earth and Space science, and there is an associated education outreach component being developed.

POSTER
Session 3b.

The 2022 Revision of National Seismic Hazard Model (NSHM) for New Zealand: Candidate Ground-Motion Models (GMMs) and Associated Hazard Sensitivities

S.S. Bora[1], B.A. Bradley[2], E. Manea[1], M.C. Gerstenberger[1], R. Lee[2], P.J. Stafford[3], G.M. Atkinson[4], and C. Dicaprio[1]

[1] *GNS Science, Lower Hutt, New Zealand*
[2] *University of Canterbury, New Zealand*
[3] *Imperial College London, United Kingdom*
[4] *Western University Ontario, Canada*

For the 2022 revision of the national seismic hazard model (NSHM-2022), the ground-motion characterization modeling (GMCM) adopts a hybrid approach (to capture epistemic uncertainty) that involves using a multimodel and backbone ground-motion modeling framework. For active shallow crustal sources seven GMMs were considered that include four global, one New Zealand specific GMM and two New Zealand specific backbone GMMs developed within the purview of NSHM-2022. Similarly, the candidate models for subduction (interface/intraslab) sources include three recently developed global GMMs (NGA-Sub) and one New Zealand specific backbone model.

The candidate GMMs were assessed primarily by performing comparisons of median ground-motions and aleatory uncertainty owing to the limited data in the magnitude and distance range that dominate hazard in the country. Nevertheless, data driven evaluations were also carried out using the global datasets in addition to the recently compiled strong motion database for New Zealand. Moreover, for subduction GMMs, corrections were also made in the median models for backarc distance scaling and in the aleatory sigma model for soil non-linear effects. We demonstrate the impact of updated GMCM on the hazard calculations: 1) by showing comparisons with respect to 2010-GMCM and 2) relative sensitivity of different GMMs and parameter choices corresponding to different source types. Final weights on different models were decided after an expert elicitation workshop.

ORAL
Special Symposium

Tsunami in Tonga from the January 2022 eruption of Hunga Volcano

Jose C. Borrero[1,2], Shane Cronin[3], Folauhola Helina Latu'ila[4], Pupunu Tukuafu[4], Nikolasi Heni[4], Ana Maea Tupou[4], Taaniela Kula[4], Ofa Fa'anunu[5], Cyprien Bosserelle[6], Patrick Lynett[2], Laura Kong[7]

[1]eCoast, Raglan [2]USC Tsunami Research Centre, [3]Univ. of Auckland, [4]Tonga Geological Services, [5]Tonga Meteorological Service, [6]NIWA, [7]International Tsunami Information Centre

jose@ecoast.co.nz

On January 15th, 2022, Hunga volcano 65 km northwest of Tongatapu, violently erupted generating a significant local and global tsunami. The Kingdom of Tonga lies astride a large and tsunamigenic subduction zone, but it has relatively few formally recorded significant tsunami. Between March and June 2022, a field team quantified tsunami runup and inundation on the main populated islands along with several smaller islands to the north. Peak tsunami heights were ~19 m in western Tongatapu and ~20 m on south-eastern Nomuka Iki island, located ~65 km SE and NE from Hunga volcano, respectively. In western Tongatapu, the largest tsunami surge overtopped a 13-15 m-high ridge along the narrow Hihifo peninsula in several locations. Analysis of tide gauge records from Nukualofa, suggest that initial tsunami surges were generated prior to the largest volcanic explosions. Further waves were generated by ~0426 UTC explosions that were accompanied by air-pressure waves. The largest tsunami wave that toppled a weather station on a 13 m-high ridge on western Tongatapu soon after 0500 UTC. The origin of this wave is currently uncertain. Smaller later tsunami continued until ~0900, coincident with a second energetic phase of eruption, and noted by eyewitnesses on Tungua and Mango Islands. Despite an extreme level of destruction caused by this tsunami the death toll was extraordinarily low (3 victims). Interviews with witnesses and analysis of videos posted on social media suggest that this can be attributed to the arrival of smaller 'pre tsunami' waves that prompted evacuations, as well as continuous tsunami education and awareness efforts in Tonga and globally. This event highlights an unexpectedly great hazard from volcanic tsunami worldwide, which in Tonga's case overprints an already extreme level of tectonic tsunami hazard. Education efforts should continue and stories of survival from this event can be used as teaching tools.

ORAL
Session 2a.

3D image of seismic attenuation along the central Alpine Fault, New Zealand, from dense temporary seismic array data

Sandra Bourguignon[1], Donna Eberhart-Phillips[1] and Stephen Bannister[1]

[1] *GNS Science, Lower Hutt, New Zealand*

s.bourguignon@gns.cri.nz

Microearthquake studies of the central Alpine Fault have shown there is little seismicity within 10-30 km of the fault trace, and abundant seismicity and a particularly shallow base to the seismogenic zone (6-8 km depth) beneath the Southern Alps Main Divide. Imaging seismic rock properties, such as Q (1/seismic attenuation), can help gain insight into the factors, lithologic, structural or environmental, influencing present seismicity rate and cutoff depth late in the Alpine Fault seismic cycle. Understanding these factors will inform simulations of earthquake rupture and modelling of deformation.

We developed 3D Qp and Qs models for the central Alpine Fault. To do so, we measured t*P and t*S values using the seismic waveforms and earthquake catalogues from GeoNet and 2008-2013 microearthquake studies (ALFA08/09, SAMBA, WIZARD) focussed on the central Alpine Fault. We supplemented these new t* values with t*P and t*S from past regional South Island studies. We inverted the t* measurements from 1338 and 1013 earthquakes for Qp and QS, respectively. Our solutions are best resolved between Hokitika and Franz Josef.

The Alpine Fault trace is clearly associated with low Q. South of the Waitaha Valley and below the region of enhanced seismicity is a 5-20km deep zone with high Q. Below 20 km depth, the crustal root of the Southern Alps crustal root has low Q, that likely reflects the presence of metamorphic fluids.

ORAL
Session 1d.

A Portal for Geoscience Webmaps and Information on the Te Riu-a-māui / Zealandia Region

Andrew Boyes[1], Jenny Black[1] and Phil Scadden[1]

[1]*Geospatial Data & Analysis, GNS Science, Lower Hutt, New Zealand.*

a.boyes@gns.cri.nz

E Tūhura - Explore Zealandia (TEZ) is a web portal which gives geoscientists and the public access to maps, graphics, and other information on Te Riu-a-Māui / Zealandia - the 5 million square kilometre continent on which New Zealand sits.

In June 2020 GNS Science launched two new map posters that provided fresh insights into Te Riu-a-Māui / Zealandia. The maps cover the bathymetry (Mortimer et al. 2020a), and the tectonic (Mortimer et al. 2020b) origins of Earth's eighth continent.

These maps are available on TEZ (https://data.gns.cri.nz/tez) as digital, zoomable, & interrogatable webmaps, incorporating the information sources from Mortimer 2020. Also available is a webmap of Geoscience data incorporating with a rich library of spatial data from GNS Science, NIWA, DOC & LINZ. New layers are added regularly as datasets become available.

The site contains web pages summarizing in plain language the discovery of the Earth's 8th continent Zealandia, an explanation on its Te Reo name Te Riu-a-Māui, & an outline of the major themes of the GNS research programme Understanding Te Riu-a-Māui / Zealandia.

We present an overview of the information & data available, and how to utilize the features of the web portal to access them. These can be applied to a wide variety of research and will be of use to anyone with an interest in Te Riu-a-Māui / Zealandia.

ORAL
Session 3b.

Investigating the lithospheric structure of New Zealand using S-to-P Receiver functions

William Buffett[1], Catherine Rychert[1], Nicholas Harmon[1] and Lisa McNeill

[1]*School of Ocean and Earth Science, University of Southampton, Southampton, United Kingdom*

w.a.buffett@soton.ac.uk

The New Zealand Subduction Zone is a unique and important location for understanding seismic phenomena. From evidence of historic megathrust events to slow slip activity and active volcanism, it can help us understand the dynamic systems of plate tectonics and natural hazards. S-to-P receiver functions provide tight constraints on lithospheric velocity discontinuities and reveal crustal structure, helped in part by a lack of susceptibility to crustal reverberations. Here, S-to-P receiver functions have been calculated using data from Geonet and IRIS-DMC to image the structure of the North Island of New Zealand. A positive velocity discontinuity interpreted as the Moho is observed at 15-25 km depth for much of the Australian Plate, with depths of 30-50 km depth for the Pacific plate, the deepest parts subduct beneath the Australian plate by Wellington. These depths agree with previous studies such as Salmon et al. (2013), where they also interpret the Moho at 20-25 km depth for most of the island. There's some inconsistency around the area of Hawke bay, where we interpret a shallower phase, this may be associated with the Slab. A negative velocity discontinuity is observed at 70 ± 7 km for the Australian plate, we interpret this as the Lithosphere-Asthenosphere boundary (LAB). The Eberhart-Phillips New Zealand Wide Velocity Model supports the interpretation of the where the slowest regions encompass the LAB. The LAB of the Pacific plate is imaged at 110 ± 10 km, with a further positive discontinuity observed immediately below at the south of the North Island, possibly associates with a melt channel. This agrees with the lithospheric thickness estimates of Stern et al. (2015), and proposed melt. The region of the melt channel in this study is also directly beneath the Manawatū slow slip events, melt buoyancy is proposed as a mechanism contributing to this correlation.

POSTER
Session 1d.

Landslides as tsunami sources in the Tasman Sea/ Te Tai-o-Rēhua

Suzanne Bull[1], Jess Hillman[1], Sally Watson[2], Malcolm Arnot[1], Lorna Strachan[3], Hannah Power[4], Kendall Mollison[4], and Paul Viskovic[1]

[1] GNS Science, Lower Hutt, New Zealand
[2] NIWA, Wellington, New Zealand.
[3] University of Auckland, Auckland, New Zealand
[4] University of Newcastle, Callahan, New South Wales, Australia

s.bull@gns.cri.nz

What can we learn by studying Aotearoa New Zealand's largest underwater landslides? Such underwater slides can generate near-shore, highly directional waves without obvious warning such as ground shaking or volcanic eruption – known as 'silent tsunami'. However, uncertainties around return rates and tsunamigenic mechanisms have largely prevented their inclusion in national tsunami hazard assessments.

This study aims to advance new physical and statistical descriptions of tsunami generated by underwater landslides using a combination of sedimentary basin analysis, marine geoscience and numerical simulations. Our approach focuses on the western margin of North Island/Te Ika-a-Maui in the Tasman Sea/Te Tai-o-Rēhua, where Aotearoa's largest-known underwater landslides (~4,000 km^3) occurred repeatedly throughout Plio-Pliestocene–Recent times (i.e., last 5 million years).

We present emerging results from this early-stage research, including new bathymetric and sub-surface geophysical data collected during two recent research voyages to the eastern Tasman. New evidence of the most recent Plio-Pleistocene event is presented, along the results of a preliminary numerical modelling study that reconstructs its dynamic evolution and tsunamigenic potential.

Large tsunamigenic underwater landslides are a rare occurrence initiated on long-term geological timescales. The results presented here highlight the need for further high-resolution modelling and more extensive data coverage to assess how ubiquitous such events were in the past, and the probability of further events in the future.

ORAL
Session 2a.

Who's using GeoTrips.org.nz? A user-based approach to optimizing web-based geoscience communication

Suzanne Bull[1], Jenny Black[1], Jeremy Houltham[1], Ben Sloboda[1] and Julian Thomson[2]

[1] GNS Science, Lower Hutt, New Zealand
[2] Out There Learning, Lower Hutt, New Zealand.

s.bull@gns.cri.nz

We present the results of a user-based study of the people and groups using GeoTrips.org.nz. GeoTrips is an award-winning, web-based catalogue of self-guided fieldtrips designed to lead the public on journeys of discovery around our beautiful landscapes and geology. Since being set up in 2015 over 400 trips have been contributed by geoscientists from all around Aotearoa-New Zealand.

Despite scientifically excellent content, the site performs relatively poorly. Google analytics show that in the 12 months prior to April 2021, GeoTrips had 22,000 visitors, and a bounce rate (i.e. user lands on the site and leaves without any actions or clicks) of 75%. Most visitors stayed on the site for less than 10 seconds and there was very little information available relating to who the key users are, and their needs, expectations, concerns, and motivations.

To understand how we can grow GeoTrips and ensure longevity of the site we undertook a user needs assessment via a user survey. The survey results along with site metrics were used to create user personas - archetypical users whose goals and characteristics represent the needs of a larger group of users. In turn the personas helped us to better understand the requirements of target users and design solutions to best satisfy users' needs.

In this poster, we present our findings: who is using GeoTrips? What does GeoTrips do well? And what does it not do so well - where are the opportunities? We explain how these results have been fed into a user-guided ‘product roadmap’ aimed at upscaling the usership, reach and impact of GeoTrips.

POSTER
Session 3b.

Deciphering the martian mantle from in-situ $^{87}Sr/^{86}Sr$ measurements on shock melted plagioclase in martian meteorites

Daniel L. Burgin[1], James M. Scott[1], Marshall C. Palmer[1] Petrus J. le Roux[2], Malcolm R. Reid[1,3], and Claudine H. Stirling[1,3]

[1] Department of Geology, University of Otago, Dunedin, New Zealand
[2] Department of Geological Sciences, University of Cape Town, South Africa
[3] Centre for Trace Element Analysis, University of Otago, Dunedin, New Zealand

danielburgin123@gmail.com

Martian rocks occur on Earth despite the lack of any return missions from Mars. These martian rocks are meteorites that have been ejected from the red planet during large-scale collisions. We have analysed the composition of 13 shergottite (igneous) martian meteorites, focusing on the chemical and isotopic compositions of shock melted plagioclase glass known as maskelynite. This glass, which forms during compression and ejection from Mars's surface, is ideal for in-situ $^{87}Sr/^{86}Sr$ analysis because it has very low Rb and low REE and, therefore, minimal interferences on $^{87}Sr/^{86}Sr$. Our sample suite shows three distinct Sr isotope groups that correspond to depleted (~0.702), intermediate (~0.712), and enriched (~0.722) compositions. The high Sr (> 130 ppm) but lack of Rb (< 3 ppm) in maskelynite ($^{87}Rb/^{86}Sr$ ratio of < 0.1) mean that the $^{87}Sr/^{86}Sr$ ratios must represent the mantle sources. The Sr isotope range is vastly wider than Earth's convecting mantle (~0.703-0.705) and confirms that the martian mantle is poorly isotopically mixed. Typically, bulk rock solution geochemistry analyses have been used to characterise the Sr isotopic composition of the martian mantle. However, most of our samples analysed for bulk rock $^{87}Sr/^{86}Sr$ by conventional solution geochemistry methods show contamination by a terrestrially-derived component and, in some cases, even after chemical leaching. Evidence for this can be seen in the infiltration of trace elements along grain boundaries and fractures but these alteration features are absent in maskelynite. Therefore, the in-situ laser ablation Sr isotope acquisition technique of maskelynite is extremely powerful because it is more rapid than conventional solution geochemistry, avoids the issue of terrestrial contamination, and provides high quality information on the martian mantle.

ORAL
Session 1b.

Defining “good” in pursuit of “better”: a collective effort to define "good" seismic data quality using New Zealand ambient noise models

Conrad Burton [1], **Sam Taylor-Offord**[1], **and Sepideh J Rastin**[1]

[1] *GNS Science, Lower Hutt, New Zealand*

c.burton@gns.cri.nz

Seismic data from Aotearoa New Zealand underpins earthquake, volcano, and tsunami monitoring as well as natural hazard risk analysis and loss modelling. Seismic data quality affects every application in these relative domains and yet little is known about whether it meets data user needs. Through a connected consultation and technical process we derived New Zealand specific data-based reference models that were guided by consultation outputs. These models took the form of individual station and network-wide ambient noise reference models like those produced by S. J. Rastin (2012) using 11 years of data from 58 NZNSN stations, the applications of which are in sensor network management and data issue characterisation – key areas for a future of smart maintenance and optimised data use. The noise models and examples of their potential uses will be presented here, ranging from detection of equipment failure and identification of underperforming or very noisy stations.

POSTER
Session 4a.

3D Visualisation model of the basement geology and caldera structure at Ōkataina Volcanic Centre

<u>Lucy Carson</u>[1], Craig Miller[1], Cécile Massiot[2], Pilar Villamor[2], Graham Leonard[2], and Samantha Alcaraz[1]

[1] GNS Science, Wairakei Research Centre, Private Bag 2000, Taupō 3352, New Zealand
[2] GNS Science, PO Box 30-368, Lower Hutt 5040, New Zealand

l.carson@gns.cri.nz

The Ōkataina Volcanic Centre (OVC) is an active, dominantly rhyolitic caldera complex in the Bay of Plenty, New Zealand. It forms the north-eastern part of Ahi Tupua – the central Taupō Volcanic Zone (TVZ), an actively rifting, NE-SW oriented caldera system overprinted by the throughgoing Taupō Rift and associated with the subduction of the Pacific Plate beneath the Australian Plate.

A simplified 3D model of the top surface of the Mesozoic greywacke basement has been created using Leapfrog Geothermal software. In the absence of drillhole data within the OVC, the depth to basement is constrained by drilling intercepts at the Kawerau Geothermal Field, and elsewhere is based on recent 3D gravity inversion modelling that provides an estimate of basement depth. The model is compatible with the active fault map and the Community Fault Model.

This is a new attempt at geological modelling of the structural architecture of the caldera complex using new geophysical data. The modelled structural network is based on a simplified interpretation of mapped NE-SW rift faults and N-S caldera collapse structures inferred from gradients in 3D gravity inversion modelling. The resulting model has an irregular rhombic grid-like network of faults and collapse structures bounding stepped fault blocks that produce the bowl-like caldera morphology.

This model is a preliminary visualization of the intra-caldera structure in the OVC, within the broader context of the TVZ rift setting. It creates a framework for further research into caldera and rift structure. The insights gained from this model will contribute to the understanding of volcanic and tectonic processes in rifted calderas worldwide, and will support the design of a potential future scientific drilling programme aiming to resolve the spatio-temporal connections between magmatic, tectonic, hydrological and microbial processes at caldera-rift intersections.

ORAL
Session 1e.

Disentangling climate and tectonic records in Plio-Pleistocene sediments in Southern Wairarapa

Jasmine Casidy[1], Cliff Atkins[1] and Michael Hannah[1]

[1] *School of Geography, Environment and Earth Science, Victoria University of Wellington, Wellington, New Zealand*

jasmine.casidy@vuw.ac.nz

Plio-Pleistocene marine sediments in the Southern Wairarapa record water depth changes related to the complex interplay of tectonics and glacio-eustatic sea level cycles (Vella and Briggs, 1971; Nowland, 2011; Hobbs, 2020). We focus on a 150 m thick sequence of coarsening upwards siltstone and limestone near Martinborough. This was deposited within the Ruataniwha seaway that existed in the Hikurangi forearc basin at the onset of cooling global climate and the transition to the Quaternary. The aim is to constrain paleowater depths, paleoenvironments and ages to better constrain the tectonic and climate signals (sea level) in the sequence.

The focus of this study is the Greycliffs Formation which stratigraphically underlies the Pukenui Limestone. The base of this limestone is marked by a pronounced increase in abundance of the cold-water scallop Psychrochlamys delicatula which is commonly used as an indicator of cold-water influx into the region. This climatic event is correlated with other basal limestones in the East Coast and Whanganui basins which are commonly used as markers for the base of the Quaternary. However, recent work has identified at least two Psychrochlamys delicatula beds within the underlying Greycliffs Formation suggesting the possibility of earlier pulses of cold-water influx and calling into question the reliability of using P. delicatula bearing limestones as stratigraphic markers.

This study utilises foraminiferal micropaleontology, macropaleontology, grainsize trends and strontium isotope dating to investigate the sequence. We have logged and sampled 10s of metres of section generating detailed measured sections and a facies scheme. Microfossil analysis has produced a faunal assemblage with 42 species and identified several biostratigraphic zones and relative water depths changes. Regular spaced shell beds occur in the upper 20m of the Greycliffs formation including three *P. delicatula* shellbeds. Future work will focus on producing a high-resolution paleo water depth record constrained by strontium dates.

POSTER
Session 2c.

Déjà vu all over again - Bola Scale Landsliding from the March 2022 Gisborne/Tairawhiti-Wairoa Storm

Murry Cave[1]

[1] *Gisborne District Council, Gisborne, New Zealand.*

murry.cave@gdc.govt.nz

The Gisborne/Tairawhiti-Wairoa region was struck by a severe storm in March 2022. The event was the result of a slow-moving heavy rain generating ex-tropical storm that passed through the region between the 21st and 30th of March. During the event, rainfall exceeding 100-year ARI levels fell over a nine-day interval. The 72-hour rainfall accumulation at Te Puia equates to an ARI of 134 years. A State of Emergency was declared on the 23rd of March and remained in force until the 30th of March.

Early in the nine-day event, flooding was concentrated around the coastal communities of Te Puia, Tokomaru Bay, Tolaga Bay and Anaura Bay but thereafter moved south impacting on the south of the Tairawhiti Region before moving into the Wairoa District. In the Gisborne Region the largest accumulations occurred on the first 3 days (21st to 23rd) while in Wairoa the rainfall peak arrived later and was overall heaviest between the 23rd and 25th of March with a secondary peak on the 28th. In Gisborne total storm rainfalls ranged from 162.5mm (East Cape) up to 684mm (Wharerata) and 614.5mm (Hikuwai). In the Wairoa District total storm rainfalls ranged from 274mm (Monarae) up to 764mm at Pukeorapa Station. These are a bit lower than Bola in 1988 which had 3-day accumulations of up to 900mm.

The extent of landsliding has been assessed using helicopter overflights, surveys along rural roads, low resolution Sentinel satellite imagery (Rosser and Ashraf 2022) and high resolution Maxar satellite imagery. This has been complemented by UAV mapping in some areas while urban aerial photogrammetry flown in February 2022 allowed for the differentiation of landslides that occurred during the November 2021 storm. Landslide densities matched or exceeded Bola landslide densities particularly in coastal hill country. As was the case after Cyclone Bola this extent of landsliding has implications on future land use which needs to be balanced with the need for sustaining the rural communities of the affected areas.

POSTER
Session 2c.

Cascading Natural Hazard Impacts on Vulnerable Communities

Murry Cave[1]

[1] Gisborne District Council, Gisborne, New Zealand.

murry.cave@gdc.govt.nz

The Gisborne/Tairawhiti region is exposed to extra-tropical storms as well as more frequent by not necessarily smaller storms driven by temperate storm systems. This paper focuses on the 5 severe storms that struck the region between June 2021 and June 2022. These occurred on the 20th June 2021, the 3rd to 7th November 2021, 7th February (Waitangi Weekend) 2022, 21st to 30th March 2022, and 12th to 14th February 2022 (Extra Tropical Cyclone Fili).

While the June 2021 storm was regional in its impact, a short intense rain cell within it passed through Tokomaru Bay resulting in a flash flood inundating low-lying homes and leaving behind extensive silt deposits. The November storm was a sustained atmospheric river with regional impacts but hit Gisborne City especially hard. A large number of landslides occurred with some isolated people with significant health issues. The Waitangi storm largely impacted East Cape and caused multiple severe landslides. Local whanau were isolated for several weeks and landslides threatened one house. The March storm as a complex event impacting wide areas. In Tokomaru several dwellings repairs were nearly complete from June 2021 and were flooded again. Families were isolated over a wide region with widespread damage to dwellings and access roads.

Such events can result in short term nationwide media interest which rapidly fades. What is often not realised is that the recovery from such events, particularly where there are cascading impacts and vulnerable communities are faced with losses and uncertainties for a long period afterwards. For a Council with a large area to cover (8,500km^2), a low ratepayer base and many low income families, managing such events and the recovery is difficult.

ORAL
Session 2a.

Arsenic zonation for mineral prospecting at Rise and Shine Shear Zone, New Zealand, using hyperspectral remote sensing

Rupsa Chakraborty[1], **Gabor Kereszturi**[1], **Reddy Pullanagari**[2], **Dave Craw**[3], **Salman Ashraf**[4] **and Patricia Durance**[5]

[1]*Geosciences, School of Agriculture and Environment, Massey University, Palmerston North, NZ*
[2]*MAF Digital Lab, School of Food and Advanced Technology, Massey University, Palmerston North, NZ*
[3]*Geology Department, University of Otago, Dunedin, NZ.*
[4]*GNS Science, Avalon, Lower Hutt, NZ*
[5] *BHP Billiton, Perth, Western Australia, Australia*

r.chakraborty@massey.ac.nz

Hyperspectral imaging (HSI) provides rich spectral information at a regional scale. Hyperspectral remote sensing measures reflected light from the Earth's surface discretized into hundreds of narrow and contiguous spectral bands. Each material has a unique reflectance profile. HSI can be used for quantitative analysis of surface composition and for classification. However, complexities such as mixed pixels, light scattering mechanisms, multi dimensionality can pose major challenges in processing and analysing the data.

Here, we present a novel method for mapping and screening for arsenic anomalies in soils along the Rise and Shine Shear Zone (RSSZ), South Island, New Zealand. The study is situated within the Otago Schist, hosting mesothermal gold mineralization within the upper green schist facies. The upper and lower green schist facies are separated by the Thomson Gorge normal fault. The study area consists of rugged terrain with sparse soil outcrops (5-70% exposure fraction), with grass/tussock vegetation cover. The study utilizes soil geochemistry data procured using pXRF for arsenic concentration of the ground training samples, along with 2m spatial resolution HSI data captured by the AisaFENIX airborne sensor. Initially we have used band selection algorithm to filter bands important to the model and relevant to geology of the area. A selection of 85 bands were then further put through Orthogonal Total Variation Component Analysis (OTVCA) to concise the information in 10 bands. OTVCA output was then classified using Random Forest (RF) classifier to map three levels of arsenic concentration in the area (<20 ppm, between 20 to 100 ppm and >100 ppm). The high arsenic concentration zones were interpreted to be related to the gold mineralization (leached from arsenopyrite). The underlying geology correlates with soil exposure, which is captured by our classification. This makes the classification analysis challenging but also shows an apparent increase in model accuracy and validates known ground points.

ORAL
Session 4b.

Geothermal: The Next Generation - Advancing the Understanding of the New Zealand's Supercritical Resources

Isabelle Chambefort[1], Craig Miller[1], Bruce Mountain[1], Brian Carey[1] and the Geothermal: The Next Generation Team[1,2,3,4,5,6,7]

[1] *GNS Science, New Zealand*
[2] *Victoria University of Wellington, New Zealand*
[3] *ETH Zurich, Switzerland*
[4] *University of Auckland, New Zealand*
[5] *Upflow, New Zealand*
[6] *Bridger Limited, New Zealand*
[7] *Traverse Environmental, New Zealand*

i.chambefort@gns.cri.nz, geothermalnextgeneration@gns.cri.nz

New Zealand is endowed with generous geothermal resources. NZ's deeper, currently untapped, supercritical geothermal resources have the potential to provide a source of renewable energy. . New Zealand's unique tectonic setting, with its active rifting arc, producing voluminous magma and outstanding heat flow, delivers exceptional opportunities for geothermal development. This New Zealand's geothermal project skills places New Zealand as a leader in geothermal energy technology. This is demonstrated since the initiation of geothermal energy utilisation over 70 years ago.

Early supercritical projects are expected to have long lead times, thus additional research and inquiry should be embarked upon now in order to ensure future supercritical geothermal developments can align with New Zealand's low carbon economy and energy sector aspirations. Sector-wide roll out of supercritical geothermal operations ideally needs to occur before 2050. Working backwards, pilot and scale up demonstration of supercritical energy production would be needed by about 2040, and thus, the first exploration wells need to be drilled by 2030 or soon after.

Started in October 2019, the *Geothermal: the Next Generation* MBIE research programme aims to resolve the critical, underpinning, geological, geochemical, and technological challenges of establishing supercritical geothermal as part of the solution for Aotearoa's carbon neutral energy future.

The research team is composed of New Zealand and overseas geophysicists, geologists, experimental geochemists, modellers, as well as, economic and Māori strategic investment advisors.

Here we present an update on the main objectives, relevance, future linkages and the initial results, three years into this challenging and strategic scientific endeavour. Aotearoa New Zealand's supercritical journey is underway.

KEYNOTE
Session 4e.

Operational template-matching for rapid aftershock analysis.

Calum J Chamberlain[1] **and Emily Warren-Smith**[2]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand.*
[2] *GNS Science, Avalon, New Zealand.*

calum.chamberlain@vuw.ac.nz

Earthquake catalogues directly following large earthquakes are often highly incomplete due to elevated rates of aftershocks and high background seismic amplitudes. Early aftershock periods, however, have the potential to provide useful information on the source dimensions of the mainshock, and on the time-varying hazard during the aftershock sequence. Hence, overcoming the methodological limitations of classical earthquake catalogues may assist earthquake response by providing more complete post-earthquake information.

Matched-filter or template-matching methods, based on cross-correlation of known earthquake waveforms with continuous data, have been shown to significantly improve the completeness of aftershock catalogues, often reducing the magnitude of completeness by one or more units, and detecting earthquakes missed by classical cataloguing methods within the “complete” part of those catalogues. Until recently, applying template-matching methods in real-time was not tractable. We have now developed efficient scalable near real-time open-source template-matching workflows, and have applied them to earthquake sequences throughout New Zealand over the last three years. In this presentation we outline the testing of our workflows, the capability of these methods to enhance aftershock catalogues in New Zealand, and the possible uses that these catalogues may have in earthquake response.

POSTER
Session 3c.

A Repeating Earthquake Catalogue for New Zealand

<u>Calum J Chamberlain</u>[1], Laura Hughes[1], Olivia D. Pita Sllim[1], John Townend[1] and Amanda M. Thomas[2]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, New Zealand.*
[2] *Department of Earth Sciences, University of Oregon, Eugene, OR, USA.*

calum.chamberlain@vuw.ac.nz

Repeating earthquakes provide a novel tool to both locate and monitor regions of faults that host creep. Because repeating earthquakes are thought to represent the repeating loading and failure of frictionally strong asperities within an otherwise creeping zone of a fault, they can be used to identify these transitional zones, and potentially monitor temporal variability in creep at high spatial resolution. The repetitive nature of repeating earthquake sources yields highly correlated waveforms over time, providing an effective means to identify repeating earthquakes. Nevertheless, accurate characterisation of whether a well-correlated event is truly repeating requires careful analysis.

In this presentation we outline the methods used to develop a repeating earthquake catalogue for New Zealand, and highlight some of the first order observations of where repeating earthquakes, and hence transitional frictional fault properties, occur in New Zealand. Initial results show high densities of repeating sources near the Southern Alpine Fault and Puysegur subduction zone, and the Taupō volcanic zone, as well as at two previously studied regions of the Hikurangi subduction margin. Detailed analysis of repeating earthquakes offshore Raukumara has highlighted repeating earthquakes concentrated at the edge of known slow-slip patches. Further focused analysis of the repeating earthquakes around Pōrangahau is presented in a related presentation by Olivia D. Pita-Sllim.

POSTER
Session 1d.

GeoNet's Shaking Layer Tool: understanding and incorporating user needs into new earthquake shaking products for Aotearoa, New Zealand.

Danielle Charlton[1], Jeremy Houltham[1], Nick Horspool[1], Tatiana Goded[1], Anna Kaiser[1], Mark Chadwick[1], Josh Groom[1] and Jose Moratalla[1]

[1]*Te Pū Ao/GNS Science, 1 Fairway Drive, Avalon, P O Box 30 368, Lower Hutt 5040, New Zealand.*

d.charlton@gns.cri.nz

The Shaking Layers Project (January 2021-June 2023) is a multidisciplinary project funded by GeoNet and RCET Endeavour Programme, providing near real-time ground shaking maps to end-users within a few minutes from an earthquake of magnitude 4 or above in New Zealand. The model combines observed ground motions from strong motion stations with ground motion models to produce spatial estimates of ground shaking for each intensity metric type.

The project is innovative as it has involved end users' perspectives and feedback from the very start. This is the first time a project is designed this way at GNS Science. Technical end users were invited to be part of a monthly panel, the public was also surveyed (over 1600 respondents), and user personas developed. This user research allowed us to create archetypal user groups (personas) that represent our key users. Which gave us clear guidance when make decision during the design process to ensure our product meets the needs of those key user groups. Further engagement is planned as the team go through the final design and public release process.

The team will present a brief overview of GeoNet's Shaking Layer Tool, further details and results from the end user collaboration and provide information to the NZ Geosciences community on how they can access Shaking Layer information through the Shaking Layer data website.

ORAL
Session 3a.

Earthquakes and Seismic Hazard in Southern New Caledonia, Southwest Pacific

Shao-Jinn Chin[1], Rupert Sutherland[1], Martha K. Savage[1], John Townend[1], Julien Collot[2], Bernard Pelletier[3], Olivier Monge[2], Finnigan Illsley-Kemp[1]

[1] School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand
[2] Service Géologique de Nouvelle-Calédonie, Nouméa, New Caledonia
[3] Géoazur (UMR 6526), IRD, Nouméa, New Caledonia

shaojinn.chin@vuw.ac.nz

We use 12 temporary and 9 permanent broadband seismometers that were operating for ~400 days from October 2018 to November 2019 to generate the first published earthquake catalogue and local magnitude function for southern New Caledonia. Local earthquakes were mostly shallower than 20 km. Hypocentres in New Hebrides-Vanuatu subduction zone are < 30 km deep west of the trench and deepen to > 100 km eastward. Our local magnitude estimates M_L for 107 earthquakes in the subduction zone are consistently 1.1 units smaller than M_w and mb over a range of M_w from 4.5 to 7.5, as determined by the USGS. Our catalogue has 460 earthquakes with $M_w \geq 3.7$ in the subduction zone and the largest event in southern New Caledonia has M_L 3.8. Seismicity rates in southern New Caledonia are low, but M_L > 5 earthquakes are 2.7 times more frequent than elsewhere in the northern Australian plate. The probability of an M_L > 5 event in 50 years is 0.6 in southern New Caledonia. Seismic shaking hazard in southern New Caledonia is dominated by local moderate-magnitude earthquakes, rather than large-magnitude subduction events. The predicted peak ground acceleration (PGA) for Nouméa at 10% probability of exceedance in 50 years is 0.08 g. Residual analysis of ground accelerations demonstrates that the hazard for Nouméa from subduction earthquakes is currently overestimated and that new regionally-specific ground motion prediction equations are needed. Our results highlight the inadequacy of current ground motion prediction equations in subduction zone footwall settings and the need for additional studies of this type of setting.

POSTER
Session 3c.

Revising the magnitudes in the New Zealand earthquake catalogue to be consistent with moment magnitude

Annemarie Christophersen[1], Sandra Bourguignon[1], David Rhoades[1], Trevor Allen[2], Chris Rollins[1], Jerome Salichon[1], John Ristau[1]

[1] *GNS Science, Lower Hutt, New Zealand*
[2] *Geoscience Australia, Canberra, Australia.*

s.bourguignon@gns.cri.nz

The current revision of the New Zealand National Seismic Hazard Model (NSHM) relies on the earthquake catalogue for the development of seismicity rate models. For consistency with the ground motion models that are calibrated to use moment magnitude MW, the magnitudes in the catalogue are ideally expressed as MW. The most commonly available magnitude in the New Zealand earthquake catalogue is a New Zealand specific local magnitude MLNZ77 that was derived in 1977. MLNZ77 – reports have been back-calculated until as early as 1931 and were routinely calculated until the introduction of the seismic processing software SeisComP3 (SC3) in 2012. Since 2012, GeoNet reports an operational rapid magnitude, called summary magnitude M, made of the weighted sum from GeoNet local magnitude-type, MLSC3 and MW(mB) network magnitudes. Regular moment tensor calculations and its derived magnitude MWNZ, were introduced in 2007, and back calculated for some earthquakes as early as 2003 when sufficient broadband stations were available. For earthquakes in the magnitude range 4 – 6, MLNZ77 and MLSC3 overestimate earthquake size compared to MWNZ. Previous studies have used the earthquakes with MWNZ -reports to derive new attenuation relations for local magnitudes, resulting in MLNZ16 and MLNZ20, the later including a depth term. In this study, we calculated MLNZ20 for around 178,000 earthquakes, from around 1 million vertical amplitude readings in the period from 2000-2011 and for around 100,000 earthquakes and again around 1 million vertical amplitude readings in the period from 2012-2020. We restricted both these datasets to ensure good quality of the data-derived regression relationships for these earthquake pairs. We applied those to the catalogue and defined a preferred magnitude. The resulting data are available as stand-alone dataset (doi: 10.21420/tap4-5s59), which is described in a GNS Science report. Here we discuss the method and summarise the key features of the dataset.

POSTER
Session 2a.

Estimating fault rupture depths in the Wellington Region: constraints from laboratory experiments, seismic relocation of earthquake depths and thermal modelling

Teik Jin Chua[1], Susan Ellis[2], Carolyn Boulton[1], Stephen Bannister[2], Donna Eberhart-Phillips[3], and André Niemeijer[4]

[1] *Victoria University, Wellington, New Zealand*
[2] *GNS Science, PO Box 30368, Lower Hutt, New Zealand*
[3] *GNS Science, Private Bag 1930, Dunedin 9054, New Zealand*
[4] *Utrecht University, Princetonlaan 8a, 3584 CB Utrecht, The Netherlands.*

s.ellis@gns.cri.nz

Understanding where earthquakes can occur is key to forecasting their maximum magnitude and source effects on ground motion. This is particularly critical in the Wellington region owing to the large projected seismic hazard and vulnerable population there. To interpret the probable depth to which faults can rupture in the upper plate, we compare measurements of frictional instability made in hydrothermal friction experiments on greywacke gouge with a relocated seismicity catalogue and thermal model of the lower North Island (along a cross-section coinciding with the Seismic Array HiKurangi Experiment (SAHKE) transect). Variability in earthquake depths and uncertainty in the vertical distribution of earthquakes above the subducting Pacific Plate were constrained using relocated earthquakes from seismicity clusters beneath Wellington and offshore Kapiti. For 15 earthquakes in the Wellington region, a point-density cloud of possible values of depth, longitude, and latitude was created to assess uncertainty in depth limits for the clusters. All well-constrained events were then plotted in earthquake-depth histograms that showed that events beneath Wellington extend down to the subducting plate interface, permitting brittle connection between upper and lower plates there. In contrast, offshore Kapiti the seismicity cutoff is ~ 5-10 km above the subducting plate. Laboratory experiments on greywacke sandstone suggest that the upper limit of unstable slip- though somewhat velocity-dependent- is at around 400-450C. Thermal models that roughly match exhumation and uplift rates, fault slip rates, surface heatflow measurements and kinematics in the Wellington region predict that the 450C isotherm intersects the subduction interface under Wellington but is ~ 5 km above it in the vicinity of the Kapiti seismic cluster. The predicted earthquake nucleation depth limits derived from seismicity cutoff depths and temperatures in thermomechanical models are roughly consistent with earthquake nucleation conditions based on greywacke friction experiments. Further improvements to our method will allow us to refine our understanding of the temperature-dependent processes that control earthquake nucleation, propagation, and arrest in New Zealand's basement rocks.

POSTER
Session 1d.

Hide and Seek: Cryptotephra Studies applied to a deep Marine core

<u>Madison Clarke</u>[1], Jenni Hopkins[1], Monica Handler[1], and Lorna Strachan[2]

[1] School of Geography Environment and Earth Science, Victoria University of Wellington, Wellington, New Zealand.
[2]School of Environment, University of Auckland, Auckland, New Zealand

madison.clarke@vuw.ac.nz

The record of volcanic activity in Aotearoa New Zealand has previously been limited to terrestrial records and macrotephra marine and lacustrine deposits. The use of cryptotephra deposits to expand the record of volcanic activity has had a high success rate in the northern hemisphere, particularly with Icelandic deposits, but its use in Aotearoa New Zealand has mostly been limited to lakes within the Auckland region.

The aim of this project is to use the International Ocean Drilling Program Site U1520 Hole D core drilled during Expedition 375 (2017) to investigate the primary vs reworked cryptotephra deposits within the upper 11 m of core. The project focuses on developing non-destructive techniques, including XRF and magnetic susceptibility data to identify cryptotephra within the deep marine sediment cores. These data were run through machine learning and statistical techniques to pinpoint sampling sites of interest within long cores to be targeted for cryptotephra investigation. Once the cryptotephra were identified, the glass shards were extracted and concentrated and, where possible, the shards were analysed for major element compositions. This permits information to be combined with the existing macroscopic tephra framework to reconstruct a more detailed record of the volcanic eruptions from the TVZ.

Here we present the initial findings from this project, including shard count profiles and geochemical data. We discuss the correlation of crypto- and macrotephra deposits within the core, and whether they represent primary or reworked deposits. We use the results to expand the current tephrochronological record.

POSTER
Session 1a

Incorporation of Recurrence Intervals and Probability of Detection in the NZ NSHM 2022 and its impact on hazard

Genevieve Coffey[1], Chris Rollins[1], Russ Van Dissen[1], Kiran Thingbaijam[1], David Rhoades[1], Matt Gerstenberger[1], and Nicola Litchfield[1]

[1] *GNS Science, Lower Hutt, New Zealand*

g.coffey@gns.cri.nz

A wealth of data about earthquake behaviour in New Zealand have been obtained through numerous paleoseismic, geologic and geodetic studies in the past fifty years. These data have been compiled in the Paleoseismic Site Database, Community Fault Model, and Geodetic Deformation Model as elements of the 2022 revision of the New Zealand National Seismic Hazard Model (NSHM).

Here we present the results of work done to incorporate paleoseismic and geodetic data into three components of the NSHM. Firstly, recurrence intervals were derived to help solve for the rates of earthquakes on faults. To do this we utilised methods employed in UCERF3 and previous work by Rhoades and Van Dissen (1994), employing a weighted combination of Brownian Passage Time, lognormal, and Poissonian recurrence distributions. Secondly, the probability of detection of surface rupturing earthquakes was calculated based on the curated earthquake catalogue produced for the 2022 NSHM to understand what subset of 'real-world' earthquakes are reflected in the paleoseismic data used to derive recurrence intervals. Finally, fault rupture rates and time since the last event were used to incorporate the conditional probability of rupture into the NSHM. This was done on faults that have slip rates ≥ 4 mm/yr, or those that have ruptured within the colonial historic period.

In addition to these results, we present and compare hazard curves to investigate the impact of time-independent and time-dependent (incorporating time since the last event) rupture rates, as well as the impact of using probability of surface rupture detection curves developed specifically for New Zealand instead of the curve developed for California in UCERF3.

ORAL
Special Symposium

Slip Rate study of the Te Puninga Fault, Hauraki Rift, New Zealand

Genevieve Coffey[1], Pilar Villamor[1] and Kate Clark[1], Joshua Hughes[2], David J. Lowe[2], Vicki Moon[2]

[1] *Department of Earth Structure and Processes, GNS Science, Lower Hutt, New Zealand*
[2] *School of Science-Te Aka Mātuatua, University of Waikato, Hamilton, New Zealand*

g.coffey@gns.cri.nz

The Hauraki Rift is a region of low historical seismicity within the back arc of the Hikurangi subduction margin. Recent acquisition of LiDAR along in the area has enabled renewed mapping of active faults in the rift, which, due to low slip rate, have subtle expression in the landscape. One of these faults, the Te Puninga Fault (TPF), was only recently identified by Persaud et al. (2016) and, beyond preliminary observations, little work has been done on the Te Puninga fault and a considerable knowledge gap exists around the seismic hazard it poses.

The TPF extends for ~30 km along the western side of the Hauraki Rift and consists of many short parallel strands. It is located within 2 km of Morrinsville and is ~30 km from Hamilton. Initial observations by Persaud et al. (2016) placed the maximum possible magnitude earthquake on the fault as Mw 6.7 or greater. As a result of this, and its proximity to population centres, it is important to accurately map and characterise the TPF. We present preliminary results of a paleoseismic investigation into the TPF that involves (1) accurately mapping the active traces of the fault using LiDAR data, (2) coupling radiocarbon dating and limited tephrochronology of deformed stratigraphy exposed in paleoseismic trenches (reported in a companion presentation by Hughes et al.) with dense topographic profiling across each strand to quantify slip rate across the fault, and (3) developing initial magnitude estimates for earthquakes along the TPF. These results serve not only to help us understand the seismic hazard of the TPF but also at the broader scale they aid in our understanding of how extension is accommodated across the North Island in a region where deformation rates are low and difficult to constrain by alternative means.

POSTER
Session 1d.

New comprehensive Pb isotopic data Elucidate novel petrogenetic processes across the Taupo Volcanic Zone

Corella Santa Cruz, Carlos R.[1]; **Stirling, Claudine H.**[2,4]; **Zellmer, Georg F.**[1]; **Straub, Susanne M.**[3]; **Brenna, Marco**[4]; **Nemeth, Karoly**[1]

[1] Volcanic Risk Solutions, Massey University, Private Bag 11222, Palmerston North 4442, New Zealand
[2] Centre for Trace Element Analysis, University of Otago, Po Box 56, Dunedin 9054, New Zealand
[3] Lamont-Doherty Earth Observatory of Columbia University, 61 Route 9W, Palisades, NY 10964, USA
[4] Department of Geology, University of Otago, Po Box 56, Dunedin 9054, New Zealand
[5] Saudi Geological Survey, Jeddah, Kingdom of Saudi Arabia
[6] Institute of Earth Physics and Space Science, Sopron, Hungary

c.santacruz@massey.ac.nz

The Taupo Volcanic Zone (TVZ) is an area of subduction zone volcanism in a rifted arc, active since 2 Ma, dominated by high-volume high-silica eruptions from large caldera-systems, and has one of the highest present-day magma production rates on Earth. Fractional crystallisation (FC) and assimilation-fractional crystallisation (AFC) have typically been modelled to account for the TVZ compositional range, utilizing the Torlesse - composite terrain greywacke crust as the main assimilant. Previous studies typically focussed on specific areas within the TVZ and only considered either basic, or intermediate, or acid magmatism. Here, we present a new and comprehensive lead isotopic dataset of the entire TVZ. The results presented here represent a spatiotemporally and compositionally comprehensive sample suite. They cover old and new volcanic products (2 Ma – Present), are distributed across the east-west and north-south extension of the TVZ and are basic through intermediate to acid in chemical composition, showing a linear lead isotopic trend. These lead isotopic compositions (based on $^{208}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$ and $^{206}Pb/^{204}Pb$ ratios) are integrated with MELTS and Magma Chamber Simulator models. Together with the strontium isotopic signatures ($^{87}Sr/^{86}Sr$ ratio), major oxide contents and trace elements concentrations at different pressures (200 MPa - 900 MPa) and low initial water contents consistent with published data (0.5 - 1.5 wt% H_2O), our findings show that FC or AFC with Torlesse greywacke crust as the assimilant cannot reasonably reproduce the observed data. Here, we will explore alternative processes, including subduction melange diapirism as one potential process to produce the intermediate to acid magmas in the TVZ.

ORAL
Session 1b.

Runout and hazard characteristics of pyroclastic density currents after encountering obstacles

Lucas Corna[1], Gert Lube[1], Ermanno Brosch[1], Jim Jones[2], Daniel Uhle[1], James Ardo[1]

[1] School of Agriculture and Environment, Massey University, Palmerston North, New Zealand
[2] School of Food and Advanced Technology, Massey University, Palmerston North, New Zealand

l.corna@massey.ac.nz

Pyroclastic Density Currents (PDCs) have the intriguing characteristics to surmount and propagate across significant topographic obstacles, potentially impacting areas that may not have been previously considered in hazard planning. We performed a series of large-scale experiments looking at the interactions of PDCs with hill-shaped obstacles of varying size and the consequences on the flow and its associated hazards up to 30 m runout.

Immediately downstream of the obstacles, we see the formation of a wake with low densities, velocities and temperatures, which dimensions increase with obstacle size, creating an unstable stratification with the hot, dense, fast-moving flow above. After the hill, the flows have lost up to c. 74 % or their initial momentum due to partial blocking of the dense underflow. The dilute turbulent overriding surge of the PDCs have also lost up to c. 50 % of their initial momentum with increasing size of the obstacles.

However, flow velocity, density and suspended particle load, as well as final runout distance and deposit characteristics are remarkably similar for all obstacle scenarios. Heat also seems to propagate with more ease downstream of large obstacles, impacting longer distances with hotter temperatures. This implies that topography and blocking have little consequences on downstream hazard impacts and that processes countering the immediate momentum loss are present. We show that obstacles create a significant drop in flow density but also allow the flows to maintain their new density contrast for longer as particles are better suspended. On another hand, internal gravity waves propagate unhindered and reach the slowing flow head more efficiently, allowing similar runouts.

POSTER
Session 1a.

H_2O and CO_2 contents of volcanic glass from the offshore TVZ – southern Havre Trough

Robert Coulter[1], **Alex Nichols**[1] **and Richard Wysoczanski**[2]

[1] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*
[2] *National Institute of Water & Atmospheric Research, Wellington, New Zealand.*

robert.coulter@pg.canterbury.ac.nz

The Taupō Volcanic Zone (TVZ) and Kermadec Arc-Havre Trough, stretching north from Te Ika-a-Māui/North Island of Aotearoa/New Zealand, are expressions of subduction-generated magmatism. A main driver of magmatism in arc settings are volatile elements, with H_2O and Co_2 being the two most abundant volatile components in arc melts. However, little to no data are available on the volatile contents of volcanic features found in the offshore TVZ – Havre Trough regions, limiting our understanding of a primary driver of melt generation in this volcanic system.

To address this knowledge gap, we have measured H_2O and CO_2 contents in glassy material from this region by Fourier-transform infrared spectroscopy. The samples analysed were collected from dredges undertaken during the 2015 TAN1315 voyage of R/V *Tangaroa*. Samples were collected from the Tūhua/Mayor Island knolls, Matatara Knoll and surroundings, and Māhina Knoll and surroundings in the offshore TVZ, in addition to a basin in the southern Havre Trough. The dredging returned an array of material, but of interest to this study was glass from pumice from the offshore TVZ and pillow lavas from the Havre Trough.

Volatile contents of erupted material may not reflect the original magmatic contents with pre- and post- eruption processes affecting the volatile concentrations. Degassing and hydration processes have the most significant impact on H_2O and CO_2. The relative concentrations of H_2O species, OH^- and molecular H_2O will be used to assess post-eruption hydration, and corrected concentrations will be used in solubility models (e.g., D-Compress) to assess degassing. These will be some of the first volatile data from these sites, enabling post-eruption and magmatic processes that affect the volatiles to be assessed.

POSTER
Session 1b.

Plutonic nature of transcrustal magmatic systems revealed by sub-micron Sr-disequilibria in plagioclase

Daniel A. Coulthard Jr.[1], Raimundo Brahm[2], Charline Lormand[3], Georg F. Zellmer[4], Naoya Sakamoto[5], Yoshiyuki Iizuka[6], Hisayoshi Yurimoto[5]

[1] *United States Geological Survey, Menlo Park, USA*
[2] *Victoria University of Wellington, Wellington, New Zealand*
[3] *Durham University, Durham, UK*
[4] *Massey University, Palmerston North, New Zealand*
[6] *Hokkaido University, Sapporo, Japan*
[6] *Academia Sinica, Taipei, Taiwan*

g.f.zellmer@massey.ac.nz

The new paradigm of transcrustal magmatic systems envisages remobilization of voluminous mush zones close to their solidus temperature with small amounts of interstitial melt. To test this paradigm, diffusion of major or trace elements across sharp compositional boundaries may be employed to obtain crystal residence times at magmatic temperatures. Plagioclase crystals are common in the wide range of magmatic composition, yet reading the chronology of their zoning archives is typically hampered by complex high-frequency zoning patterns in major oxides that determines trace element partitioning and diffusion behaviour. Here we present stacked CMOS-type active pixel sensor (SCAPS) ion microprobe images yielding submicron-resolution Sr and major element zonation in volcanic plagioclase microantecrysts from the Tongariro Volcanic Centre (TgVC), Taupo Volcanic Zone. Fourier-transform spatial frequency analysis of zoning patterns and their forward diffusion towards equilibration allows parameterization of diffusive decay of spatial frequencies and approximation of pre-eruptive initial zoning profiles. We find pre-eruptive crystal residence at magmatic temperatures of the order of days for TgVC microantecrysts. These timescales are inconsistent with long crystal residence at elevated temperatures. Thus, at the TgVC, transcrustal magmatism is characterized by ephemeral temperature spikes of small magma batches and ephemeral remobilisation of small volumes of rapidly cooled dyke rocks.

ORAL
Session 1b.

Subaqueous Geomorphology of Lake Whakatipu and Implications for Shoreline Hazards

Steph Coursey[1,2], Ian Fuller[1], Joshu Mountjoy[2], Samuel McColl[3], and Sean Fitzsimons[4]

[1] *School of Agriculture and Environment, Massey University, Palmerston North, NZ*
[2] *Ocean Geology Group, National institute of Water and Atmospheric Research, Wellington, NZ*
[3] *GNS Science – Te Pū Ao, Wellington, NZ*
[4] *Te Iho Whenua, School of Geography, University of Otago, Dunedin, NZ*

s.coursey@massey.ac.nz

Sub-lacustrine mass-movement processes have received little attention, particularly in Aotearoa, and their causes are poorly understood. Investigation of the post-glacial development of lake basins allows for the evaluation of landslide-related hazards associated with these dynamic environments. All the major natural lakes in Aotearoa's Southern Alps are associated with deep glacial trough valleys, where rapid sedimentation and infilling by active river deltas produces highly dynamic systems. High-resolution bathymetric data of Lake Wakatipu was acquired by NIWA in 2019. These data provide an opportunity to study the sub-lacustrine geomorphology, and to assess the sediment dynamics and associated hazards, of this iconic and culturally significant lake.

We have used the bathymetric data to map features along the lake floor, producing a geomorphic map of the entire lake. The mapping has revealed a dynamic environment, including a subaqueous canyon and channel in the upper end of the lake beginning at the Rees-Dart delta. Crescentic-shaped bedforms dominate the subaqueous delta and canyon, with wavelengths of up to 150 m. There is evidence for episodes of erosion along the channel represented by terrace-like features and knickpoints, and for channel avulsions. In other locations along the canyon, there is evidence of lake-floor landsliding, suggesting potential hazard and a mechanism of sediment reworking within the lake. It is likely that extensive sediment deposition is obscuring some depositional features related to subaqueous landsliding. We plan to use seismic refraction and repeat bathymetric surveys in selected locations to support our landform interpretations and further develop an understanding of the dynamics and hazards of this lake basin.

POSTER
Session 2b.

Dairy farming exposure and impacts from extreme coastal flooding and sea level rise

Heather Craig[1], Alec Wild[2], and Ryan Paulik[3]

[1] National Institute of Weather and Atmospheric Research (NIWA), 10 Kyle Street, Riccarton, Christchurch 8011, New Zealand.
[2] Aon New Zealand, 29 Customs Street West, Auckland 1010, New Zealand.
[3] National Institute of Weather and Atmospheric Research (NIWA), 301 Evans Bay Parade, Hataitai, Wellington 6021, New Zealand.

heather.craig@niwa.co.nz

This study quantifies exposure and categorises impacts to Aotearoa-New Zealand (A-NZ) dairy farms from the cumulative effects of extreme sea level (ESL) events and climate change-driven sea level rise (SLR). This assessment was undertaken by analysing the following data with the RiskScape modelling engine: 1) the AgriBase dataset to spatially identify dairy farms; 2) a static coastal inundation model of 10, 100, 200 and 500-year annual recurrence interval (ARI) ESL events at 0 m, 0.5 m, 1 m, 1.5 m and 2 m SLR increments; and 3) an impact state scheme relating percentage of farm inundated and depth of flooding at milking shed locations to categorise the severity of damage. Through this analysis we highlight the increasing vulnerability of the dairy industry to coastal inundation, with 472 farms negatively impacted (at or greater than Impact State 1) by a 10-year ARI event and 1276 farms exposed to a 500-year ARI event at current sea levels, rising to 1276 (10-year ARI) and 1344 farms (500-year ARI) with 2 m SLR. SLR is identified as the main factor driving this increase in exposure and severity of impacts to dairying, with the increase in the number of farms impacted in a 500-year compared to 10-year event only 5% greater when considered with 1 m of SLR, compared to 37% greater at 0 m SLR.

This has significant implications for A-NZ and other countries where the dairy industry is of high economic and social importance, demonstrating the need for targeted climate change adaptation and disaster risk reduction measures are increasingly required to reduce the exposure and vulnerability of dairy farms.

POSTER
Session 2d.

A "Big Boom" – a multi-perspective view of what drove the 15 January 2022 Hunga eruption, Tonga

<u>Shane Cronin</u>[1], Taaniela Kula[2], Ingrid Ukstins[1], Frank Ramos[3], Joali Paredes-Marino[1], Sung-Hyun Park[4], Marta Ribo-Gene[5], James White[6], Rachel Baxter[6], Marco Brenna[6], Alexa Van Eaton[7], Jose Borrero[8], Sam Purkis[9], Steven Ward[10], David Adams[1], Folauhola Helina Latu'ila[2], Pupunu Tukafu[2], Geoff Kilgour[11], Simon Barker[12], Larry Mastin[6], Michael Pavolonis[13], and James Garvin[14]

[1]The University of Auckland
[2]Tonga Geology Services
[3]New Mexico State University
[4]Korean Polar Research Institute
[5]Auckland University of Technology
[6]Otago University
[7]United States Geological Survey, Cascades Volcano Observatory, Vancouver, Washington, USA
[8]East Coast Lab
[9]University of Miami
[10]UC Santa Cruz
[11]GNS Science
[12]Victoria University of Wellington
[13]NOAA/NESDIS Center for Satellite Applications and Research, Advanced Satellite Products Branch, Madison, Wisconsin, USA
[14]NASA Goddard Space Flight Center, Maryland, USA

s.cronin@auckland.ac.nz

Hunga Volcano (Tonga) is a ~6 km-diameter caldera with an emergent rim and a pre-eruption shallow caldera 140-150 m below sea level. The latest eruption sequence began on 20 Dec 2021, near a vent active in 2014-15. On 14 January 2022 a >20 km-high plume formed and was followed by 18 hours of harmonic sea-level disturbance. The climactic event on 15 Jan began at 03:47 UTC and reached a peak eruption rate of ~10^9 kg/s, producing global air-pressure waves, tsunami and a >55 km-high eruption column. The bulk composition was a 56-57 wt% SiO_2 andesite. Mingled, phenocryst- and microlite-poor glass spans 50-66 wt% SiO_2 over scales of microns to millimeters. The later PDC phase was more mafic. The thin, concentric fall deposit at 65-100 km is poorly sorted and fine-grained (4-7 wt% >1 mm). Juvenile clasts are dense (>2.7 g/cm^3), with isolated and collapsed vesicles. Pumice lapilli (up to 50 mm) fell first (densities of 0.8-2.0 g/cm^3). Over 70% of fine particles show hackle lines, stepped fractures, and conchoidal fractures. Geochemical and isotopic data suggests that the eruption was triggered by immiscible magma mixing between three andesitic melts. The mixing drove intense gas pressurization of the magmatic and hydrothermal system. As the hydrothermal seal catastrophically failed, rapid decompression and fracturing led to runaway magma rise, re-activation of caldera faults and seawater infiltrating the edifice. Intense magma-water and magmatic-gas driven explosions generated tsunami at 04:15 and 04:25 UTC, with sudden caldera collapse at ~05:00 triggering the largest tsunami. The total caldera collapse during involved at least 7.1 km^3 of DRE.

ORAL
Session 2a.

Making GeoNet data more accessible for big data projects – GeoNet, the cloud and the AWS Open Data program

Elisabetta D'Anastasio[1], Josh Groom[1], Mark Chadwick[1], Callum Morris[1], Jonathan B. Hanson[1], Richard Guest[1] and the GeoNet team[1]

[1] *GNS Science Te Pū Ao, Lower Hutt, New Zealand*

e.danastasio@gns.cri.nz

GeoNet runs a geophysical infrastructure from which a diverse set of data are collected and distributed. The GeoNet Data Archive contains more than 30 years and 100 TB of raw and processed data that have substantially contributed to the understanding of Aotearoa New Zealand geodynamics and tectonic hazard. Some of those datasets have a large volume and difficulties in accessing those has hindered in the past their full exploitation. GeoNet is observing shifts in user behavior related to large data requests that standard access mechanisms were not designed to deliver.

In 2018-19, GeoNet migrated its entire archive to a cloud infrastructure based on Amazon Web Service (AWS). This enhanced the archive longevity and robustness, but a shift in how data were distributed to GeoNet users was necessary to control data distribution costs.

In 2021-22, GeoNet signed to the AWS Open Data Sponsorship Program, that covers the cost of storage and distribution for publicly available high-value cloud-optimized datasets and makes them accessible for analysis on AWS. GeoNet datasets are now available to researchers, learning institutions, and the public globally via the Registry of AWS Open Data (https://registry.opendata.aws/geonet/). The GeoNet GNSS, tsunami gauge, seismic and camera data archive are now available via standard GeoNet channels and via AWS. Other datasets will be added in time to mirror and make more accessible all the diverse range of GeoNet data.

This initiative will make geophysical data more accessible and faster to download and analyse. Researchers can now download large volumes of data directly from AWS. More significantly, researchers are now enabled to develop cloud-based data analysis with the GeoNet archive readily available.

This work is the culmination of several years of work and would not have been possible without the visionary contribution and support of EQC and current and past GeoNet team members.

POSTER
Session 4a

Understanding communication processes and decision making during different stages of volcanic activity in Aotearoa New Zealand

Manomita Das[1], Julia S. Becker[1], Emma E. H. Doyle[1], Danielle Charlton[2], Sally H. Potter[2], Graham S. Leonard[2], David M. Johnston[1], Lauren J. Vinnell[1], Mary Anne Clive[2], Carol Stewart[1], Kelvin Tapuke[1], Sara K. McBride[3], Janine Krippner[4], Nico Fournier[2], Craig Miller[2] and Hollei Gabrielsen[5]

[1] Joint Centre for Disaster Research, Massey University, Wellington, New Zealand
[2] GNS Science, Lower Hutt, New Zealand
[3] United States Geological Survey, Menlo Park, CA, U.S.A
[4] University of Waikato, Hamilton, New Zealand
[5] Department of Conservation, Turangi, New Zealand

j.becker@massey.ac.nz

Through a structured review of New Zealand literature on communication and decision making about volcanic activity, we find that communication varies in volume, sources, and channels throughout different stages (i.e., quiescence, unrest, short- or long-term eruptive phases, and recovery). Aotearoa New Zealand has multiple active volcanoes and experiences frequent volcanic unrest periods. Existing studies in New Zealand mostly focus on communication and decision-making related to certain volcanic sites or hazards during volcanic unrest or eruptions. An integrated understanding of volcano communication across the differing stages remains absent. A better understanding of communication over such stages can help improve advice provision arrangements, and guidelines for two-way knowledge transfer. This presentation takes a longitudinal approach and presents an overview of the range of communication and decision-making that happens during the various stages. Through a review of New Zealand-specific literature, we attempt to draw out commonalities across contextualised studies and answer the following questions: What decisions are made during the different stages of volcanic activity? What are the information needs? How is communication currently occurring? Who are the stakeholders? What is communicated? and What remains lacking? The review findings suggest that communication in pre-eruptive stages happens through a range of sources like observatories, government agencies, tourism providers and others, for the primary purposes of knowledge dissemination and preparing plans. However, during unrest and eruptive stages the information flow becomes comparatively streamlined, often led by official agencies and partner organizations with defined mandates. Eventually, discrete streams of communication emerge, catering to specific information requirements in the post-eruption stages, often being local in scale and involving responding agencies and community representatives. While further study is needed on these aspects, these findings can help improve future information for decision-making purposes for different stages of volcanic activity.

ORAL
Session 3a.

Challenging the paradigm of ^{238}U-excesses dominating arc settings: A Uranium-series isotopic investigation of Mt Taranaki, New Zealand

Alex Davidson[1], Simon Turner[1] and Shane Cronin[2]

[1] *School of Natural Sciences, Macquarie University, Sydney, Australia.*
[2] *School of Environment, University of Auckland, Auckland, New Zealand.*

Alexandra.davidson@hdr.mq.edu.au

Rear arc volcanism is typically potassic in composition but its origins are not well understood. In New Zealand, Mount Taranaki stratovolcano is most commonly attributed to subduction-related magmatism but is located 400 km behind the Hikurangi arc-trench system where seismic evidence for a Wadati-Benioff zone is ambiguous. Alternative magma generation scenarios have subsequently been proposed, invoking lithospheric delamination and asthenosphere inflow. For the purpose of understanding the magma generation scenario in greater detail, we have undertaken the first Uranium-series disequilibria analysis for a suite of high-K andesitic Taranaki pyroclastic rocks aged between 0.35 to 22 ka. All but one of these have ^{230}Th excesses (up to 45%) and form a broad horizontal array on the U-Th equiline diagram. The ^{230}Th excesses cannot be explained by crystal fractionation or crustal assimilation and may instead be indicative of the addition of sediment melts into a depleted mantle wedge or of an eclogitic source. To further model the source characteristics, Sr, Nd and O isotope data has been collected from a complementary suite of samples and presented herewithin. Irrespective of the ultimate origin of the magmas, the horizontal U-Th isotope array constrains the total time elapsed from partial melting to eruption to 4.5 ± 0.59 kyr. This implies short residence times and rapid magma ascent rates that may help explain the periodic variations of eruption frequency and composition seen in the long-lived tephra record of this volcano.

ORAL
Session 1a.

Decadal Scale Variability in Marine Primary Productivity Inferred from Stable Nitrogen Isotopes in Deep-Sea Corals

Ashley N. Davis[1,2], Daniel J. Sinclair[1], Dianne M. Tracey[2], Erik Behrens[2], Stewart J. Fallon[3], Sarah J. Bury[2], Julie C. S. Brown[2], Josette Delgado[2], Christopher J. Somes[4], and Nicholas T. Hitt[1]

[1] School of Geography, Earth and Environment, Victoria University of Wellington, Wellington, New Zealand
[2] National Institute of Water and Atmospheric Research, Wellington, New Zealand
[3]Research School of Earth Sciences, Australian National University, Canberra, Australia
[4]GEOMAR Helmholz Centre for Ocean Research Kiel, Kiel, Germany

ashley.davis@vuw.ac.nz

The ocean around Aotearoa New Zealand is very productive due to the mixing of warm subtropical water and cool subantarctic water rich in nitrogen and phosphorus compounds along the subtropical front. High levels of primary production in the region act as a carbon sink and support several commercial fisheries. Changes in physical oceanography around New Zealand, namely the acceleration of the South Pacific Gyre (SPG) over the 20th century, is altering subtropical currents causing them to transport warmer macronutrient-poor water further south. Such changes in water circulation can alter the distribution of nutrients and subsequently impact biological communities. Both physical and biogeochemical oceanic processes naturally vary over time, however, there is still a lack of biogeochemical records prior to the instrumental era with which to study past natural variability.

Stable nitrogen isotopes ($\delta^{15}N$) are a useful tool to study changes in marine primary productivity and nutrient cycling. High resolution timeseries of $\delta^{15}N$ values can be reconstructed from long-lived proteinaceous deep-sea black corals which reflect the $\delta^{15}N$ of surface ocean particulate organic matter. Here we present $\delta^{15}N$ records from six black corals at yearly to decadal-scale resolution from the north and east of New Zealand that collectively cover the last millennium. Reconstructed $\delta^{15}N$ values ranged from around 7 to 14 ‰, and the records show similar multi-decadal variability on timescales of ~80 years. We are also investigating the multi-decadal variability in climate models to determine if similar patterns are evident.

POSTER
Session 4d.

Sub-bottom Profiler Dating of Glacial Horizons and the Timing of Carbonate Mound Formation on the Southern Hikurangi Margin

Bryan Davy[1], Gareth Crutchley[2], Jess Hillman[1], Joshu Mountjoy[3] and Ingo Pecher[4]

[1]GNS Science, Avalon, Lower Hutt New Zealand
[2]GEOMAR Helmholtz Centre for Ocean Research, Kiel, Germany
[3] NIWA, Hataitai, Wellington, New Zealand
[4]University of Auckland, Auckland, New Zealand

b.davy@gns.cri.nz

Modern interferometric sub-bottom profilers can record vertical horizon resolution to 40 cm and achieve penetration up to 100 m sub-seafloor, in favourable conditions. The high-resolution data enable the recognition of reflectors corresponding to past glacial-interglacial intervals, as well as intervening reflectors corresponding to stadial low-stands. The technique has been previously applied using the “Atlas Parasound” sub-bottom profiler in investigating the timing of pockmark formation on the Southwestern Chatham Rise (Davy et al. 2010, Stott et al. 2019). We apply this technique to two selected sites on ridgetops of the Southern Hikurangi Margin, beyond the influence of current erosion, mass transport deposits, and recent deformation, and surveyed using the “Kongsberg TOPAS PS-18” sub-bottom profiler, onboard R/V Tangaroa during cruise TAN1808.

Examined sites are on Kekerengu Bank and West Uruti Ridge. The Kekerengu Bank is the southernmost accretionary ridge of the Hikurangi Margin. Kekerengu Bank is highly faulted, rich in interpreted seafloor carbonate mounds, and prolific seafloor methane venting. The Uruti Ridge region, off the Wairarapa Coast, is a mature accretionary ridge with a prominent bottom simulating reflection (BSR), fault-controlled fluid migration pathways, seafloor carbonate mounds and methane venting. It has been well studied by seismic reflection analysis (e.g., Crutchley et al. 2015) as well as carbonate distribution and seep epifaunal communities (e.g., Liebetrau et al., 2010, Bowden et al. 2013).

Coincident TOPAS and seismic reflection profiles at both sites reveal a correlation between the Glacial Maximum/end of ice age reflectors and the occurrence of carbonate mound formation. This presentation will discuss these findings and their implications for the timing of seafloor methane venting at the Southern Hikurangi Margin.

ORAL
Session 2e.

Marine Avian Diversity in the Paleocene of New Zealand

Vanesa L. De Pietri[1], Erica Crouch[2], Leigh Love[1], Al Mannering[1], Gerald Mayr[3], Catherine Reid[1], R. Paul Scofield[1,2].

[1] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*
[2] *GNS Science, Lower Hutt, New Zealand*
[3] *Senckenberg Research Institute Frankfurt, Frankfurt am Main, Germany*
[4] *Canterbury Museum, Christchurch, New Zealand*

vanesa.depietri@canterbury.ac.nz

Understanding the evolutionary processes that drove the diversification of modern birds after the Cretaceous/Paleogene mass extinction event 66 million years ago (Ma) has long been hampered by a sparse Paleocene (66–56 Ma) global fossil record. Cretaceous–Paleogene marine sediments exposed in the Waipara River, North Canterbury, have held regional and global scientific importance since the 1800s. In the 1980s, complete and well-preserved fossil penguins were recovered from the ca. 62.5–56 Ma Waipara Greensand. More recently, discoveries of giant penguins, tropicbirds and bony-toothed birds, have further underscored the role of Zealandia as a hub for seabird evolution, and have begun to reshape our understanding of ancient marine bird faunas and their significance in assessing the impact of changing environmental conditions during the early Paleogene on vertebrate faunas.

Here we provide an overview of our research, in which we aim to develop a comprehensive fossil record of marine birds from the Waipara Greensand to enhance our understanding of their taxonomic diversity and paleobiology. Improving stratigraphic control of the collected specimens will be essential for deciphering key evolutionary relationships and revealing the extent and timing of early diversification events in different seabird lineages. Analyses of microfossils in samples of the surrounding matrix associated with these bird fossils will not only allow us to refine the age of the sediments but will also facilitate palaeo-environmental reconstructions. This will allow us to further explore how ecological and environmental changes during the Paleocene, at regional and global scales, have influenced the composition and diversity of these early vertebrate faunas.

ORAL
Session 1c.

New bathymetric map of Lake Rotoiti, New Zealand

Cornel E J de Ronde[1], Fabio Caratori Tontini[2] and Jenny A Black[3]

[1] Department of Earth Resources and Materials, GNS Science, Lower Hutt, New Zealand
[2] Dipartimento di scienze della terra, Università degli Studi di Genova, Genoa, Italy.
[3] Department of Data Science and Geohazard Monitoring, GNS Science, Lower Hutt, New Zealand

cornel.deronde@gns.cri.nz

A new bathymetric map of Lake Rotoiti is the second map to be produced in the GNS Science Rotorua lakes map series. The bathymetric survey was undertaken in 2012 using the survey motor boat *Elaine*, with a Kongsberg EM3002D dual head multibeam echo sounder, coupled with a ROVINS inertial navigation system, mapping the lakefloor at ~1 m resolution. Sound velocity measurements recorded continuously while QINSy software was used for data acquisition, and CARIS and Qimera for data processing. All sounding data were recorded when the lake level was 279.1 masl with the survey using the WGS 84 Geodetic datum. An additional, closely spaced survey covering 0.57 km^2 was done in 2014 to record water column anomalies (bubble plumes) in Hauparu Bay. Magnetic (2016 and 2017), gravity and heat flow (both 2020) surveys have also been conducted.

A total of 294.6 km of survey lines were run with a vessel speed of 5-6 knots, covering an area of 30.11 km^2, or ~89% of the lake surface area; depths shallower than 5 m were not mapped. The maximum depth recorded was 128.6 m. The bathymetry is dominated by a large basin in the eastern end of the lake, a narrow gorge in the western end of the lake and a series of nested craters in the deepest part of the lake, offshore Hauparu Bay. The craters appear to be part of a larger (~1 km diameter) maar and may represent hydrothermal eruption craters. Elsewhere, hundreds of pock marks signify episodes of gas discharge on the lake floor, with those offshore Te Akau Point active, while the remainder largely inactive. The Hauparu craters are venting hot water and noticeable bubble plumes and are coincident with the highest heat flow recorded in the lake of up to ~140 W/m^2, representing a sizeable sublacustrine geothermal system.

POSTER
Session 1e.

The geology and geophysics of Lake Rotoiti, New Zealand: Implications for sublacustrine geothermal activity

Cornel EJ de Ronde[1], Fabio Catatori Tontini[2], Sharon L Walker[3], Tineke J Steward[1], Daniel J Fornari[4], Valerie K Stucker[5] and Jenny A Black[6]

[1] Department of Earth Resources and Materials, GNS Science, Lower Hutt, New Zealand
2 Dipartimento di scienze della terra, Università degli Studi di Genova, Genoa, Italy
3 Pacific Environmental Laboratory, NOAA, Seattle, USA
4 Woods Hole Oceanographic Institution, Woods Hole, USA
5 Earth and Environmental Science Laboratories, GNS Science, Lower Hutt, New Zealand
6 Department of Data Science and Geohazard Monitoring, GNS Science, Lower Hutt, New Zealand

cornel.deronde@gns.cri.nz

A number of surveys of Lake Rotoiti were undertaken as part of an ongoing project on sublacustrine geothermal activity within the Okataina Volcanic Centre (OVC). These include: bathymetry, gravity, magnetics, heatflow, water column sampling and lakefloor photography. The lake has an area of ~34 km^2 of which 30.11 km^2 (~89%) was covered in the bathymetric survey, with the remainder too shallow (<5 m). The deepest point in the survey was 128.6 m. The ~1m resolution bathymetry reveals a number of features on the lakefloor, including; a cluster of pockmarks actively discharging gas in the western bay end of the lake, a well-defined gorge in the western arm of the lake showing a river once flowed to the east, a broad area with outcropping geology in the eastern part of the lake and a ~1 km diameter area of numerous, nested craters that are discharging gas and hot water.

The gravity data show a broad correlation between positive anomalies and outcropping geology, with a negative anomaly in the eastern end of the lake likely due to sediment infill. Similarly, the magnetic data show positive anomalies associated with outcrops, with a clearly defined arcuate anomaly in the southeastern part of the lake related to lavas from the northern margin of the Haroharo caldera. Negative magnetic anomalies occur across the lake in the gorge area marking a possible extension of the Taheke geothermal system, along the south-central lake margin as it abuts the Tikitere geothermal system, over the hydrothermally active crater area, and the deeper parts of the eastern basin. Heat flow anomalies clearly demarcate the OVC boundary indicating a first-order control on fluid flow, with the highest heat flow measurements (max ~140 W/m^2) made in the nested craters area, outlining a significant sublacustrine geothermal system.

ORAL
Session 1e.

Disaggregating landslide risk: What drives Landslide Risk in Franz Josef and Fox Glacier Valleys?

Saskia de Vilder[1], Chris Massey[1], Biljana Lukovic[1], Tony Taig[2], and Regine Morgenstern[1]

[1]GNS Science, Lower Hutt, Wellington, New Zealand
[2]TTAC Ltd, Marston, Chesire, UK.

s.devilder@gns.cri.nz

Franz Josef and Fox Glacier Valleys are popular tourist destinations that experience landslide hazards in response to earthquakes, high rainfall and de-glaciation. To understand the life-safety risk to visitors we undertook a quantitative risk analysis (QRA) of debris avalanches, debris flows and rockfalls along roads and tracks in both valleys. We considered earthquake induced landslides, given the proximal location to the Alpine Fault, and 'non-earthquake' induced landslides, as we could not establish a relationship between rainfall and snowmelt with landslide occurrence.

For each trigger type, we collated landslide inventories, created landslide susceptibility maps, determined landslide frequency – magnitude relationships and undertook detailed numerical runout modelling. Given the lack of inventory data for earthquake induced landslides on the West Coast, we used relationships from the 2016 M_W 7.8 Kaikoura, 1968 M_W 7.1 Inangahua and 1929 M_W 7.8 Murchison earthquake events to inform potential earthquake induced landsliding in the valleys for different levels of ground shaking, categorized into peak ground acceleration (PGA) bands. We combined the hazard information for earthquake and non-earthquake induced landslides with the spatio-temporal probability of an individual and their vulnerability, to generate four risk metrices, which include the local personal risk (LPR), the risk per trip for visitors, the annual individual fatality risk (AIFR), and societal risk.

Our analysis reveals that the main drivers of risk in both valleys are non-earthquake induced landslides, when using time-independent seismic hazard inputs. In particular, landslides volume classes of 10,000 m^3 and 50,000m^3 dominate the risk profile of each valley, with these volume classes representing the mid-range of landslide sizes that can occur in each valley. While the contribution to risk from non-earthquake induced landslides is high, societal risk is dominated by earthquake events with PGA > 0.6 g. This detailed understanding of landslide risk holds implications for risk management practices.

ORAL
Session 4c.

'Slipping' into the sea: can upper plate faults produce coastal subsidence along the Hikurangi margin?

Jaime Delano[1], Andy Howell[1,2], Kate Clark[2], and Timothy Stahl[1]

[1] *School of Earth and Environment, Te Whare Wānanga o Waitaha* | *University of Canterbury, Christchurch, Aotearoa New Zealand*
[2] *Te Pū Ao* | *GNS Science, Lower Hutt, Aotearoa New Zealand*

jaime.delano@pg.canterbury.ac.nz

Earthquakes near the coast have the potential to create cascading hazards as land level changes interact with sea level. In particular, coseismic subsidence will exacerbate the effects of ongoing sea level rise, storm surges, tsunami, and tidal flooding. Near Napier, Aotearoa New Zealand, rapid subsidence in the paleoseismic record is typically attributed to subduction zone earthquakes while uplift is attributed to upper plate faults. We investigate coastal coseismic deformation near Napier with elastic dislocation models of upper plate fault and subduction interface earthquakes. Using slip constraints from historical events and fault geometries from nearby seismic surveys, we capture a suite of plausible earthquakes and their associated surface deformation. We compared our results to to paleoseismic uplift and subsidence records preserved at Ahuriri Lagoon, which includes eight rapid subsidence (c. 0.5 to 1.2 m) and two rapid uplift events over the last c. 7,000 years. Our modelling results show that several offshore upper plate fault source geometries are capable of producing subsidence of c. 0.5–1 m at Ahuriri Lagoon at recurrence intervals of c. 1–4 kyr, and a wide range of plausible subsidence-inducing subduction interface earthquakes. Our findings show that both upper plate faults and subduction interface earthquakes may have contributed to the subsidence events recorded at Ahuriri Lagoon. The potential for both earthquake sources to produce similar coastal subsidence complicates the interpretation of paleoseismic records, particularly those related to smaller magnitude (M_w 7–8) subduction events that manifest similarly to smaller upper plate earthquakes in the paleoseismic record. Models of sea-level rise and earthquake multi-hazards that do not include the effects of upper plate faulting will mischaracterize risk to coastal communities.

POSTER
Session 2a.

Evaluation of short-term eruption forecasting options at Whakaari, New Zealand

David Dempsey[1], Shane Cronin[2], Alberto Ardid[1] and Andreas Kempa-Liehr[2]

[1] University of Canterbury, Christchurch, New Zealand
[2] University of Auckland, Auckland, New Zealand.

david.dempsey@canterbury.ac.nz

Phreatic explosions at tourist-visited volcanoes are difficult to forecast, as illustrated by the deadly 2019 Whakaari (New Zealand) eruption. Quantifying eruption likelihood is essential for risk calculations that underpin volcano access decisions and disaster response. Here, we develop two models for short-term (48-hour) probabilistic forecasting of phreatic eruptions at Whakaari, and evaluate their accuracy alongside expert elicitation. The two models are based on pseudo-prospective analysis of seven Whakaari eruptions whose precursors were identified by time-series feature engineering of continuous seismic data.

The first model, an alarm-style system, could anticipate six out of seven eruptions at the cost of 14 alarm days each year. When an alarm is in effect, the probability of eruption is 8.1% in 48-hours, about 126 times higher than outside the alarm. The second model used isotonic calibration to map forecast model output onto a probability scale. When applied 48-hours prior to the Dec 2019 eruption, this method indicated an eruption probability up to 400 times higher than the background.

Finally, we quantified the accuracy of these data-driven forecasts as well as expert elicitation. To do this, we used a forecast skill score that was benchmarked against a model based on the average rate of eruptions at Whakaari between 2011 and 2019. This score highlighted the conditions under which the different forecasting approaches performed well, and where potential improvements could be made.

ORAL
Session 2a.

Characterisation of the vertical and lateral subsurface heterogeneity in loess soils using qualitative (morphological) and quantitative (k-means) techniques

Kirstin Deuss[1], Peter Almond[2], Sam Carrick[1], John Triantafilis[1]

[1] *Manaaki Whenua Landcare Research, Lincoln, New Zealand*
[2] *Department of Soil and Physical Sciences, Lincoln University, Canterbury, New Zealand.*

Peter.almond@lincoln.ac.nz

Loess-mantled landscapes may have complex subsurface stratigraphy that produces distinctive patterns of soil variability related to the exhumation of buried loess sheets on hillslopes. Hillslope soils may be composite, including subsoil horizons inherited from paleosols formed in buried loess sheets, which themselves may be overprinted by contemporary pedogenesis (welded soils). Identifying paleosol-derived horizons has an element of subjectivity. Additionally, their relevance to characterising soil pattern and properties is untested. In this study, a dissected, loess-mantled downland with multiple thin loess sheets was surveyed to conceptualise the nature of loess sheet exposure within the soil mantle. Soil samples were collected from five depths and characterised for physical, hydraulic and chemical attributes. Principal component analysis (PCA) was conducted on the attribute dataset to test the robustness of morphological soil description and classification in identifying the most important sources of attribute variability. The *k*-means algorithm was employed to assess how well an objective, quantitative method of horizon classification aligned with qualitative horizon designation. Results indicated that drainage basin hillslopes cut across four buried loess sheets. Interfluve soils formed entirely in the uppermost loess sheet. Hillslope soils were composite; comprising upper soil horizons formed in mobile colluvial material overlying paleosol horizons inherited from buried loess sheets. PCA results indicated that morphologically-assigned horizons were able to capture the most significant variation in soil attributes. The *k*-means clusters reflect sensible groupings that are easily explained by pedogenic processes and gave almost equivalent results to morphological horizon designation. Vertical horizonation, resulting from top-down pedogenesis, appeared to be the dominant effect in these soils; however, hydraulic properties were also influenced by the loess stratigraphy. These results demonstrate that morphological horizon designation effectively partitions variability in important soil properties. A more refined understanding of the soil-geomorphology of loess-mantled downlands may lead to better soil-landscape models, more accurate soil maps and better characterisation of soil variability.

POSTER
Session 2c.

Model Uncertainty - What Needs to be Communicated in Hazard and Risk Models

Dhungana A[1], Doyle E, Prasanna R , McDonald G[2] , and Paton D[3]

[1] *Joint Centre for Disaster Research, Massey University, Wellington, New Zealand*
[2] *ME Research, Auckland, New Zealand*
[3] *College of Health & Human Sciences, Charles Darwin University, Australia*

We present a conceptual structure for considering model uncertainties, enabling us to identify those that should be the focus for improved communication between scientists and policy decision-makers. Scientists and modelers design different mathematical and computational models with an aim to support decision-making for hazard and risk management. However, uncertainties are manifested at different stages of the modelling process- starting from data and information inputs, during model runs, and when generating output. Additionally, decision-makers and scientists' or modelers' values and judgments add another layer of uncertainty along with the underlying deep uncertainties. Effective communication of these model uncertainties is not just helpful to manage the risk but also helps to inform more robust and adaptive decision-making, while also enhancing trust in the model itself.

Hence, based on a series of interviews with a) modelers and scientists; and b) hazard or risk managers and policymakers, this study has developed a conceptual structure for considering the uncertainties in the overall modeling process, depicting where and what should be communicated. Our conceptual structure is represented by a doughnut conceptualization of the 'modelling environment' consisting of four major sections: a) input data; b) model selections and model runs; c) inference and projections; and d) subjective judgment and values of both scientists and decision-makers.

Within these four major sections, there are different sources which need effective communication if improvements in policy decisions are to be realized. In addition, this structure also considers deep uncertainty. While it may not be possible to qualify or quantify such deep uncertainty, its presence needs to be recognised to support robust decision making.

Next steps include testing this conceptual framework through risk and hazard models via New Zealand case studies. This process will generate a guideline for communicating these uncertainties at the interface of scientific assessment and risk and recovery decision-making.

POSTER
Session 2a.

Kororā: a Public Portal for the NZ NSHM

Chris DiCaprio[1], Ben Chamberlain[1], Chris Chamberlain[1], Qianye Lin[1], Matt Gerstenberger[1], and Rachel Kirkman[1]

[1] *GNS Science, Lower Hutt, New Zealand*

c.dicaprio@gns.cri.nz

One of the goals of the 2022 NZ NSHM revision is to provide model results in an easy to access maner to a wide range of technical end-users and the general public. The NZ NSHM webapp, "Kororā", provides the primary end-user interface to the model. Via Kororā users can access model results such as hazard curves, uniform hazard spectra, hazard maps, and disaggregations. In addition, information about the construction of the model, input files, and scientific reports provides useful context and reproducability.

By using the same technology stack for research and end-users we have been able to accelerate the scientific analysis and model curation process. An application API, made available to NSHM scientists and technical users of the model can further facilitate access to results and scientific exploration.

In this presentation we will share the development process of the API and webapp, demonstrate the working application, and discuss future development and additional features.

POSTER
Special Symposium

Computational Infrastructure of the NZ-NSHM: how to calculate REALLY BIG seismic hazard models

Chris DiCaprio[1], Chris Chamberlain[1], Sanjay Bora[1], Brendon Bradley[2], Matt Gerstenberger[1], Anne Hulsey[3], Marco Pagani[4], and Michele Simionato[5]

[1] *GNS Science, Lower Hutt, New Zealand*
[2] *University of Canterbury, Christchurch, New Zealand*
[3] *University of Auckland, Auckland, New Zealand*
[4] *GEM Foundation, Pavia, Italy and Adjunct Professor, ICRM-NTU, Singapore*
[5] *GEM Foundation, Pavia, Italy*

c.dicaprio@gns.cri.nz

The 2022 New Zealand National Seismic Hazard Model (NZ NSHM) represents a massive revision of the NZ NSHM across both seismicity rate model (SRM) and ground-motion characterization model (GMCM) components. A primary goal of this model is to capture a large range of epistemic uncertainty in both source and ground motion. As a result, the final SRM logic tree comprises 324 branches and the GMCM) logic tree comprises 3024 branches. The final logic tree contains nearly 1 million branches, posing a significant computational challenge.

Our approach to the problem is to break the logic tree into several parts, dividing it by source components (active shallow crust, Hikurangi-Kermadec subduction interface, Puysegur subduction interface, and subduction slab) which are considered independent. Hazard curves can be practically calculated for individual source components. Weighted mean and quantile hazard curves are then calculated from the constituent parts in a post-processing phase. This approach has additional advantages as it allows us to easily reconstruct all hazard curve realizations for the purposes of exploring individual components of the hazard model, performing sensitivity tests, calculating new aggregate statistics, and performing disaggregations over the full logic tree.

The large number of source components of the NZ NSHM also poses a data management challenge. We've developed tools to make access to model components and metadata easy and ubiquitous. This facilitates sharing of results among the scientific team, tracking components of the large SRM logic tree, and providing model components to the public.

ORAL
Special Symposium

Geochemical fingerprinting of sediment sources infilling Whakaraupō | Lyttelton Harbour, New Zealand

Zoë Dietrich[1,2,3] Catherine Reid[3], Darren Gravley[2,3], and Sam Hampton[2,3,4]

[1] Bowdoin College, Brunswick, Maine, USA.
[2]Frontiers Abroad, frontiersabroad.com
[3]University of Canterbury, Christchurch, New Zealand
[4]VolcanicKED, Christchurch, New Zealand

catherine.reid@canterbury.ac.nz

Intertidal beaches and mudflats are ecologically important habitats, and the Whakaraupō | Lyttelton Harbour mudflats have been identified as an area of Significant Natural Value by Environment Canterbury. Sedimentation is a key process impacting the health of near-shore environments and is a pressing ecological issue for Whakaraupō | Lyttelton Harbour. However, while the potential sources of sediment are known, they have not yet been quantified in the accumulated harbour sediments. We sampled surface sediments around the perimeter of the harbour and applied geochemical (pXRF), grainsize, and componentry analyses to determine modern surface sediment sources. These analyses were repeated with a sediment core to investigate historical sediment sources over the last ~300 years.

Predictably, volcanic-derived materials dominate modern Whakaraupō | Lyttelton Harbour accumulated sediments, shed via streams from the surrounding volcanic hills. Sediments also include eroded loess with inputs notable in Head of the Bay east to Diamond Harbour from the adjacent Barrys Bay loess. Marine sediments from Pegasus Bay are likely transported not only into the outer harbour, but into the central and upper harbour regions as well.

Core sediments, interpreted to have been deposited prior to European settlement, reveal mud-sized marine sediments were transported into Head of the Bay from Pegasus Bay and/or Waimakariri longshore drift and constituted a main sediment source, in addition to volcanic-derived materials. Around the time of European settlement and land clearing, Head of the Bay sediment sources shifted from primarily marine and volcanic-derived to Barrys Bay loess. Further anthropogenic activities in the 1980s-90s likely resulted in increased hillslope erosion and subsequent mudflat deposition of Barrys Bay loess. Foraminifera decrease in abundance following the switch to loess dominated sediments, and cockle shells disappear from the record.

ORAL
Session 4d.

Paleomagnetic constraints on Holocene lava flows eruption ages at Ruapehu, Aotearoa New Zealand

Pedro Doll[1], Ben Kennedy[1], Gillian Turner[2], Alex Nichols[1], Annika Greve, Jim Cole[1], Dougal Townsend[3], and Graham Leonard[3]

[1] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*
[2] *School of Chemical and Physical Sciences, Victoria University of Wellington, Wellington, New Zealand.*
[2] *GNS Science Avalon, Lower Hut, New Zealand.*

pedro.doll@pg.canterbury.ac.nz

Detailed knowledge of the chronology of past eruptions is key for producing accurate volcanic hazard assessments. In Aotearoa New Zealand and particularly at Mt Ruapehu, most studies of Holocene eruptions including dating have focused on explosive events, leaving effusive deposits largely overlooked. At least 16 distinct lava flows were erupted from Ruapehu in Holocene times, but constraining their eruption ages has been so far challenging due to the limitations of conventional radiometric dating methods.

In this study we present eruption age constraints for 12 Holocene lava flows at Ruapehu based on new paleomagnetic data and its correlation with an updated paleosecular variation record for Aotearoa New Zealand. We have been able to reduce the eruption age uncertainty of six of them to less than 1000 yr and to less than 300 yr for three of these. Preliminary results indicate that effusive eruptions were emplaced on the northern slopes of the volcano throughout the Holocene until at least 3400 BP, and flowed to the east in the Whangaehu Valley (the current outflow from Ruapehu's crater lake) until as late as 1400 BP. These are significantly younger eruption ages than previous 7900 and 2050 BP cited in previous studies for these areas, respectively, suggesting that voluminous effusive eruptions at Ruapehu occurred more recently than previously thought.

These results will be combined with new cosmogenic ^{3}He exposure ages and complemented with more paleomagnetic data to further reduce the uncertainty of the obtained eruption ages. This work will constitute a major step towards a comprehensive understanding of Ruapehu's Holocene effusive activity and associated hazard, and will contribute to improving our understanding of the volcanic hazards in the southern section of the Taupō Volcanic Zone.

POSTER
Session 1a

DEVELOPING FLOODPLAIN SEDIMENT ARCHIVES TO UNDERSTAND EROSION AND FLOOD HISTORIES IN CONTRASTING CATCHMENTS

Imogen Doyle[1], Ian Fuller[1], Sean Fitzsimons[2], Sam McColl[3] and Mark Macklin[4]

[1] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*
[2] *School of Geography, University of Otago, Dunedin, New Zealand.*
[3]*GNS Science, New Zealand.*
[4]*School of Geography, University of Lincoln, Lincoln, United Kingdom.*

Immy.doyle@gmail.com

Understanding the pathways and patterns of erosion and sediment mobilisation is essential to successfully mitigate erosion. Floodplain sediments record catchment histories of erosion and flooding, which provide important insights into the drivers of sediment mobilisation and transport, including the influence of human induced landscape change. We focus on two contrasting catchments, the Whanganui catchment, North Island and the Oreti catchment, Southland, New Zealand. Steep, narrow valleys confine the Whanganui for much of its reach, resulting from Quaternary uplift of the weakly lithified sandstone, siltstone and mudstone of the Whanganui Basin. The Oreti, by contrast, meanders across a broad floodplain for much of its lower reaches, confined only in more recent history by agricultural practice, erosion mitigation and flood mitigation measures. Investigation of high-resolution sediment archives from Atene, a valley meander cut-off in the lower reaches of the Whanganui Gorge, revealed a 2000-year flood history (Fuller et al., 2019). A further three cores from Atene and five cores from abandoned paleochannels of the lower Oreti, collected as part of the Smarter Targeting of Erosion Control (STEC) program are presented. Particle size analysis (PSA), geochemical analysis (ITRAX), computed tomography scanning (CT) and magnetic susceptibility have been used to identify and distinguish flood units. Radiocarbon dating extends the Whanganui record to a maximum age of 4458 ± BP and the Oreti record to 149 ± 20 BP. In spanning approximately ~4.5 ka years, the Whanganui archive will track the impacts of late Holocene climate change, landscape response to the 232 AD Taupō eruption and human arrival and settlement within the catchment. In Oreti the record reflects a more recent climate history and the influence of human settlement and agriculture on the floodplain. Organic material sampled from the cores will establish age depth models constraining the timing and magnitude of floods and records of erosional events recorded at the sites. ITRAX data will facilitate the evaluation of flood magnitude and frequency at high resolution, providing insight into temporal patterns of event magnitude and frequency.

POSTER
Session 2b.

The influence of basement terranes on tectonic deformation: joint earthquake travel-time and ambient noise tomography of the southern

Donna Eberhart-Philllips, Mark Williamson Stirling et al.

University of Otago

The South Island lithosphere, consisting of multiple amalgamated terranes, currently undergoes oblique collision with major faulting, crustal thickening and subduction along the plate boundary. We examine crustal properties of the relatively low-strain region east of the lithospheric plate boundary, combining earthquake travel-time tomography with surface wave observations. This enhances spatial resolution in low seismicity areas, improves shallow resolution and sharpens velocity gradients between terranes. We are expanding the study area offshore eastern Otago, with active source data recorded on at onshore stations; and in Fiordland we are running a temporary network. Southern Alps results indicate high Vp schist upper crust. Similarly, Central Otago ranges exhibit high Vp with northeast trending structure, and distinct northwest trending ranges characterize the northern margin. The Otago schist shows thick lower crust, while contrasting higher Vp below 15-km depth characterizes the Matai terrane and Median batholith, backstops during accretion and deformation. Comparison of sparse seismicity, structural domains and geodynamic modelling shows how Cenozoic structures relate to deeper properties. Seismicity within the schist tends to be distributed within key transition regions rather than along specific faults, and these zones tend to show low Vp and low Qp. The most prominent seismicity zone is along the Southern Alps transition to northern Otago ranges. Faulting and brittle deformation along the Southern Alps margin corresponds to the eastern edge of ductile crustal thickening above the bending of strong oceanic lower crust. The thick weak crust rheology of Otago, relative to Canterbury, enables broad deformation, with numerous active faults that may not persist to depth. Along the southern stronger plutonic terranes, there is a band of sparse deeper (15-30 km) seismicity, consistent with strong elastic brittle crust.

ORAL
Session 1d.

Transient fluctuations in stress and slip caused by geometric irregularities in shear zones: Field examples and numerical model analogues for active subduction interface deformation

Susan Ellis[1], Steven A.F. Smith[2], Matthew S. Tarling[3], Marianne Negrini[2], Samantha J. Allan[2], Marshall Palmer[2] and Cecilia Viti[4]

[1]*GNS Science, PO Box 30368, Lower Hutt, New Zealand*
[2]*Department of Geology, University of Otago, Dunedin, New Zealand*
[3]*Department of Earth and Planetary Sciences, McGill University, Montréal, QC, Canada*
[4]*Università degli Studi di Siena, Siena, Italy.*

s.ellis@gns.cri.nz

We use 2-D numerical models to explore the development of incremental crack-seal textures in a fault-bound dilational jog. The model is based on a field example within a metre-scale phacoid embedded within a wide “block-in-matrix”-type (melange) serpentinite shear zone at the base of the Dun Mountain ophiolite (Miner River, Nelson, New Zealand). Slip on two overlapping fault surfaces cutting through the phacoid results from kinematic loading due to creep in the surrounding serpentinite matrix, and the dilational stepover between the two faults evolves in to an incrementally-developed serpentine vein.

We show how periodic exceedance of the tensile strength at the contact between the sealed vein and host rock leads to episodic opening and deposition of a new crack-seal band, where the band thickness (opening amount) for each opening event is limited by the release of localised stress concentrations built up around the tips of the stepover-bounding faults. The numerical models produce a repeated cycle of rapid cracking followed by precipitation of new material at both crack margins, until the crack is sealed. The dilational jog stress release is independent of the crack length-scale but depends on the tensile strength of the host material. However, the overall static stress drop of the fault/jog system scales with crack length in the jog. The stress to drive the system cycles up and down by the stress drop, with its base level controlled by the static driving stress that would be needed to drive a single planar fault. Geometric irregularities leading to the formation of dilational jogs can prevent an otherwise stable or conditionally stable fault or shear zone from displacing at a steady rate, and cause local transient stress and slip pulses, analogous to episodic tremor and slip observed along active subduction interfaces.

ORAL
Session 1d.

Timescales of Magmatic Processes at Ōkataina Volcanic Centre from Fe-Mg Diffusion in Orthopyroxenes

Hannah Elms[1], Daniel Morgan[2], Simon Barker[1], Colin Wilson[1] and Bruce Charlier[1]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand*
[2] *School of Earth and Environment, University of Leeds, Leeds, United Kingdom*

hannah.elms@vuw.ac.nz

One of the main challenges in assessing the risk posed by an active volcano is determining the likely timescales over which its magmatic processes operate. Constraining pre-eruptive timescales is important for understanding the likely range of signals and warning times a volcano may give prior to an eruption. Here we present the results of a study into the timescales of pre-eruptive magmatic processes operating at Ōkataina volcano, in the northern part of the central Taupō Volcanic Zone.

We use Fe-Mg diffusion across initially sharp compositional boundaries in orthopyroxene from three rhyolitic eruptive episodes covering the three main vent regions of the young Ōkataina system (the 15.6 ka Rotorua episode from the Ōkareka Embayment, the 13.8 ka Waiohau episode from Mt. Tarawera, and the 5.5 ka Whakatāne episode from the Haroharo Massif). Coupled with melt chemistry data and evidence from physical volcanology, this study shows how rapidly the magmatic systems involved can recharge from dormancy into an eruption-ready state. A Monte Carlo model was used to ensure full consideration of the (often large) uncertainties associated with diffusion timescales such as these.

Our findings suggest that recharging (or priming) of the magmatic system at Ōkataina occupied times on the order of decades up to a few centuries prior to eruption, with residence times for individual, eruptible melt-dominant magma bodies being on the order of years to decades. Processes which can potentially trigger the primed system into eruption (or significant unrest), for example heating processes associated with the injection of mafic magma, may only take a few months to a year to take effect. These results highlight the importance of present-day geophysical monitoring in detecting changes in the volcano over yearly to decadal timescales, which are relevant to the possible assembly of eruptible magma bodies.

POSTER
Session 1e.

Deciphering the impact of climate variability on the remote alpine lake ecosystem of Lake Bright, New Zealand

Julian Eschenroeder[1], Chris Moy[1], Sebastian Naeher[2], Marcus Vandergoes[2], Jamie Howarth[3], Claire Shepherd[2]

[1] *Department of Geology, University of Otago, Dunedin, New Zealand*
[2] *GNS Science, Lower Hutt, New Zealand.*
[3] *School of Geography Environment and Earth Science, Victoria University of Wellington, Wellington, New Zealand*

Julian.eschenroeder@postgrad.otago.ac.nz

Lake ecosystems in New Zealand are under pressure by human-induced overfertilization and accelerating climate change. To better understand the processes that aquatic communities and lake water quality might undergo in the years to come, and to develop successful mitigation and conservation strategies, it is important to understand how lake systems react to a range of climate conditions. Here, we investigate sediment cores obtained from a remote alpine lake in Fiordland National Park, to evaluate the impact local climate has on changes in productivity and water quality.

For this study, a 1.6 m long sediment core was recovered from the centre of Lake Bright as part of the MBIE-funded Lakes 380 programme in September 2019. Lake productivity, as well as changes in the provenance and composition of clastic and organic matter, were reconstructed from a combination of XRF-scanning, hyperspectral imaging, the concentration and stable isotope composition of C and N, biogenic silica abundance, and the analysis of lipid biomarkers. Analysis of organic geochemical proxies will further enable the reconstruction of local air temperatures and hydroclimate.

A radiocarbon chronology indicates that the recovered core spans the last 4 ka, enabling an investigation of ecosystem conditions before the arrival of humans in New Zealand. Initial biomarker data indicates that the greatest proportion of organic matter is derived from vascular plants from the lake catchment. Non-destructive XRF and hyperspectral scans of the core indicate changes in algal productivity while a trend to more reducing conditions is observed in the uppermost portion of the record. We will present these results, combined with a stable isotope stratigraphy, biogenic silica concentrations, and climate reconstructions of the last 2ka, to deconvolve changes in organic matter provenance and better understand how changing climate impacts remote alpine lake ecosystems.

POSTER
Session 2c.

Recent Sedimentation History and Foraminifera Distribution in Governors Bay, New Zealand

Joshua Evans, Catherine Reid, and Darren Gravley

School of Earth and Environment, University of Canterbury, Christchurch, New Zealand

jde54@uclive.ac.nz

Governors Bay is the northwesternmost of three bays found at the western end of Whakaraupō Lyttleton Harbour. Governors Bay is tidally controlled, being largely a mudflat in and around low tide. Whakaraupō is a part of Banks Peninsula and comprises a series of overlapping Miocene volcanic cones of primarily basalt to trachytic composition, with two linear rhyolitic dome complexes that extend as peninsulas into the modern day head of the harbour. On top of the volcanics, up to forty metres of Quaternary loess blankets the more gentle slopes. Whakaraupō is open to the Pacific Ocean at its eastern end and marine waters and sediment are distributed throughout the harbour and bays driven by dynamic circulation of tidal currents.

The goal of this thesis is to determine changing dominant sources of sediment intake in Governors Bay in recent history using XRF fingerprinting, to correlate those changes with the evolution of the surrounding bay and harbour, and to use foraminifera to provide further clarity on the local paleoenvironment. Of particular interest are the impact of anthropogenic influences: the widescale removal of tree cover and use of the harbour as a major shipping port under Pākehā governorship is predicted to have resulted in a significant increase in sedimentation rate, particularly from loess and loess colluvium.

To achieve this goal, surface samples will be taken from Governors Bay at low tide, as well as from several nearby streams and volcanic outcrops to acquire analogues for local terrestrial sources. Additionally, a sediment core will be taken within Governors Bay to determine the sources of past sediment and changes in foraminifera communities over the last few hundred years.

POSTER
Session 2d.

The NGMC in Response Mode: Examples from the March 5th East Cape Earthquake

Jessica Fensom[1], David N Nicholls[1], Ryan R Brock[1], Renee Cameron-Bennett[1], Andriy Legenkyy[1], Anna O'Hara[1], Connor M J Rapley[1], Sam J Wiffen[1], Mathew Crighton[1], Geranicky Delisatra[1], Holly J Godfrey[1], Holly Harvey-Wishart[1], Lachlan Hill[1], Dean R Jackson[1], James D B McClintock[1], Rachael Prichard-Thorsen[1], Caleb Rapson Nuñez del Prado[1], Michael J Ross[1], Kevin Siemer[1], Eveanjelene Snee[1], Callum Snell[1], Alex Thomas-Long[1], Tamiko Watson[1], Michael J Wood[1] and Clinton Zirk[1]

[1] *National Geohazards Monitoring Centre, GNS Science Te Pū Ao, Lower Hutt, New Zealand*

j.fensom@gns.cri.nz; d.nicholls@gns.cri.nz

The National Geohazard Monitoring Centre Te Puna Mōrearea i te Rū (NGMC), provides round-the-clock monitoring of New Zealand's four main geological perils: earthquakes, tsunami, volcanoes, and landslides. The NGMC locates ~25,000 earthquakes a year and evaluates their tsunami threat to New Zealand.

But what does the NGMC do when a large earthquake occurs?

Looking back on the March 5th 2021 M7.3 East Cape earthquake is a good way to understand how the centre operates in a large response.

The earthquake was detected on seismic stations across the country, triggering an event in our software off the coast of East Cape; this was supported by additional information from the Pacific Tsunami Warning Centre. Tsunami DART Buoys located closest to the event, NZC and NZE, automatically activated enhanced monitoring mode after recording the first p-wave arrivals from the earthquake. Seismic waves on the volcano drums triggered the Eastern Ruapehu Lahar Warning System, paging the NGMC and Volcano duty officer.

NEMA was informed of the event and the Tsunami Experts Panel (TEP) was convened to determine the tsunami threat to New Zealand. The NGMC, on advice from the TEP, provided NEMA with a tsunami threat map which informed their evacuation warnings. The strong motion stations at East Cape showed peak ground acceleration measurements of more than 0.2G, indicating landslide risk. The Earthquake Induced Landslide tool was run to produce a map of locations at risk of landslides; this was provided to the landslide duty officer.

Following this initial response, the NGMC continued enhanced monitoring of wave arrivals on the DART buoys and tide gauges, while locating aftershocks. In the two weeks following the event, 2400 aftershocks were located- an average of 179 Earthquakes per day. The NGMC continued enhanced monitoring following these events for two weeks. The aftershock sequence is still ongoing.

POSTER
Session 3c.

Validation of ground-motion simulation approaches on the 2011 Mw6.2 Christchurch earthquake, New Zealand

Laëtitia Foundotos[1], Anna Kaiser[1], Bill Fry[1] and Luce Lacoua[1,2]

[1] GNS Science, Lower Hutt, New Zealand
[2] Department of Geology, University of Otago, Dunedin, New Zealand

l.foundotos@gns.cri.nz

In this study, we simulate the ground-motions generated by the Mw6.2 Christchurch earthquake that struck the Canterbury region on 22 February 2011. To simulate the rupture process on the fault plane, we used a method based on an extended kinematic fractal source model. To set up the input parameters providing the best opportunity to reproduce the recordings of the Christchurch earthquake, slip distribution, size, and geometry of the fault plane were chosen according to published source inversion studies.

Then, to produce realistic synthetic accelerograms, this source model was combined with the seismic wave-field propagated in the geological medium. Two different approaches have been tested and validated. In a first part, we used a semi-empirical simulation method based upon the Empirical Green's Functions approach. The idea is to simulate the ground-motions produced by a large earthquake by summing the recordings of small earthquakes that occurred in the region of interest. In a second part, we applied a purely numerical approach based upon the Spectral Element Method by using the 3-D velocity model available for the Canterbury region.

We also investigated the framework of a blind simulation approach by implementing a logic-tree approach to take into account uncertainties on input source parameters. We considered a large number of random realizations of slip distribution on the fault plane, sufficiently different from each other to be associated with a variability of rupture processes likely to occur. As a validation, the simulated ground-motions were compared at 84 stations of the GeoNet seismic network to the ground-motions recorded during the Christchurch earthquake. This case study has allowed us to test performances of both simulation approaches and to provide useful elements for potential application to the reassessment of historical events and the generation of earthquake scenarios in New Zealand.

POSTER
Session 4a.

Geochemical Mapping of Aotearoa's Marine Sediments: an update for Bay of Islands area

G.E. Frontin-Rollet[1], R. J. Wysoczanski[1], V. Rigalleau[2], M. R. Handler[3] and K. L. Maier[1]

[1] *National Institute of Water and Atmospheric Research, Wellington, New Zealand.*
[2] *Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany.*
[3] *School of Geography, Environment & Earth Science, Te Herenga Waka–Victoria University of Wellington.*

grace.frontinrollet@niwa.co.nz

Aotearoa New Zealand's offshore sediments are highly diverse and are derived from several sources such as terrigenous erosion, authigenic mineral formation, biological activity, and volcanic eruptions. All sources leave a unique geochemical signature, which can be interrogated geospatially to provide critical information for applications such as sediment provenance, extent of mineral resources, regions of high ecotoxicity, and habitat mapping. However, many areas in Aotearoa's extensive marine territory lack sufficient geochemical sediment data to elucidate geospatial patterns and further offshore characterisation.

Using over 100 surficial sediment analyses, we will present preliminary compositional maps across the Bay of Islands region. Data for geochemical maps were collected using portable x-ray fluorescence, which provides geochemical analyses for seven major elements and eight trace elements. Data were calibrated using Certified Reference Materials and internal standards to create linear and weighted regression models. Internal Standards were verified using benchtop x-ray fluorescence by two laboratories with excellent agreement between results. Increased accuracy from on average +/- 15% to +/-3-4% through calibration enables fast and cost-effective acquisition of semi-quantitative data.

This work supplements geochemical mapping that has been completed on the Bay of Plenty region and is a part of a larger project goal to characterise the geochemistry of Aotearoa's entire costal region.

ORAL
Session 4d.

Physics to Resilience: Next Generation Earthquake and Tsunami Response

Bill Fry[1], Andy Nicol[2], Anna Kaiser[1], Mika Liao[2], William Power[1], Nick Horspool[1], SJ McCurrach[3], Ken Gledhill[1], Andy Howell[1, 2], Jose Borerro[5], Chris Massey[1], Bruce Shaw[6], Laura Hughes[9], Matt Gerstenberger[1], Mark Stirling[7], David Burbidge[1], David Dempsey[2], Caroline Holden[8], Emily Lane[4], Camilla Penney[2], Chris Moore[10], Jen Andrews[1], Florent Aden[1], Chris Zweck[2], Richard Smith[1] and the RCET and RNC EQ/Tsu teams.

[1] *Te Pu Ao, GNS Science, Lower Hutt, New Zealand*
[2] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*
[3] *Earthquake Commission, Wellington, New Zealand*
[4] *NIWA, Taihoro Nukurangi*
[5] *ECoast, Raglan, New Zealand*
[6] *Columbia University, NY, USA*
[7] *Department of Geology, University of Otago, Dunedin, New Zealand*
[8] *SeismoCity Ltd, Wellington, New Zealand*
[9] *Victoria University of Wellington, Wellington, New Zealand*
[10] *Pacific Marine Environmental Laboratory, U.S. NOAA*

b.fry@gns.cri.nz

Public funding of science is increasingly leveraged to provide direct benefit to society. This evolution of government priorities encourages the mutually beneficial alignment of research programmes to deliver improved outcomes, many of which would not have been possible through isolated research. In this talk, we present one such case.

We will first give an update of the Resilience to Nature's Challenges (RNC) national science challenge Earthquake and Tsunami Programme. This programme has implemented NZ's first national-scale earthquake simulator. Our current working national earthquake models represent hundreds of thousands of years of possible earthquakes in New Zealand. Earthquakes in this synthetic seismicity model exhibit remarkable complexity, beyond that usually considered in scenario-based event response planning.

Ongoing efforts are aimed at evaluating the usefulness of these earthquake models for application to some of NZ's biggest earthquake challenges. The scope of our current applications includes 1) next-generation seismic and tsunami hazard modelling and 2) providing input scenarios to improve large local and regional earthquake and tsunami response tools.

We will show how the RNC synthetic seismicity catalogue is being used to test response tools and early warning procedures. As an example, we will show testing and application of regional tsunami early warning algorithms under the Rapid Characterisation of Earthquakes and Tsunamis (R-CET) MBIE Endeavour programme. The 5 March, 2021 earthquakes and tsunamis were a (painfully early!) bellwether of our tsunami forecasting efforts in R-CET. While not yet fully operational, we successfully used direct tsunami observations recorded on the NZ DART network to help underpin advice that led to an improved national tsunami response. Tangible response gains were realized in improved estimation of likely tsunami threat duration leading to more rapid and informed de-escalation and cancellation of a national warning than would have likely occurred without the NZ DART network data and the complementarity of R-CET and RNC workstreams.

KEYNOTE
Session 4a.

New near real-time automated beachballs for earthquakes in New Zealand and the southwest Pacific

Bill Fry[1], Chris Zweck[1], Anthony Jamelot, and Florent Aden[1]

[1] *Te Pū Ao, Awa kairangi, Aotearoa.*
[2] *Centre Polynésien de Prévention Des Tsunamis (CPPT), Tahiti*

b.fry@gns.cri.nz

Earthquake science and earthquake event response are predicated on quantifying the magnitude of earthquakes. Many methods exist to quantify an earthquake's size and location. Most methods have strengths and limitations. Typically, local earthquake estimates are based on first wave arrivals and the maximum recorded amplitudes on seismograms. These estimates are quick – often available in the minutes after a large earthquake. Unfortunately, local magnitudes are also plagued by two key limitations: 1) they estimate the hypocentre of the earthquake rather than its centroid and 2) they saturate with increasing magnitude, meaning they usually underestimate the most significant earthquakes of about M6.5+.

In this talk, we present New Zealand's first automated w-phase solution that has recently been implemented under the RCET programme. W-phase earthquake solutions provide information about the size, geometry and location of an earthquake. They also inform us about the "normalcy" of the earthquake, or how much of its energy can be explained by a simple double-couple source. Importantly, w-phase solutions are 1) the most accurate and repeatable way of rapidly quantifying earthquake magnitude for very large earthquakes (Mw6.5+) and 2) they provide us with estimates of the earthquake centroid rather than hypocentre. Further, they are the gold-standard for use in rapid tsunami early warning.

We will introduce the new tool and give examples of recorded events over the last 6 months. We will also discuss how this new information can be used in future event response and future hazard assessments and present some of its limitations. We will also show some seismic beachballs.

POSTER
Session 3c.

Petrogenesis of Brothers submarine volcano and associate hybrid seafloor massive sulfide deposit

Ariadni Georgatou[1], **Cornel de Ronde**[1], **David Adams**[2] **and Bruce Charlier**[3]

[1] *GNS Science,1 Fairway Drive, Lower Hutt 5040, New Zealand*
[2] *The University of Auckland, Auckland 1010, New Zealand*
[3] *Victoria University of Wellington, Wellington 6140, New Zealand*

a.georgatou@gns.cri.nz

Brothers active volcano, situated along the Kermadec arc, is one of the most well-studied submarine systems associated to sea floor massive sulfide deposits (SMS). With known hydrothermal and magmatic input, and metal-rich black smoker chimneys on the seafloor (up to Cu=36 wt.% and Au=90 ppm), Brothers presents similarities to shallow parts of magmatic-hydrothermal systems in subaerial volcanic arcs associated to porphyry-epithermal deposits. Here we investigate the petrogenetic processes controlling the behaviour of metals and volatiles along magma evolution, with depth and time through the study of fresh samples collected by an ROV along a vertical 370 m thick stratigraphic column at the NE side of the caldera wall.

High-resolution continuous visual feed combined to bulk rock chemistry depth profiles (floor-1825 mbsl to rim-1450 mbsl), reveal an alternation between massive, blocky, and lineated-ropy dacitic lava flows (SiO_2=64-65 wt.%), interrupted by the sporadic occurrence of tuffaceous sediments, providing additional stratigraphic and geochemical context to previous IODP findings. With time bulk MgO, Cu and Co, decrease, but variations are minor: (in ppm) Zn=170-177, Cu=1.4-13, Co=7.0-8.4, Mo=1.6-4.4, and (in ppb) Au=0.6-0.8, Pt=0.08-0.11 and Pd<0.14. The exception poses a high-K calc-alkaline andesite sample (SiO_2=62 wt.%) accounting for a massive lava flow collected at 1773 mbsl, presenting the highest (in ppm) Cu (40), Co (10), Ni (7.5) and (in ppb) Au (1.5), Pt (0.99), Pd (0.27) contents in the entire transect. While the latter high Cu values of the bulk rock are confirmed by high Cu_{median} also in the glass of the andesite (16 ppm) compared to lower Cu_{median} in the glass of the dacites (6 ppm), the opposite is documented for Au, accounting for lower Au_{median} in the andesite-glass (≤1.4 ppb=bdl) compared to the dacite-glass (4.5 ppb). Overall, our findings suggest decoupling of Cu and Au, as we move towards shallower crustal levels.

POSTER
Session 1b.

The 2022 Aotearoa New Zealand National Seismic Hazard Model

MC Gerstenberger[1], Sanjay Bora[1] Brendon Bradley[2], Chris DiCaprio[1], Anna Kaiser[1], Elena Manea[1,] Andy Nicol[2], Mark Stirling[3], Kiran Thingbaijam[1] Russ Van Dissen[1] and the NSHM Team

[1] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*
[2] *Department of Forestry, The University of Tangimoana, Manawatu, New Zealand.*

m.gerstenberger@gns.cri.nz

The 2022 Aotearoa New Zealand Seismic Hazard model is a significant revision in all model components. Changes to the seismicity rate model (SRM) include a focus on removing strict segmentation from ruptures on known faults. This allows for modelling of more realistic ruptures including uncertainty in both magnitude and length of possible ruptures. Additionally, more low-probability high-impact ruptures were included than were possible in the past. Specific low-seismicity region models were used that allow for the greater variability in occurrence rates that are observed in similar regions around the world. Finally, the SRM targets a 100-year forecast and models the variability in the occurrence rate that is greater than has been included in the past.

The Ground Motion Characterisation Model (GMCM) includes the use of multiple ground models (GMMs) for each tectonic type and includes internationally developed models (e.g., NGA). A new ground motion database has been compiled for assessment of the international models and for the development of two NZ backbone GMMs. The GMCM is a significant departure from past NSHMs and produces noticeably different ground shaking forecasts, both in median spectral values (and shape) and epistemic uncertainty. The large number of models used allow for the hazard results to include a large range of uncertainty in what the true hazard is.

Overall, the hazard forecast is increased in almost all parts of New Zealand compared to the 2010 model. On average the increase is about 50%, but this can vary significantly for any location or shaking frequency. Importantly, the revision estimates shaking for Vs30 rather than NZ Site Class, and this makes comparison to previous models challenging; there is no clear mapping between them. Finally, the range of increases are from roughly no change to more than doubling of the hazard.

ORAL
Special Symposium

RCET Contribution to Rapid Tsunami Threat Characterization

Ken Gledhill[1] **and Bill Fry**[1]

[1] *GNS Science, Wellington, New Zealand*

k.gledhill@gns.cri.nz; b.fry@gns.cri.nz

The bold challenge for tsunami science is how to characterize quickly and accurately the tsunami source to enable time-varying threat forecasts to facilitate effective public response. Ideally, a fully characterized tsunami source would be available within 10 minutes of event initiation to allow effective response at local, regional, and ocean-wide distances. This goal was the outcome of a 2018 expert symposium in Paris. Forecasting tsunami impacts is fundamentally a battle against uncertainty which is very large following event initiation but reduces as more data arrives and modelling is performed. The life cycle of a tsunami threat includes the detection of a tsunami event, characterization of the source, forecasting the potential time-varying impacts on coastal regions, the response of civil society and finally identification when the threat has passed.

The Rapid Characterisation of Earthquakes & Tsunami (RCET) research programme was formulated in response to the bold challenge above, and the requirements to forecast earthquake shaking impacts. Tsunamis are caused by the displacement of large volumes of water and the response to that displacement. RCET is applying a variety of techniques to characterize earthquake sources to allow forecasting of shaking and time-varying tsunami impacts. Around 80% of all tsunamis are the result of large undersea earthquakes making the identification of such events important for tsunami forecasting. Combining earthquake techniques (W-Phase, back-projection, strong motion centroid, GNSS, etc.) with the analysis of data from the recently established 12-site New Zealand DART buoy network provides powerful tools to quickly reduce the tsunami source uncertainties, forecast when, and where, and the likely severity and duration of tsunami impacts. The inclusion of the DART network allows the identification of non-earthquake sources in the tsunami threat lifecycle. RCET research proved very effective during recent tsunami events, including the Tonga - Hunga Ha'apai volcano-tsunami event in January 2022.

ORAL
Session 3c.

True Plate Tectonics Mechanisms

Tomasz Tomek Glowacki

tomek@tegassociates.co.nz

According to current publications, scientists are still unsure what mechanism is behind the movement of tectonic plates. Thermal convection favoured over many decades has finally been discarded. Promoted currently "The Plate Pushing and Slab Pulling, tidal drag and potential energy" theories are awkwardly justified leaving many questions unanswered. Scientists' divagations on this subject usually end: "*The mechanisms driving plate motion and the Earth's geodynamics are still not entirely clarified*". The following presentation is based on the fundamental laws of physics and current discoveries from other disciplines. It reveals that by recognizing the accelerations (or decelerations) of the Earth or its part, we can identify the forces acting on plates. Only by having that knowledge, we can begin to draw the correct conclusions and build computer programs that stimulate tectonic movements. Particularly intriguing is the mechanism responsible for moving plates along the Moon's equatorial plane.

POSTER
Session 1d.

After the big event: Aftershock analysis and the Mw 7.2 March 2021 East Cape Sequence

Alejandra Gomez[1], Jerome Salichon[1], John Ristau[1], Jonathan B. Hanson[1], Mathew Crighton[1], Tamiko Watson[1]

[1]*GNS Science Te Pū Ao, Lower Hutt, New Zealand*

a.gomez@gns.cri.nz

The GeoNet earthquake locating, monitoring, alerting, and processing system regularly faces spikes and long tails of aftershock activity following significant events. This creates a variety of challenges for real time analysis and for curating entries in the earthquake catalogue. While responding to a significant geological event is a relatively rapid process, responding to the subsequent sequence of events can be more complex and require more time for analysis.

An aftershock analysis starts in the National Geohazard Monitoring Centre, where a team of analysts will assess the sequence rapidly. The exponential increase in the number of events as well as the overlapping and tightly spaced phase arrivals can stress the system and limit the human analysts. These rapid solutions can have higher uncertainties and require further analysis.

The initial assessment plays a key role in assessing and responding to the potential hazardous consequences from the main event and to inform the seismicity rates that are key to probabilistic forecasts. However, further analysis is usually necessary and the aim of GeoNet is to improve the quality of the aftershock solutions with time.

We present an example of the review process carried out for the aftershock sequence of the 5 March 2021 East Cape earthquake. This local sequence was complicated a few hours later by Mw 7.3 and Mw 8.1 earthquakes near Raoul Island. Manually reviewing these sequences was necessary and critical due to the nature of the simultaneous sequences. We reviewed 15 days of data and emphasised on the reliability and consistency of phase picking. After the data was reanalysed, 2400 events were relocated, and 300 new events were added to the catalogue. We will also present moment tensor solutions from the Mw 7.2 main event and aftershock sequence. This sequence will be presented and preliminarily discussed.

POSTER
Session 2a.

Development of a Chemotaxonomic Classification of New Zealand Plants – Implications for Using Biomarkers to Reconstruct Our Bioheritage

Aileen Gordon[1], **Sebastian Naeher**[2], **Holly Winton**[1], **Andrew Rees**[1], **Liz Kennedy**[2], **and Ian Raine**[2]

[1] *Victoria University of Wellington, Wellington, New Zealand.*
[2] *GNS Science, Lower Hutt, New Zealand.*

aileen.gordon@vuw.ac.nz

Aotearoa-New Zealand's geographical isolation means that it is host to many unique forms of plant life, with ~84% of native plants being endemic. Factors such as land-use changes, introduced pests and climate change can lead to major changes in vegetation. This may impact plant biodiversity, with ~46% of New Zealand's native vascular plants currently at risk of extinction.

We propose to use organic geochemical constituents of plants (i.e., lipid biomarkers) to reconstruct changes in New Zealand's vegetation, offering a novel approach to understanding New Zealand's bioheritage. Internationally, biomarkers have been used as indicators of past vegetation composition (e.g., gymnosperm- vs angiosperm-plants, trees vs grasses); however, our current understanding of lipid biomarker composition in New Zealand plants is limited.

In this study, we investigate which biomarkers may be diagnostic of different types of native plants and aim to develop indicators to reconstruct past changes in vegetation composition using biomarkers from environmental archives.

We present biomarkers from 89 New Zealand plants, mainly comprised of angiosperms, with ten conifers and six fern species. These plant species were selected to represent a broad range of New Zealand plants, with a focus on plants found in the Tasman mountains of New Zealand's South Island. Potential chemotaxonomic indicators found in these plant species include n-alkanes, fatty acids, alcohols, and plant terpenoids (e.g., β-amyrin, lupeol, oleanoic acid, etc).

We will compare biomarker indicators developed from the 89 New Zealand plants with plant biomarker and pollen data from a sediment core in Adelaide Tarn, an alpine lake in the Tasman Mountains, Nelson. We will test the specificity and suitability of lipid biomarkers as indicators of vegetation changes in the lake's catchment over the past ~14,000 years. Using biomarkers as a palaeoecological proxy will add another line of evidence to environmental reconstructions, strengthening our understanding of New Zealand's paleoecology.

POSTER
Session 2c.

Seismic and gravity constraints on the stratigraphy of the Siple Coast region underlying the Kamb Ice Stream, Antarctica

Andrew R. Gorman[1], Caitlin Hall[1], Laurine van Haastrecht[1,2], Jenny A. Black[3], Huw Horgan[2], Gavin Dunbar[2], Gary S. Wilson[1,3], Matthew Tankserley[2] and Bob Dagg[1]

[1] *Department of Geology, University of Otago, Dunedin, New Zealand*
[2] *Antarctic Research Centre, Victoria University of Wellington, Wellington, New Zealand*
[3] *GNS Science, Lower Hutt, Wellington, New Zealand.*

andrew.gorman@otago.ac.nz

Sediments underlying the Kamb Ice Stream grounding line on the Siple Coast of the West Antarctic Ice Sheet (WAIS) potentially contain an important record of WAIS dynamics through the Quaternary. Notably, ROSETTA airborne-gravity data identified a gravity low that may correspond to a sedimentary sub-basin there. This region was successfully cored at the HWD1/KIS1 site (Lat/Long?) to a shallow depth (0.5m) in the 2019/20 season and is a prime target for deep drilling in 2023/4.

Focused geophysical datasets provide some details of the sub-ice-shelf ocean and sedimentary units that may be encountered there. Surveying has included a grid of about 73 km of seismic data collected during three seasons since early 2015, complemented by finely sampled gravity transects and a coarser regional gravity grid. Seismic acquisition parameters vary slightly from survey to survey. The preferred configuration involved a 0.8 to 2.4 kg explosive charge frozen into 25 m deep hot-water-drilled holes, recorded by a 96-channel symmetrically split array with a 10 m geophone spacing. Processed seismic data show a mostly flat layered seafloor lying beneath the ocean cavity with at least 200 m of sub-horizontally layered strata containing a number of mappable unconformities. We present a synthesis of the seismic and gravity data collected to date and propose a possible stratigraphic history for the region based on the imaged units.

ORAL
Session 2c.

Regional amplified warming in the Southwest Pacific during the mid–Pliocene (3.3–3.0 Ma)

Georgia Grant[1], Jonny Williams[2], Sebastian Naeher[1], Osamu Seki[3], Molly O. Patterson[4], Joe Prebble[1], Masanobu Yamamoto[3], Erik Behrens[2], Erin McClymont[5] and Katelyn Johnson[1]

[1] *GNS Science, Lower Hutt, New Zealand*
[2] *NIWA, Wellington, New Zealand*
[3] *Hokkaido University, Sapporo, Hokkaido, Japan*
[4] *SUNY Binghamton University, New York, America*
[5] *Durham University, Durham, United Kingdom*

G.Grant@gns.cri.nz

Global climate models are unable to accurately resolve the complex distribution of heat by ocean and atmospheric circulation and thus to accurately determine patterns of regional response to future climate projections. The New Zealand Earth System Model (NZESM) was developed based on the United Kingdom Earth System Model (UKESM) to include a nested ocean grid in the Southwest Pacific with 80% greater latitudinal resolution. Here we use regional paleoclimate data in the Southwest Pacific from the mid-Pliocene Warm Period (mPWP; 3.3-3.0 Ma) to assess the distribution of warming of climate projections from the NZESM and UKESM.

With reported interglacial warming of ~2-3° C under ~400 ppm atmospheric CO_2, the mPWP is considered an analogue for future warming under mid–range greenhouse gas emission scenarios. We investigate the magnitude of sea surface temperature (SST) warming for seven sites across the Southwest Pacific Ocean during glacial and interglacial conditions through the mPWP, using biomarker paleothermometry based on sedimentary distributions of alkenones (i.e., $U_{37}^{K'}$ index) and isoprenoid glycerol dialkyl glycerol tetraethers (i.e., TEX_{86} index).

Under the Intergovernmental Panel on Climate Change (IPCC) mid-range emissions scenario (SSP2-4.5) for 2° C of global warming by 2036–2045 AD, NZESM and parent UKESM show 2° C and 1.4° C warming, respectively, for the Southwest Pacific sites, which are more consistent with global averages. During the mPWP, mean interglacial SSTs were +4.2 ± 2.5° C across the Southwest Pacific sites. This is presumed to reflect the long-term earth system response to higher CO_2 but still highlights an amplified warming in the Southwest Pacific compared to interglacial global averages of the mPWP (~2-3° C). We note the NZESM better replicates the wider distribution of warming around New Zealand observed in the mPWP SSTs, compared to UKESM.

ORAL
Session 2c.

GNS Science's journey to be carbon neutral by 2025

Angela G Griffin[1], **Gary Wilson**[1] **and GNS Science Carbonreduce project team**[1]

[1] *GNS Science, PO Box 30368, Lower Hutt 5010, New Zealand*

a.griffin@gns.cri.nz

GNS Science has been tracking its carbon emissions from some of its largest emitting activities for more than a decade, before joining the Toitū Envirocare carbonreduce programme (previously known as CEMARS) in 2020. By joining the programme, GNS Science can now accurately measure the carbon emissions related to our science and to our organisation, and put strategies in place to manage and reduce impacts.

We have used the 2018-2019 financial year as a baseline, from which our emissions reduction targets will be measured against. Compilation of data from various sources related to our operational and organisational activities, including fieldwork and the staff commute, took place prior to joining the programme. Working with suppliers and vendors to acquire data for reporting has been a learning experience, and not always successful.

By reporting on Scope 1, 2 & 3 emissions, GNS Science's carbon emission total has reduced by ~14% since 2018-2019 (3218.44 tonnes CO_2e to 2112.26 tCO_2e in 2020-2021). Our top 10 emission sources equate to ~90% of our total emissions, with some of the biggest emitters being air travel, the staff commute, electricity, natural gas use and diesel vehicle use. Refrigerant leaks are also a concern, with a one-off leak creating 742.50 tCO_2e in 2020-2021.

We have set targets to reduce (rather than offset) the total net emissions by 20% by 2025. Subtargets relating to the biggest emissions are ambitious, however by engaging all of GNS (including the Board), we are confident that we can meet them. Data from our 2019-2020 and 2020-2021 financial years provides an indication of what can be achieved, when forced to reduce carbon-emitting activities and provide some guidance as to how to manage our emissions while maintaining our business.

ORAL
Session 2c,

Deep magma sources feeding eruptions from Red Crater, Tongariro

Kerstin Gruender[1], Simon J Barker[1], and Michael C Rowe[2]

[1] Victoria University of Wellington, Wellington, New Zealand
[2] School of Environment, University of Auckland, Auckland, New Zealand

kerstin.gruender@vuw.ac.nz

Andesite volcanoes are characteristic features of subduction zones that are ultimately driven and sustained by magma recharge from the mantle. However, crustal magmatic systems are complex and primitive magma compositions are mostly overprinted by mixing processes before eruption, obscuring signatures of deeper crustal levels and the mantle. Geochemical analysis of crystal cargoes of erupted magmas, especially early-formed minerals like olivine, can provide insights into deep magmatic processes. Tongariro is a large composite andesite volcano located in one of New Zealand's most volcanically active areas at the southern end of the Taupo Volcanic Zone (TVZ). We present new data on the magmatic driving force behind young (<1.8 ka) eruptions from Red Crater, one of Tongariro's currently active vents that last erupted in the early 1900s.

Sampled basaltic andesite scoria contains rapidly quenched primitive olivine (Fo_{85-90}) with abundant glassy melt inclusions which we have analysed for major, volatile and trace element concentrations. We identify at least three olivine and two melt inclusion populations, with compositions that are amongst the most primitive melts reported in the TVZ. Our initial interpretation supports the pre-eruptive recharge of primitive Mg-rich magma from a deep mantle source, interaction with at least one mid-lower crustal magma reservoir, followed by rapid ascent and eruption, as recorded by crystal and melt inclusion populations, mineral textures and zoning. This research provides insights into Tongariro's deeper volcanic magma system and will help to improve our knowledge about magma sources feeding eruptions in this area and contribute to our general understanding of andesite petrogenesis at continental subduction zones.

POSTER
Session 1b.

Geological Insights into the Eruptive History of the World's Largest "Dirty" Geyser: Waimangu Geyser 1900-1904, Waimangu Volcanic Valley, New Zealand

Annahlise Hall and Shane Cronin

School of Environment, University of Auckland, Auckland, New Zealand.

Ahal294@aucklanduni.ac.nz

The Waimangu Volcanic Valley of the Taupo Volcanic Zone in New Zealand was activated following the 1886 Tarawera eruption. Among its first geothermal features was the 1900-1904 Waimangu Geyser. At the time, this was the world's largest geyser, producing atypically vigorous and unusually ash-rich eruptions from a ~75 by 120 m-wide crater, which made it unclear whether the activity represented geothermal or magmatic processes. Deposits around the geyser were examined alongside historical imagery to interpret the geyser's origins. A 2.5 m-thick sequence of poorly sorted geyser tuffs were identified ~80 m northeast of the geyser vent, stratigraphically above the 1886 Rotomahana mud. Twenty-one samples of tuff/lapilli tuff beds were examined for grain-size distribution, lithology, and particle characteristics. Clay minerals assessed using XRD and SWIR spectroscopy were dominated by mixed-layered illite-smectite, suggesting a formation at ~150-220°C within alkali chloride waters below the geyser site. No evidence of fresh magma/glass proved the eruptions were not phreatomagmatically induced. Grain-size results suggest the geyser began vigorously, ejecting more coarser (>16 mm), mainly recycled 1886 basaltic scoria and Rotomahana mud particles. By contrast, later geyser activity ejected a greater proportion of finer (<64 µm) rhyolitic fragments from deeper horizons (e.g., Earthquake Flat Ignimbrite). Fining and lithological deposit changes demonstrate a deepening eruption locus and waning particle ejection energy through the geysers' lifetime. Geyser deposits and historical imagery expressed hybrid behaviour between hot spring "geysering" and intermittent small hydrothermal explosions, with the most violent explosions producing steam-rich pyroclastic surges. Steam-driven hydrothermal eruptions were driven by ejecta fall-back and intermittent collapse of the surface crater walls and/or the subterranean hot-spring plumbing system. Each vent-blocking episode trapped heated meteoric waters that induced excess fluid overpressures. The weak and thixotropic nature of Rotomahana Mud enhanced this process. From our results, we propose a new category of hybrid geyser behaviour caused when a hot spring cannot maintain a stable plumbing system in thixotropic and/or friable and unstable fine substrate sediments (e.g., recently emplaced pyroclastic deposits). Extensive Rotomahana Mud deposits remain in the Waimangu Valley. Thus, changes in the vent structures, especially of new hot-spring features, in geothermal fields should be monitored for possible initiation of similar hazardous hybrid geyser-hydrothermal eruptions.

POSTER
Session 1a.

Insights into the 15 January 2022 Hunga eruption (Kingdom of Tonga) through non-juvenile pyroclasts

Kyle Hamilton[1], Jie Wu[1], Shane Cronin[1], Ingrid Ukstins[1], David Adams[1] and Joa Paredes Marino[1]

[1] *School of Environment, University of Auckland, Auckland, New Zealand*

kham615@aucklanduni.ac.nz

To understand the geological and hydrothermal properties of pre-eruption submarine Hunga volcano, we examined the mineralogy, petrology and geochemistry of non-juvenile "lithic" pyroclasts within ash from the catastrophic 15 January 2022 eruption. The lithics make up ~10 vol% of the ash deposit. Lithic lithologies include (in order of abundance): pale grey dense lava (~43%), highly crystalline lava (24%), altered lava (21%), dark grey glassy lava (10%); red/oxidised scoria (~2%). Lithics show a broad spectrum of textures from pure glasses to aphanitic and porphyritic rocks, some with near 100% crystalline intergranular texture. The rocks are mainly andesitic, containing plagioclase and pyroxene (cpx>opx) with rare Fe-oxide. Hydrothermal alteration is common; secondary minerals include anhydrite/gypsum, pyrite, chalcopyrite, quartz. Plagioclase/feldspar composition is skewed towards a mode at An_{89-90}, but spans a wide range with a long tail of low-An numbers, compared with the 2022 primary products. Pyroxene Mg numbers from the lithics occupy a lower range (Mg# 15-87 vs ~35-93 for 2022), and glass has larger variations and higher concentrations in SiO_2 (52-68 vs 53-66 wt%). Estimates of crystallisation conditions using pyroxene pairs and melt Sr-Ba in equilibrium with plagioclase, indicate significant shallow ponding and crystallisation before eruption of these edifice rocks. Thus, the rocks represent the mainly evolved/upper parts of the whole system. Collectively, the lithics include shallow cumulates, lavas,Insi and related pyroclastics erupted below sea level. These products are consistent with samples collected from the islands spanning the last 2000 years of activity from Hunga. They suggest that the edifice has built up slowly from successive small-magnitude eruptions from the shallow magmatic system. The upper edifice collapsed in the catastrophic 2022 eruption, which sampled deeper components of the magmatic system not seen since pre-2022 materials.

POSTER
Session 1b.

Estimating the distribution of melt beneath the Okataina Caldera, New Zealand: An integrated approach using geodesy, seismology and magnetotellurics

Ian Hamling[1], Geoff Kilgour[2], Sigrun Hreinsdottir[1], Edward Bertrand[1], and Stephen Bannister[1]

[1] GNS Science, Lower Hutt, New Zealand
[2] GNS Science, Wairakei Research Centre, Taupo, New Zealand

i.hamling@gns.cri.nz

The inversion of geodetic data to estimate the position and depth of an inflating or contracting magmatic body is inherently non-unique. A priori information and complementary datasets (e.g. as Magnetotellurics (MT) and seismicity) are often used to fix the depth and position of the source prior to inversion. However, these datasets are typically used in isolation and in a qualitative manner. Here we use geodetic (InSAR and GNSS), seismological and MT data acquired over the Okataina Caldera, New Zealand, and perform a joint inversion where MT data are directly included in the inversion of surface deformation data. Geodetic data acquired over the last ~20 years have shown subsidence across the Okataina caldera and surrounding areas of up to ~15 mm/yr focussed beneath the two geologically active linear vent zones (i.e., Haroharo and Tarawera) and within the northern Ngakuru graben. Assuming the subsidence is largely being driven by the ongoing cooling and contraction of melt, we estimate the distribution of contraction beneath the region. With the inclusion of MT data in the inversion, we estimate an annual volume loss of 0.007 km3/yr, less than half the volume predicted by unconstrained inversions. We suggest that the observed seismicity in the vicinity of the caldera is driven by the long-term stressing from the contracting magma as well as periodic fluid and gas release into zones of increased permeability surrounding the cooling intrusion. Furthermore, we show that simple cooling models can explain long-term, near-linear, subsidence rates for periods of tens to hundreds of years.

ORAL
Session1e.

Towards the development of a routine, hi-resolution, InSAR derived deformation dataset for Aotearoa

Ian Hamling[1], Phaedra Upton[1], Conrad Burton[1], Chris Worts[1], Joe Manning[1] And Matt Bray[2]

[1] *GNS Science, Lower Hutt, New Zealand*
[2] *SatSense Ltd, Leeds, UK*

i.hamling@gns.cri.nz

The surface of our planet is constantly deforming and changing shape. Whether from the build-up and release of tectonic strain before and after an earthquake, the movement of magma in the crust, removal of resources (e.g. water, oil and gas) or landslides; accurate measurements of how the surface is deforming provides critical insights into subsurface processes which can have large impacts on society. In the past measuring deformation was time consuming, expensive and in some cases required an observer to venture into difficult or dangerous regions to make measurements. However, the development of a technique known as Interferometric Synthetic Aperture Radar (InSAR) in the early 90s has revolutionized the way we measure the deformation of the Earth's surface. By comparing the phase information from radar signals produced by satellites orbiting ~700 km above the Earth, we can measure millimeter scale surface displacements over thousands of square kilometres. Unlike past radar missions which provided limited numbers of acquisitions across New Zealand, the launch of the Sentinel-1 constellation in late 2014 now routinely images New Zealand every 6-12 days over the entire country. This data has transformed InSAR into a low-cost, practical tool for routine monitoring providing measurements at spatial resolutions of ~4 x 14 m. At these resolutions, InSAR has become a viable solution for providing hi-resolution up to date timeseries at a national scale opening up opportunities for urban and infrastructure monitoring. However, the computational and storage challenges of providing robust, up to date deformation timeseries at full resolution are not trivial. Here we demonstrate the wealth of opportunities InSAR can offer and detail GNS's collaboration with commercial partners to generate a nationwide deformation datasets for improved understanding of New Zealand's evolving land surface

POSTER
Session 4b.

Distributed Acoustic Sensing (DAS) for geophysical applications in Aotearoa, New Zealand

Shahna Haneef[1], Kasper van Wijk[1,] Neil Broderick[1], Ludmila Adam[1], and Nader Issa[2]

[1] *Dodd-Walls Centre and Department of Physics, University of Auckland, New Zealand*
[2] *Terra15 Technologies Pty Ltd, Perth, Australia.*

k.vanwijk@auckland.ac.nz

Distributed Acoustic Sensing (DAS) is a rapidly evolving technique to measure vibrations of a fibre optic cable. Because of the ubiquity of fibre in telecommunications, the potential for DAS is immense. Applications vary from monitoring infrastructure to subsurface characterization. We can use DAS with existing fibre optic cable installations, or wih purposly deployed fibres, such as in the Deep Fault Drilling Project 2.

To seize on the opportunities for DAS in geosciences in Aotearoa, we recently acquired a DAS interrogator. A DAS interrogator sends a laser pulse down the fibre optic cable, and detects weak reflections of the laser light from inpurities inherent to every fibre optic cable. The arrival time of the reflection is combined with the velocity of the light in the fibre to determine the location of this impurity. When vibrations move the fibre, so do the impurities. Changes in the arrival times of reflections from these impurities provide infomation about the local vibrations in the ground.

Our first measurements with our DAS system were on the campus of the University of Auckland in an existing unused ("dark") fibre. In this presentation, we will introduce DAS technology and applications, and show our first results of monitoring building activity on campus, and the detection of earthquakes.

ORAL
Session 4b.

A preliminary study of late Holocene sedimentary records from Te Whakaraupō | Lyttelton Harbour, New Zealand

Johanna Hanson[1], **Catherine Reid**[1], **Matiu Prebble**[1], **James Shulmeister**[1], **Chris Moy**[2], **Quan Hua**[3], **and Atun Zawadzki**[3]

[1] *School of Earth and Environment, University of Canterbury, 20 Kirkwood Avenue, Upper Riccarton, Christchurch 8041, New Zealand*

[2] *Department of Geology, University of Otago, 362 Leith Street, North Dunedin, Dunedin 9016, New Zealand*

[3] *Australian Nuclear Science and Technology Organisation, New Illawarra Road, Lucas Heights, New South Wales 2234, Australia.*

johanna.hanson@pg.canterbury.ac.nz

Limited research has been conducted on Holocene records from Horomaka | Banks Peninsula, New Zealand. Changes in past environmental conditions (e.g., relative sea levels, changes in vegetation and sediment mobility) and how the landscape has changed over the Holocene (particularly human landscape alteration), is not well understood in this area. Our research will provide insight into the links between marine and terrestrial proxies to investigate past environmental changes around Horomaka. Sediment cores from Te Whakaraupō | Lyttelton Harbour, Kawatea | Okains Bay and Te Wairewa | Lake Forsyth will underpin palaeoecological, sedimentological and geochemical research to better understand environmental changes over the late Holocene.

A 3.4 m shallow-marine sediment core collected from Head of the Bay, Te Whakaraupō | Lyttelton Harbour records the infilling of the harbour over the last several thousand years. Foraminiferal and geochemical analyses were conducted to examine past environmental conditions and sedimentation changes over the Holocene. Rapid infilling of the harbour is shown in three distinct horizons which show a shift from low intertidal to high intertidal and then to present day salt marsh. This is correlated by our X-ray Fluorescence data which shows increased variability in terrigenous sediment and organic content at the top of the record.

Future analyses on this core will include pollen and micro-charcoal analyses and grain size analysis to further understand environmental changes at Horomaka. This research will present important information on a previously understudied area regarding past marine and terrestrial environmental change and sedimentation rates over the late Holocene. Our research will also help inform the management response to future climate change and increased urban development in the harbour.

POSTER
Session 2c.

The New Zealand Deep-ocean and Reporting on Tsunamis (DART) Network: Update and Data Access Steps Forward

Jonathan B. Hanson[1], Megan Madley[1], Jerome Salichon[1], Mark Chadwick[1], Richard Guest[1], Jeremy Houltham[1], Elizabeth Garlick[1], Anna Davison[1], and GeoNet[1]

[1]GNS Science, Lower Hutt, New Zealand

m.madley@gns.cri.nz

Between 2019 and 2021, New Zealand deployed a deep ocean network of sensors to monitor ocean heights around its shores and the Southwestern Pacific Ocean. The array consists of 12 DART tsunameters, or bottom pressure recorders (BPR), that monitor tsunamis from the Hikurangi, Kermadec, Tonga, and Vanuatu subduction zones. This collaborative effort between multiple scientific institutes and government agencies (including NEMA, GNS, NIWA, MFAT) represents a big step forward for tsunami monitoring and research.

Monitoring mode (sample rate 15min, transmission rate every 6 hours) records the current deep-sea tides, while high-rate triggered modes (15s data sampling, with variable transmission) capture any abnormal sea-level fluctuations exceeding certain ‘trigger’ values. Trigger events are captured by the NGMC and information from them is used for research and response. Roughly every 2 years, the bottom pressure recorder (BPR) instruments are recovered from their offshore sites and the data downloaded from them provides the raw, original, 15s continuous dataset from the past 2-year period since their deployment.

Improvements in the data access and usage have culminated in this dataset being made more searchable, downloadable and plottable through a common time-series API and data discovery GUI named TILDE as well as a DART specific visualisation on the GeoNet website. Monitoring, triggered and post deployment water height data is available (15s data from 2019 to 2021 for A, C and E; and from 2020 to 2022 for B, F, G, H and I). The de-tided data is later calculated using tidal constituents (which are made freely available).

Recent examples from this dataset will be presented to illustrate access and dataset improvements, as well as insights into some data management and operational learnings, including how to cite this dataset properly. We’d also be really keen to hear any feedback from DART data users.

POSTER
Session 2b.

Mesh Design for inversion model resolution of the magmatic system beneath Mount Tongariro, New Zealand

Wiebke Heise, Charles Williams, Peter McGavin, Grant Caldwell, Ted Bertrand, Stephen Bannister, Yoshiya Usui, and Geoff Kilgour

Tongariro Volcanic Centre is a large andesite-dacite stratovolcano complex located at the southern end of the Taupo Volcanic Zone which is located above the subduction of the Pacific plate below the Australian plate in the central North Island of New Zealand. Data from 128 magnetotelluric (MT) measurements have been modelled with a 3-D inversion code which uses an unstructured tetrahedral mesh and can model the pronounced topography of the Tongariro Volcanic Centre.

We test different mesh sizes to investigate the resolution of the MT model at different depths. Main focus was the depth were magma storage is predicted at ~ 5-10km depth. We show the influence of mesh design and smoothing parameter alpha on the 3D-inversion result.

The resulting 3-D resistivity model shows the near surface hydrothermal system and its connection to a deeper magmatic source. Comparison with the seismic tomography shows a good correlation of low Qp and low electrical resistivity values suggesting that the magmatic source at depth extends to the east of the volcanic complex. Together seismicity, electrical resistivity, seismic tomography and petrological data give a coherent picture of the magmatic system of the Tongariro volcanic centre that agrees well with the conceptual geological model.

ORAL
Session 1a.

GeoDiscoveryNZ and ANZIC: A Decadal Strategic Vision

Stuart Henrys[1], Ron Hackney[2], GeoDiscoveryNZ and ANZIC members[3]

[1] *GNS Science, P.O. Box 30368, Lower Hutt 5040, New Zealand*
[2] *Research School of Earth Sciences, The Australian National University, Acton ACT 2601 Australia*
[3] https://iodp.org.au/about/anzic-members/

s.henrys@gns.cri.nz

Down-under, membership of international scientific drilling programs (IODP and ICDP) has accelerated globally-coordinated Earth Systems science research in Australasia and the Southern Ocean in the last two decades. Our vision for the next decade is to advance new mission -led scientific drilling projects that will make discoveries leading to improved decision making and advances policy to ensure our lands and seas are safe and sustainable. Our goal is to mature existing proposals and launch new projects, inspire early career researchers, grow wider use of existing digital databases, promote partnerships that will help secure long-term co-funding, and foster a wider perspective of Oceania to include our Pacific neighbours in the ANZIC community.

In 2020 the Earth science community has established a 30-year new science plan, Exploring Earth by Scientific Ocean Drilling; 2050 Science Framework, focusing on understanding Earth's Natural Hazards, Cycles and Rates, and Health and Habitability. Over the next decade, GeoDiscoveryNZ and ANZIC together will expand promotion for scientific research and work with partners to address climate change and hazard challenges. We will endeavour to fill critical gaps in our understanding of natural hazard precursors and the short- and long-term earth responses. We are also aware of the need to increase our ability to measure and monitor processes and perils. To reduce the vulnerability of social human-infrastructure systems to climate change requires improved understanding of the earth's climate system. To do this, we will continue to research our past land and seascapes. Furthermore, we will make sure that legacy datasets and collections are analysed and explore integrated multidisciplinary virtual expeditions. Our global partnerships are essential for growing capability and bringing significant new knowledge and critical thinking down-under as well as attracting additional scientific infrastructure and equipment.

POSTER
Session 2e.

Geochemistry: What can it tell us about eruption explosivity?

Brenda Contla Hernandez[1], Melody Whitehead[2], Mark Bebbington[1,2], and Michael C. Rowe[3]

[1] *School of Mathematical and Computational Sciences, Massey University, Palmerston North, New Zealand*
[2] *Volcanic Risk Solutions, Massey University, Palmerston North, New Zealand*
[3] *School of Environment, University of Auckland, Auckland, New Zealand*

b.hernandez@massey.ac.nz

It is generally agreed that the magma composition is an important factor in determining eruption explosivity. However, quantitative linkages between geochemical data and eruption style remain ambiguous. This presentation provides insights obtained from statistical analysis of geochemical data from whole-rock analysis of Holocene eruptive products. Data from the GEOROC database is matched against eruption style (VEI) from the GVP catalogue for 459 eruptions from 155 volcanoes. The aim is to identify possible relationships and key parameters, and the robustness of their correlations.

Several methods from a variety of ML methods (including Naïve Bayes, Random Forest, Support Vector Machines, among others) were used to identify possible relationships between geochemical data and VEI, as well as possible limitations on the use of each method. The preliminary results indicate that eruptions with VEI 0 and 5, 6 and 7 are more definitely influenced by the magma compositions than eruptions of more moderate intensity. Geochemistry seems to have little predictive power for eruptions with VEI 1,2,3 and 4. We hope to build on these results by developing a forecasting procedure for the geochemistry of the next eruption, and thus statistically inform robust eruption scenarios.

ORAL
Session 4a.

Aggregate opportunity modelling for New Zealand

Matthew P Hill[1]

[1] *GNS Science, 1 Fairway Drive, Avalon, Lower Hutt, New Zealand*

m.hill@gns.cri.nz

Efficient utilisation of New Zealand's aggregate resources is critical to supporting infrastructure development as well as reducing operational and transport costs related to extraction of the raw materials. To achieve this, aggregate sources and the quality of those resources needs to be identified, they must be reserved from competing land interests wherever possible, they should be extracted close to their markets and the requirements and concerns of all stakeholders should be understood.

A mineral potential modelling approach has been used to identify places with opportunity for future hard rock and gravel extraction across New Zealand. Geographic information system (GIS) software has been used to build a spatial model of the critical components of aggregate opportunity using digital geological, land-use, statistical and geographic data. Model components include source rocks, land use, future demand, supporting infrastructure and cultural sensitivity that use 23 mappable criteria layers. These are combined using the fuzzy logic expert-weighted spatial modelling technique to qualitatively rank aggregate resource opportunities at a national scale.

The resulting maps and their GIS-based equivalent datasets of gravel and hard rock aggregate opportunity can be used to manage aggregate resources, generate targets for exploration activities and provide insight into future resources.

POSTER
Session 4f.

Mapping and analysis of the structure and topology of a brittle-ductile fault swarm at Crawford Knob, Franz Josef, New Zealand

Matthew P. Hill[1], Susan M. Ellis[1], and Timothy A. Little[2]

[1] GNS Science, 1 Fairway Drive, Avalon, Lower Hutt, 5010
[2] Victoria University of Wellington, P.O. Box 600, Wellington, 6040

m.hill@gns.cri.nz

We present surface and structural models of a swarm of subparallel faults exposed in a glaciated outcrop near Franz Josef Glacier, in the Southern Alps of New Zealand. These structures are inferred to have slipped at ~20 km deep in the hanging-wall Alpine Schist of the Alpine Fault under conditions that were variably brittle to ductile as the Pacific Plate was tilted and uplifted. Using field mapping, real-time kinematic GPS and digital images from a remotely piloted aircraft system (RPAS, also known as a drone), we have created a digital surface model of the outcrop and orthophotographs at a ground resolution of ~1 cm to map compositional layering in the metasediments and the array of brittle-ductile faults displacing them. In order of decreasing relative age (and average thickness), displaced markers in the schist include primary psammite and pelite beds, quartz veins, and a deformational foliation. The surface models have been used to create 2-D transects and a 3-D model where faults are projected down-dip, to determine the connectivity, topology and intersection types of the fault swarm. Lithological variations, particularly the interface between pelitic and psammitic schist, were a primary control on the topology of the fault network and the spacing between faults.

This study also provided an opportunity to compare geological observations made in person while in the field with those that could be recognised from high-resolution remotely sensed data. We conclude that using an RPAS to collect detailed data is advantageous as it can acquire data for rock outcrops rapidly and at inaccessible locations; however, some features that were observed in the field could not be easily distinguished in the digital datasets. Therefore, a combination where mapping from remotely sensed data is guided by field observations, such as in this study, is an excellent hybrid mapping technique.

POSTER
Session 1c.

Redefining the southern extent of the Hikurangi Margin gas hydrate province

Jess IT Hillman[1], **Gareth Crutchley**[2], **Bryan Davy**[1], **Sally Watson**[3] **and Joshu Mountjoy**[3]

[1] GNS Science, Avalon, Lower Hutt, Aotearoa New Zealand
[2] GEOMAR Helmholtz Centre for Ocean Research, Kiel, Germany
[3] NIWA, Hataitai, Wellington, Aotearoa New Zealand

j.hillman@gns.cri.nz

The Hikurangi Margin hosts Aotearoa New Zealand's largest gas hydrate province. Prior to the acquisition of new seismic data in 2018, little was known about the southern extent of the Hikurangi Margin gas hydrate province offshore Kaikōura. Using geophysical data acquired during voyage TAN1808 we investigate the extent and characteristics of gas hydrates in this region. During the same voyage, water column imaging data were acquired, revealing the location of several active gas seeps. These data revealed seepage extending up to 130 km farther south than previously identified, along the mid-slope Kēkerengū Bank thrust ridge. Offshore Kaikōura, seepage is widespread along the crest of Kēkerengū Bank, with the southernmost site located in the Kōwhai Sea Valleys (Watson et al. 2020).

Recently acquired seismic data, combined with existing industry seismic data, allow us to determine the relationship between gas hydrate occurrence and deformation associated with the Hikurangi Subduction zone. The southern limit of the gas hydrate province may well coincide with the southern termination of tectonic-derived deformation. Sediments in the southern Hikurangi Margin have experienced pronounced compaction and horizontal compression due to impingement of the Chatham Rise on the deformation front, in addition to extensive erosion and highly variable sedimentation rates associated with the Kaikōura Canyon system. We investigate the relationship between fluid migration, gas hydrate formation and enhanced deformation in this area. At present, no evidence indicating the presence of gas hydrates has been observed south of Kaikōura along the east coast of Te Waipounamu South Island, although there is evidence for shallow gas and possible seep sites in the area. In addition, we use newly acquired subsurface data to investigate the relationship between fluid flow processes and the dynamic seafloor topography of the submarine canyons in this region.

ORAL
Session 2e.

the human footprint on the seabed: case studies from the southern Hikurangi

<u>Jess IT Hillman</u>[1], Sarah Seabrook[2], Sally Watson[2], Xanthe Smith[3], McKenzie Jones[3], Dave Bowden[2], and Ashley Rowden[2,3]

[1] *GNS Science, Avalon, Lower Hutt, Aotearoa New Zealand*
[2] *NIWA, Hataitai, Wellington, Aotearoa New Zealand*
[3] *Victoria University of Wellington – Te Herenga Waka, Aotearoa New Zealand*

j.hillman@gns.cri.nz

Humans have considerable, widespread, and ever-increasing impact on the health of oceans worldwide. Most seabed habitats globally have been impacted by human stressors in some form (Halpern et al., 2019), from the coast to the deepest parts of the oceans. In Aotearoa/New Zealand the offshore exclusive economic zone is ~15 times the land area and supports a range of industries and as a result hosts numerous human pressures including fisheries, pollution, and resource extraction. Seafloor seeps are abundant along the Hikurangi Margin (Watson et al. 2019), and support dynamic, highly productive local ecosystems. These seeps are predominantly located along the crest of thrust ridges that have formed due to subduction related deformation. The structural complexity and localised sources of production provided by seep systems support commercially important fisheries species, such as those targeted by benthic trawlers (Bowden et al. 2013, Seabrook et al. 2019).

Benthic trawling around Aotearoa New Zealand is constrained to water depths of <1500 m. Recent video data, acquired using remotely operated vehicles (ROVs), has highlighted contrasts in seabed morphology and species abundance between active seep sites within, and outside of, the designated trawling zone. At some sites the direct impact of trawling, such as trawl marks on the seafloor, is clear, whilst at others the effect is marked by the lack of seep fauna. ROV video footage of the seabed also reveals the presence of rubbish at numerous locations.

We document observations from recent voyages along the southern Hikurangi, highlighting locations where humans have impacted the seabed. We contrast sites across different depth ranges and localities along the margin to emphasise the impact of different human activities on seabed habitats. Results presented are critical for marine environmental planning to ensure the sustainability of human activities in the oceans around Aotearoa New Zealand, particularly under future climate change projections including reduced deep sea food supply.

POSTER
Session 2e.

Auckland's Fossil Fuel CO_2 Emissions: A Bottom-up Inventory Informed by Atmospheric Radiocarbon Observations

Timothy W. Hilton[1], Elizabeth D. Keller[1], Sapthala Karalliyadda[1], Adrian Benson[1], Lucas Domingues[1], Harrison O'Sullivan-Moffat[1], Hayden Young[1], Jeremy Parry-Thompson[1], Nikita Turton[1], Sally Gray[2], Gordon Brailsford[2], Rowena Moss[2], Lucy Hutyra[3], Kevin Gurney[4], and Jocelyn C. Turnbull[1]

[1] *GNS Science Te Pū Ao, Lower Hutt, New Zealand*
[2] *NIWA Taihoro Nukurangi, Wellington, New Zealand*
[3] *Boston University, Boston, Massachusetts, USA*
[4] *Northern Arizona University, Flagstaff, Arizona, USA*

t.hilton@gns.cri.nz

The largest city in New Zealand, Auckland is home to roughly 1.5 million people -- one third of New Zealand's population. Despite a large urban population, the city contains a significant amount of green space that can act as a carbon sink to offset anthropogenic fossil fuel emissions. We use a high resolution (street segments and buildings, hourly) bottom-up inventory of Auckland's fossil fuel carbon dioxide emissions from a variety of data sources. We use these emissions estimates in combination with the UrbanVPRM land surface model to estimate the net carbon balance of the Auckland region. We compare this carbon balance estimate with atmospheric observations of CO_2 and $^{14}CO_2$ collected from in-situ sensors and flasks across the city as part of the CarbonWatch NZ project. CarbonWatch NZ uses atmospheric observations and modelling to assess New Zealand's progress toward its obligations under the Paris Agreement and New Zealand's Zero Carbon Act.

ORAL
Session 4d.

A Kinematic Model of New Zealand Fault Slip Rates and Distributed Deformation

Hamish Hirschberg[1] **and Rupert Sutherland**[1]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand*

hamish.hirschberg@vuw.ac.nz

We use fault slip rates to construct a kinematic model of the New Zealand plate boundary zone that represents deformation averaged over several seismic cycles and includes slip rates on major faults and strain rates between faults. We additionally create a model of strain rate style from fault slip rates. We use a non-linear regression method to solve for a velocity field with embedded faults that is consistent with slip rate observations, our strain rate style model and plate motions. The resulting kinematic velocity model provides a good fit to observations, balances on-fault and off-fault deformation and shows the major features of the plate boundary. The model provides estimates of shortening on the Hikurangi subduction zone ranging from 45±8 mm/yr to 20±3 mm/yr from north to south. Large strains are predicted adjacent to the Alpine fault, indicating ∼9 mm/yr of plate motion that is not accounted for by existing models of fault slip rates. In northeastern North Island, there is a difference of 5-10 mm/yr from contemporary kinematics, which suggests an inaccuracy in our long-term velocity field due to limited observations.

ORAL
Session 1d.

Engaging with End-users Towards an Earthquake Early Warning System for New Zealand

Caroline Holden[1,2], Rasika Nandana[1] and Martha Savage[2]

[1] *SeismoCity Ltd, Wellington, New Zealand*
[2] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington.*

caroline.holden@seismocity.co.nz

Earthquake early warning systems (EQEWS) should be part of an Earthquake Resilience toolkit as they can potentially save injuries and lives. The Sendai Framework of disaster risk reduction 2015-2030 has 7 global targets including “Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to people by 2030”. However New Zealand does not currently operate a national EQEWS. What strategy needs to be adopted to get there?

EQEWS relies on 3 pillars: earthquake science, sensor and communication technologies, and end-users. Scientists have made tremendous progress in earthquake science and related EQEWS algorithms. Sensor technology and communication engineering constantly evolve allowing to "save precious seconds" (Prasanna et al., 2022). Finally there is an appetite for EQEWS in New Zealand (Becker et al., 2020).

- Funded by RNC2, we are currently developing a simulation toolbox to engage with national end-users (EQC and NEMA for example) by developing:
- realistic input parameters (current state of the National network of instrumentation, investment required to upgrade/maintain for desired warning levels and uncertainties),
- realistic simulation models (EQEW algorithms tested on realistic earthquake catalogs)
- statistical outputs that can be converted into a dollar value. Benefits such as life safety can be quantified by the economic cost by mapping the cost to society from minor-major injuries. The benefit of a EQEWS on providing damage avoidance strategies for structures and infrastructure can also be directly valued economically.

Any proposed strategy to support EQEWS implementation needs to take into account already existing community resilience. Any new response systems need to work in harmony or inform current practices rather than being disruptive and confusing for the public.

ORAL
Session 3c.

High-frequency Ground-shaking Simulations for Alpine Fault Earthquake Scenarios

Caroline Holden[1,2], Townend[2] J, Chamberlain[2] C.J, Warren-Smith E.[3], Juarez-Garfias I.C.[2], and Pita-Sllim O.[2]

[1] *SeismoCity Ltd, Wellington, New Zealand*
[2] *School of Geog., Env., and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand.*
[3] *GNS Science, Lower Hutt, New Zealand*

Caroline.Holden@seismocity.co.nz

As part of the Southern Alps Long Skinny Array (SALSA) project, ~35+ seismometers have been deployed with 10–12 km spacing along a 450 km-long section of the Alpine Fault. SALSA is focused on determining the ground motions likely to be produced by a future Alpine Fault earthquake. This project is addressing three principal objectives: 1. Determine the Alpine Fault's subsurface geometry, present-day slip rates, and spatial variations in how tectonic stresses are currently accumulating on the fault; 2. Estimate the ground shaking that would be recorded at seismometers throughout central and southern New Zealand by localised slip at different points on the Alpine Fault; focusing on the synthesis of long-period Green's functions representing accurate path effects between sources distributed along the fault and population centers throughout the South Island. and 3. Calculate the ground shaking hazard from geologically-informed earthquake rupture scenarios. To achieve objective 3, the synthesis of high-frequency ground motion still needs to be addressed, however, and this will rely on better characterization of stress drops (Objective1) and attenuation models. Along with attenuation, stress drop affects synthetic spectra markedly. In this presentation we will address the influence of stress drop variation and of the attenuation function on high-frequency ground-shaking for Alpine Fault earthquakes.

POSTER
Session 2a.

A High-Resolution Precipitation Record from a Cook Islands Speleothem: Evidence for a Teleconnection with Northern Hemisphere Climate During MIS 3

Gavin Holden[1], and Dan Sinclair[1]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand*

Gavin.holden@vuw.ac.nz

Here we present a high-resolution paleoprecipitation record extracted from a stalagmite from Aitu, southern Cook Islands (20°0.0’ S 158^{0}5.0’W). Aitu is a karstic makatea island located south of the present-day mean position of the South Pacific Convergence Zone (SPCZ). The SPCZ is known to make large deviations from its mean position in response to variations in tropical climate, which manifest as regional-scale changes in the distribution of precipitation. This record covers the early and middle parts of Marine Isotope Stage 3 (MIS 3), with up to sub-decadal scale resolution in the fastest growing section. Stable isotope ($\delta^{18}O$, $\delta^{13}C$) and trace element (Mg, Sr) variations indicate large-amplitude changes in precipitation lasting up to 1000 years. For the time-period 39-37.4 ka, these variations are very similar to the NGRIP $\delta^{18}O$ record, and the wettest period coincides with Heinrich Stadial 4. Furthermore, there is a transition from a wetter to a drier climate that coincides with Dansgaard-Oeshger event 8. There is a similar but weaker relationship between precipitation and the NGRIP $\delta^{18}O$ record for the time-period 56.5-55.3 ka. The remarkable similarity between the Aitu precipitation and NGRIP $\delta^{18}O$ records, particularly for the time-period 39-37.4 ka implies that there is a teleconnection between the tropical Pacific and the Northern Hemisphere high-latitudes that is non-stationary in time. The Aitu record also suggests that the response of the SPCZ to changes in Northern Hemisphere climate may be more complex than rotation or north-south migration, with the possibility that the SPCZ has at least two components that can act independently of each other.

POSTER
Session 4d.

Making Sense of Paleocene Zealandia

Christopher J. Hollis[1], Sebastian Naeher[2] Christopher D. Clowes[2], B. David A. Naafs[3], Richard D. Pancost[3], Richard Sykes[2], Molly M. Range[4], Brian K. Arbic[4], Brandon C. Johnson[5], Vasily Titov[6], and Ted. C. Moore[4].

[1] *Victoria University of Wellington, Wellington, New Zealand*
[2] *GNS Science, Lower Hutt, New Zealand.*
[3] *Organic Geochemistry Unit, School of Chemistry, School of Earth Sciences, and Cabot Institute for the Environment, University of Bristol, Bristol, UK.*
[4] *Department of Earth and Environmental Sciences, University of Michigan, Ann Arbor, USA.*
[5] *Department of Earth, Atmospheric, and Planetary Science, Purdue University, West Lafayette, USA*
[6] *National Oceanic and Atmospheric Administration, Pacific Marine Environmental Lab, Seattle, USA*

Chris.hollis@vuw.ac.nz

Recent research helps to resolve two long-standing mysteries in local Paleocene stratigraphy and in turn demonstrate the pronounced impact of past global changes on Zealandia's environment. The first mystery relates to the Cretaceous/Paleogene boundary (KPB). Why does Zealandia have such a patchy record of this event, especially in North Island's East Coast Basin, where the KPB coincides with deposition of glauconitic sands and in some places olistostromes? Even in the most complete sections in northeastern South Island, the KPB is marked by short hiatuses and evidence of erosion. It turns out the eastern margin of Zealandia may have felt the full force of the KPB megatsunami. Modelling predicts that the impact of a 14 km-diameter asteroid in Mexico generated a 1.5 km high wave. Primary trajectories modelled for the tsunami lay to the northeast and southwest of the impact site. Eastern Zealandia is predicted to have experienced waves over 10 m high and flow velocities >1 m/s (Range et al. 2022, AGU Advances).

The second mystery relates to the deposition of the Waipawa Formation, an organic-rich mid-Paleocene mudstone. Why does this potential petroleum source rock occur in some settings but not in others, and what caused the apparent regressive episode that led to its deposition? We find that organic matter in Waipawa Formation is mainly degraded terrestrial plant material, which was swept into the offshore sedimentary basins during short-lived climatic cooling that is linked to a drawdown of CO_2 (Hollis et al., 2022, Clim. Past 18, 1295-1320). This cooling event marks a significant perturbation in the long-term Paleocene–Eocene warming trend, perhaps caused by a brief cessation in volcanic outgassing of CO_2. Base-level fall, linked to cooling and expansion of ephemeral ice sheets, flushed terrestrial biomass into offshore depocentres in some settings and caused erosion and condensed successions in others.

ORAL
Session 2c.

Hydrological monitoring and speleothem analysis to trace modern and historic climate extremes in Hawke's Bay, New Zealand

Sebastian N. Höpker[1], Darden King[2], Richard NiaNia[2] and Adam Hartland[1,3]

[1] Te Aka Mātuatua - School of Science, University of Waikato, Hamilton, New Zealand
[2] Pōhaturoa Ahuwhenua Trust, Gisborne, New Zealand
[3] Lincoln Agritech Ltd, Hamilton, New Zealand

seb.hoepker@gmail.com

Cave systems present a major vector for water transfer and storage in karst landscapes, often including subterranean streams that channel a substantial proportion of the total recharge. Carbonate deposits (speleothems) within limestone caves are in turn sensitive to flow rates and chemistry of infiltrating dripwater, and thereby serve as valuable archives of a range of environmental and climatic processes. The analysis of speleothem geochemical signatures in combination with detailed karst hydrological studies thus presents a promising approach for improving our understanding of modern and historic extreme climate events, particularly floods and droughts.

With view to developing a new Holocene climate record in eastern New Zealand, our study aims to integrate a hydrological and spatial analysis of stream networks on Mt Whakapunake, Hawke's Bay, with speleothem-based climate reconstructions from Te Reinga Cave situated on the mountain. Specifically, we aim to comprehensively monitor external and within-cave atmospheric conditions, as well as the flow and hydrochemistry of subterranean and surficial discharge. Significantly, the complicated hydrological network of Mt Whakapunake, including streams inside Te Reinga Cave, are confirmed to feed the water for the spring supplying the Te Reinga Marae.

Our objectives are two-fold. Firstly, we seek to collect baseline data to characterise the hydrological and chemical variability of subterranean and surface water on Mt Whakapunake and Te Reinga Cave. Importantly, monitoring will cover the harvest period of the overlying pine forest plantation, providing the rare opportunity to comprehensively document associated changes to flow patterns and chemistry of streams, cave discharge, and the Marae spring. Secondly, we aim to use the collected information from hydrological and cave monitoring to corroborate speleothem-based climate reconstructions from Te Reinga Cave, specifically in regards of historic extreme climate events and rainfall variability.

POSTER
Session 4d.

GeoNet's Shaking Layer Tool: Automatic generation of maps of near-real time ground shaking for post-event response

Nick Horspool[1], Tatiana Goded[1], Anna Kaiser[1], Mark Chadwick[1], Danielle Charlton[1], Jeremy Houltham[1], Josh Groom[1], and Jose Moratalla[1]

[1]Te Pū Ao/GNS Science, 1 Fairway Drive, Avalon, P O Box 30 368, Lower Hutt 5040, New Zealand.

a.kaiser@gns.cri.nz

Information on ground shaking following an earthquake is important for many applications from emergency response, engineering assessments, infrastructure management, insurance claim estimation and research. GeoNet, along with the RCET Endeavour programme, is developing a tool, named Shaking Layers, that produces maps of ground shaking across New Zealand in the minutes after an earthquake. Shaking Layers uses the USGS ShakeMap software to create maps of PGA, PGV, MMI and Sa(T) for M4.0 and above earthquakes. The model combines observed ground motions from strong motion stations with ground motion models to produce spatial estimates of ground shaking for each intensity metric type. The first maps are available within 10-20 minutes of an earthquake. The maps are automatically generated and updated in the first instance, and can be manually updated by GNS Science seismologists if new information is available, such as a fault rupture model, earthquake tectonic type, moment tensor solutions and felt reports. This presentation will give an overview of GeoNet's Shaking Layer Tool and outline to the NZ Geosciences community how they can access Shaking Layer information through the GeoNet website, the Shaking Layer data website, and an API.

ORAL
Session 3c.

Growth of complex volcanic ash aggregates in the Tierra Blanca Joven eruption of Ilopango Caldera, El Salvador

Henry Hoult[1*], Richard Brown[1], Alexa Van Eaton[2], Walter Hernandez[3], Katherine Dobson[4], and Bryan Woodward[1]

[1] Department of Earth Sciences, University of Durham, Durham, DH1 3LE, United Kingdom
[2] U.S. Geological Survey, Cascades Volcano Observatory, Vancouver, Washington, 98683 USA
[3] Universidad de El Salvador, Ciudad Universitaria, San Salvador, El Salvador
[4] Civil & Environmental Engineering, University of Strathclyde, Glasgow, G1 1XJ, United Kingdom

**Now at: School of Earth and Environment, University of Canterbury, Private Bag 4800, Christchurch, 8140, New Zealand*

henry.hoult@pg.canterbury.ac.nz

Volcanic ash aggregation influences ash dispersal patterns by forming aggregates with greater terminal velocities than their constituent particles that prematurely remove fine ash from eruption plumes. Aggregates can range from simple particle clusters to centimetre-sized, subspherical complex aggregates comprised of multiple internal layers. The latter, also known as accretionary lapilli, are often associated with the deposits of pyroclastic density currents and co-ignimbrite plumes. Experiments investigating aggregation under different ambient conditions have reproduced aggregates with basic internal structures. Aggregate size, particle size distribution and particle arrangement have been shown to reflect binding force strength and ambient particle size distributions. The mechanisms governing complex aggregate formation, however, remain elusive. We present a novel facies classification scheme for the internal layers of complex aggregates that grew during the ~431 CE phreatoplinian Tierra Blanca Joven eruption of Ilopango Caldera, El Salvador. Using high-resolution SEM imaging, facies are distinguished based on quantitative and qualitative analyses of particle size distribution, porosity and fabric. Building on previous experimental work, we interpret variation between facies to reflect changes in ambient liquid water availability, particle concentration and grainsize distribution. Complex aggregates develop their internal structure during passage through ash clouds generated by vent-derived plumes and pyroclastic density currents. Samples with similar facies occurrence orders are inferred to share a common growth history. We also show complex aggregate growth to be dominated by the accretion of smaller pre-formed aggregates rather than individual particles. Similarities between the complex aggregates of this study and those elsewhere (e.g., Oruanui, New Zealand) suggest the Tierra Blanca Joven aggregates are representative of wider accretionary lapilli formation and ash aggregation processes.

POSTER
Session 1a.

Quantitative lacustrine paleoseismology may reveal the rupture direction of the 1717 CE Alpine Fault earthquake

Jamie Howarth[1], Adelaine Moody[1], Sean Fitzsimons[2], Russ Van Dissen[3], Tim Little[1], Jesse Kearse[1] and Marcus Vandergoes[3]

[1] *School of Geography, Earth and Environmental Science, Te Herenga Waka/Victoria University of Wellington, Wellington, New Zealand*
[2] *School of Geography, University of Otago, Dunedin, New Zealand.*
[3] *GNS Science, Lower Hutt, New Zealand*

jamie.howarth@vuw.ac.nz

The spatial distribution of earthquake ground shaking is controlled by the location, magnitude and rupture direction of an earthquake. Paleoseismic investigation can provide invaluable information on the location and magnitude of prehistoric large earthquakes but reconstruction of rupture direction has proved challenging. Recent work comparing the spatial distribution of ground motions to turbidite emplacement associated with the 2016 M_w7.8 Kaikōura earthquake has shown that turbidite paleoseismology may provide a tool for reconstructing rupture direction (Howarth et al., 2021). Here we use a network of seven lakes throughout the northern South Island of New Zealand to constrain the spatial distribution of ground motions and rupture direction of the most recent M_w>8.0 earthquake on the Alpine Fault that occurred in ~1717 CE. Precise chronologies developed from a combination of ^{210}Pb, biostratigraphy and ^{14}C dating were used to identify the sedimentary signatures (ranging from in-situ deformation structures to deposits resulting from subaqueous mass-wasting, and earthquake-related processes in the lake catchments) of historic earthquakes in the lakes to constrain the relationship between ground motions and the observed earthquake signatures. These calibrations were used to reconstruct the spatial distribution of ground motions associated with the 1717 CE Alpine Fault earthquake by identifying deposits formed by this earthquake using the precise chronologies and assigning ground motions based on the type of sedimentary signature associated with the earthquake. Preliminary comparison of the reconstructed spatial distribution of ground motions and physics-based ground motion simulations that account for rupture direction show that the 1717 CE rupture most likely had a south to north rupture direction. Ongoing work aims to establish whether the Alpine Fault has a preferential rupture direction by examining the shaking distributions of preceding earthquakes. Our work shows the potential of lacustrine paleoseismology for reconstructing the location, magnitude and now rupture direction of past earthquakes.

ORAL
Session 2a.

Uncertainty: Where do individuals think it comes from? Understanding mental models of natural hazards science and advice.

Emma E. H. Doyle[1], Jessica Thompson[1], Stephen Hill[2], Matt Williams[2], Douglas Paton[3], Sara Harrison[4], Ann Bostrom[5], and Julia Becker[1]

[1]Joint Centre for Disaster Research, Massey University, PO Box 756, Wellington, 6140, NZ;
[2]School of Psychology, Massey University, Private Bag 11-222 Palmerston North, 4442, NZ; Private Bag 102-904, North Shore, Auckland 0745 NZ;
[3]College of Health and Human Sciences, Charles Darwin University, Darwin, Australia
[4]GNS Science, Avalon, Lower Hutt, NZ.
[5]Evans School, University of Washington, PO Box 353055, Seattle, WA USA

E.E.Hudson-Doyle@massey.ac.nz

The science associated with assessing natural hazards and informing decision-makers contains many layers of complex and interacting uncertainties. This is compounded by the evolving nature of response needs, and the changing network of communication pathways. Further, varied understanding about what scientific uncertainty is, and where it comes from, affects people's trust in and use of science advice. It is thus crucial to understand these diverse perspectives. This enables scientists and science advisors to use the shared concepts underlying associated mental models to develop effective communication strategies that engender and maintain trust.

To understand perceptions of uncertainty associated with natural hazards science and advice, we conducted twenty-five mental model interviews in Aotearoa NZ with a diverse range of participants involved in risk, from physical scientists, through to policy writers, emergency managers, and the public. These three-phase interviews included initial elicitation of free thoughts about uncertainty, a mental model mapping activity, and a closing semi-structured interview protocol to explore further questions around scientific processes and an individual's philosophy of science. Qualitative analysis led to the construction of key themes, including: (a) the importance of recognizing the role of human behaviours, (b) understanding the 'actors' involved as sources of uncertainty alongside data sources, (c) acknowledging influences such as governance and funding decisions, and (d) the difficulty that most participants had in defining what uncertainty actually is.

Participants highlighted the positive role of uncertainty for promoting debate and as a catalyst for further inquiry. They demonstrated a level of comfort with uncertainty and advocated for 'sitting with uncertainty' for transparent reporting in advice. We present these findings to enhance hazard and risk communication, alongside the design of our interview methodology, which could be adapted for participatory and co-development research to build shared understanding of the science and uncertainties involved in natural hazard risk assessment.

ORAL
Session 3a.

Using 3D textures to assess magma-water interaction dynamics across varying conditions at Hunga volcano

Mila Huebsch[1], Joa Paredes-Mariño[1], Ingrid Ukstins[1], Jie Wu[1], David Adams[1], Shane Cronin[1], Mathieu Colombier[2], Anton Maksimenko[3], Matthew Cameron[3], Ian Schipper[4], Annaleise Klein[3], Mark Tobin[3], Jitraporn Vongsvivut[3], Taaniela Kula[5], Marco Brenna[6], James White[6], Rachael Baxter[6], and Marshall Palmer[6]

[1] *School of Environment, University of Auckland, Auckland, New Zealand*
[2] *Department for Earth and Environmental Sciences, Ludwig-Maximilians-University, Munich, Germany.*
[3] *The Australian Synchrotron, Australia's Nuclear Science and Technology Organisation, Melbourne, Australia.*
[4] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand.*
[5] *Tonga Geological Services, Ministry of Lands and Natural Resources, Nuku'alofa, Tonga.*
[6] *Department of Geology, University of Otago, Dunedin, New Zealand.*

mila.huebsch@auckland.ac.nz

On January 15th, 2022, the submarine caldera volcano Hunga, in the Kingdom of Tonga, created an extremely high eruption plume (55-57 km) dominated by ash-sized material and a high water/aerosol content. The fall distribution, extending at least 260 km from the volcano, and fine grainsize, with 36 wt.% (± 5 wt.%) of analyzed ash finer than 63 µm, contrast with typical Plinian eruptions. The measured observations of this eruption do not fit current models of eruption column generation and energy release, possibly due to poorly understood magma-water interaction processes. External water may amplify magma fragmentation and bolster explosivity, in a feedback loop between micro-fragmentation and ongoing direct contact between magma and water. During such a large-scale event, variable rates and styles of magma-water interaction can occur over time and space, in different water depths and sub-sea floor confinement conditions. Pyroclastic products and syn-eruption observations across subaerial, shallow subaqueous, and deep subaqueous stages of the 2022 Hunga eruption provide a unique opportunity to explore the diverse modes of magma-water interaction. We present textural analysis of internal crystal and vesicle distributions, and particle surface morphology, using 3D X-ray tomography data (~15 µm resolution) obtained at the ANSTO Australian Synchrotron, supplemented by 2D SEM imagery (~100 nm resolution). These analyses are used in combination with in situ geochemical analysis by electron probe microanalysis to identify syn-eruptive magma crystallization, gas exsolution, and fragmentation processes. By comparing pyroclastic products of each style of activity at Hunga, we explore the varying consequences of rapid quenching on eruption dynamics and the significance of primary and secondary fragmentation in submarine explosive eruptions.

ORAL
Session 1a.

SO_2 emissions from explosive basaltic eruptions at Okataina

Ery Hughes[1], **Geoff Kilgour**[1], **and Jon Blundy**[2]

[1] *Volcanology Team, Te Pū Ao | GNS Science, Aotearoa New Zealand.*
[2] *Department of Earth Sciences, University of Oxford, UK.*

e.hughes@gns.cri.nz

Volcanic SO_2 emissions can lead to global impacts on climate and health, depending on the magnitude and injection height into the atmosphere. Global impacts are caused by the conversion of SO_2 into aerosols, which can lead to significant solar screening for weeks to months after an eruption. The effects of basaltic volcanism are typically associated with long-lived fissure eruptions, which have local to global impacts (e.g., Kīlauea 2018, Laki 1783–1784, flood basalts). However, short-lived explosive basaltic volcanism can also inject significant SO_2 into the upper atmosphere affecting the local (and potentially even global) climate, environment, and health outcomes (e.g., Ambae 2018–2019, Sunset Crater 1085 CE). The Okataina Volcanic Centre (OVC) is the source of voluminous rhyolitic volcanism but also explosive basaltic eruptions. In this work, we focus on the SO_2 released from these basaltic explosive eruptions using the petrologic method.

We quantify the minimum SO_2 released from OVC basalts (Okareka 23.5 ka, Rotokawau 3.4 ka, Kaharoa 0.6 ka, and Tarawera 1886 CE) by combining sulfur concentrations in melt inclusions (up to 3200 ppm S) with erupted volumes derived from existing isopach maps. The basaltic Plinian eruption of Tarawera released up to ~4 Tg SO_2 over ~5 hours; the smaller eruption of Rotokawau potentially released up to ~10 Tg SO_2 over a much longer time period; and Okareka and Kaharoa released much less SO_2 due to their small erupted volumes (for comparison, Krakatau 1883 CE released 5.6 Tg SO_2). Rotokawau likely had significant local impacts due to the large SO_2 release and low plume heights (5–7 km). The significant SO_2 emissions from Tarawera, combined with the high injection heights (~28 km), supports recent work showing southern hemisphere cooling 1–2 years after the eruption. This highlights the potential impacts of eruptions of these sulphur-rich magmas from the OVC.

ORAL
Session 1e.

Using a multi-volatile thermodynamic model to understand the effects of sulphur on silicate magmas

Ery Hughes[1,2], Lee Saper[2,3], Philippa Liggins[4] and Edward Stolper[2]

[1] *Volcanology Team, Te Pū Ao | GNS Science, Aotearoa New Zealand.*
[2] *Division of Geological and Planetary Sciences, Caltech, California USA.*
[3] *School of GeoSciences, University of Edinburgh, UK.*
[4] *Department of Earth Sciences, University of Cambridge, UK.*

e.hughes@gns.cri.nz

Basaltic magmas in the Okataina Volcanic Centre (OVC) are sulphur rich, containing up to 3200 ppm S. More generally, sulphur is the third most abundant volatile element in silicate magmas after hydrogen and carbon. It is present in several phases (e.g., silicate melt, vapor, FeS-rich melt, solid and liquid sulphates) and multiple species and oxidation states in silicate melt (e.g., S^{2-} and SO_4^{2-}) and vapor (e.g., S_2, SO_2, H_2S, and OCS). Despite the resulting complex behaviour of sulphur in magmatic systems with changing intensive variables (e.g., temperature, pressure, and oxygen fugacity), there has been considerable progress recently in the development of thermodynamic models of these systems that provide a framework for understanding these complexities.

We present a multi-volatile (COHS) thermodynamic model of silicate melt ± vapor ± sulphide melt ± anhydrite to understand how sulphur behaves in basaltic magmas in the crust. We use this model to understand the cause of the sulphur solubility minimum and maximum in silicate melts that have been observed experimentally. The sulphur solubility minimum can have important consequences, including that calculations of the pressure of vapor-saturation using the volatile concentration measured in glass melt inclusions and submarine glasses require the inclusion of S along with H_2O and CO_2. Otherwise, these calculations can significantly underestimate the actual entrapment or eruption pressure, especially for relatively oxidised systems such as arc and hotspot magmas. The sulphur solubility maximum for silicate melts (± vapor) coexisting with sulphide liquid and anhydrite can be used to set limits of magmatic f_{O2} and on the sulphur-carrying capacity of a silicate magma. The latter is important during mantle melting, ore deposit formation, and SO_2 emissions during explosive volcanism. We also explore how sulphur degassing influences oxygen fugacity during depressurization, and that the sign of the effect changes at the sulphur solubility minimum.

POSTER
Session 1b.

Stratigraphy and Age of Volcano-fluvial and Tephra Deposits Associated with Te Puninga Fault, Morrinsville, Hauraki Basin

Joshua W. Hughes[1], David J. Lowe[1], Pilar Villamor[2], Vicki G. Moon[1], Kate J. Clark[2], Philippa Morris[2], George R. McQuillan[1], Alicia Medialdea[3], Genevieve Coffey[2], Kelvin Berryman[4], Robert Langridge[2], Alan G. Hogg[1], Brent V. Alloway[5], Yaasameen Shalla[6], and Olivia Mark[6]

[1]School of Science/Te Aka Mātuatua, University of Waikato, Hamilton, New Zealand
[2]GNS Science, Lower Hutt, New Zealand
[3]National Research Centre on Human Evolution (CENIEH), Burgos, Spain
[4]Berryman Research and Consulting, 18 Cluny Road, Plimmerton, Porirua 5026, New Zealand
[5]Geohazard Assessment Services, Auckland, New Zealand
[6]School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand

jh354@students.waikato.ac.nz

The newly-recognised Te Puninga Fault has the potential to produce earthquakes of magnitude Mw 6.7, and hence poses a hazard to the adjacent community of Morrinsville and surrounding region[1]. To study the fault's paleoseismic history, two trenches (named Arnold and Rylands) were excavated across two traces in February 2021 as part of a joint EQC/Marsden-funded project led by GNS Science with support from Waikato University. Two main lithologic units were exposed: the lower comprises volcano-fluvial sediments of the Hinuera Formation (HFm) (mainly bedded sands with occasional peaty lenses) deposited by the ancestral Waikato River, and the upper comprises a composite mantle of post-Hinuera tephra deposits ~0.7 m in thickness, the basal tephra possibly being 23.5-cal-ka Okareka tephra. In both trenches, the scarp was sufficiently high (~4 m) for different soils to form as a result of varying ground-water conditions upon represented lithologies across the fault scarp: Gley Soils are associated with lower HFm deposits, whereas Allophanic Soils[2] are prevalent within upper HFm deposits capped by tephras. Radiocarbon (^{14}C) dating and tephrochronology were used to determine a chronology of the deposits (OSL sampling was also undertaken: results pending). A laterally-continuous peat lens, including leaf material, in the lowermost part of HFm within Arnolds trench yielded ^{14}C-ages ranging from 23.5 to 24.9 cal ka, consistent with HFm deposition by the Waikato River prior to its avulsion at Piarere[3] into Hamilton Basin after ~23.5 cal ka. Within lowermost Rylands trench, another peat layer was dated at 11.5 cal ka, suggesting ~1.5 m of post-Hinuera alluvium had been deposited at this site – most likely from nearby Piako River. Two visible tephra layers, represented by laterally discontinuous pumiceous lapilli and fine ash lenses occurring close to the ground surface were identified as Taupo (AD 232 ± 10) and Kaharoa (AD 1314 ± 12) tephras, respectively.

POSTER
Session 2a.

Assessing Tsunami Hazard in New Zealand using a Long Time Scale Synthetic Earthquake Catalogue

Laura Hughes[1], William Power[2], Emily Lane[3], Martha Savage[1], Richard Arnold[1], Andy Howell[2,4], Bruce Shaw[5], Bill Fry[2], and Andy Nicol[4]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand*
[2] *GNS Science, Lower Hutt, New Zealand*
[3] *National Institute of Water and Atmospheric Research (NIWA), Christchurch, New Zealand*
[4] *University of Canterbury, Christchurch, New Zealand*
[5] *Lamont Doherty Earth Observatory, Columbia University, Palisades NY 10964*

laura.hughes@vuw.ac.nz

A tsunami with devastating, wide-reaching consequences affecting New Zealand is a significant hazard that needs to be analysed and quantified. The Puysegur Subduction Zone to the south, the Hikurangi Margin to the east, and the Tonga-Kermadec Subduction Zone to the north, all have the potential to generate catastrophic tsunamis, like those observed in Sumatra–Andaman in 2004 and Japan in 2011. Additionally, there are numerous offshore crustal faults that have tsunamigenic potential. While far-field tsunamis occur frequently, we focus on near-field tsunamis as they have the potential to be more devastating, both in their overall size and because there may be little time between the earthquake and the arrival of the resulting tsunami at the coast. In the near-field, complexities of the tsunami source are influential on the waves impacting the coast, and it is important to incorporate these effects when assessing probabilistic tsunami hazard and risk. Previous tsunami hazard studies have started to examine this infrequent but potentially deadly hazard, using models of past tsunamis, as well as possible future events assuming the estimated magnitude ranges of the faults concerned. We use a 30,000-year subset of a synthetic earthquake catalogue created using RSQSim (Rate and State Earthquake Simulator). From the RSQSim output, earthquake deformation models for events >M7 were produced and input to COMCOT (Cornell Multi-grid Coupled Tsunami model) to model the resulting tsunamis. Preliminary results, using a total of 2,595 tsunami simulations, allow us to begin to assess the near-field tsunami hazard. Maximum wave heights at coast range from 0.1-28m, with 15% of the maximum wave heights at coast exceeding 5m. In the Hawke's Bay and Wellington regions, maximum wave heights at coast of ~15m and ~17m, respectively, were observed, while for the 2,500-year return period, wave heights at the coast of ~10m and ~9m, respectively, were observed.

ORAL
Session 2a.

BIROC-H20: A new way to process FTIR spectra of olivine hosted basaltic melt inclusions

David Huijser[1], **Elaine Smid[2], Michael Rowe[2] and Jan M Lindsay[2]**

[1] *School of Mathematics and Statistics,Victoria University of Wellington, Wellington, New Zealand*
[2] *School of Environment, The University of Auckland, Auckland, New Zealand*

david.huijser@vuw.ac.nz

Fourier Transform Infrared Spectrometry (FTIR) analysis is a popular technique used to estimate pre-eruptive H_2O and CO_2 concentrations in mineral-hosted pockets of silicate melts (melt inclusions and embayments; MI and ME, respectively). As technology and volcanological knowledge become more sophisticated, there is an increasing interest in using high-resolution FTIR techniques to assess volatile heterogeneity within silicate glasses. However, many challenges exist when processing large amounts of spectral data, and these currently cannot be resolved using existing software. To address these issues, we are creating a new, open-access Python software package, BIROC-H2O (basaltic IR analysis of carbon dioxide and water in host olivine), designed to batch-process high-resolution spectral 2D FTIR map files collected on olivine-hosted, basaltic MI and ME. The code offers novel features such as the ability to batch process a large number of spectra; automated thickness calculations from spectra containing interference fringes, allowing for variable thicknesses across the sample; thickness extrapolations for map files with partial interference fringes; corrections for host olivine contamination; and a robust error handling strategy. Outputs include a table of H_2O and CO_2 concentrations from each spectral analysis, กฎheat mapกฏ images of H_2O concentrations, CO_2 concentrations, and thicknesses across the sample, and error estimations on these variables. This code is suited to process both single FTIR spectral files and 2D spectral map files collected on basaltic glass samples and may be modified to analyze other glass and mineral compositions.

ORAL
Session 4a.

A Visual Exploration of the Epistemic Uncertainty in Seismic Hazard

Anne Hulsey[1], Chris DiCaprio[2], Sanjay Bora[2], Chris Rollins[2], Brendon Bradley[3], Russ Van Dissen[2], and Matt Gerstenberger[2]

[1] *Department of Civil and Environmental Engineering, University of Auckland, Auckland, New Zealand*
[2] *GNS Science, Lower Hutt, New Zealand*
[3] *Department of Civil and Natural Resources Engineering, University of Canterbury, Christchurch, New Zealand.*

anne.hulsey@auckland.ac.nz

This presentation will provide visual representation of the epistemic uncertainty in the New Zealand National Seismic Hazard Model (NSHM), comparing uncertainty across sites and considering which underlying features drive the uncertainty. A primary characteristic of the updated NSHM is the inclusion of epistemic uncertainty. This inclusion increases the complexity of the new NSHM as compared to the previous version with its single source model and single set of ground motion characterization models. A side effect of the scientific improvements in this regard is that the new NSHM is more difficult to internalize and develop intuition for. Hazard maps can only show one metric, such as the mean of the distribution of shaking intensities for a given probability of exceedance. Pairing hazard maps with other visual representations, including the full distribution of shaking intensities at a selection of sites, provides a better understanding of the NSHM output. The distributions can also be interrogated based on the underlying source and ground motion characterization models, showing how these features impact that distributions at various sites, intensity measures, and probabilities of exceedance.

ORAL
Special Symposium

Earthquake timings and fault interactions in central New Zealand

Jade Humphrey[1], Andy Nicol[1], Andy Howell[1,2], Nicola Litchfield[2], Russ Van Dissen[2], Rob Langridge[2], and Bill Fry[2]

[1] School of Earth and Environment, University of Canterbury, Christchurch, New Zealand
[2] GNS Science, Lower Hutt, New Zealand.

jade.humphrey@pg.canterbury.ac.nz

Forecasting the probability and magnitude of future large magnitude earthquakes is typically dependent on information collected from paleoearthquakes. These paleorecords are often incomplete and timing of earthquakes are imprecisely dated, which impacts our ability to estimate their slip and recurrence intervals. Historical events demonstrate that many large earthquakes rupture multiple faults with complex rupture patterns.

To improve understanding of the importance and controlling factors of multi-fault earthquakes, we compare the timing of earthquakes between active faults in central New Zealand. We use a compilation of more than 150 existing radiocarbon dates recalibrated using OxCal V4.4 to determine the timing of earthquakes. Bayesian statistics are applied to test and quantify the probability of earthquake synchroneity between different faults and segments of the same fault.

The refined data provides improvements for the timing of paleoearthquakes for the faults studied. These new ages indicate that in some cases, the timings of surface-rupturing earthquakes vary between faults. In other cases, inferred paleoearthquakes on different faults are approximately the same age, suggesting interactions across fault systems. These “synchronous” earthquakes occurred during time windows of up to 150 years, with the most striking event recorded on the Wellington, Wairarapa and subduction thrust faults at approximately 700-850 cal. yrs BP. The apparent synchroneity of earthquakes could indicate the occurrence of large multi-fault ruptures and/or earthquake clusters, both of which may suggest stress transfer and interactions between faults on timescales of seconds to hundreds of years. These fault interactions have important implications for seismic hazard in central New Zealand and will be used to inform physics-based earthquake modelling.

ORAL
Session 2a.

Radiometric Sm-Nd dating of Orogenic Scheelite, Central Otago, New Zealand

Mark Ireland, James Scott,[1] Marshall Palmer,[1] Petrus le Roux,[2] Claudine Stirling,[1] and Malcolm Reid[1]

[1] *Department of Geology, University of Otago, Dunedin*
[2] *Department of Geological Sciences, University of Cape Town, South Africa*

irema098@student.otago.ac.nz

We have attempted to date scheelite (CaWO4) mineralisation in Otago's metamorphogenic gold (Au)- tungsten (W) deposits using samarium (Sm) and neodymium (Nd) isotopes. Scheelite in magmatic systems has previously been shown to have age-dating potential via the in-situ acquisition of Sm and Nd isotopes (Palmer et al. 2021). However, metamorphogenic scheelite deposits are more difficult because the Nd concentrations are very low (commonly < 100 ppm Nd).

Here, we applied a new technique to dating scheelite from Bonnie Jean in the Glenorchy scheelite field, the Alta Lode in the Bendigo goldfield, and from pit and core samples at Macraes Mine, all in Otago. These samples were first texturally and geochemically characterised using a scanning electron microscope, cathodoluminescence, and laser ablation inductively coupled plasma mass spectrometry. Our data showed internal Nd isotopic variation in single scheelite crystals that relates to decay over time from different growth zones whereas $^{87}Sr/^{86}Sr$ isotopes are homogeneous. Using a newly acquired microdrill at the University of Otago, we extracted precise micro-zones of scheelite and then obtained $^{143}Nd/^{144}Nd$, calculated $^{147}Sm/^{144}Nd$ ratios, and measured bulk trace element concentrations. These ratios define isochron ages and scheelite $^{143}Nd/^{144}Nd$ "initials" within single samples.

Since little geochronological data has been collected on Otago Au-W deposits, characterising microdomains within scheelite provides a method for obtaining the age of mineralisation and the isotopic composition of the mineralising fluids, which can then be matched to potential source rocks or fluid pathways. Understanding when mineralisation events occurred helps refine our understanding of the Au-W mineralisation history of Otago.

POSTER
Session 4f.

Do silica secreting organisms regulate climate on Earth?

Terry T. Isson and Sofia Rauzi

Te Aka Mātuatua, University of Waikato (Tauranga), BOP, Tauranga, New Zealand

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Atmospheric CO_2 levels are believed to have evolved dramatically over Earth's multi-billion-year evolution, and played a prominent role in sustaining habitable surface conditions. Yet, the mechanisms responsible for sustaining elevated early-Earth CO_2 levels remain debated. Here, we propose that a late Precambrian shift in marine clay authigenesis (and associated CO_2 release) could account for this transition. This process would have fostered enhanced carbon recycling within the ocean and atmosphere, rendering a shift in the efficiency of carbon sequestration. The timing of this transition substantiates the idea that the rise of silica secreting organisms played an important role driving one of the most critical environmental transitions in Earth's history. Further, we will discuss geochemical evidence suggesting that marine siliceous ecosystem decline could have led to sustained early-Triassic warmth in the wake of Earth's most severe mass extinction event. This work highlights the need to better quantify the synergistic effects of environmental change on siliceous organisms and vice versa for a more complete understanding of how life respond to and shape hyperthermal events.

ORAL
Session 2e.

Accounting for earthquake rates' temporal and spatial variability through least-information Uniform Rate Zone forecasts

Pablo Iturrieta[1,4], Matt Gerstenberger[2], Chris Rollins[2], Russ van Dissen[2], Ting Wang[3] and Danijel Schorlemmer[1]

[1] *Helmholtz Centre Potsdam, GFZ German Research Centre for Geosciences, Potsdam, Germany*
[2] *GNS Science, Lower Hutt, New Zealand*
[3] *Department of Mathematics and Statistics, University of Otago, Dunedin, New Zealand*
[4] *University of Potsdam, Potsdam, Germany*

pciturri@gfz-potsdam.de

The distribution of earthquakes in time and space is seldom stationary. In low-seismicity regions, non-stationarity and data scarcity may preclude a significant statistical analysis. We investigate the performance of stationary Poisson forecasts (such as smoothed-seismicity models - SSM) in terms of the available training data. We design bootstrap experiments for multiple pairs of consecutive training/forecast windows of a catalogue to: (i) analyse the lowest available training data in which SSM performs spatially better than the least-informative Uniform Rate Zone (URZ) model; (ii) characterise the rate temporal variability in terms of its over-dispersion and non-stationarity. The experiments rely on the assumption that catalogues from high-seismicity regions can be used as proxy of long-term low-seismicity. Results show rate variability up to 10 times higher as predicted by Poisson, and evidence the impact of non-stationarity in assuming a constant mean rate in training-forecast periods. Analytical distributions are used to describe rate variability, which are conditioned to the information available from a training period. Under the assumption that strain-rate is related to time scales of earthquake interactions, we devise a data-driven method based on strain rate maps to delineate spatially URZs. A rate distribution is inferred for each URZ from the training events within. We provide forecasts for the update of the NSHM model, which have increased rates up to 10 times higher in extensive low-seismicity regions, compared to optimised SSM. The impact of the forecasts is the hazard, by implementing a negative-binomial distribution in the hazard integral. For a 10% exceedance probability in 50 years, using URZ with rate variability descriptions increases the expected PGA up to 0.16 g in low-seismicity regions (e.g. Auckland, Dunedin) compared to SSM. Our results highlight the relevance, as well as the feasibility, of including analytical formulations of seismicity that extend beyond the inadequate stationary-Poisson description of seismicity.

POSTER
Special Symposium

Constraints on the Hunga Tonga-Hunga Ha'apai eruption processes from remote magnetic field measurements of volcanic lightning

Paul A. Jarvis[1], Grant Caldwell[1], Chris Noble[2] and Yasuo Ogawa[3]

[1] GNS Science, Lower Hutt, New Zealand
[2]MetService, Wellington, New Zealand
[3]Volcanic Fluid Research Centre, Tokyo Institute of Technology, Tokyo, Japan

p.jarvis@gns.cri.nz

The January 15th 2022 eruption of Hunga Tonga-Hunga Ha'apai (HTHH) was hugely impactful for the Kingdom of Tonga and beyond, as well as being unique in the time of human observations for the scale of various associated physical phenomena. These include an eruption column height of 58 km, acoustic booms heard as far away as Alaska, an atmospheric Lamb wave that propagated across the globe and an atmospherically-coupled tsunami. Another remarkable feature was the intensity of volcanic lightning generated during the eruption, with the Vaisala Global Lightning Detection Network (GLD360) recording over 3×10^5 lightning strikes in the vicinity of HTHH over a 2 hour period, and a maximum rate of more than 5000 strikes per minute.

We first correlate observations of the electromagnetic (EM) signal generated by the lightning, as recorded by magnetotelluric stations in New Zealand and Japan, and the distribution of lightning strikes, as recorded by the GLD360 network. We then combine these data with satellite imagery and air pressure perturbations associated with the Lamb wave to show that fluctuations in the low frequency EM field correlate with key events in the eruption sequence. Additionally, by including insights from teleseismic and infrasonic signals, we can impose some constraints on the timeline of the eruption. Finally, the spatiotemporal distribution of the lightning strikes, together with satellite imagery, provides insights into the dynamics of umbrella spreading and the internal distribution of vorticity and particle concentration. Our results therefore have implications for the source conditions of both ashfall and tsunami models and, thus, for assessing the impact of both this eruption and potential future activity.

POSTER
Session 1a.

interaction between vortices and settling-driven gravitational instabilities at the base of volcanic clouds

Paul A. Jarvis[1,2], Allan Fries[1], Jonathan Lemus[1], Costanza Bonadonna[1], Amanda Clarke[3], Jeremy Phillips[4] and Irene Manzella[5,6]

[1] Department of Earth Sciences, University of Geneva, Geneva, Switzerland
[2]GNS Science, Lower Hutt, New Zealand
[3]School of Earth and Space Exploration, Arizona State University, Tempe, Arizona, USA
[4]School of Earth Sciences, University of Bristol, Bristol, UK
[5]School of Geography, Earth and Environmental Sciences, University of Plymouth, Plymouth, UK
[6]Faculty of Geo-Information Science and Earth Observation, Department of Applied of Science, University of Twente, Netherlands

p.jarvis@gns.cri.nz

Ash sedimentation from volcanic clouds often occurs through downward-propagating columns, called fingers, which have velocities exceeding the terminal settling velocities of fine ash, e.g., Ruapehu 1996, New Zealand; Eyjafjallajökull 2010, Iceland. Subsequently, fine ash sediments closer to the vent than would otherwise be expected, impacting both deposit interpretations and dispersal forecasts. Whilst previous studies have shown that ash fingers can form from a settling-driven gravitational instability (SDGI), these investigations typically consider simplified scenarios where there is no ambient motion. Here, we extend these studies by using analogue experiments to consider the effect of volcanic cloud spreading on the formation and evolution of ash fingers.

In our experiments, a turbulent suspension of glass beads in fresh water (the analogue volcanic cloud) spreads as a gravity current over a denser, sugar solution (the analogue atmosphere). By varying the particle volume fraction in the suspension, we control the density difference between the current and the ambient and, consequently, the spreading rate. At low spreading rates, fingers resulting from the SDGI are observed to form with a wavelength on the order of centimeters, comparable to those observed in static experiments and simulations. Conversely, at high spreading rates, turbulent vortices, generated by the Kelvin-Helmholtz instability (KHI) and with a wavelength of 10s of centimeters, occur at the current base and are sufficiently strong to re-entrain particles into the current, inhibiting sedimentation. However, at intermediate spreading rates, the SDGI fingers become modulated by the Kelvin-Helmholtz vortices to generate larger, downwelling plumes at the Kelvin-Helmholtz wavelength.

Our results suggest that shear at the base of volcanic clouds can increase the wavelength of fingers by an order of magnitude. Since the downward velocity of fingers depends on their size, this therefore needs to be taken into account when developing parameterisations of the effect of SDGIs on ash dispersal.

ORAL
Session 1a.

New Zealand National Lidar and Regional Applications

Bjorn Johns[1] and Murry Cave[2]

[1] Toitū Te Whenua Land Information New Zealand, Wellington, New Zealand
[2] Gisborne District Council, Gisborne, New Zealand.

bjohns@linz.govt.nz

Airborne lidar data will be available for 80% of New Zealand by 2024. The Toitū Te Whenua Land Information New Zealand (LINZ) National Elevation Programme is working with councils in this ambitious endeavour that is resulting in new lidar datasets from across most of New Zealand over the next few years. The data is made available in a consistent format and under open license (data.linz.govt.nz), and it includes a large amount of coverage of unpopulated terrain where lidar has not been captured before. It is of value to the geosciences in its ability to accurately map the land in three dimensions leading to change detection, geomorphological mapping, identification of natural hazards, etc. The Elevation Aotearoa (elevationaotearoa.co.nz) initiative complements the data and provides user guides, examples, and other information to facilitate uptake and highlight use cases.

The Gisborne/Tairawhiti District was one of the first to achieve full coverage and the data is in active use. Geoscience applications underway include differencing of the Waipaoa River, gravel fluxes in the Waiapu, urban landslide mapping, enhanced land use capability mapping and active fault mapping.

ORAL
Session 2a.

A new approach to quantify sediment conveyance following the 2016 Kaikōura earthquake, New Zealand

<u>Katie Jones</u>[1,2], Jamie Howarth[1], Chris Massey[2] and Pascal Sirguey[3]

[1] *School of Geography, Environment and Earth Sciences, Victoria University, Wellington, New Zealand*
[2] *Engineering Geology Team, GNS Science, Lower Hutt, New Zealand*
[3] *School of Surveying, University of Otago, Dunedin, New Zealand*

katie.jones@vuw.ac.nz

Evaluating the influence of earthquakes on erosion, landscape evolution and sediment-related hazards requires quantifying the volume and velocity of post-seismic sediment cascades. Following the 2016 M_W7.8 Kaikōura earthquake in New Zealand, the volume of post-seismic erosion was quantified directly by measuring the ground surface change between 4 lidar surveys captured in 2016, 2017, 2019 and 2021. Along with volumes, the rates at which this sediment was eroded from hillslopes, delivered off-slope to channels and exported from the range front as bedload were determined using differencing of multi-temporal lidar surveys. A total of 10.51 ± 0.21 M m^3 of sediment was post-seismically eroded within the Hapuku Catchment, equal to 25% of the co-seismic landslide debris volume within the catchment. The majority, 24% of the total debris volume, was delivered to the riverbed. In the first 5 years after the earthquake, sediment equal to 9% of the total debris volume was transported beyond the range front of the Seaward Kaikōura Ranges. In the Kowhai Catchment 1.78 ± 0.07 M m^3 of sediment was post-seismically eroded, equal to 11% of the co-seismic landslide debris volume within the catchment. The volume delivered to the riverbed was equal to 8% of the total debris volume, and the volume transported beyond the range front of the Seaward Kaikōura Ranges over 5 years represented 5% of the total debris volume. The higher volumes within the Hapuku Catchment reflected the evacuation of the 17 M m^3 (source volume) rock avalanche which dammed the Hapuku River, with 9.09 ± 0.14 M m^3 of sediment removed from this single landslide, resulting in considerable downstream aggradation.

ORAL
Session 4b.

Mapping stress drop variations along the Alpine Fault to investigate conditional rupture segmentation

Ilma del Carmen Juarez-Garfias[1], Emily Warren-Smith[2], John Townend[1] and Rachel Abercrombie[3]

[1] School of Geography, Environment and Earth Sciences, Victoria University of Wellington
[2] GNS Science
[3] Department of Earth and Environment, Boston University

Ilmadelcarmen.juarezgarfias@vuw.ac.nz

The Alpine Fault (AF) is an active transform fault that is late in its cycle of large earthquakes. Paleoseismic results reveal that places along the fault, which coincide with along-strike changes in geometry, kinematics and slip rates, act as conditional barriers to rupture. The geometry, seismicity rates and geology of the AF differ between three segments; North Westland (NW), Central (C) and South Westland (SW) but it is unclear whether earthquake source properties also vary between those segments.

We use an Empirical Green's Function (EGF) approach to calculate stress drops of moderate-magnitude (M_L2-4.4) earthquakes occurring on or near the AF. We use data from the permanent GeoNet network and temporary networks including the Dense Westland Arrays Researching Fault Segmentation (DWARFS) network installed in early 2019.

We make separate P- and S-wave measurements of stress drop for 95 earthquakes occurring within 5 km of the AF. The stress drops range between 1 and 352 MPa and show good agreement with stress drops measured in studies elsewhere in New Zealand and worldwide. We see no dependence of stress drop values on depth, magnitude or focal mechanism, but do see variation in average stress drop values along strike. We obtain median values of 8 and 9 MPa for P- and S-waves, respectively, for the SW/C segment boundary zone; of 17 and 39 MPa for the C segment; and of 15 and 19 MPa for the NW/C segment boundary zone. We observe no systematic differences in stress drop along either the NW or C segments, but median values are slightly higher than those of the SW segment. This may indicate that the differences in fault geometry, slip, and seismicity of the SW segment may have a bigger effect on stress drops there than for other segments, or that the SW segment is weaker overall.

POSTER
Session 2a.

Comparing forward models with observations of fracture-induced shear wave anisotropy in the Taupō Volcanic Zone.

Siru Jylhänkangas[1], **Martha Savage**[2] **and Cécile Massiot**[3]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand.*
[2] *Institute of Geological and Nuclear Sciences Limited, New Zealand.*

siru.jylhankangas@hotmail.fi

Supercritical geothermal resource could provide large amounts of sustainable, renewable electricity. A challenge is to find permeable fractured rocks beneath conventional drilled depth. Seismic anisotropy can be used as a supporting method to map reservoirs, magma intrusions and stress fields. Shear-wave splitting has potential to map fractured rocks at 3.5-8 km depth in the Taupō Volcanic Zone. Shear-wave splitting and anisotropy through rocks containing fractures with specific orientation, infill composition and volume fraction, are modelled. The theoretical anisotropy calculated can then be compared with real seismic records. The modelled anisotropy will then be compared with real earthquake recordings to infer the density and orientations of the fracture networks. Forward models are computed with the MSAT code and seismic anisotropy calculated using Multiple Filter Automatic Splitting Technique (MFAST) tool. Model fracture densities are approximated and iterated through a range of values, then synthetic earthquakes are propagated through them. The model anisotropies are compared to the ones calculated from real earthquakes.

After completing 2562 iterations varying model input parameters, we found that for the fluid-filled fractures, only the fracture density per unit volume and the orientation relative to earthquake arrival affects the shear wave splitting. The rocks with fractures filled with solid material, such as quartz, appear more isotropic and the average aggregate density is similar to the host rock; this leads to smaller time delays between split wave phases. The orientation and the time delay between the two orthogonally polarized shear wave phases can be used to approximate the orientation of the features causing the splitting, as well as the relative fraction of these features within the rock mass along the earthquake path. The exact material inside the fractures is hard to determine from shear wave splitting only, and other analyses such as Vp/Vs ratios need to be considered.

POSTER
Session 4e.

Rapid Characterisation of Earthquakes & Tsunami (R-CET Programme) –The local earthquake challenge

Anna Kaiser[1], Bill Fry[1], Jen Andrews[1], Yannik Behr[1], Nick Horspool[1], Florent Aden[1], Katie Jacobs[1], Elisabetta D'Anastasio[1], Emily Warren-Smith[1], Calum Chamberlain[2], Chris Zweck[1], Laëtitia Foundotos[1], Jose Moratalla[1], and Luce Lacoua[3]

[1] *GNS Science, Lower Hutt, New Zealand.*
[2] *Victoria University of Wellington, New Zealand*
[3] *University of Otago, New Zealand*

a.kaiser@gns.cri.nz

The R-CET Endeavour programme aims to advance and test modern methods to rapidly characterise earthquakes and tsunami, providing critical early information for response. R-CET's three working groups focus on (i) local earthquakes, (ii) SW Pacific and Kermadec earthquakes, and (iii) science to practice and community engagement. Here, we present an overview of the Local Earthquake Group progress.

Rapid characterisation of local earthquakes is necessary not just to understand how the ground has ruptured, but to underpin rapid forecasts of an earthquake's likely impacts, e.g. tsunami, shaking, loss/damage, ground deformation, landslides, liquefaction and aftershock distribution/likelihood. Over the last decade of large earthquakes to impact New Zealand, robust models of an earthquake and its shaking have typically taken days to weeks to develop, such that the initial response relies on a 'point source' model (epicentre and magnitude). The increasing availability and density of real-time seismic and geodetic (GNSS) data from the GeoNet network opens up new possibilities to apply modern characterisation algorithms in near real-time.

We are actively exploring a suite of prototype earthquake tools designed to rapidly determine (i) centroid & robust magnitude (Mww), (ii) finite fault extent, rupture direction and orientation, (iii) spatial and temporal energy release, (iv) shaking (ShakingLayer), (v) geodetic displacements and geodetic finite fault and (v) detect and map aftershocks. The prototype tools are currently being used to create a suite of test products for major historical earthquake scenarios (e.g. Kaikōura and Dusky Sound earthquakes). This helps us build a timeline around what information could be available and when for first responders during the next big earthquake. It also allows us to test how we might best integrate complementary tools to build an improved common picture of an earthquake and its impacts. In the future we also intend to extend the scenarios to include large earthquake ruptures from the synthetic catalogue developed under the Resilience Science Challenge.

ORAL
Session 3c.

Using InSAR and GNSS to characterise present-day vertical land movement at New Zealand coastal strips

Jesse Kearse[1], Tim Stern[1], Ian Hamling[2], Simon Lamb[1] and Sigrun Hreinsdóttir[2].

[1] *Victoria University of Wellington, New Zealand.*
[2] *GNS Science.*

jesse@kearse.co.nz

Today, the average rate of global mean sea-level rise is ~3 mm/y and is expected to increase in the future. This represents a hazard to low elevation coastal zones worldwide. Yet, before global sea-level projections can be used to characterize future coastal flood hazard at a local scale, the effects of tectonics (and other processes) that drive vertical land motion (VLM) must be considered. To assess present-day VLM at New Zealand coastal strips, we generate new InSAR datasets using Sentinel-1 SAR images acquired between 2015-2021. From these data we derive maps of line-of-sight velocity and time-varying displacements at a spatial resolution of hundreds of meters. Where possible, we tie these InSAR products to the velocity field determined by the national GNSS network. We also combine data from multiple satellite look directions, and three-component GNSS to estimate the vertical rates of displacement. We also compare these snapshots of present-day rates of VLM derived from space-based data with geological proxies of vertical displacement, such as uplifted marine terraces. We focus our analysis of VLM on coastal strips such as Christchurch City, the Bay of Plenty, and Whanganui region, and the urban areas of Auckland, Wellington, and Dunedin. Our results are preliminary, yet we observe patterns of uplift and subsidence at rates of up ~8 mm/y. The new InSAR data show spatial variability in the rates of vertical deformation on the scale of hundreds of meters to tens of kilometres. This research demonstrates the need for such data to accurately characterise and monitor VLM at coastal cities, where anthropogenic processes such as groundwater extraction and loading of young sediments create signals of uplift and subsidence at high spatial frequency, and which have important consequences for the impact of future sea-level rise.

POSTER
Session 4b.

Modelling the probability of inundation with Bayesian Networks: A pilot study in the Hauraki Plains

Elizabeth D. Keller[1,2], Georgia Grant[1], Annemarie Christophersen[1], Phil Mourot[3] and Lara Clarke[1]

[1] *GNS Science, Lower Hutt, New Zealand*
[2] *Antarctic Research Centre, Victoria University of Wellington, Wellington, New Zealand*
[3] *Waikato Regional Council, Hamilton, New Zealand*

L.Keller@gns.cri.nz

We describe a pilot study to develop and test the application of Bayesian Networks (BNs) to estimate current and future probability of coastal inundation due to climate change, focusing on issues faced by the Hauraki District in Waikato. BNs offer a complementary and efficient alternative to the use of multiple, computationally intensive process-based models to assess the likelihood of inundation and/or flooding, with the added benefit of explicitly including uncertainties. This pilot study was stakeholder-driven and developed in consultation with the Waikato Regional Council, who identified the operation of the Kauaeranga Spillway as a significant risk in the region. The operation of the spillway requires closure of State Highway 25, restricting access to Thames and interrupting essential services. We present a prototype model describing the likelihood of the operation of the Kauaeranga Spillway, given the intensity and amount of rain received over the last 120 hours and ensuing river height and flow rate. The information derived from the model is intended to assist stakeholders in planning infrastructure development and maintenance, earlier warning systems and better communication of imminent road closures.

ORAL
Session 2d.

Integration of Airborne Electromagnetic models with ground geophysics and detailed borehole data: Heretaunga Plains

Richard Kellett[1], Zara Rawlinson[2], Angela Griffin[1], Maïwenn Herpe[2], Mark Lawrence[1], Julie Lee[1], Tusar Sahoo[1], Conny Tschritter[2], and Simon Harper[3]

[1] GNS Science, Lower Hutt, New Zealand.
[2] GNS Science, Wairakei, New Zealand.
[3] Hawkes Bay Regional Council, Napier, New Zealand.

r.kellett@gns.cri.nz

As part of the Hawke's Bay 3D Aquifer Mapping Project (3DAMP), airborne electromagnetic data have been collected over the Heretaunga Plains. The project is a three-year initiative (2019 – 2022) jointly funded by the Provincial Growth Fund (Kānoa Regional Economic Development & Investment Unit), Hawke's Bay Regional Council (HBRC) and GNS Science (GNS).
The SkyTEM survey comprised 2610 km of flight lines across the Heretaunga Plains, offshore, and along the Ngaruroro River. These data provide a dense network of resistivity models extending to a depth of 300 m. Electrical resistivity is primarily controlled by porosity, pore water salinity, clay content, and matrix composition. Ground-based geophysical data are available for comparison with the airborne data, and to infill gaps in the SkyTEM coverage around urban centres. The primary purpose of 3DAMP is to build a well calibrated, laterally uniform hydrogeological model across Hawke's Bay. The area has over 5800 boreholes and a set of twelve deep (>100 m) boreholes/wells were interpreted / re-interpreted based on the models derived from the geophysical surveys. These boreholes included:

- Three boreholes previously drilled for geological and hydrogeological research: Awatoto, Flaxmere, and Tollemache
- Two wells previously drilled for petroleum exploration: Whakatu-1 and Taradale-1
- Six deep groundwater wells from the HBRC well database
- One new borehole drilled as part of 3DAMP

The area has been mapped previously during several hydrogeological and Quaternary mapping projects and these models provide a basis for the regional interpretation. The detailed interpretation of the sub-surface in terms of resistivity units, based on the analysis of the 12 borehole localities, is providing a clearer picture of the lateral changes in strata between wells. Additionally, the average depth of the entire borehole dataset is 32 m, so the interpretation of the deeper strata will rely on the geophysical model.

ORAL
Session 4b.

Fossil seabirds from the Pliocene of Taranaki, New Zealand

Sophie Kelly[1], **Paul Scofield**[2], **Catherine Reid**[1] **and Vanesa De Pietri**[1]

[1] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand.*
[2] *Canterbury Museum, Rolleston Avenue, Christchurch, New Zealand.*

sophie.kelly@pg.canterbury.ac.nz

Procellariiformes are an order of pelagic seabirds including albatrosses, petrels and shearwaters that have a biogeographic range across the world's oceans. They are a key component of today's avifauna and had a similar crucial role in past ecosystems, being survived by multiple fossil specimens. The islands of New Zealand are particularly important for procellariiform diversity and evolution and have been a favoured habitat for at least 16 million years. However, many fossil seabird specimens in New Zealand are sitting idle in collections across the country, waiting to be interpreted.

The aim of this research is to study the emerging pre-Quaternary avian fossil record of procellariiforms from Pliocene marine deposits in the Taranaki region. Twelve fossil specimens from the Canterbury Museum collection will be analysed using a comparative morphology approach utilising both extinct and extant species from regional collections and literature. This involves assessing osteological characters using various techniques from manual measurements to computer modelling from CT scan data. The differences between the specimens and the comparative material will be quantified to warrant generic or specific differentiation of the twelve fossils.

The description of these specimens will allow gaps in the knowledge of procellariiform evolution to be investigated, including revealing their taxonomic diversity in Taranaki during the Pliocene which is unresolved and covers a period before major Quaternary avian extinction events. Comparisons between the diversity before and after the onset of these climate related extinctions will highlight their impact on seabird ecology. Other key gaps addressed by this research include the scarcity of published material on Pliocene seabird fossils, the unclear evolutionary relationships between procellariiform species, and uncertain taxonomic affiliations of previously described fossils. This project is unique as it involves multiple contemporaneous specimens from a single region allowing the extent of the fossil seabird fauna in Taranaki to be explored.

POSTER
Session 2c.

Virtual fieldtrips to volcanoes- 10 year perspective

Ben Kennedy[1], Jonathan Davidson[1], Alexander Watson[1], Alison Jolley[2], Timothy Martin[3], Sriparna Saha[1], Rie Hjørnegaard Malm[4], Kristen Rune Skalborg Hansen[4], Lene Møller Madsen[4], Robert Evans[4], and Kelvin Tapuke[5]

[1] School of Earth and Environment, University of Canterbury, Christchurch, New Zealand
[2]Te Puna Ako – Centre for Tertiary Teaching & Learning, University of Waikato, Hamilton, New Zealand.
[3]Elon University, North Carolina
[4]Department of Science education, University of Copenhagen
[5]Partnerships Advisor, ECLIPSE Program, New Zealand.

Ben.kennedy@canterbury.ac.nz

For over 10 years we have been creating virtual fieldtrips with the initial goal to give students the genuine experience and feeling of in-person fieldtrips. To deliver virtual fieldtrips we have trialed fully immersive worlds, 360 videos, 3D visualizations, bicultural content and a Massive Open Online Course (MOOC) with automated feedback. We have used virtual fieldtrips to take students to places they would otherwise not be able to go and to familiarize students with field skills and content before going into the field in order to maximize learning. Our research results from student interviews, focus groups and pre-post measures of learning show that students enjoy and engage well with the digital content, although we are still far from an immersive in-person field experience.

In this presentation we will focus on general recommendations developed from a combination of literature reviews, instructor experience, and student feedback. These recommendations include: (1) The digital approach of the virtual fieldtrip should be guided by content, skills, and attitude-based learning goals. (2) Build a mutually beneficial interdisciplinary team from your university (including educational research graduate students) - this lessens workload and provides longevity. (3) In-field videos (instructional and 360) with interviews (starring course instructor and highlighting diverse role-models) allow for a good connection between students, staff and the place. (4) Keep technology as simple as possible (e.g., tools students are familiar with like Google Earth); however, an interactive, 3D perspective can add new learning opportunities to a in person fieldtrips.

Looking to the future, we are continuing to develop new ways that support students in genuine exploration and discovery on virtual fieldtrips. Such interactive virtual fieldtrips could be a suitable replacement for lecture content in a flipped classroom or as preparatory exercises for in-person fieldtrips, and as in-person fieldtrip replacements when appropriate.

ORAL
Session 3b.

Porosity, strength, and alteration – Volcano stability assessment using VNIR-SWIR reflectance spectroscopy

Gabor Kereszturi[1], Michael Heap[2,3], Lauren N. Schaefer[4], Herlan Darmawan[5], Frances M. Deegan[6], Ben Kennedy[7], Jean-Christophe Komorowski[8], Stuart Mead[1], Marina Rosas-Carbajal[8], Amy Ryan[9], Valentin R. Troll[6], Marlène Villeneuve[10] and Thomas R. Walter[11]

[1]Volcanic Risk Solutions, School of Agriculture & Environment, Massey University, Palmerston North, New Zealand
[2] Institut Terre et Environnement, Université de Strasbourg, CNRS, Strasbourg, France
[3] Institut Universitaire de France (IUF), Paris, France
[4] Geologic Hazards Science Center, U.S. Geological Survey, Golden, CO, USA
[5] Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Gadjah Mada, Yogyakarta, Indonesia
[6] Department of Earth Sciences, Section for Natural Resources and Sustainable Development (NRHU), Uppsala University, Sweden
[7] Geological Sciences, University of Canterbury, Christchurch, New Zealand
[8] Université de Paris, Institut de Physique du Globe de Paris, CNRS, Paris, France
[9] Department of Earth and Environmental Sciences, University of Minnesota, USA
[10] Subsurface Engineering, Montanuniversität Leoben, Leoben, Austria
[11] GFZ German Research Centre for Geosciences, \Potsdam, Germany

g.kereszturi@massey.ac.nz

Volcanic rocks are characterised by pore and crack structures that can govern hydrothermal fluid transport, volcanic outgassing, and the strength and stability of a rock mass. Volcano slope stability analysis is a critical component of volcanic hazard assessments and monitoring. Here, visible to shortwave infrared (350–2500 nm; VNIR–SWIR) reflected light spectroscopy on laboratory-tested rock samples from Ruapehu, Ohakuri, Whakaari, and Banks Peninsula (New Zealand), Merapi (Indonesia), Chaos Crags (USA), Styrian Basin (Austria) and La Soufrière de Guadeloupe (Eastern Caribbean) volcanoes was used to design a novel rapid chemometric-based method to estimate uniaxial compressive strength (UCS) and porosity. Our Partial Least Squares Regression models return moderate accuracies for both UCS and porosity, with R^2 of 0.427–0.493 and Mean Absolute Percentage Error (MAPE) of 0.212–0.391. When laboratory-measured porosity is included with spectral data, UCS prediction reaches an R^2 of 0.82 and MAPE of 0.105. Our models highlight that the observed changes in the UCS are coupled with subtle mineralogical changes due to hydrothermal alteration at wavelengths of 360–438, 532–597, 1405–1455, 2179–2272, and 2460–2490 nm. Hydrothermal alteration can reduce the strength of the volcanic rocks by replacing strong volcanic glass and primary minerals in the groundmass with weaker secondary minerals, including sulfates and phyllosilicates, but it can also increase strength because of porosity-filling precipitation and/or silicification. Our approach highlights that spectroscopy can provide a first order assessment of rock strength and/or porosity or be used to complement laboratory porosity-based predictive models. VNIR-SWIR spectroscopy therefore provides an accurate non-destructive way of assessing rock strength and alteration mineralogy, even from remote sensing platforms.

ORAL
Session 1a.

An overall assessment of volcanic unrest at Ruapehu in early 2022

Geoff Kilgour[1], Luana Alves[2], Cameron Asher[1], Yannik Behr[1], Karen Britten[1], Bruce Christenson[2], Nico Fournier[1], Ian Hamling[3], Jonathan Hanson[3], Sigrun Hreinsdottir[3], Ery Hughes[2], Paul Jarvis[3], Richard Johnson[1], Graham Leonard[3], Agnes Mazot[1], Craig Miller[1], Michael Rosenberg[1], Brad Scott[1], Jackson Shanks[1], and Steve Sherburn[1]

[1] *Wairakei Research Centre, GNS Science, Taupō, New Zealand*
[2] *National Isotope Centre, Gracefield, GNS Science, New Zealand*
[3] *Avalon Campus, GNS Science, Lower Hutt, New Zealand*

g.kilgour@gns.cri.nz

Ruapehu has historically been a very active volcano, with regular, small phreatic and phreatomagmatic eruptions punctuated by rare larger magmatic eruptions in the last 130 years. The last magmatic phase occurred during the 1995-1996 eruption episode, and since then, phreatic eruptions in 2006 and 2007 have been the only clear eruptive activity at Ruapehu. Since the phreatic eruption in 2007, volcanic unrest has been minor, except for a short period in May-July 2016, when high gas output accompanied high (~45 °C) Crater Lake (Te Wai ā-moe) temperatures and moderately high tremor levels, and the volcanic alert level was raised to VAL 2.

In mid to late March of 2022, Crater Lake temperature began rising from ~27 °C to ~32 °C as part of a typical heating episode. Lake heating to a maximum of ~40 °C shortly after the volcanic tremor peaked. This episode of volcanic tremor was characterised by a rising trend over 1.5 months with 4 short lived phases of enhanced energy release and 2 further during the declining phase. This period of tremor is the strongest tremor episode at Ruapehu in the past two decades. High SO_2 flux measurements were recorded in early April, whereas Crater Lake chemistry data showed no clear signs of an elevated magmatic signature. Analysis of deformation data (InSAR and GNSS) were inconclusive, in part due to snowfall causing signal incoherence in the InSAR data.

Historically high SO_2 flux and tremor magnitudes indicate that the signals of the March to June 2022 unrest period were caused by the arrested ascent of magma above the upper crustal magma reservoir. Analysis of tremor source location suggests magma may have stalled at the basement/volcanics boundary at a depth of ~2 to 3 km below the summit, probably controlled by a strong crustal density contrast. Results from Crater Lake fluid and gas analyses, combined with limited deformation signals indicates that magma did not ascend far enough to significantly interact with the Crater Lake hydrothermal system. This unrest period likely represents the first magmatic intrusion at Ruapehu since 1995-1996.

POSTER
Session 1a.

Quantifying ballistic ejecta in volcanic deposits: a case study of the 1886 Tarawera eruption

Geoff Kilgour[1], Paul Jarvis[2], Marco Michelini[3], Karen Strehlow[4], and Ery Hughes[5]

[1] Wairakei Research Centre, GNS Science, Taupō, New Zealand
[2] Avalon Campus, GNS Science, Lower Hutt, New Zealand
[3]Department of Geology and Environmental Science, University of Pittsburgh, USA
[4]MITIGA solutions, Barcelona, Spain
[5] National Isotope Centre, Gracefield, GNS Science,

g.kilgour@gns.cri.nz

Traditional approaches to quantify volcanic plume height and cross wind speed relies on the measurement of the largest lithic fragments in pumiceous/scoriaceous tephra fall deposits. Lithic isopleths are often constructed based on a small number (as little as 5) of lithics at locations spread over a wide geographical area around the purported vent. This approach can be complicated, especially in proximal locations, where ballistic ejecta can skew the sampling of the largest lithic clasts to much coarser values and hence the plumes heights are overestimated.

We document the presence of oversized clasts in the medial to distal portion of the 1886 Tarawera fall deposit. Oversized clasts are statistically classified relative to the host subunit grain size distribution. There are two distinct oversized lithic types: variably dense basaltic scoria blocks/bombs and lapilli, and rhyolite lava lithic bombs and lapilli. Based on the size, density and number of oversized clasts, we suggest that they were emplaced along ballistic trajectories, possibly modified by the Plinian plume.

We have modelled the ejection velocity, angle and tail wind speed to account for the dispersal using existing ballistic codes. Our results indicate that very high ejection velocities are required from purely ballistic ejection velocities and explore the impact of clast spinning. We plan to further quantify the impact of ballistic ejecta on the lithic component of the 1886 deposit and seek to explore the validity of lithic isopleths already compiled.

POSTER
Session 1a.

An evolving story of the geology of the Manawatū Saddle: Evidence from the Manawatū -Tararua Highway.

Philip Kirk[1], <u>Ben Dixon</u>[1], Ben Whiteman[1] and Grace O'Sullivan[2]

[1] *Aurecon New Zealand Ltd*
[2] *Seequent Ltd, New Zealand.*

philip.kirk@aurecongroup.com

Construction is well underway on the new Te Ahu a Turanga Alliance Manawatū–Tararua Highway, which traverses the southern Ruahine Range between Saddle Road and the Manawatū Gorge. The highway is over 6 km long, and features a new bridge over the Manawatu River as well as numerous large cuts.

The highway is formed predominantly on the extremely-weak, marine sedimentary rocks of the Plio-Pleistocene Manawatū seaway, but the underlying greywacke basement rock has been encountered locally in the central and eastern parts of the project.

Ground investigations and construction works have greatly improved our knowledge of the geology of the area, enabling refinements to be made to published mapping and stratigraphy of the area and providing considerable additional detail about deformation and timing of activity around previously recognised faults (eg Mohaka, Raukawa) and the recognition of new structures.

Detailed models of interbedded conglomerates and sandstones were prepared to understand artesian groundwater conditions at one of the bridge sites, and to assist the design of cut slopes through these materials.

Three dimensional geology models based on project-stratigraphy were prepared to aid design, and these have been updated during construction as new information is gathered from ongoing earthworks and supplementary investigations.

ORAL
Session 4c.

Integrating XRF-ratios for Arctic paleoenvironmental reconstructions

Christine T. Kollsgård[1], Jan Sverre Laberg[1], Tom Arne Rydningen[1], Katrine Husum[2], Amando P. E. Lasabuda[1], Matthias Forwick[1] and Christopher M. Moy[3]

1 Department of Geosciences, UiT The Arctic University of Norway, Tromsø, Norway
2 Norwegian Polar Institute, Longyearbyen, Norway
3 Department of Geology, University of Otago, Dunedin, New Zealand

christine.t.kollsgard@uit.no

The northern Barents Sea continental slope is a key area for understanding the past behavior and dynamics of the northern parts of the Svalbard-Barents Sea Ice Sheet and the paleoceanography of the Eurasian part of the Arctic Ocean. We have reconstructed the sedimentary processes and paleoenvironment of the Kvitøya Trough Mouth Fan and adjacent slope and analyzed how the variability is reflected in the elemental composition of the sediment. Our aim is to establish more robust interpretations and to improve the use of XRF (X-Ray Fluorescence) core scanning data in the region.

Six sediment gravity cores were examined to establish the lithostratigraphy and recognize past sedimentary processes. Their timing has been constrained by radiocarbon-dated microfossils and correlating magnetic susceptibility measurements. Wet-bulk density, shear strength, water content, grain size, sediment color and structures were considered to define the physical characteristics of three main lithofacies. In addition, all the cores have been scanned using the Avaatech XRF core scanner (10, 30 and 50 kV at 1 mm resolution) to obtain element ratios.

Results show that identifying the source of predominantly muddy sediment deposited within a large basin such as the Arctic Ocean can be difficult based on lithostratigraphy alone. By integrating the elemental composition of the sediment, we find connections between the different lithofacies and their origin that may be extrapolated to cores with lower temporal resolution in the area. Thereby, we may easier identify the past sedimentary process(es) involved, i.e., ice rafting, contourites, or turbidites and link them to the paleoenvironment.

POSTER
Session 4d.

New constraints on the age and timescale of activity of the Puketerata maar-lava dome complex, Taupō Volcanic Zone, New Zealand

Szabolcs Kósik[1], Takeshi Hasegawa[2], Martin Danišík[3], Károly Németh[4,5], Makoto Okada[2], Bjarne Friedrichs[6,7], and Axel K. Schmitt[6]

[1] *Horizons Regional Council, Private Bag 11025, Palmerston North 4442, New Zealand*
[2] *Department of Earth Sciences, College of Science, Ibaraki University, 2-1-1 Bunkyo, Mito 310-8512, Japan*
[3] *Western Australia ThermoChronology Facility, John de Laeter Centre, Curtin University, Perth, WA 6845, Australia*
[4] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*
[5] *Institute of Earth Physics and Space Science, Sopron, Hungary*
[6] *Institute of Earth Sciences, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 236, D-7 120 Heidelberg, Germany*
[7] *Department of Environment and Biodiversity, Paris-Lodron-University of Salzburg, Hellbrunnerstraße 34, 5020, Salzburg, Austria*

szabolcs.kosik@gmail.com

Accurate dating of young eruptions from volcanoes with explosive activity is essential for forecasting future eruptions and for defining the hazardscape of volcanic fields. However, precise dating of Quaternary eruptions is often challenging due to limited number of applicable dating methods or lack of datable eruptive phases. Moreover, small volume eruptions, despite their significance on regional scale, have traditionally deserved less attention than their large volume counterparts.

Puketerata is a maar-lava dome complex in the central Taupō Volcanic Zone (New Zealand). It encompasses mafic and silicic phreatomagmatic eruptions with well-preserved silicic pyroclastic deposits sourced from closely spaced vents. Its most recent activity is estimated to ca. 16 ka based on medial and distal stratigraphic surveys.

Here we carried out two independent age determinations and an additional paleomagnetic analysis on the volcanic succession of the Puketerata maar-lava dome complex with an aim to unravel the timing of volcanic activity.

Combined U-Th disequilibrium and (U-Th)/He dating of zircon from two lava domes yielded eruption ages of 11.3 ± 2.6 ka and 11.3 ± 1.7 ka, which are concordant with the radiocarbon ages of 11.3-11.7 ka obtained on charred coal from the base of the pyroclastic sequence.

Paleomagnetic data on the lavas from the two lava domes suggest at least ~100 years difference between their emplacements. Our geochronological results and new stratigraphic observations suggest that the most recent eruptions occurred only at ca. 11.5 ka, which is significantly younger than previously thought.

ORAL
Session 1a.

Landscape evolution and quantification of long-term erosion rates in the Hautapu River catchment, New Zealand

Szabolcs Kósik[1], Callum Rees[1], Malcolm Todd[1], Alan S. Palmer[2], Manuela Tost[3], and William McKay[1]

[1]Horizons Regional Council, Palmerston North, New Zealand
[2]School of Agriculture and Environment, Massey University, Palmerston North, New Zealand
[3] WSP New Zealand, Gisborne, New Zealand

szabolcs.kosik@horizons.govt.nz

Quantifying erosion is fundamental to understanding the significance of surface processes and protecting our natural soil resources. Here, we focus on the spatio-temporal patterns of river incision and landscape formation along the Hautapu River, with the aim of informing soil conservation measures.

The study area contains deeply incised landscapes formed in Late Miocene to Pliocene, weakly consolidated sedimentary strata. A suite of Late Pleistocene river terraces has been superimposed over this older marine succession. Cover beds of loess and tephra overlie the river terraces, providing a chronostratigraphic framework. Channelized mass-flow deposits of the Mataroa Formation (125-150 ka), derived from collapse of Mt Ruapehu andesite stratovolcano (Tost et al., 2015), overlie the Greatford Terrace.

The topographic position of these mass-flow deposits is used to reconstruct the paleogeomorphology of a 180-km^2 area of the Hautapu catchment. The depth of incision and total erosion are obtained by comparing the reconstructed surface with present day topography.

The landscape within the upper Hautapu River catchment provides evidence of channel abandonment. The most recent channel avulsion event likely occurred during the late Pleistocene (c. <15 ka) and is associated with the abandonment of the Mangoiwa Stream valley and establishment of the current Hautapu River channel. This event is thought to have occurred as a result of uplift and associated faulting along the Snowgrass Dome.

Total erosion and average sediment yields calculated for the past c. 150 ka indicate approximately 7-8 times higher long-term sediment yields than modelled values calculated for present day conditions (Dymond et al., 2016). Accelerated erosion during glacial and stadial periods, evidenced by fluvial aggradation, is considered to have effectively stripped topsoil from deforested highlands leading to greatly increased sediment yields. Subsequent landscape stabilisation and soil formation during the Holocene is associated with a reduction in sediment supply and enhanced fluvial incision.

POSTER
Session 2b.

Geomorphological evolution of the Ngāuruhoe summit from the 1800s to the present day

Janine Krippner[1], Geoff Kilgour[2], Adrian Pittari[1], and Brad Scott[2]

[1] School of Science, University of Waikato, Hamilton, New Zealand
[2] GNS Science, Wairakei Research Centre, Taupō, New Zealand

jkrippne@waikato.ac.nz

Eruptive activity over about 9,000 years in the southern Tongariro Volcanic Centre formed the young Ngāuruhoe cone, with the present-day summit geomorphology largely resulting from eruptions in the 1950s and 1970s. Frequent geomorphological changes to the summit area have been documented through written accounts, sketches, photographs, and video, allowing us to constrain eruption and morphological details from the mid-1800s onwards. Alternating explosive and effusive activity during 1954-75 produced the scoria cone and ballistic ejecta that currently form much of the summit area, with the southern rim defined by "Owen Peak'' that has been present since before the mid-1800s. The evolving summit morphology has modulated the direction of recent lava flows, pyroclastic density currents, ballistic ejecta, and avalanches largely towards the N and NW. Subsequent erosion including rockfalls has contributed to infilling the youngest vent, and continued rockfalls within the summit cone pose a clear hazard to anyone entering the current crater.

ORAL
Session 1a.

Microbial gas generation and gas hydrate formation at the New Zealand Hikurangi Margin

Karsten F. Kroeger[1], Gareth J. Crutchley[2], Jess I.T. Hillman[1], Francesco Turco[3], and Philip M. Barnes[4]

[1] *GNS Science, 1 Fairway Drive, Lower Hutt 5011, New Zealand*
[2] *GEOMAR Helmholtz Centre for Ocean Research Kiel, Wischhofstr. 1-3, 24148 Kiel, Germany*
[3] *University of Otago, 362 Leith Street, Dunedin 9016, New Zealand*
[4] *National Institute of Water and Atmospheric Research (NIWA), 301 Evans Bay Parade, Wellington 6021, New Zealand*

k.kroeger@gns.cri.nz

The widespread occurrence of gas hydrates along the southern Hikurangi Margin is documented by bottom simulating reflectors (BSRs). High amplitude reflections within the hydrate stability zone (HSZ) indicate the presence of concentrated gas hydrates. Such zones of high reflectivity are most pronounced beneath thrust ridges and are likely associated with sandy turbidite deposits. In structurally more mature thrust ridges these reflections shift to the landward side of anticlines. In some instances, more than one BSR is present. These remnant BSRs indicate past extents of the HSZ and demonstrate the dynamic evolution of the gas hydrate system.

To better understand controls on gas hydrate occurrence and distribution, we have constructed 2D and 3D basin models to predict gas generation, migration and gas hydrate formation. We use these models to assess the impact of faults and sedimentary architecture on gas hydrate distribution. By forward modelling burial and deformation and change in physical properties, we investigate the response of the gas hydrate system to dynamic change.

Models reproduce the distribution of gas hydrates as indicated by high amplitude seismic reflections within the HSZ. The landward enrichment with increasing thrust ridge age is predicted to be the result of microbial gas generated beneath the HSZ during rapid burial of evolving trough basins. This gas then migrates along permeable strata into the HSZ. Back-thrusts further divert gas into the landward limbs of anticlines. The burial of gas hydrates by ongoing seafloor sedimentation leads to their dissociation and recycling of gas. This is consistent with double BSRs likely caused by remnant gas at the older (deeper) base of the HSZ. Conversely, erosion results in incorporation of older BSRs into the HSZ. Modelling helps to identify these remnant BSRs and to better understand the dynamic nature of the gas hydrate system at a deforming convergent margin.

ORAL
Session 2e.

The PULSE Network: Building an Earthquake Catalogue to Understand SSE-Earthquake interaction on the Hikurangi Subduction Zone

Stephen Kwong[1], M. Savage[1], Emily Warren-Smith[2], Katie Jacobs[2], L. Wallace[2,3], and K. Mochizuki[4]

[1] Victoria University of Wellington, Wellington, New Zealand
[2] GNS Science, Lower Hutt, New Zealand
[3] University of Texas Institute of Geophysics, Austin, TX, USA
[4]ERI, University of Tokyo, Japan

Stephen.kwong@vuw.ac.nz

Resolving the mechanisms that drive Slow Slip Events (SSEs) and understanding the physical changes they cause to a fault zone, are important in improving our forecasts of when a fault will fail. The PULSE project (Physical processes UnderLying Slow Earthquakes) aims to observe and characterise the physical changes to a fault zone prior to slow earthquakes. To do this, the PULSE Network consisting of 55 onshore (48 seismic, and 7 geodetic) instruments, and 26 offshore (10 seismic and 16 geodetic) instruments was deployed, located in the Porangahau region, where SSEs occur approximately every 5 years. This dense network will allow us to generate a high resolution, high precision microearthquake catalogue spanning the slow-slip and inter slow-slip period.

Since the start of the deployment (1st June 2021) to the 31st July 2022, the GeoNet network recorded 3513 earthquakes within our deployment area. We expect our network to at least double this due to the density of stations. To produce the microearthquake catalogue, the Seisbench implementation of the automatic earthquake picker EQTransformer will be applied over the continuous data. We tested EQTransformer by manually picking 90 events from June 2021 – September 2021 using the GeoNet and PULSE network, resulting in 7482 manual picks over 71 stations, spanning magnitudes 0.9 - 4.9. By comparing the picks from EQTransformer to the manual picks, we settle on a 0.1 pick threshold (the probability value at which EQTransformer accepts picks) and an overlap of 55 seconds. This represents a 92% overlap (EQTransformer takes 60s trace windows), necessitated by EQTransformer's bias to the start of the trace. This yields a good trade-off between pick accuracy (~0.06s), detection rates (~95%) and false detection rate (~2%). We plan to investigate this further on an existing catalogue to confirm these finding before we apply the picker to the PULSE data.

POSTER
Session 1d.

Improving large magnitudes for New Zealand

Luce Lacoua[1,2], Bill Fry[2], Andrew Gorman[1], Yi-Wun Mika Liao[2,3], Camilla Penney[2,3], Laetitia Foundotos[2] and Donna Eberhart-Phillips[4]

[1] Department of Geology, University of Otago/Te Whare Wānanga o Ōtākou, Dunedin, New Zealand
[2] GNS Science, Lower Hutt, New Zealand
[3] School of Earth and Environment, University of Canterbury/Te Whare Wānanga o Waitaha, Christchurch, New Zealand
[4] GNS Science, Dunedin, New Zealand

luce.lacoua@postgrad.otago.ac.nz

As a part of the Rapid Characterization of Earthquakes and Tsunami (RCET) project, we aim to improve rapid analysis of large local and regional earthquakes by refining automated moment tensor inversions. We are developing synthetic earthquake waveforms to refine W-phase inversions for ~Mw5+ earthquakes in New Zealand and Mw6.5+ earthquakes in the southwest Pacific, including the Hikurangi-Kermadec subduction zone. Unlike simpler automated magnitude determinations routinely used to analyze earthquakes in NZ, the W phase does not saturate with magnitude, making it better at quantifying Mw for the largest earthquakes. It also provides the centroid, rather than the hypocentre of an earthquake, allowing better estimation of the spatial distribution of shaking impacts. We are currently calculating w-phase solutions within 20 minutes of earthquake origins.

To improve W-phase solutions for NZ, we are attempting to generate 3D Green's Functions, which provide the ground displacement in time and space considering a finite source.To this end, we use SPECFEM3D, a finite elements method based software that simulates wave propagation. Synthetic ruptures catalogs produced by RSQSim (Rate and State Earthquake Simulator) under the RNC2 project and a regional velocity model will be used to respectively build the seismic sources and the mesh required as inputs.

First, I will run simulations using 2 different velocity models to create a mesh of New Zealand. I will use a global 3D Earth model and a regional model adapted to New Zealand context. Comparing these simulations will show if a more refined model designed for New Zealand gives more relevant waveforms to use in the W phase inversion algorithm than a global model.

Then, I will use the produced waveforms to optimise the W phase inversion algorithm. We will ask if using 3D Green's functions instead of the actual 1D Green's functions improves the inversion.

POSTER
Session 4a.

Sharing the Science Beneath Our Feet: Preparing for the next Alpine Fault earthquake

Alice Lake-Hammond[1] and Caroline Orchiston[2]

[1] *AF8 [Alpine Fault magnitude 8], South Island, New Zealand*
[2] *Centre for Sustainability, University of Otago, Dunedin, New Zealand*

alicelh@af8.org.nz, caroline.orchiston@otago.ac.nz

The *AF8 Roadshow: The Science Beneath Our Feet* is a key risk communication and engagement activity led by AF8 [Alpine Fault magnitude 8], a collaborative programme of work between science and emergency management aimed at increasing societal preparedness for the next Alpine Fault earthquake.

Scientific evidence has shown that the Alpine Fault has a history of generating regular, large earthquakes. Newly updated probabilities suggest there is a 75% chance of an Alpine Fault earthquake occurring in the next 50 years, and that there is an 82% chance it will be a magnitude 8+ event (Howarth et al. 2021). Hazard and risk modelling indicates that the impacts of an earthquake this size will have major implications for the entire South Island, and will generate a disaster of national significance (Orchiston et al. 2018). A primary objective of AF8 has been to increase public awareness and preparedness for a future Alpine Fault earthquake. It is vital that the public understand the implications of this science in their local context and are enabled to take action to be better prepared.

The AF8 Roadshow shares Alpine Fault hazard and impact science alongside preparedness information with South Island communities. It is designed to enable conversations, activate local knowledge, and support informed decision-making to increase intergenerational awareness of, and our preparedness for, a future event. Past events have shown New Zealanders are great at coming together to support each other in an emergency. The AF8 Roadshow encourages people to have these conversations in advance, through a combination of school visits and public talks.

This presentation will explain how the AF8 Roadshow communicates the hazard risk and stimulates conversations to support informed decision-making. We include learnings and insights about communicating complex, and potentially scary, science to enable action rather than causing fear and fatalism.

ORAL
Session 3a.

Listening to a basaltic fissure eruption: Key findings from the 2021 Fagradalsfjall eruption, Iceland

Oliver Lamb[1,2], Julia Gestrich[3], Talfan Barnie[4], Kristín Jónsdóttir[4], Cécile Ducrocq[5], Michael Shore[1], Jonathan Lees[1] and Stephen Lee[6]

[1] Dept. of Earth, Marine, and Environmental Sciences, UNC at Chapel Hill, NC, USA
[2] Te Pū Ao - GNS Science, Wairakei Research Centre, Taupō, New Zealand
[3] Alaska Volcano Observatory, Geophysical Institute, University of Alaska Fairbanks, Fairbanks, AK, USA.
[4] Icelandic Met Office, Reykjavik, Iceland.
[5] Nordic Volcanological Centre, Institute of Earth Sciences, University of Iceland, Reykjavik, Iceland
[6] US Army Research Laboratory, Army Research Office, Durham, NC, USA.

o.lamb@gns.cri.nz

The 2021 eruption of Fagradalsfjall in south-west Iceland provided a rare opportunity to observe and describe eruptive activity from a persistent fissure event. The eruption, which began on 19th March 2021, was characterized by persistent effusive activity punctuated by lava fountaining events and lava flows eventually covered an area of approximately 4.8 km^2. Here we describe key observations and analysis conducted on acoustic data recorded by a four-element infrasound microphone array deployed 800 m from the vents. After 2nd May, activity became focused at one vent which displayed highly periodic lava fountain eruptions for approximately 6 weeks. This was followed by an extended period of pulsating effusive activity punctuated by temporary pauses of up to a week, before the eruption halted in early September 2021. We investigated the characteristics of the acoustics during various eruptive phases and compared them with complementary geophysical and observational data in order to illustrate the nature of the acoustic sources, with a particular focus on the acoustics generated during the lava fountaining. We observed a complex eruptive sequence during each lava fountain event: acoustic tremor during peak fountaining was followed by Strombolian-style activity with distinct high-amplitude impulsive waveforms. Quantitative comparisons to jet noise spectra finds complex turbulence acoustics during each event, with evidence of variations in the wavefield centred on peak lava fountain heights. Strombolian explosions could mostly be modelled by oscillations of bursting gas slugs, with a minor number of events exhibiting Helmholtz resonance behaviour instead. We find an increase in bubble radii between early and late May, suggesting a widening of the upper conduit during the lava fountain sequence. Acoustic recordings of basaltic fissure eruptions are rare and provide a unique insight into the dynamics of high-velocity multiphase volcanic eruptions.

ORAL
Session 4b.

Earthquake-controlled episodic growth of a Holocene stalagmite, eastern North Island, New Zealand.

Jeffrey Lang[1], Joel Baker[1], Julie Rowland[1], Paul Williams[1], Brooke Waterson[1], Kate Clark[2], John Hellstrom[3], Ingrid Ukstins[1], Simon Barker[4], Colin Wilson[4], Adam Hartland[5], Travis Cross[1], Christopher Wood[2]

[1] *School of Environment, The University of Auckland, Auckland, New Zealand*
[2] *GNS Science, Lower Hutt, New Zealand*
[3] *School of Earth Sciences, University of Melbourne, Melbourne, Australia*
[4] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand*
[5] *Environmental Research Institute, School of Science, The University of Waikato, Hamilton, New Zealand*

jlan103@aucklanduni.ac.nz

The Hikurangi Subduction Margin (HSM) represents a major seismic hazard, with potential for generating great ($M_W > 8$) earthquakes and tsunamis. Subduction margins present unique challenges for palaeoseismic research and new techniques are needed to complement current methods. We investigate damaged cave deposits and speleothem growth changes in caves near Wairoa, Hawke's Bay, for evidence of past seismic events. We present a high-resolution chronology for a stalagmite (TRA), based on discontinuities in the calcite fabric, U–Th dates, and annually resolved trace element cycles. We identified major growth hiatuses defining 17 instances of growth onset or cessation since 4.7 ka, during which TRA only grew for 740 ± 150 yr. We propose that strong ground shaking periodically altered fluid pathways above TRA leading to cut-off or renewal of its drip supply, and/or increased host rock permeability leading to changes in cave air pCO_2 and dripwater calcite supersaturation that prevented calcite growth.

We compared TRA's growth history with the HSM palaeoseismic record, which includes eight possible subduction earthquakes since ~5 ka. Seven coincide within age error with a major growth onset or cessation in TRA. The additional TRA growth events could represent proximal upper plate earthquakes. Based on these temporal links, we suggest earthquake shaking exerted a primary control on growth of TRA via changes to fluid pathways above the cave. Several hiatus-like discontinuities also occur in the decades following the inferred margin-correlated ~0.85 ka HSM earthquake, which might reflect lower intensity events. Although other factors could modulate stalagmite growth (e.g., climate and volcanic eruptions), the TRA growth history appears most compatible with the HSM palaeo-earthquake record. The growth behaviour of TRA will be compared with ~100 other dated damage features and growth changes in Wairoa caves and stalagmites, to further assess the links with HSM and upper plate earthquakes.

ORAL
Session 2a.

The fault in our Horizons: Regional active fault mapping updates

Rob Langridge[1], Regine Morgenstern[1], Dougal Townsend[1], Nicola Litchfield[1], Genevieve Coffey[1] and Ian Lowe[2]

[1]Paleoseismology Team, GNS Science, P O Box 30-368, Lower Hutt 5040, New Zealand
[2]Horizons Regional Council, Private Bag 11025, Palmerston North 4442, New Zealand.

r.langridge@gns.cri nz

GNS Science has partnered with Horizons Regional Council to update active fault data across Horizons' seven districts. The major goals of this program were to: i) provide detailed mapping of active fault locations using airborne light detection and ranging (LiDAR) data and a new regional photogrammetry-derived digital surface model (DSM); ii) use this data to develop Fault Avoidance Zones (FAZs) according to the MfE Active Fault Guidelines for building on or near active faults; and (iii) update recurrence interval (RI) data for faults that can be used with FAZs, or where appropriate with Fault Awareness Areas (FAAs).

The districts were generally tackled from south to north, from Horowhenua, to Palmerston North, Manawatū, Rangitikei, Whanganui, Ruapehu and lastly Tararua District. Several new faults were located as part of this study, (e.g., the Tokomaru Fault in Horowhenua), and in some cases known active folds were found to have active faults associated with them, (e.g., Feilding Anticline/Rauoterangi Fault in Manawatū.

Fault activity varies across the region. Tararua and Ruapehu districts have the largest number of named active faults and also those with shorter recurrence intervals falling into RI Class I (≤2000 yr) and II (>2000 to ≤3500 yr), as they are associated with the Hikurangi Subduction forearc and Taupō Rift, respectively. This work resulted in follow-up paleoseismic studies on the Northern Ōhāriu, Makuri-Waewaepa and Rauoterangi faults. The Rauoterangi Fault extends through the town of Feilding beneath pre-existing infrastructure and residences. Trenching has confirmed past ruptures on the eastern of two active fault strands and a revision of RI Class.

FAZs or FAAs have now been generated for most of the active faults in Horizons region and can be used as a decision-making tool at cadastral scale. Results of this work are being used by individual district councils for planning and building decisions.

ORAL
Session 2a.

Sedimentation Patterns in a Small Modern Anthropogenically-Influenced Estuary, Otuwhero Inlet, Abel Tasman

Mark JF Lawrence[1], Salman Ashraf[1] Henry Gard[1] and Barbara Lyndsell[1]

[1] *GNS Science, 1 Fairway Drive, Lower Hutt, New Zealand*

m.lawrence@gns.cri.nz

Otuwhero Inlet is located just south of Abel Tasman National Park and about 2.5 km north of Kaiterteri, and flows into Tasman Bay. Anecdotally, inlet characteristics have changed significantly in recent years due to land-use factors such as forestry, tourism, and built infrastructure. As a first step in understanding the resultant changes in sedimentation patterns a methodology has been developed, aimed at comparing the modern system with that of the recent past (<100 years).

The modern system was characterised by identifying a range of estuarine sub-environments using a combination of modern satellite imagery and ground mapping of geomorphic features and associated sedimentary structures. The distribution of flora and fauna was also documented. To augment the mapping and feature identification, 57 shallow surface samples (≤5 cm depth) were obtained from a series of transverse and longitudinal transects representing the fluvially dominated to fully marine dominated parts of the estuary. In addition, nine shallow (<1.0 m long) cores were acquired. The samples were obtained for grain size analysis, to provide additional information on sediment entrainment, transport and deposition, further refining the estuarine sub-environment classification. This methodology is analogous to that of Simon et al (2021), published while this project was being undertaken. The modern sub-environment classification was then used as a guide for mapping features on a series of historical air photographs that were georeferenced to the modern satellite imagery.

Identified sub-environments range from fluvial channels to offshore bars. The air photographs showed significant changes in major estuary features since 1952. For example, the main channel has moved southwards and has been confined by stop banks. Significant aggradation has occurred probably as a result of Cyclone Gita and upstream logging operations. Overall, there has been noticeable shifting of sub-environments over a relatively short time.

ORAL
Session 2d.

Experimental Constraints on Homogenization of Plagioclase-Hosted Melt Inclusions from Plagioclase Ultraphyric Basalts

K.R. Lewis[1,2], G. K. Ustunisik[1,3], andR. L. Nielsen[1,4]

[1] Department of Geology and Geological Engineering, SDSM&T, Rapid City, SD, 57701-3995, USA
[2] School of Earth and Environment, University of Canterbury, Private Bag 4800 Christchurch, 8140 NZ
[3] Department of Earth and Planetary Sciences, AMNH, New York, NY, 10024, USA
[4] CEOAS, Oregon State Univ., Corvallis, OR 97730, USA

Kristen.lewis@pg.canterbury.ac.nz

Melt inclusions (MI) in early crystallizing phases are often used to determine the composition of melts prior to fractionation, mixing, and degassing. However, MI compositions can be modified by post entrapment processes (PEP) during transport and eruption, thus complicating MI analysis. Many PEP can be reversed through homogenization, or melting near the temperature of MI entrapment and quenching to form a homogenous glass. Homogenization, in turn, may introduce changes in MI composition during the heating process. In order to interpret MIs, we must understand how sensitive MI composition is to homogenization conditions. Here we present a series of homogenization experiments designed to determine the best methodology for the homogenization of plagioclase hosted MI from plagioclase ultraphyric basalts (PUBs). These were run as a time series at at 1 bar (30 min, 4 h, 1 day, 4 days, and 8 days) and 7.5 kbars (2 and 4 days) for two samples of differing anorthite content (Juan de Fuca and Blanco Fracture Zone). Our results show that both samples exhibited time dependent compositional drift from low pressure homogenization. Long run times (4 and 8 days) at 1 bar display depletion halos in the plagioclase host surrounding the MI, while the 7.5 kbar experiments do not. The results are consistent with compositional drift caused by crystal relaxation; where the internal pressure within the MI (pressure of entrapment) coupled with lower confining pressure during homogenization (1 bar) cause a change in partitioning behavior. This suggests that MI homogenization is best accomplished at high pressure (pressure of entrapment) or short run times (30 min), where the least amount of compositional drift occurs.

ORAL
Session 1b.

The most recent fissure feed and lava-producing eruptions of the Arxan-Chaihe Volcanic Field (ACVF), NE China

Bo'xin Li[1], Károly Németh[1,2,3], Julie Palmer[1], Alan Palmer[1], and Vladyslav Zakharovskyi[1]

[1] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*
[2] *Saudi Geological Survey, Jeddah, Kingdom of Saudi Arabia*
[3] *Institute of Earth Physics and Space Science, Sopron, Hungary*

doomlee1216@gmail.com

The surface morphology and textures of the most recent lava flows of ACVF exhibit features of 'a'ā, transitional and pahoehoe lavas, tubes, ponded lava, and tumuli. The vent distribution on both sides of Halaha River (significant fluvial systems run through ACVF) shows near-parallel elongated patterns indicating strong link between vent locations and old structural elements of the basement. The study area hosts the Holocene (~2000 BP) vents of Yanshan ("the Triple Vent") and Da Heigou. Their eruptive products of scoriaceous ash, lapilli and lava flows are indicative for Strombolian-style eruptive history. Fissure eruption is the predominant type across ACVF. Sentinel Satellite Images of the youngest lava flows indicated up to 17-km runout distance of the flows that infilled major gentle sloping alluvial deposit-filled valleys. GIS-based analyses revealed a total lava flow inundation area of about 80 km^2, lava volume of ~0.5 km^3 and a minimum of 40 to up to 400 days of effusive periods using analogue eruption rate values. Cross sections across and along flow axis suggested that the flows emplaced on a very gentle sloping pre-eruptive landscape (<2 degrees). Applying Q-LavHA QGIS plug-in, lava flow simulations were performed to model lava flow emplacement dynamics. Extracted flow parameters were then used to apply to vent opening on present day morphology to estimate lava flow inundation from future effusive events. This simulation indicated that fissure or elongated areal distribution of numerous vents in the Da Heigou and/or Yanshan region can generate maximum lava inundation that would affect the majority of the UNESCO Global Geopark hosting the ACVF, including major disruption in the roading network. This result sheds light on the need to consider lava flow hazard in the geopark operation as well as consideration of a more focused volcanic hazard education program within the geopark.

POSTER
Session 1a.

The role of frictional heterogeneities in the earthquake cycle

Yi-Wun Mika Liao[1, 2], Bill Fry[1], Andy Howell[1, 2], Andy Nicol[2], Charles Williams[1], and Chris Rollins[1]

[1] *GNS Science, Lower Hutt, New Zealand*
[2] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand.*

m.liao@gns.cri.nz

Determination of earthquake source models for seismic and tsunami hazard assessments is difficult and highly uncertain. Information such as recurrence interval and origin of earthquakes and probability of multiple-segment rupture etc. is often unknown, especially for large earthquakes (M>7.0). Earthquake simulators such as RSQSim, based on rate-and-state friction models, generate long-term synthetic earthquake catalogues on a system of known faults. They also provide a clear pathway to future generations of seismic and tsunami hazard models in which ground motions are calculated by modelling the seismic wavefield, having the ability to include variability in the earthquake source process. Importantly, modelling the earthquake cycle also provides a previously elusive pathway toward the ambitious goal of probabilistic tsunami risk modelling. Here we test the effects of varying a priori input parameters during RSQSim modelling. We explore the effects of different initial stress models and rate-and-state constants (a and b) for earthquake cycle simulations of the Hikurangi-Kermadec subduction zone, one of the most observationally undersampled earthquake source regions on the planet. We compare our results with the magnitude frequency distribution of the observed earthquake catalogue and empirical scaling laws as a first-order test. Using variable values instead of a uniform value for initial stress on the fault plane generates more realistic synthetic earthquake catalogues. Co-seismic ruptures become less characteristic as well when the heterogeneity of initial stress is considered. The comparison of rupture area scaling, co-seismic slip and stress drop obtained simultaneously with the synthetic catalogues indicates that smaller b (with fixed a) could result in smaller co-seismic slips and stress drops and scaling consistent with empirical scaling laws. Our results provide a more objective way to assess earthquake-related hazard and hope for hazard assessment and emergency response planning.

ORAL
Session 2a.

New Zealand Paleoseismic Site Database

Nicola Litchfield[1], Jade Humphrey[2], Regine Morgenstern[1], Robert Langridge[1], Genevieve Coffey[1], and Russ Van Dissen[1]

[1] GNS Science, 1 Fairway Drive, Avalon, Lower Hutt, New Zealand
[2] School of Earth and Environment, University of Canterbury, Christchurch, New Zealand.

n.litchfield@gns.cri.nz

The New Zealand Paleoseismic Site Database (site database) is a new database that contains paleoseismic data (grouped into Slip Rate, Earthquake (EQ) Timings and Recurrence Interval (RI), and Single-Event Displacement (SED)), collated at specific sites along active faults throughout NZ. These are primarily on-land faults, but some information on offshore faults are included. The site database was developed as part of the NZ National Seismic Hazard Model 2022 Revision Project (NZ NSHM 2022) but will be useful for a range of other purposes. The database and reports are available for download at https://doi.org/10.21420/QFNX-0M28.

The site database was adapted from existing databases such as the UCERF3 geologic-slip-rate data and the NZ Active Faults Database AF.Points layer. Each site has a grid reference and is generally a single paleoseismic site (e.g., a trench site), but some published data combined from two or more sites are also included. Most sites are assigned to faults in the NZ Community Fault Model version 1.0 (NZ CFM v1.0).

Version 1.0 was compiled in 2020 and 2021 from both published and unpublished data and many sites were relocated using LiDAR or orthophoto data. The slip rate dataset is the largest, with 862 sites situated on 189 CFM faults. These were used to inform the slip rates in the NZ CFM v1.0. The EQ Timings and RI dataset contains 304 sites and 953 records (individual past earthquakes and combined records) situated on 99 CFM faults. The SED dataset contains 970 sites and 17 combined records situated on 90 CFM faults. One application of these datasets in the NZ NSHM 2022 where EQ timings and SED data were used to derive RIs for numerous crustal faults. These RIs were then utilised as inversion constraints in the NZ NSHM 2022 to determine rupture rates for faults throughout NZ.

POSTER
Special Symposium

Zealandian Brachiopod faunas and the Jurassic Crises

Donald MacFarlan

13 Fairfax Terrrace Frankleigh Park 4310 New Zealand

donald.macfarlan@xtra.co.nz

The Late Triassic brachiopod fauna of Zealandia was established by the Oretian (Late Carnian-Norian), with some elements present from the Middle Triassic. This fauna forms part of the distinctive Maorian fauna. Some elements are cosmopolitan, but others (notably *Clavigera* and *Rastelligera*) have a restricted Southern Hemisphere distribution. In general diversity declines through the Late Triassic.

A few new genera appeared in the Late Norian – Rhaetian, including *Zugmayerella*, *Rhaetina* and possibly *Zeilleria* (all cosmopolitan), and in the Upper Otapirian, *Callospiriferina*, a widespread Early Jurassic genus.

Most elements of the Maorian fauna disappeared at the end-Triassic crisis but a few species survived into the Jurassic. The rhynchonellides include *Sakawairhynchia marokopana*, *S. mokauensis* and *Vincentirhynchia pomeyroli*. The terebratulide *Zeilleria spiculata* flourished in the Earliest Jurassic of the Otapiri section in Southland.

A diverse Early Jurassic fauna appeared, with rhynchonellides the dominant group. Affinities are generally cosmopolitan. Shallow-water or nearshore environments in the Otapiri Valley yield *Callospiriferina*, *Aucklandirhynchia*, *Caledorhynchia* and *Callospiriferina*. *Lobothyris* and *Zeilleria* are ubiquitous, and *Herangirhynchia, Spiriferina* and *Cisnerospira* are widespread in deeper-water or offshore faunas. The offshore fauna extends as high as the Toarcian (Upper Ururoan) *Dactylioceras* bed at Kawhia. The ammonites in this bed are from the top of the Early Toarcian (Crassum zone) and post-date the Toarcian event in Europe and South America by about three million years. Early Jurassic brachiopods are of smaller size than those of the Late Triassic or later Jurassic.

Middle Jurassic brachiopod faunas are generally shallow-water. An incomer is the Tethyan *Kutchithyris*. *Aucklandirhynchia*, *Caledorhynchia* and *Loboidothyris* make up most of the fauna.

Brachiopods are common in the Heterian (Oxfordian) Captain Kings Shellbed at and south of Kawhia and in some overlying beds, but in the uppermost Heterian, Ohauan and Puaroan, brachiopods are much less common. *Holcothyris* and *Disculina* continue the Tethyan aspect.

ORAL
Session 1c.

Preliminary results of an avo analysis in the southern hsm: insights into fluid and pressure regimes

Michael Macnaughtan[1], Ingo Pecher[2] and Lorna Strachan[1]

[1] *School of Environment, The University of Auckland, Auckland, New Zealand.*
[2] *Department of Geophysics. Texas A&M University, Corpus Christi, The United States of America*

mmac731@aucklanduni.ac.nz

Characterising an active subduction margin's deeply-buried fluid and pressure regime is imperative when addressing seismogenic potential. Deep, compaction-related expulsion of fluids (e.g. H_2O and CH_4) may fundamentally influence plate coupling by locally modifying the interface's frictional regime. Seismogenesis and slip patterns at a plate interface are often directly controlled by the occurrence accumulated fluids at normal and high pressures. As part of a wider study into the seismogenic potential of the southern Hikurangi Subduction Margin (HSM), we have embarked on an amplitude versus offset (AVO) analysis with the aim of delineating the occurrence of fluids and estimate their pressure regime at the plate interface. Carbon-bearing fluids are hypothesized to be stratigraphically trapped by impermeable strata which may result in a widespread fluid overpressure regime. We present results from an initial AVO effect analysis that shows the existence of AVO signatures in the southern HSM. Definition of AVO signatures and interpretation of fluid escape structures (FES) provides the conceptual framework for a wider AVO inversion study that aims to characterise fluid type at the subduction interface.

We interpret AVO signatures present in current two-dimensional seismic data and interpret anomalous seismic structures potentially related to fluid-escape at the subduction interface. Stratal sequences of interest previously summarized by Davy et al. (2008) and Plaza-Faverola et al. (2012) are: The Mesozoic Sequence (MES) (70-100 Ma) composed of redeposited, low-energy clastic sediments and Sequence Y, composed of mudstones and nannofossil chalks aged 70-32 Ma. Brightening and dimming effects such as those defined by Rutherford and Williams (1989) are interpreted in MES-Sequence Y strata on the Chatham Rise and parallel with the subduction interface under the Hikurangi Trough. Geologically, these reflectivity variations could be the product of contrasting lithologies or pore fluid type (Chopra and Castagna, 2014).

POSTER
Session 4e.

Signals from the deep – Triggers observed on the New Zealand Deep-ocean and Reporting on Tsunamis (DART) Network

Megan Madley[1], Jean Roger[1], Jonathan B. Hanson[1], David Burbidge[1], William Power[1], Aditya Gusman[1], Xiaoming Wang[1]

[1]*GNS Science, Lower Hutt, New Zealand*

m.madley@gns.cri.nz

In 2019, New Zealand implemented a deep ocean network to monitor changes in sea level around its shores and the Southwestern Pacific Ocean. This is a collaborative effort between multiple scientific institutes and government agencies. The array consists of 12 DART tsunameters which focus on monitoring tsunamis from the Hikurangi, Kermadec, Tonga, and Vanuatu subduction zones. Regular, 15 minute, water pressure observations are reported by the DART sea floor pressure recorders which infer the sea-level height above the pressure recorder. Any abnormal fluctuations in sea-level which matches certain criteria causes the instrument to 'trigger'. When in triggered/response mode the sampling period reported back to GNS Science decreases to 15 seconds. This signal is known as an auto-trigger. When a DART is auto-triggered, the National Geohazard Monitoring Centre (NGMC), along with the Tsunami Experts Panel (TEP), if activated, assess the potential threat to New Zealand, evaluating if the auto-trigger is linked to any tsunami waves that could threaten the coast of New Zealand.

We have generated an auto-trigger catalogue to assess signals as they come in and to avoid numerous parasitic activations that could be related to non-tsunami waves like sensor offset, internal waves, seismic shaking, atmospheric pressure jumps, etc. This catalogue will allow the NGMC and GNS responders to quickly assess auto-triggers and then decide if the TEP or further activations are required. This catalogue currently consists of six different auto-trigger categories: Earthquakes, Tsunamis, Positive and Negative Spikes, Subsidence/Offset and Multiple Spikes. These categories are evolving as we develop a better understanding on their origins (instrumental, natural phenomenon or human induced). A few examples of these auto-trigger events will be presented including the February 2021 Loyalty Islands event, the triplet earthquake events in March 2021, signals seen at NZA of unknown origin, and the January 2022 Hunga Tonga-Hunga Ha'apai event.

POSTER
Session 2b.

Dynamic seafloor environments – High-resolution measurements from Kaikōura Submarine Canyon

<u>Katherine L. Maier</u>, Scott D. Nodder, Stacy Deppeler, Oliver Twigge, Peter Gerring, Grace E. Frontin-Rollet and Joshu Mountjoy

National Institute of Water and Atmospheric Research, Te Whanganui-a-Tara Wellington, Aotearoa New Zealand

Katie.Maier@niwa.co.nz

Submarine canyons act as critical links between continental shelf settings and deep-sea environments. Previous biogeoscience studies in Kaikōura Submarine Canyon show its role in offshore sediment transport and hosting abundant marine life (De Leo et al., 2010; Mountjoy et al., 2018). Kaikōura Canyon experienced landsliding and evacuation of sediment triggered by a 2016 M_w7.8 earthquake, resulting in substantial changes to canyon morphology and an event deposit across much of Hikurangi Trough (Mountjoy et al., 2018). Little is known about the canyon seafloor environment and frequency of sediment transport between these large 'canyon-flushing' events.

Results of a pilot study conducted in Kaikōura Canyon following the 2016 event suggest that the canyon floor is a dynamic sediment transport environment on timescales much shorter than earthquake recurrence intervals. The experiment measured and sampled sediment transported near the seafloor and deposited on the seabed along the Kaikōura Canyon axial channel. The experiment focused on three locations between 900 and 1500 metres water depth with a sediment trap and instruments mounted on a mooring at ~15-16 metres above the seafloor and on a benthic lander at ~1-2 metres above the seafloor. Multicores were collected across the sediment-water interface at each site. Benthic landers were deployed for less than three weeks, providing unique high-resolution measurements and a detailed view of near-seafloor, day-to-day canyon sedimentary dynamics.

Preliminary results suggest that sediment flux is considerably higher than other non-canyon deep-ocean environments. Sediment fluxes and organic carbon composition appear to vary with distance down-canyon, distance above the seafloor, and over time. Our new measurements and extensive sample set suggest that the 2016 event has resulted in locally complex erosion and deposition along Kaikōura Canyon related to ongoing re-filling of the canyon and continued transport of sediment and organic carbon into deeper ocean environments.

ORAL
Session 2e.

Evaluation of site parameters to inform seismic site characterization in New Zealand

Elena Manea[1,3], Anna Kaiser[1], Liam Wotherspoon[2], Andrew Stolte[2], Matthew Hill[1], and Matt Gerstenberger[1]

[1] GNS Science,1 Fairway Drive, Avalon, Lower Hutt 5040, New Zealand
[2] Faculty of Engineering, Department of Civil and Environmental Engineering, University of Auckland, 20 Symonds Street, Auckland 1010, New Zealand
[3] National Institute for Earth Physics, 12 Calugareni, Măgurele 077125, Ilfov, Romania

e.manea@gns.cri.nz

Performance of the built environment during earthquakes is strongly influenced by local and regional variations in the ground conditions, with site and topographic effects influencing the amplitude and frequency content of ground motions. While modern ground motion models typically use time-averaged shear-wave velocity to 30 m depth (Vs30) to represent site effects, recent studies have shown that this parameter alone is not able to quantify the strong amplifications observed in sedimentary basins nor the observed topographic effects at stations located on the hills.

In this study we evaluate and map the fundamental (fsite) and predominant (fpred) frequencies of resonance site parameters across the New Zealand GeoNet strong and weak motion monitoring network. This is done by performing horizontal-to-vertical spectral ratio (HVSR) analysis on long-term ambient vibration data and on an earthquake database developed as part of the revised New Zealand National Seismic Hazard Model. For this, we select a subset of the database containing waveforms of all the events with Mw≥4 and depths <200km, recorded across 870 seismic stations.

At a number of stations multiple ambient vibration-based HVSR peaks were identified and attributed to the complex local geological structure. The earthquake HVSRs show a migration of the fpred from fsite to higher modes mostly at stations located in the Wellington and Canterbury basins. Strong topographic amplification peaks were also observed at sites outside the basins on surrounding rock slopes.

This work will enable future research to explore advanced regional and site-specific modelling methods to better account for amplification at the local scale.

ORAL
Special Symposium

Intermediate-Depth Earthquakes Beneath the Central Taupō Volcanic Zone: Where, Why, and How?

Olivia Mark[1], Finnigan Illsley-Kemp[1], John Townend[1], and Eleanor R H Mestel[1]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand*

markoliv@myvuw.ac.nz

Studies have shown that melt inclusions from Taupō and Okataina calderas in the Taupō Volcanic Zone have distinct deep subduction fluid signatures, and that the mantle source feeding these calderas has a high percent of mantle melting. The deep fluids are inferred to be released through dehydration embrittlement in the subducting slab, a process which causes intermediate-depth (50-300 km) earthquakes. In this study, we investigate the underlying mechanisms of this process by calculating locations and focal mechanisms for these earthquakes, using data from the ECLIPSE and GeoNet networks. So far, 506 earthquakes detected by GeoNet at depths of 50–300km beneath the central North Island have been re-picked and accurately located using the New Zealand-wide 3D velocity model from Eberhart-Philips et al (2010). Hypocentre location depth errors have been computed for each earthquake and are typically ±6 km. Focal mechanisms for 66 events have been extracted for analysis, based on how well constrained the earthquake location and the focal mechanism separation is. The refined hypocentres and newly calculated focal mechanisms reveal sub-clusters of seismicity at different depths and positions with respect to the plate interface, and a wide variation in faulting geometries. Waveform analysis is being used to identify seismic arrivals of converted and reflected P and S phases, such as at the plate interface or in the overriding moho, that could aid in refining the earthquakes' hypocentres with respect to the interface. These results will be interpreted in the context of melt flux into the mantle with the aim of establishing a link between intermediate-depth seismicity, magmatism, and volcanism in the central Taupō Volcanic Zone.

POSTER
Session 1d.

Flow Units of the Rangataua Lava Flows

A. Marshall[1], A. R. L. Nichols[1], B. Kennedy[1], T. Waight[2], and P. Doll[1]

[1]School of Earth and Environment, University of Canterbury, Christchurch, New Zealand
[2] Department of Geosciences and Natural Resource Management, University of Copenhagen, Copenhagen, Denmark

ama623@uclive.ac.nz

Ruapehu's constructive history consisted largely of effusive eruptions, but their extent in Holocene times is poorly constrained. The Rangataua lava flows are significantly larger than any other flow on the volcano and extend for at least 14 km, almost reaching the town of Ohakune. Little is known about its emplacement, origin, and flow behaviour, but whole rock geochemistry has been used to separate three flow units: proximal, medial, and distal. This project aims to study stratigraphic relationships of the Rangataua lavas based on geomorphology, crystallinity, and mineral chemistry, to better understand the effusive eruption history of Ruapehu. LIDAR surface imagery was used to investigate the geomorphology of the flow units, backscattered electron images collected using scanning electron microscopy were analysed to determine microlite and phenocryst abundances, and electron microprobe analysis was undertaken to measure mineral and glass geochemistry.

Geomorphology of the flow units provides evidence for three flow units and indicates that the medial flow unit is stratigraphically oldest, underlying the proximal and distal units. Each unit has distinct phenocryst populations, and microlite proportions as well as mineral chemistry and glass composition. The distinct chemistry and crystallisation history of each unit supports distinct magma batches for the three units. In addition, microlite and phenocryst proportions increase by ~10% in the direction of flow within each flow unit, providing evidence that crystallization continued as the lava was flowing with implications for evolving viscosity during emplacement.

This work adds to ongoing hazard assessment conducted by GNS and DOC, and is part of a larger body of work that is investigating the effusive history of Ruapehu.

POSTER
Session 1a.

CALDERA: a scientific drilling idea to unravel Connections Among Life, geo-Dynamics and Eruptions in a Rifting Arc caldera

Cécile Massiot[1], Craig Cary[2], Craig Miller[1], Pilar Villamor[1], Hiroshi Asanuma[3], Eric Boyd[4], Matthew Stott[5], Matteo Lelli[6], Karen Lloyd[7], David D. McNamara[8], Santanu Misra[9], Doug R. Schmitt[10], Guido Ventura[11], Pujun Wang[12], Ludmila Adam[13], Geoff Kilgour[1], Sarah Milicich[1], Alex Nichols[5], Shane Rooyakkers[1], Agnes Mazot[1], Sadiq Zarrouk[13], and Ery Hughes[1]

[1] GNS Science, Lower Hutt, New Zealand.
[2] University of Waikato, Hamilton, New Zealand.
[3] National Institute of Advanced Industrial Science and Technology, Fukushima Renewable Energy Research Institute, Koriyama, Japan
[4] Montana State University, U.S.A.
[5] University of Canterbury, Christchurch, New Zealand.
[6] National Research Council (CNR), Institute of Geosciences and Earth Resources (IGG), Italy
[7] University of Tennessee, Knoxville, U.S.A.
[8] University of Liverpool, U.K.
[9] Indian Institute of Technology, Kanpur (IIT Kanpur), India
[10] Purdue University, U.S.A.
[11] INGV, Roma, Italy
[12] Jilin University, China
[13] University of Auckland, Auckland, New Zealand

c.massiot@gns.cri.nz

Caldera volcanoes produce Earth's largest explosive eruptions, generate seismicity both independent and associated with unrest and eruptive periods, host mineral and geothermal resources that interact with groundwater, and support a largely unexplored biosphere. Volcanic, tectonic, hydrologic and biologic processes in calderas are intimately connected, yet poorly understood, and require subsurface observations. The project "Connections Among Life, geo-Dynamics and Eruptions in a Rifting Arc caldera (CALDERA)" aims to obtain drill cores, downhole measurements and monitoring data from the Okataina Volcanic Centre (OVC), one of two large active silicic calderas in the actively rifting Taupō Volcanic Zone, Aotearoa New Zealand.

CALDERA is ideally suited to address fundamental questions on caldera processes that include: 1) How do caldera magmatic plumbing systems and their eruptive behaviour mature and evolve? 2) How do complex crustal stresses vary in caldera regions and affect geo-hydro-bio-processes? 3) What controls fluid flow and chemistry in calderas? 4) What are the physicochemical conditions that drive subsurface microbial community structure, function and activity? 5) How to predict the onset and style of caldera unrest and eruptions?

We invite scientists to contribute to the design of this project in the exceptional OVC settings and strengthen linkages with other ongoing research and scientific drilling programmes. An international workshop supported by the International Continental Scientific Drilling Program (ICDP) is planned in January 2023. The significant scientific discoveries will underpin 1) resilience to volcanic and seismic hazards; 2) sustainable management of groundwater and geothermal resources, and 3) understanding of subsurface microbial diversity, function and geobiological interactions. These topics are all potent for compelling education and outreach efforts, at the OVC and globally.

ORAL
Session 1e.

Identifying rupture cascades on the Alpine-Marlborough Fault System using lacustrine paleoseismology

Alexandra Matheson[1], Jamie Howarth[1], Sean Fitzsimons[2], Adelaine Moody[1], Jenny Dahl[3] and Marcus Vandergoes[3]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand.*
[2] *School of Geography, University of Otago, Dunedin, New Zealand.*
[3] *GNS Science, Lower Hutt, New Zealand.*

alex.matheson@vuw.ac.nz

Precisely dated records of prehistoric seismicity are important for discerning spatiotemporal patterns of large earthquakes. Earthquake simulators have been used to show that rupture cascade, a pattern of earthquake occurrence in which a high magnitude earthquake on one fault hastens the occurrence of failure on nearby faults, could be a prevalent behaviour of the interconnected Alpine and Marlborough Fault System (MFS). Recent work has increased precision of ages for major earthquakes on the Alpine Fault, but paleoearthquakes on the MFS have been only imprecisely dated, liming investigations of possible sequences of Alpine and MFS earthquakes.

This project uses 6-metre sediment cores retrieved from Lake Tennyson, North Canterbury, to generate a record of large earthquakes in the vicinity of major Marlborough faults (Awatere, Clarence, Hope) and the northern section of the Alpine Fault. A combination of non-destructive (CT, ITRAX and hyperspectral scanning) and destructive analyses (grainsize, C/N ratios, diatoms) are used to develop a lithofacies model that distinguishes the sedimentary signature of high intensity shaking from those produced by other disturbance phenomena. Event ages with decadal precision are generated using a combination of Pb-210 and C-14 dating combined with Bayesian age-depth modelling. Preliminary results indicate seven high intensity shaking events have impacted the site in the last 2000 years, the most recent of which is likely to be the historic 1848 Mw7.5 Awatere earthquake. Temporal clustering is also evident in the record, with the most recent six events all occurring in the last 1000 years, while another 1000 years separate events six and seven. The next steps will be to compare the timing of high intensity shaking events recorded in other lakes that span the transition between the central section of the Alpine fault and the MFS to identify potential rupture cascades.

POSTER
Session 2a.

Modelling Earthquake Sources in Aotearoa using Joint Analysis of Seismological and Geodetic Data

Ashleigh Matheson[1], Calum Chamberlain[1] and John Townend[1]

[1] *School of Geography Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand*

ashleighmatheson@gmail.com

Aotearoa is located along the boundary of the Pacific and Australian tectonic plates, making it vulnerable to large and potentially damaging earthquakes. Modelling the source processes of these earthquakes is critical in understanding how they are generated and in mitigating earthquake-related risks. The robustness of an earthquake source model can be improved by the inclusion of multiple independent datasets: in particular, the differing sensitivities and geometries of seismic and geodetic datasets can be combined in 'joint' inversions to generate enhanced source models. Moment tensor solutions are routinely produced for earthquakes in Aotearoa via analysis of broadband seismometer waveforms alone[1]. For large earthquakes (e.g., the Darfield, Cook Strait, and Kaikōura earthquakes), ad hoc models incorporating multiple datasets are often published by different groups, but the wide variety of modelling methods employed in some cases renders comparisons between different seismic events difficult.

In this presentation we discuss the development of a semi-automatic method of computing robust seismic source models routinely for all shallow moderate-to-large earthquakes in Aotearoa. Our models incorporate broadband and strong-motion data from GeoNet's national seismometer network in conjunction with static geodetic displacements from GeoNet GNSS receivers and high-rate geodetic data from the PositioNZ network. We synthesise waveforms and offsets using Green's functions computed from regionally-appropriate 1D velocity models. We invert in a Bayesian bootstrapping framework and compute robust earthquake source models with meaningful uncertainties for all source parameters. This approach will enable meaningful comparison between earthquakes in Aotearoa and improve the quality and size of the source model catalogue.

POSTER
Session 2a.

FAIR Principles applied to high-value geoscience datasets

Maria Mavroeidi[1] and Mark Rattenbury[1]

[1] GNS Science, PO Box 30368, Lower Hutt.

m.mavroeidi@gns.cri.nz

The FAIR Principles (Wilkinson et al. 2016) were developed to increase the reuse of digital data both by people and machines. To be FAIR -compliant, data should be Findable, Accessible, Interoperable and Reusable. GNS Science is committed to making its data FAIR. We have assessed the FAIR compliance for 27 datasets associated with GNS Science's eight Nationally Significant Collections and Databases (NSCD) as well as 23 high-value natural hazards datasets (NHDs), documented the process and created a roadmap to increase FAIR compliance.

The Findable dimension is largely met by GNS Science's Dataset Catalogue that links metadata to datasets. The metadata registered in the catalogue are harvested by other catalogues, registries and search engines. Findability has been further improved with the use of Digital Object Identifiers (DOIs).

The Accessible dimension requires data can be retrieved with open internet protocols (http, ftp) and extensive use of APIs both of which are employed by GNS Science.

The Interoperable dimension requires data to be open standard or commonly used formats. Where resources allow, GNS Science data are provided in machine-readable formats and are accompanied by community accepted vocabularies.

The Reusable dimension requires rich metadata, particularly around data provenance and licensing. For sensitive and restricted data, the conditions around access and reuse are clearly articulated through GNS Science metadata.

Available FAIR assessment tools have been adapted and used to evaluate FAIR compliance of these high-value geoscience datasets. In terms of average scores, the eight NSCDs are 92% Findable, 83% Accessible, 64% Interoperable and 70% Reusable, whereas the four NHDs are 77% Findable, 59% Accessible, 32% Interoperable and 48% Reusable. The higher FAIR scores for the NSCD datasets reflect the consistent levels of funding directed towards their information management. There is potential for further improvement in FAIR compliance for all datasets.

ORAL
Session 4a.

Palaeomagnetic records of the Laschamp and Mono Lake geomagnetic excursions from Tongariro, New Zealand

Adrija Mazumdar[1], and Gillian Turner[2]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand*
[2] *School of Chemical and Physical Sciences, Victoria University of Wellington, Wellington, New Zealand*

adrijamazumdar@gmail.com

Palaeomagnetic records of the Laschamp (~41 ka) and Mono Lake (~33 ka) geomagnetic excursions have been discovered in volcanic and sedimentary records globally, however records from the southern hemisphere are rare. This research presents direction and intensity estimates of characteristic remanent magnetization from 46 - 24 ka lavas ($^{40}Ar/^{39}Ar$) from the Tongariro Volcanic Centre (TgVC), supplementing the existing New Zealand dataset, which includes data from the TgVC and the Auckland Volcanic Field. Results address controversies regarding the timing and morphology of the excursion to understand features and the underlying geodynamo mechanism.

Palaeodirection results showed evidence of reversed and intermediate polarities around ~43 ka and ~31 ka. Palaeointensity estimates made using traditional Thellier-type methods were anomalously low from three of four studied sites of Mono Lake and post-Laschamp ages. Additional Shaw-type experiments were conducted to test the efficacy of the method. Results showed an unequivocal record of both excursions in the TgVC, with strong support for full polarity reversals of the field during both excursions and decay of field strength to ~20 - 30%. Mapping of virtual geomagnetic pole (VGP) positions suggests that the field evolved through complex non-dipole field configurations during both events.

However, possible underlying dipolar control is indicated by an apparent favoured VGP longitude over the Americas that is identified in both excursions, separated by 10 ky. Support for this hypothesis is observed in the simple, wide, clockwise VGP loop proposed, and in the correlation of VGP positions across global datasets for both the Mono Lake and Laschamp excursions. Palaeointensity results indicate a period of anomalously low field strength over the studied period, which may have given rise to intermittent periods of greater non-dipole field strengths, during which a possible Laschamp-rebound event is identified at ~38 ka corresponding with Japanese sediment records.

POSTER
Session 1a.

Understanding the variability of pollen in Hikurangi Subduction Margin deep marine turbidites for paleoclimate reconstruction

Laura McDonald[1], Lorna Strachan[1], Katherine Holt[2], Helen Bostock[3], Adam McArthur[4], Philip Barnes[5], Katie Maier[5], Alan Orpin[5], and Grace Frontin-Rollet[5].

[1] School of Environment, The University of Auckland, Auckland, New Zealand.
[2] School of Agriculture and Environment, Massey University, Palmerston North, New Zealand.
[3] School of Earth and Environmental Sciences, The University of Queensland, Brisbane, Australia.
[4] School of Earth and Environment, University of Leeds, Leeds, United Kingdom.
[5] National Institute of Water and Atmospheric Research, Wellington, New Zealand.

lmcd461@aucklanduni.ac.nz

Pollen is a valuable and reputable tool for reconstructing paleoclimate. Pollen preserved within marine records captures the onshore vegetation response to changing climate states and other drivers. To effectively use pollen preserved within the sediments of active marine sedimentary systems, such as the Hikurangi Subduction Margin (HSM), the distribution of palynomorphs within turbidite event beds must be understood.

We present preliminary results from short sediment cores collected from the HSM, comparing palynomorph assemblages from channel and overbank facies from Holocene turbidites, which have varying bed thicknesses, grain-sizes and degrees of bioturbation. Our sample set also includes a freshly deposited bed produced from offshore slope failure caused by the M7.8 2016 Kaikōura earthquake. Pollen analysis, CT imaging, magnetic susceptibility measurements, density measurements, laser grain-size analysis and carbonate analysis are being used to investigate the relationships between turbidite facies and palynomorph assemblages. We hypothesise that results will capture evidence of sorting of palynomorphs according to size, morphology and exine thickness. We also expect to see variability in palynomorph assemblages from turbidites from two contrasting HSM environments: one record from within the active Hikurangi Channel (670 km down-channel, ~3400 mbsl) and the other record from the adjacent channel overbank (~3200 mbsl). We also compare pre-human arrival (>1718 cal yr BP) pollen in turbidites from the Kaikōura and Māhia Canyons to determine if there is a unique palynomorph assemblage signature from these sources.

The results of this preliminary study will guide the sampling strategy for the 500 m long Late Quaternary (1.85 Ma) IODP U1520 marine record from the HSM to target turbidite beds or intervals within beds, which capture the most representative pollen record in order to facilitate paleoclimate reconstruction from this unique core, which spans a range of key climatic events including glacial-interglacial transitions and the Mid-Pleistocene Transition.

POSTER
Session 2c.

INVESTIGATING AND MODELLING COSEISMIC AVULSION HAZARDS: A NEW APPROACH FOR EARTHQUAKE AND FLOOD HAZARD ASSESSMENT

Erin McEwan[1], Timothy Stahl[1], Andrew Howell[1,2], Robert Langridge[2], and Matthew Wilson[1,3]

[1] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*
[2] *GNS Science, Avalon, Lower Hutt, New Zealand*
[3] *Geospatial Research Institute, University of Canterbury, Christchurch, New Zealand*

e.g.mcewan@gmail.com

Earthquake surface ruptures can abruptly alter the course of rivers, causing the partial, or full avulsion of flow outside of the established channel. Noteworthy examples of this phenomenon have been documented historically, with accounts suggesting the 1812 Reelfoot Fault rupture caused the temporary reversal of the Mississippi River, and blocked a tributary to form Reelfoot Lake. Fault-rupture induced river avulsion (FIRA) events pose a clear hazard to modern society, yet factors influencing the risk of, and spatial severity of such phenomena have not been investigated in detail. Here, we examine the 2016 Kaikōura earthquake, where Papatea Fault offset caused a partial avulsion of the braided Waiau Toa | Clarence River. We developed a 2D hydrodynamic model to reproduce the salient characteristics of the coseismic avulsion, and to analyse possible alternate scenarios. Calibration was achieved using post-event lidar, with the methodology then applied to 2012 'pre-event' lidar deformed with a synthetic scarp reflecting Papatea Fault displacement vectors. Accuracy was assessed using a binary confusion matrix, revealing spatial accuracy scores ranging from 64% to 78% when accounting for floodplain bias, and as a high as ~90% overall. The FIRA flood modelling method demonstrates that with some knowledge of fault location, kinematics, and river regime, it is possible to model potential FIRA avulsion scenarios ahead of time. New Zealand is home to thousands of fault-river intersections, and climate change is expected to increase the severity and frequency of flood events; yet earthquake and flooding hazards are considered independently despite being able to occur concurrently. Flood models that ignore the presence of active faults may therefore ignore, or underestimate the extent, severity and spatial form of inundation following seismic events. FIRA modelling also has important implications in paleoseismology and provides a powerful way to better understand landscape evolution driven by fault and river interactions.

ORAL
Session 2b.

Probabilistic volcanic mass flow hazard assessment using statistical surrogates of deterministic simulations

Stuart Mead[1], Jonathan Procter[1] and Mark Bebbington[1]

[1] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*

s.mead@massey.ac.nz

Probabilistic volcanic hazard assessments require (1) an identification of the hazardous volcanic source; (2) estimation of the magnitude-frequency relationship for the volcanic process; (3) quantification of the dependence of hazard on magnitude and external conditions; and (4) estimation of hazard exceedance from the magnitude-frequency and hazard intensity relationship. For volcanic mass flows, quantification of the hazard is typically undertaken through computationally expensive mass flow simulators. However, this computational expense restricts the number of samples that can be used to produce a probabilistic assessment and limits the ability to rapidly update hazard assessments in response to changing source probabilities. We develop an alternate approach to defining hazard intensity through a surrogate model that provides a continuous estimate of simulation outputs at negligible computational expense, demonstrated through a probabilistic hazard assessment of dome collapse (block-and-ash) flows at Taranaki volcano, New Zealand. A Gaussian Process emulator trained on a database of simulations is used as the surrogate model of hazard intensity across the input space of possible dome collapse volumes and configurations, which is then sampled using a volume-frequency relationship of dome collapse flows. The demonstrated technique is a tractable solution to the problem of probabilistic volcanic hazard assessment, with the surrogates providing a good approximation of the simulator at very limited computational expense, and is generally applicable to volcanic hazard and geo-hazard assessments that are limited by the demands of numerical simulations.

POSTER
Session 2a.

Crustal anisotropy monitoring at Whakaari/White Island Volcano

D. Mengesha[1], M. Savage[1] and A. Jolly[2]

[1]*Victoria University of Wellington, PO Box 600, New Zealand*
[2]*Hawaiian Volcano Observatory (HVO)*

dagimyoseph.mengesha@vuw.ac.nz

Shear-wave splitting analysis was employed to monitor stress changes associated with magma accumulation at Whakaari volcano, New Zealand. Whakaari was investigated because of its recent eruptions following a decade of inactivity. This enables investigation of temporal variations in the stress field during quiescent, inter-eruptive, and eruptive periods.

Shear-wave splitting analysis detects crustal anisotropy, predominantly caused by micro-cracks. On entering an anisotropic medium, a linearly-polarized shear wave splits into two perpendicular components travelling at different velocities. The faster shear-wave component is commonly observed sub-parallel to the crack alignment and the direction of the maximum compressive stress. The delay time between the two components represents a combination of crack density and path length. These two parameters, fast direction and delay time, are routinely measured using shear-wave splitting. Some studies have observed increased delay times prior to eruptions on short to medium timescales (days to months).

Specific changes in anisotropy during 2019 at Whakaari were investigated using automatic processing techniques to determine the best parameters for measuring shear wave splitting rapidly and reliably. Preliminary results suggest that there might be changes over time in this parameter. During the month of June, the fast directions are concentrated parallel to the crater wall for the two measurement stations, which is in contrast to the measurements seen for other months, where fast direction signals are always observed along multiple orientations. We also consistently observed variations in average delay time when the fast directions changed.

Shear-wave splitting measurements have changed, potentially from time variation in stress, or that the earthquakes are moving through a heterogeneous medium. We will test these hypotheses by comparing the variations in earthquake location and splitting parameters.

POSTER
Session 2a.

Three years of earthquake activity at Taupō volcano investigated with an enhanced seismic network

<u>Eleanor R.H. Mestel</u>[1], Finnigan Illsley-Kemp[1], Martha K. Savage[1], Colin J.N. Wilson[1] and Bubs Smith[2]

[1] *Te Kura Tātai Aro Whenua School of Geography, Environment and Earth Sciences, Te Herenga Waka Victoria University of Wellington, Wellington, New Zealand.*
[2] *Ngāti Tūwharetoa, Tūrangi, New Zealand.*

el.mestel@vuw.ac.nz

Taupō is a frequently active rhyolitic caldera volcano that displays background seismicity and surface deformation, with periods of elevated unrest on roughly decadal timescales. Any resumption of eruptive activity at the volcano poses a major source of hazard, and interactions between the magma reservoir and the regional tectonics that lead to unrest and possible eruption are not well understood. We use data from a temporary seismometer network (ECLIPSE), combined with data from the permanent local GeoNet seismometers, to yield a detailed picture of the present state of the volcano. The ECLIPSE broadband seismometer network was deployed across 14 sites from October 2019 – May 2022, taking a co-production approach to the research to work with local communities and colleagues. We present results of the analysis of the seismicity at Taupō over the last three years including: automatic picking and event association; locations; relative relocations; magnitudes; and focal mechanisms. The earthquakes are located using a new 1D velocity model inverted specifically for the region below and around the volcano. Characterising the background seismicity at Taupō and relating it to past unrest events (in 2019) and models of the young magmatic system improves our understanding of one of Aotearoa's most dangerous volcanoes. This study in particular will aid in interpretation of ongoing and future seismic activity at Taupō, including the most recent period of elevated seismicity, which began in May 2022.

ORAL
Session 1a.

The integrated history of repeated caldera formation and infill at the Okataina Volcanic Centre: Insights from 3D gravity and magnetic models.

Craig Miller, **Jenny Barretto[2], Vaughan Stagpoole[2], Fabio Caratori-Tontini[3], Thomas Brakenrig[1] and Edward Bertrand[2]**

[1] *GNS Science Wairakei Research Centre, Private Bag 2000, Taupo, New Zealand*
[2] *GNS Science, PO Box 30-368, Lower Hutt, New Zealand.*
[3] *University of Genoa, Department of Earth Sciences, Environment and Life (DISTAV), viale Benedetto XV 5, 16132, Genova, Italy*

c.miller@gns.cri.nz

Multistage collapse caldera create complex geological structures that are often buried by kilometers of infill, making study of their origins difficult from outcrop alone. Here we present new gravity and aeromagnetic data compilations derived from terrestrial, lake and airborne surveys to investigate the buried internal structure of the Okataina Volcanic Centre (OVC) and interpret its stages of development. Magnetic highs (1300 nT) are caused by a combination of thick lava flows and domes that infill the collapse structures, as well as deeper feeder structures/dyke complexes that extend below the basement to at least 6 km depth. Several large rhyolite flows are conspicuously non-magnetic and create negative residual anomalies that we interpret to relate to their magnetic mineral deficient nature, rather than hydrothermal alteration. Hydrothermal alteration is limited to topographically low areas near the topographic collapse margins suggesting fluid circulation within the caldera exploits shallow structures.

The gravity data show a -62 mGal residual gravity low associated with the OVC, with the steepest gradients occurring inside the topographic margins. The gradient of the gravity low is stepped towards its lowest point near the outlet of Lake Tarawera. Each step is interpreted as relating to the buried structural collapse margins of the Utu, Matahina and Rotoiti catastrophic caldera forming eruptions, creating a nested caldera structure. Buried caldera margins associated with oldest Utu/Matahina eruptions may play a role in the location of the youngest Tarawera eruptions. We propose smaller amplitude gravity lows that extend outside the topographic margins of the caldera are related to lateral magma migration to the south-west, towards eruption vents within the caldera. 3D gravity inversion, including models numerically constrained by a 3D magnetotelluric model, suggest a caldera depth of 5000±500 m that accumulated over at least 3 collapse episodes along with rifting induced subsidence in the past 550 ka.

POSTER
Session 1e.

Textural characteristics of tephra formations as a proxy for understanding the impacts of a collapse cycle on the eruptive products at stratovolcanoes.

Shannen Mills[1], Jonathan Procter[1], Anke Zernack[1], Stuart Mead[1], and Ian Schipper[2]

[1] School of Agriculture and Environment, Massey University, Palmerston North, New Zealand
[2] School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington

s.mills@massey.ac.nz

Quantifying the shape, abundance and size of bubbles within pumice clasts can provide information on the growth rate and nucleation processes of bubbles within the magma and thus insights into eruptive dynamics. This study investigates a stratigraphic sequence of eruptive units, which encompasses two collapse events to shed light on how eruptive styles varied over that time in response to edifice failure. Between 20-30,000 years ago, Mt. Taranaki experienced two edifice failures in close succession, producing the 27.3 ka Ngaere Formation (5.85 km^3) and the 24.8 ka Pungarehu Formation (7.5 km^3) debris-avalanche deposits (DAD) that strongly altered the morphology of the edifice. Over this period, at least 28 sub-Plinian eruptions occurred that produced the Poto and Paetahi Formations. Changing the morphology of the edifice and conduit through collapse events can impact magmatic pathways and in turn influence fragmentation, altering the textural characteristics of the deposited juvenile material.

We analysed pumices from each of these eruptive events using 3D synchrotron X-Ray tomography to determine the influence these collapse events and the changing morphology of the cone and conduit had on eruptive activity. The textural information together with sedimentological, geochemical and lithological data allowed us to recreate and compare eruption parameters that produced the observed deposits. The sequence records a series of sub-Plinian eruptive events that decrease in magnitude prior to collapse as the conduit becomes progressively constrained and increases in magnitude following the collapse as pressure is released and magma pathways are open. Our analysis of changing eruptive activity will ultimately aid in providing more information for future computational simulation of eruptive events and risk assessments.

ORAL
Session 1a.

The landscape evolution within a confined active distal ring plain environment, Central North Island.

Michael Morgan[1], Jonathan Procter[1]

[1] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*

michaelateamorgan@gmail.com

The Upper Whanganui River catchment between Aukopae and the Central Plateau contains a ~340 ka record of volcanism within an fluvially active, evolving catchment. A combination of volcanism, tectonism and changing climate have caused significant change within the system. From previous studies, both the Whakapapa and Whanganui Rivers have had periods of mass flow activity, sourced from the Tongariro Volcanic Centre (TgVC), however the influence on this system by external factors such as climate and tectonism have not been explored. In addition to this, the region has been subjected to several large rhyolitic eruptions by the proximal Taupo Volcanic Zone (TVZ), of which the larger events are known to be landscape altering events. The full extent of the influence of the rhyolitic products was unknown, along with the respective deposit's spatial distribution and preservation. Extensive mapping shows that volcanic activity and faulting are the major contributors to the morphology and sediment production in the catchment. Movement along the National Park and Raurimu Fault systems has resulted in the abandonment of the oldest observed volcaniclastic surfaces, with the lower surface controlled by a combination of volcaniclastic sediment influx and climactic influence on the volcanic edifices, thus the resulting are formed as a result of combined volcaniclastic and epiclastic deposits. Ruapehu Volcano is the most productive volcano with regards to sediment into the system, with Tongariro observed to contributing minimally. The TVZ caldera forming events have caused significant system resets; the Whakamaru ignimbrite is preserved as inverted valleys, with the modern fluvial systems incising into the softer country rock. The Oruanui ignimbrite caused significant valley infill via reworked ignimbrite and tephra deposits occurring within the active channels immediately after the event. The 232 AD Taupo event again caused a significant disturbance to the system, infilling and resetting the channel levels within the current bounds of the modern river valley and causing rerouting of entire systems. Significant rapid, reworking and remobilization of the deposits occurred resulting a range of complex sedimentary structures.

POSTER
Session 1a.

High-resolution surveying of landslides using UAV-mounted LiDAR

Regine Morgenstern[1], Jason Farr[1], Saskia de Vilder[1], Andrew Boyes[1], Andrea Wolter[1] and Chris Massey[1]

[1] GNS Science, 1 Fairway Drive, Avalon, Lower Hutt 5011, New Zealand

r.morgenstern@gns.cri.nz

Unmanned Aerial Vehicle (UAV)-mounted Light Detection and Ranging (LiDAR) is becoming an increasingly popular and accessible means of collecting accurate and high-resolution topographic data for geospatial analysis. This innovative technology is particularly useful for medium (km^2)-scale vegetated, steep or complex terrain, or when light conditions change, which can make more traditional methods such as photogrammetry, Terrestrial Laser Scanning (TLS) or Airborne Laser Scanning (ALS) challenging or time/cost intensive. Our UAV-mounted LiDAR system consists of a DJI M600 Pro mounted with a Riegl MiniVUX-2UAV LiDAR sensor, Applanix APX-20 Inertial Measurement Unit (IMU) and AV14 Global Navigation Satellite System (GNSS) antenna and a Sony A6000 camera, which was used to survey landslides and slopes at Cape Kidnappers and Fox Glacier, and in the Kaikōura and Gisborne regions. Ground Station Pro was used for mission planning and data were processed, cleaned and classified using POSPac, RiProcess and Leica Cyclone 3DR software. At Cape Kidnappers, the Rambo software package was further utilised to classify changes between two data epochs (October 2021 and April 2022) into individual erosion events. Outputs at each site are high-resolution, colourised point clouds and bare ground models, assisting in analysis of site characterisation and evolution. At Cape Kidnappers, rockfall events between ~0.1 m^3 to 47,000 m^3 were accurately detected using this technique. Validation using test flights show average achievable point density of ~100 pts/m^2 for a standard flight at 80 m altitude and speed of 7.5 m/s. Baseline and repeat surveys were used to identify slope instability, understand movement mechanisms, quantify volumetric change, reference monitoring equipment and assess the magnitude-frequency relationships of rockfall events. Such accurate, spatially-complete and robust methods of data acquisition are imperative for improving situational awareness, informing risk models and decision-making and forecasting impacts related to rainfall-, earthquake- and climate-induced landslides and landslide dams across New Zealand.

POSTER
Session 4b.

The Taranaki 3D Cluster Buster: A Regional Scale Seismic Dataset enabled by High-Performance Computing

Steve Morice[1], Alex Sharples[1], Roland Swift[1], Ian Brewer[1], and Tim Carter[1]

[1] *Todd Energy, New Plymouth, New Zealand*

smorice@toddenergy.co.nz

A new workflow has been developed for merging multiple seismic datasets that enables regional-scale high-resolution stratigraphic interpretation, and is computationally tractable on Todd Energy's 35 TeraFLOPS High-Performance Computing (HPC) cluster.

The majority of Taranaki's known hydrocarbon reservoirs are situated along a ~130 km-long north-south belt in the footwall of the Taranaki Fault. This area is covered by a patchwork of onshore and offshore 2D and 3D seismic surveys acquired and processed between the 1950s and the present day. Understanding the major depositional controls on an individual reservoir's architecture requires regional seismic analysis, however mainstream seismic interpretation platforms are not designed for simultaneously interpreting multiple seismic datasets.

The industry-standard format for 3D seismic data (known as "SEG-Y") assumes that traces are arranged in a regular rectangular grid with a defined origin and rotation angle, usually derived from the survey's geometry. Trace spacings vary from 6.25 m for very dense surveys to 50 m for sparse surveys.

Merging two 3D seismic datasets requires re-gridding the data onto a common grid. Existing approaches to this range from simple nearest-neighbour trace re-assignment to full pre-stack de-migration / remigration, and options in between. Simple re-gridding can be performed interactively on a workstation but suffers from aliasing and Moiré pattern artifacts which can preclude stratigraphic seismic attribute interpretation. Full pre-stack remigration can require days or weeks of compute time on the world's most powerful computers and therefore is typically cost-prohibitive.

Todd Energy's new workflow is based on Seismic Un*x (Cohen & Stockwell, 2022) and bespoke algorithms. The workflow retains the full stratigraphic resolution of the input datasets, and can merge two ~200 km^2 3D surveys (~2 million traces) in less than 24 hours on Todd's in-house HPC cluster. This presentation describes the workflow and key challenges in the creation of the "Taranaki 3D Cluster Buster" dataset.

ORAL
Session 4a.

Mesozoic to Present Day Structural Fabric of the Auckland Region

James Muirhead et al.

University of Auckland

Although not considered as seismically or volcanically hazardous as other regions of the North Island (e.g., Taupō Volcanic Zone, North Island Dextral Fault Belt), geological and geophysical data in the Auckland region do support ongoing and hazardous earthquake and volcanic processes. Additionally, abundant outcrop exposures on Auckland's coast provide a window into the crustal fabric that formed, and was perhaps exploited, during past volcanic and tectonic events in the region. Here we present a compilation of the Mesozoic to Present Day structural fabric of the Auckland region. Results reveal pervasive NE- and NW-oriented structural trends observed in lithologies from the Mesozoic to Present Day, supporting ongoing reactivation of inherited basement weaknesses. Miocene lithologies (Waitākere and Waitematā Groups) are primarily dissected by NE-trending extensional structures (faults, joints, dikes and veins), suggesting a phase of NW-directed Miocene extension, with these structures representing a potential continuation of the Taranaki Basin. Vent alignment patterns in Pleistocene volcanic fields (South Auckland volcanic field) similarly exhibit NE- and NW-trends, revealing that ascending magmas potentially exploit this pre-existing structural grain en-route to eruption. Geomorphic lineaments (linear ridges and valleys) show a dominant NE-trend, which mimics the pervasive NE-trending structures. In all, these data illustrate how present and past surface, volcanic and earthquake processes in the Auckland region are likely affected by inherited crustal weaknesses.

POSTER
Session 1d.

Tracing organic matter derived from Australian dust and bushfires in New Zealand using lipid biomarkers

Sebastian Naeher[1], Phil M. Novis[2], Perry Davy[1], Pauline Grierson[3], Micheline Campbell[4], Andy Baker[4] and John Hunt[2]

[1] GNS Science, Lower Hutt, New Zealand
2 Manaaki Whenua-Landcare Research, Lincoln, New Zealand
3 University of Western Australia, Perth, Australia
4 University of New South Wales, Sydney, Australia

s.naeher@gns.cri.nz

In recent years, devastating wildfires have affected several countries around the globe (e.g. Australia, Russia, Brazil, USA, Canada and several European countries). Wildfires are thought to increase in frequency, intensity and severity due to climate change. Aridity and droughts have also increased the likelihood of fires in some parts of New Zealand. Australian bushfires and dust transport are a presumed accelerator of glacial melt in New Zealand through their effect on snow albedo.

In this study, we investigate the applicability of lipid biomarkers (i.e., organic compounds derived from algae, bacteria and plants) as indicators of dust provenance, in particular to distinguish sources from Australia and New Zealand. In a "source-to-sink" approach, we investigated biomarkers in Australian ash samples, air filter samples from air quality monitoring stations near Auckland and Wellington and dust collected from glaciers in the New Zealand alps.

While diagnostic biomass burning markers such as levoglucosan and polycyclic aromatic hydrocarbons (PAHs) were present in the Australian ash and New Zealand air filter samples, they were absent in dust from New Zealand glaciers. Instead, these were dominated by indicators of terrestrial, organic matter sources such as high-molecular weight *n*-alkanes, *n*-alcohols, fatty acids, plant-derived sterols and terpenoids. In a time-series of New Zealand air filter samples, levoglucosan levels peaked when Australian dust/bushfire impacts to New Zealand were thought to be highest based on meteorological conditions. However, filters were also dominated by soil organic matter, with different molecular signatures if sourced from Australia.

Despite indications of some alteration in biomarker fingerprints during transport and after deposition on New Zealand's glaciers, we demonstrate that biomarkers are useful tracers of dust transport from Australia to New Zealand and can distinguish sources of organic matter from these countries.

ORAL
Session 4d.

Investigating bacterial 3-hydroxy fatty acids as new indicators of past air temperature in lake sediments from New Zealand

Sebastian Naeher[1], Steven Rosenberg[2], A. Kweku K. Yamoah[3,4], James A. Bendle[4], Bella Duncan[2], and Marcus J. Vandergoes[1]

[1] *GNS Science, Lower Hutt, New Zealand*
[2] *Victoria University of Wellington, Wellington, New Zealand*
[3] *University of York, York, UK*
[4] *University of Birmingham, Birmingham, UK*

s.naeher@gns.cri.nz

Glycerol dialkyl glycerol tetraethers (GDGTs), the most widely used terrestrial temperature proxies, have been characterized by over- and underestimation of reconstructed mean annual air temperature (MAAT) in some studies. These uncertainties have been acerbated partly due to our inability to link the branched-GDGTs to a group or specific bacteria source and the difficulty in distinguishing between transported GDGTs from surrounding soils and in-situ production. Based on the relative distributions of 3-hydroxy-fatty acids (3-OH-FAs), sourced from the outer membrane of Gram-negative bacteria, an alternate novel terrestrial biomarker proxy for temperature reconstructions has been developed. Preliminary studies in contemporary soils, stalagmites and lake sediments correlating bacterial 3-OH-FA compositions to air temperature and pH have shown promising results. However, their performance under discrete physical and chemical conditions remains largely unexplored.

In this study, we have analysed 3-OH-FA distributions in surface sediments of 143 lakes across New Zealand. The lakes studied span a large diversity of lake and catchment sizes, water depths, geographic locations (latitude and altitude), productivity/trophic level, catchment vegetation and land-use. 3-OH-FAs were detected in the sediments of all lakes and generally showed a correlation with monitored air temperatures. The strongest corelation was shown in a sub-set of remote lakes along an altitudinal transect with limited human impact where the ratio of anteiso to normal C_{17} 3-OH-FAs (RAN17 index) and iso to normal C_{17} homologues (RIN17 index) correlate with mean annual air temperature with R^2 of 0.65 and 0.58, respectively. Therefore, 3-OH-FAs have great potential as new indicators applicable to the reconstruction of past air temperatures from sediments of New Zealand's lakes.

POSTER
Session 4d.

GeoNet's Strong Motion Network: 21 Years of Products & Services

Muriel Naguit[1], Jerome Salichon[1] and John Young[1]

[1] *GNS Science, 1 Fairway Drive, Avalon, Lower Hutt, New Zealand*

J.Salichon@gns.cri.nz

Seismic strong motion data is a core component in fields of Seismology and Earthquake Engineering. Since GeoNet came into being in July 2001, this non-profit project improved the strong motion data as one of its base products and service for end-users including Engineers, Seismologists, Seismic Risk & Hazard Specialists and Urban Planners.

GeoNet operates under the Data Science & Geohazards Monitoring Department of GNS Science and primarily funded by the New Zealand Earthquake Commission (EQC). With highly-integrated system, GeoNet offers data collection and processing, real-time monitoring, rapid response and event analysis for various natural hazards –earthquake being the main item. GeoNet's network of over 315 strong motion stations situated strategically in New Zealand generates an ensemble of data products available within minutes of an earthquake – thanks to the real-time transmission of continuous data streams and near-real time data processing and accessibility.

Over the span of 21 years, the strong motion data grows dramatically along with denser networks, upgraded data transmission and better instrumentation. The advent of new technology makes large databases more dynamic and accessible, even supported by webservices to access seismic waveforms, metadata and catalogues in a robust and rapid fashion. The GeoNet strong motion network supports free-field and the NZ widespread locality, where strong motion instruments complement the weak motion instruments for rapid ground motion assessment and near-event source information. There are also 20 structural array sites in selected buildings and bridges that support earthquake engineering initiatives in improving NZ seismic design and in the upgrade of structural mitigation measures. At present, the GeoNet project along with teams of specialists, continuously cater to the requirements of its end-users to offer quality products and support services.

POSTER
Session 3c.

Composition and structure of hot spring digitate sinter: preparation for remote sampling on Mars

Ema. E Nersezova[1], Michael. C Rowe[1], Kathleen. A Campbell[1], Steven Ruff[2], Andrew Ang[3], Steven Matthews[4], Thomas Loho[4] and Niamh Galligan[1]

[1]School of Environment, University of Auckland, Auckland, New Zealand.
[2]School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287, USA.
[3]Department of Mechanical Engineering and Product Design Engineering, Faculty of Science, Engineering and Technology, "Surface Engineering for Advanced Materials"- SEAM, Swinburne University of Technology, H38, P.O. Box 218, Hawthorn, VIC, 3122, Australia.
[4]Department of Chemical and Materials Engineering, University of Auckland, Auckland 1010, New Zealand.

ema.nersezova@auckland.ac.nz

In 2007, Mars rover Spirit detected opaline silica deposits near sulfate-rich soils, adjacent to the identified volcanic feature Home Plate, in Gusev crater, Mars. Deposition of opaline silica, interpreted as siliceous sinter, in a volcanic setting is strong evidence for an ancient hydrothermal system in this area, implying the existence of past aqueous and potentially habitable environments on Mars. Remarkably, the deposits found on Mars are texturally similar to digitate sinter structures found in terrestrial hot springs on Earth. As biogenic activity is involved in producing textures seen in modern sinters, this suggests that microbial life may also be involved in the formation of the Mars deposits and still be fossilised within.

Without more detailed knowledge of the depositional environment of siliceous deposits on Mars, it is important to prepare for potential mechanical and physical diversity by utilizing analogues representing the full spectrum of fluid compositions and morphologies exhibited on Earth. Micro-computed tomography (micro-CT) and nano-indentation are employed to determine porosity and silica hardness, respectively, due to the small size and irregular shapes of the digitate sinter. Synchrotron micro- X-ray fluorescence mapping (S-µXRF), scanning electron microscopy (SEM) and electron microprobe analysis (EMPA) are utilized to resolve nano-scale features (SEM) and in-situ chemical variation (S-µXRF and EMPA) across digitate structures to provide a direct comparison between hardness and composition. Micro-CT results indicate a range of textures within the digitate and low total porosities, with values from 4.6-21%. Hardness measurements suggests significant variations corresponding to stromatolitic laminae within the digitate, with maximum values ranging from 10-16 GPa. Combining these data allows us to estimate strength for terrestrial digitate sinters; heterogenous distribution of microporosity, and subsequently strength, appears to be largely controlled by silicified microbes, providing critical constraints for future potential remote sampling mechanisms.

ORAL
Session 4b.

Using tree-ring growth anomalies to date earthquakes

Sophie Newsham[1], Andy Nicol[1], Andrew Lorrey[2], Gretel Boswijk[3] and Timothy Martin[4]

[1] *School of Earth and Environment, University of Canterbury, New Zealand.*
[2] *Climate Atmosphere and Hazards Centre, National Institute of Water and Atmospheric Research LTD. (NIWA), Auckland, New Zealand.*
[3] *Faculty of Science and Environment, University of Auckland, New Zealand*
[4] *Forest Ecologist (Independent), Whangarei, New Zealand*

Sophia.newsham@pg.canterbury.ac.nz

Tree-ring growth patterns have been used to date large prehistoric earthquakes, which can impact tree growth through ground shaking, ground-surface rupture and changes in local hydrology. These impacts may produce anomalies in the width of annual tree rings that are distinguishable from the impacts of climate or disease. The precision of tree-ring dating is typically <10 years and can add complementary precision for other paleoseismic dating methods, thereby improving our understanding of earthquake recurrence intervals.

Prior work by Wells et al. (1999) used tree rings to infer the timing of the last major rupture on the Alpine Fault at 1717 A.D. Our research builds on that study to evaluate uncertainties on the timing of the proposed 1717 A.D. earthquake, and to constrain the spatial extent of a purported earthquake in 1826 A.D. Our investigation combines existing tree-ring data from *Libocedrus bidwillii* (NZ cedar) and *Lophozonia menziesii (*silver beech) trees at nine sites along the Alpine Fault with new data from *Lophozonia menziesii* trees at three sites in South Westland. First order methods included an analysis of inter-site tree-ring growth pattern correlations and differentiation of potential climatic and seismic signals.

In this poster we present preliminary results of our research for discussion. Investigations to date may indicate that the timing of the ~1717 A.D. is less precisely known than previously thought and that the 1826 A.D. earthquake impacted tree-ring growth at least as far north as South Westland. Our work supports the use of dendrochronology to date earthquakes and supports its use for earthquake risk reduction in Aotearoa New Zealand.

POSTER
Session 2e.

Underground Storage of Green hydrogen in Aotearoa

Andy Nicol[1], David Dempsey[1], Edward Yates[1], Karen Higgs[2], Mac Beggs[3], Ludmila Adam[4], and Alan Bischoff[1,5]

[1] University of Canterbury, Private Bag 4800, Christchurch, New Zealand
[2] The Old Church Rooms, Bryn-y-maen, Conwy, LL28 5EN, United Kingdom
[3] Retired, Martinborough, New Zealand
[4] School of Environment, University of Auckland, Private Bag 92019, Auckland 1142, New Zealand
[5] Geological Survey of Finland (GTK), P.O. Box 96, FI-02151 Espoo, Finland

andy.nicol@canterbury.ac.nz

Green hydrogen, generated from excess renewable electricity, will be an important component of a future zero-emissions energy system in Aotearoa for both renewable electricity and hydrogen applications (e.g., transportation and industrial feedstock). Maximising the value of hydrogen energy will require cost-effective methods for meeting increasing storage demands. Storage volumes of porous rock reservoirs, here referred to as Underground Hydrogen Storage (UHS), will permit larger-scale hydrogen production and provide sufficient capacity for managing out-of-phase supply and demand cycles.

For UHS to be effective in porous-media, the geological system must have sufficient storage capacity, deliverability (injection and extraction rates), and security of containment to meet operational specifications and budgetary requirements. The multitude of hydrocarbon accumulations in the Taranaki region demonstrate that sandstone sedimentary strata can form effective reservoir systems for gas and liquid hydrocarbons. Reservoir sandstones and seal mudstones in Taranaki are dominated by silicate minerals (e.g., quartz, feldspars and clay) that are unlikely to undergo significant alteration over typical hydrogen storage life cycles of months to years. However, sample analysis and chemical modelling is required to predict the degree of rock reactivity, the products of reaction, and resulting changes in rock properties.

Preliminary static reservoir models for depleted gas fields in Taranaki suggest total hydrogen storage capacities of 1-5 PJ, with transfer rates of <1 to ~30 TJ/d. Based on the available geological data UHS is feasible in Aotearoa and will require additional site-specific work programmes prior to operationalisation to confirm storage system parameters (e.g., reservoir capacity, containment efficiency and transfer rates).

ORAL
Session 4e.

Palaeo-activity of large, deep-seated landslides in the Rangitikei Catchment, New Zealand

Ella Nisbet[1], Kat Holt[1], Sam McColl[2] Ian Fuller[1], Alan Palmer[1], and Andrew Neverman[3]

[1] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*
[2] *GNS Science, New Zealand*
[3] *Manaaki-Whenua Landcare Research, New Zealand*

e.e.nisbet@massey.ac.nz

Large (>2ha), deep seated landslides are hazardous and a key agent of hillslope erosion and sediment generation. For most parts of the world, long-term patterns of failure are unknown, precluding comprehensive assessments of hazard and sediment delivery dynamics. In New Zealand, >7000 large deep-seated landslides are known from mapping, with many situated within the Neogene-aged marine sedimentary soft rocks that cover about 15% of the country. Soft-rock landslides are typically slow-moving (mm – m a year), with cumulative displacements damaging land and infrastructure, and they can provide a chronic supply of sediment to rivers. They can also fail rapidly such as with the 1979 Abbottsford Land slide.

In New Zealand, little is known about the ages of pre-historic soft-rock landslides, limiting our ability to assess failure patterns. This current research aims to narrow this knowledge gap by dating soft-rock landslides across the central North Island. In particular, our objective is to assess the long-term patterns of failure and sediment delivery within soft rock terrain, to help contextualize modern day movement rates and sediment delivery. To cost-effectively date multiple landslides we are developing an innovative morphometric landslide dating approach, which quantifies landslide age (i.e., youthfulness of the morphological expression) from high-resolution elevation data. We will calibrate this method with absolute age data produced from radiocarbon dating of organic matter which accumulates within the depressions formed within landslide deposits.

Herein we present preliminary results of the morphometric dating tool development, and absolute age data for two landslides in the central North Island, within the Rangitikei Catchment: Torere and Poroa landslides. By contributing new knowledge on failure patterns of major landslides, this research helps to guide land and hazard management decisions.

POSTER
Session 2b.

Importance of near-bed lateral processes in biogenic fluxes to the seafloor in deep-water environments, Aotearoa New Zealand

Scott D. Nodder[1], Matt Pinkerton[1], Malcolm R. Clark[1], Kate L. Maier[1], Jessica V. Wilks[2], Andrés S. Rigual-Hernández[3] and Gerard and C. A. Duineveld[4]

[1] *National Institute of Water & Atmospheric Research (NIWA), Wellington, Aotearoa New Zealand.*
[2] *Department of Biological Sciences, Macquarie University, North Ryde, NSW, Australia.*
[3] *Department of Geology, Universidad de Salamanca, Salamanca 37008, Spain.*
[4] *Royal Netherlands Institute for Sea Research (NIOZ), Texel, The Netherlands.*

scott.nodder@niwa.co.nz

Vertical fluxes of biogenic carbon, nitrogen, silica and carbonate are key components of elemental and biogeochemical cycles in the ocean. Global models of vertical particle flux generally assume a power law relationship whereby organic fluxes reduce exponentially with increasing depth. In many deep-sea environments, however, where fluxes have been measured simultaneously in the water column and near-seabed, it is apparent that such simplistic models do not always hold, with deeper fluxes higher than or asynchronous with near-surface fluxes. The main causes of increasing flux with water depth are inferred to be the wider particle source area of deeper traps, mid-water particle scavenging and repackaging, especially by zooplankton, and on continental margins, lateral inputs of advected material.

In the Aotearoa New Zealand region, particle fluxes in subtropical (STW), subantarctic (SAW) and Subtropical Frontal Zone (STFZ) waters commonly display such features. Higher near-bed fluxes at upper to lower bathyal depths are observed in STW and SAW, east of New Zealand, with the organic carbon flux contributions from deeper traps effectively alleviating postulated deficits in the annual energy demands of deep-sea benthic communities. Coastal benthic diatoms, conspicuous in fluxes within northern STFZ waters on the Chatham Rise, indicate that biogenic materials can be transported as much as 400 km away from their original loci. On the crest of the rise and in Kaikōura Canyon, fluxes measured at 15 m above the seafloor can be up to an order of magnitude lower than those measured at 2 m above the seafloor due to localised seabed disturbances, highlighting the importance of near-bed fluxes in elemental cycling and benthic remineralisation processes.

These observations raise doubts about the robustness of globally applied flux models to the region, especially if these are not locally validated with sediment trap field data, and also have implications for regional paleoenvironmental reconstructions.

ORAL
Session 2e.

Providing a tephrochronological framework for 10myrs of deposition in the Southern Wairarapa

Libby O'Brien[1], Jenni Hopkins[1], Dene Carroll[1] and Michael Hannah[1]

[1] *School of Environmental and Earth Sciences, Te Herenga Waka- Victoria University of Wellington, New Zealand*

libby.obrien@vuw.ac.nz

The Southern Wairarapa occupies a fore arc section of the Hikurangi Margin and has been subjected to several changes in tectonic regime over the last 10myrs. The progressive shallowing of the depositional environment from deep sea sedimentation to shallow shore face and fluvial systems has resulted in a range of sedimentary facies. Superimposed on regressions and transgressions are several 40kyr glacio-eustatic motifs. Also discovered within this stratigraphy are a significant number of tephra deposits. These are likely from the Taupo Volcanic Zone (TVZ) as well as its understudied predecessors- the Tauranga (TgaVZ) and Coromandel Volcanic Zones (CVZ) and have helped to provide temporal markers within studies focused on the stratigraphy. However, due to limitations on tephrochronological methods at the time, as well as many newly identified deposits, it is time this area was revisited with a focus on creating a cohesive tephrochronology for the region.

In order to provide data which is comparable to a cohesive database, the methods and analytical conditions used will align with those outlined by TephraNZ (Hopkins et al., 2021). The identification of glass geochemistry through EPMA and LA-ICP-MS is being undertaken in tandem with the radiometric U/Pb/Th analysis of zircons. Primarily, this aims to further constrain the sedimentation rates and temporal deposition of multiple regional formations and in conjunction with this, information may be provided on the ash fallout of many understudied eruptions from the TgaVZ and CVZ.

ORAL
Session 1a.

Seismic and gravity surveys characterise Discovery Deep, Antarctica

Will J. Oliver[1], Andrew R. Gorman[1], M. Hamish Bowman[1], Jenny A. Black[2], and Matthew Tankersley[3]

[1] Department of Geology, University of Otago, Dunedin, New Zealand
[2]Institute of Geological and Nuclear Science, Lower Hutt, Wellington, New Zealand.
[3]Antarctic Research Centre, Victoria University of Wellington, Wellington, New Zealand

will.oliver@postgrad.otago.ac.nz

The Discovery Deep area of the western Ross Ice Shelf has been identified as a possible site for future paleoclimate drilling based on legacy regional-scale seismic studies and more recent satellite and airborne geophysical studies. To further assess the suitability of drilling in this target area, seismic reflection and gravity surveys were undertaken during the 2021-2022 summer.

A 30 km long seismic reflection survey (96 channel, 10 m spacing of spiked geophones, 800 g Pentex sources at 25 m depth) imaged the details of the seafloor and underlying stratigraphy. A 2 km spaced Lacoste and Romberg D-meter gravity grid (1 km along the seismic line) ties past regional gravity and bathymetry models in the region of the detailed seismic survey.

The surveys provide new control for models of the bathymetry, sedimentary basin and local crustal units. The seismic data image an anticlinal package of sedimentary units that have been eroded near to the seafloor. Furthermore, the absence of seafloor-draping strata in the seismic data indicates that there is very little Holocene sediment on the ocean floor where it is imaged. That said, the seismic image shows no break in the slope of the seafloor which plunges shoreward (west) at about 0.4°, suggesting that the bottom of the basin at Discovery Deep is yet to be imaged.

A second seismic reflection survey was conducted along the central 2.7 km of the original survey using a 300 m long towed snow streamer (96 channel, 3.125 m spacing of gimballed geophones, 0.1 kg detonator cord surface shots). The snow streamer method was found to be about four times as efficient (in distance covered per day) as the traditional spiked geophone survey method. The quality of the stacks is comparable (lower frequency content but absence of a source ghost in the streamer data.)

POSTER
Session 4b.

Using the 2016 Kaikōura earthquake to test hypotheses that underpin turbidite paleoseismology

Alan R. Orpin[1], Jamie D. Howarth[2], Stephanie E. Tickle[2], Scott D. Nodder[1], Katherine L. Maier[1], Lorna J. Strachan[3] and TAN2109 science team

[1]National Institute of Water and Atmospheric Research (NIWA), Greta Point, Wellington 6021.
[2]School of Geography, Environmental and Earth Sciences, Victoria University of Wellington 6140.
[3]School of Environment, University of Auckland, Auckland 1142, New Zealand.

alan.orpin@niwa.co.nz

Paleo-earthquake records generated from submarine turbidites have been used to produce arguably the longest and most complete records of subduction zone earthquakes around the globe. Such records provide potentially vital information for earthquake forecasting but the basis for them has been vigorously debated by earthquake geoscientists. Debate about the rigour of turbidite derived earthquake records exists because there are few examples where the relationships between the fault(s) that rupture in an earthquake, the spatial extent of strong ground-shaking, and the deposition of co-seismic turbidites have been observed. Our presentation will summarise highlights gleaned from the RV *Tangaroa* voyage in October 2021 that leveraged the unique opportunity afforded by the 2016 Kaikōura earthquake – one of the best measured earthquakes in history – to test hypotheses that underpin turbidite paleoseismology. We collected new high-quality short cores from closely spaced sites within selected submarine canyons on the southern Hikurangi margin, building on the success of three previous coring campaigns (TAN1613, TAN1705 and TAN1906) that show co-seismic turbidites are reliable 'natural seismometers' (Howarth et al., 2021). The science objectives for our most recent voyage to the Hikurangi subduction margin included densification of coring targets for high-resolution geological characterisation (CT and micro-XRF scanning) and sampling (texture and composition) allow critical appraisal of the following: (1)"the confluence test"; (2) variability in longitudinal and thalweg-to-levee turbidite deposition within the Hikurangi Channel; (3) potential influence of different turbidite source areas; (4) spatial sampling representativeness of coring methods and the possible influences of short-wavelength bedforms on core recovery and sedimentological features; and, (5) biological modification by bioturbation and its impact on event preservation in the sedimentary record.

ORAL
Session

Assessing the Pliocene–Recent erosion history of the eastern Southern Alps using cosmogenic radionuclides, tracer techniques and grain size analyses

Juergen Oesterle[1], Kevin P. Norton[1], Claire E. Lukens[2], Fritz Schlunegger[3], Matthew W. Sagar[4], Klaus Wilcken[5] and Ningsheng Wang[1]

[1] School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand.
[2] Department of Life and Environmental Sciences, University of California, Merced, USA.
[3] Institute of Geological Sciences, University of Bern, Bern, Switzerland.
[4] GNS Science, Lower Hutt, New Zealand.
[5] Centre for Accelerator Science, Australian Nuclear Science and Technology Organisation, Sydney, Australia.

juergen.oesterle@vuw.ac.nz

The *Southern Alps / Kā Tiritiri o te Moana* have attracted scientists to study the interactions between climate and tectonics for decades. It has long been argued that tectonic uplift of this orogen is approximately balanced by surface erosion. The prevailing westerly airflow at the latitudes of the Southern Alps has created a strong orographic effect with precipitation decreasing sharply across the orogen's main divide. The signature of this orographic effect is apparent in erosion rates that decrease from west to east, and from the dominant types of erosional processes that operate on either side of the orogen's main divide. Most studies quantifying erosion over geologic timescales have focussed on the wetter—but areally significantly smaller—side of the orogen. Here, we seek to quantify the Pliocene-Recent erosion history of the Southern Alps' much larger eastern side using cosmogenic radionuclides (^{10}Be and ^{26}Al), tracer techniques (U–Pb) and a grain size analysis (e.g., D_{84}, D_{96}/D_{50}; subscripts denote percentiles of riverbed grain size distribution) on fluvial deposits in Canterbury that record concomitant erosion of this mountain range. Cosmogenic radionuclides provide a powerful tool to constrain erosion rates on timescales of 100–100,000 years, which is the temporal range at which tectonic and climatic forcings overlap and meso-scale stratigraphic architecture is created, thereby offering critical insights into the dynamics between tectonics, climate, and erosion. Detrital grain U–Pb analysis of the fluvial deposits will be used to establish the sediment's provenance, while a grain size analysis of the river sediments will provide insights into associated past stream dynamics. With this multi-method study, we seek to constrain both spatial patterns and catchment-scale rates of erosion of the Southern Alps, as well as their changes through time. Finally, this research will provide a benchmark for assessments of anthropogenically influenced erosion.

POSTER
Session 2b.

Urban Methane Emissions in Auckland, New Zealand

Harrison O'Sullivan-Moffat[1,2], Jocelyn Turnbull[1], David O'Sullivan[2] and Lucas Gatti Domingues[1]

[1] *National Isotope Centre, GNS Science, Lower Hutt 5010, New Zealand*
[2] *Te Herenga Waka - Victoria University of Wellington, Kelburn 6012, New Zealand.*

osulliharr@myvuw.ac.nz

Methane is the second most important greenhouse gas and methane emissions from urban areas make up about 10% of New Zealand's total methane emissions. Urban methane emissions can be more more easily mitigated in New Zealand than agriculture methane emissions, however, urban emissions are currently poorly constrained.

Using a car equipped with a cavity ring-down spectrometer for atmospheric methane concentration measurement, we mapped urban methane emissions in Auckland, New Zealand. The results confirm there is a significant contribution to the methane budget from all of the known sources from landfills, wastewater treatment plants, and natural gas infrastructure (which is >80% methane in New Zealand). The observations suggest that domestic methane emissions could be a significant, but poorly constrained, contribution.

During the mobile survey campaign, several suburbs (Stonefields, Meadowbank, Point Chevalier, and Point England) were repeatedly sampled for methane concentrations. All suburbs except Point England (which has no natural gas infrastructure) had numerous, small, methane sources present throughout the day, the number of small methane sources increases during the evening. Constant leaks throughout the day are likely from persistent leaks in the natural gas infrastructure, the larger number of transient leaks are associated with the "behind the meter" emissions. These emissions are from leaking pipes/gas appliances within the house, on/off pulses and emission of un-combusted methane from gas appliances. This research contributes to understanding of the Auckland city carbon budget as part of CarbonWatchNZ.

POSTER
Session 4e.

Taupō volcano's restless nature revealed by 42 years of deformation surveys, 1979–2021

Peter Otway[2], Finnigan Illsley-Kemp[1], and Eleanor R H Mestel[1]

[1] *School of Geography, Environment, and Earth Science, Victoria University of Wellington, Wellington, New Zealand*
[2] *Formerly of GNS Science, Wairakei Research Centre, Taupō, New Zealand.*

finnigan.illsleykemp@vuw.ac.nz

Lake Taupō conceals a large caldera volcano which last erupted in 232 AD. The volcano is still active, and is regularly associated with earthquake activity and ground deformation. In 1979 a surveying experiment began to monitor vertical deformation around the lake. It utilised the surface of the lake for detecting small movements of the lakebed by making regular observations at 22 fixed points – survey stations – around the lake. The programme continues today with 4 surveys being made annually. In this presentation, we present this unique 42 year-long dataset, and draw conclusions on its implications in terms of volcanic and tectonic deformation. The dataset confirms that vertical deformation is occurring in the lakebed. We observe long periods of slow deformation, dominated by subsidence totalling 140 mm in the Taupō Fault Belt at the northern end of the lake near Kinloch. This subsidence is interrupted by uplift episodes now reaching 160 mm in the northeastern sector, near Horomatangi Reefs, containing the most recent active vents. A further uplift episode is currently occurring in 2022. We suggest that the subsidence is primarily tectonic while inflation episodes are driven by upward migration of magma to more shallow levels during periods of volcanic unrest.

ORAL
Session 1a.

Extreme facies variation and pyroxene megacrysts: a magmatic to volcanic approach to unravel the emplacement mechanisms of the Te Onepoto flank system, Lyttelton Volcanic Complex.

Geneva Overwater[1], Darren Graveley[1], and Alex Nichols[1]

[1]*School of Earth and Environment, University of Canterbury, Christchurch, New Zealand.*

geneva.overwater@pg.canterbury.ac.nz

Flank eruptions on large composite volcanoes pose a significant hazard to nearby people and infrastructure (e.g. Mt Etna and Kīlauea). Studying an ancient flank scoria cone, such as at Te Onepoto (Taylors Mistake) on the Lyttelton Volcanic Complex (LVC; Te Pataka-o-Rakaihautu), provides an opportunity to view the cone in cross section to understand how flank eruptive styles and hazards may change over time.

We mapped and described a complex volcanic sequence across an ~80m long cliff and shore platform exposure at Te Onepoto. We identify seven volcanic facies and their emplacement mechanisms based on deposit morphology and grain/clast attributes (size, sorting, componentry). From oldest to youngest, facies include: lapilli-bomb dominated pyroclastic fall, ash dominated pyroclastic fall, agglutinated pyroclastic fall, fluidal peperite, blocky hyaloclastite, massive flow-banded lava, and a dike. Miocene sea level elevations, similar to present day, place the cone in a tidal environment and it is one of tens to hundreds of unmapped flank cones on the LVC that may have interacted with the shallow marine environment.

Large pyroxene crystals (≤2mm) inherent to all facies, and gabbroic lithics (~10 - 90% pyroxene) may be linked to a common magmatic source tapped throughout the Te Onepoto eruptive-intrusive sequence. We intend to assess the relationship between the pyroxenes and their host melt from the plutonic (erupted gabbro lithics) to volcanic (pyroclastic and lava deposits) realm. To do this we will identify equilibrium and non-equilibrium textures of pyroxenes using backscattered electron images. Then, we will use the geochemistry of selected pyroxenes core and rim compositions (analysed by electron microprobe) to test for equilibrium between the pyroxenes and their host melt (glass) compositions. Based on our findings, we will develop a magmatic-volcanic model for the Te Onepoto scoria cone sequence, to explain the observed volcanic facies/eruption styles and pre-eruptive mineral-melt chemistry.

POSTER
Session 1a.

The timing of Dun Mountain Ophiolite emplacement via Rb-Sr isotope dating of metasomatic reactions along the Livingstone Fault

Marshall Palmer[1], James Scott[1], Steven Smith[1], Petrus le Roux[2], Chris Harris[2], Marianne Negrini[1], and Matthew Tarling[3]

[1] Department of Geology, University of Otago, Dunedin, New Zealand
[2] Department of Geological Sciences, University of Cape Town, Rondebosch, South Africa
[3] Department of Earth and Planetary Sciences, McGill University, Montréal, Québec, Canada

marshall.palmer@otago.ac.nz

Juxtaposition of the Dun Mountain Ophiolite (oceanic lithosphere) and the Caples Terrane (continental lithosphere) represents a major tectonic event in the accretionary development of Zealandia; however, the timing of faulting is poorly constrained. There are several complete exposures of the Livingstone Fault in South Westland, including at Beresford Pass, where quartzofeldspathic schist of the Caples Terrane are faulted against the ultramafic base (peridotites and serpentinites) of the ophiolite. At this boundary, metasomatic alteration of the schist, driven by the significant geochemical contrast between the ultramafic and quartzofeldspathic rocks, provides an important opportunity to date the timing of juxtaposition using $^{87}Sr/^{86}Sr$ isotopes. We show that metasomatic alteration of the schist resulted in near complete removal of Rb due to the loss of mica, an increased modal abundance of metasomatic actinolite and appearance of metasomatic garnet and hedenbergite. Because Rb was removed from the metasomatized schist, its $^{87}Sr/^{86}Sr$ composition was essentially frozen at the time of metasomatism, while the $^{87}Sr/^{86}Sr$ composition of unaltered schist evolved due to the radioactive decay of ^{87}Rb. Back calculating the present day $^{87}Sr/^{86}Sr$ composition of the unaltered schist to the frozen $^{87}Sr/^{86}Sr$ composition of the metasomatized schist yields a date of 170 Ma + 5 Ma. This date is broadly consistent with geological reconstructions of the Triassic-Jurassic Zealandia margin and provides a minimum age constraint on the timing of juxtaposition of Caples Terrane and Dun Mountain Ophiolite and therefore the closure of the vast ocean basin along the eastern margin of Gondwana.

ORAL
Session 1c.

A tale of extreme fragmentation: the volcanic ash from Hunga Eruption

Joali Paredes-Mariño[1], James D. L. White[2], Tobias Dürig[3], Rachael Baxter[2], Shane J. Cronin[1], Taaniela Kula[4], Ingrid Ukstins[1], Jie Wu[1], David Adams[1], Marco Brenna[2], and Isabelle Brooks-Clarke[1]

[1] School of Environment, University of Auckland, Auckland, New Zealand
[2] Department of Geology, University of Otago, Dunedin, New Zealand
[3] Institute of Earth Sciences, University of Iceland, Reykjavik, Iceland
[4] Tonga Geological Services, Government of the Kingdom of Tonga, Tonga

joa.paredes.marino@auckland.ac.nz

The underwater eruption of Hunga Volcano, on January 15 2022, blasted an enormous eruptive plume of at least 55 km high. The dynamics of ash plume expansion and atmospheric pressure waves were unlike anything seen before. The explosivity of this event does not agree, a priori, with the crystal-poor andesitic magma erupted (57-63 wt.% silica glass). Ashfall was reported on all inhabited islands of Tonga, except the northern Nuia group, >300 km from the volcano, with measured thicknesses from 4 to < 0.1 cm. Deposits were sampled from four islands across the Kingdom of Tonga within 10 days of the eruption. Grain-size and morphological analyses were completed to assist local response authorities. The tephra (500-5600 μm) comprises, on average, dark pumice (43%), light pumice (21%), blocky glass (25%), banded pumice (4%), lithics (6%) and free-crystals (Pl, Cpx, Opx) (1%). The specific gravity of particles ranges from 0.4-1.0 (few and rare LP lapilli) to ~2.1-2.8 (ash grade). Scanning electron images show that pumices have a variable vesicularity, from dense glassy blocky particles; glassy particles with isolated vesicles and weakly deformed; and a lower percentage of microvesicular and reticular pumices. The general characteristics imply that magmatic vesiculation, as well as deformation and collapse, must have occurred prior to magma-water interaction, possibly driving a primary fragmentation process. This could be a combination of rapid decompression and explosive magmatic gas release, along with highly-efficient crack-confined phreatomagmatism, accelerated by stress waves and thermal contraction rapidly increasing a magma surface area for interaction. The ash is fine-grained and poorly sorted overall, with 8 wt.% finer than 10 μm and <0.05 wt.% finer than 1 μm. Variations in the mode and sorting of ash fall at different locations from the vent show that there was potentially complex dispersal of ash from different phases of the 11-hour-long eruption.

POSTER
Session 1a.

Provenance of Miocene–Pleistocene conglomerates in the northern Canterbury Basin: implications for exhumation along the Pacific–Australian plate boundary

Matthew Parker[1], Kari Bassett[1], Matthew Sagar[2], Greg Browne[2] and Alexander Nichols[1]

[1] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*
[2] *GNS Science, Lower Hutt, New Zealand.*

matt.parker@pg.canterbury.ac.nz

Late Cenozoic strata of the northern Canterbury Basin record uplift and erosion of the adjacent Kā Tiritiri o Te Moana/Southern Alps and Kaikōura ranges at the transition from oblique subduction to oblique strike-slip on the Australian–Pacific plate boundary. This study focuses on the provenance of Miocene–Pleistocene conglomerates, sampled along a c. 170 km northeast–southwest transect across different terranes of the Torlesse Composite Terrane (TCT; Rakaia, Kaweka and Pahau terranes). We use the mineralogy, geochemistry and detrital zircon (DZ) U–Pb geochronology of conglomerate clasts and sandstones to reconstruct sediment transport pathways and thereby constrain areas of exhumation.

Conglomerate clasts are dominated by weathered greywacke clasts with minor limestone, altered volcanic and sandstone/siltstone clasts. The petrography and geochemistry of greywacke clasts confirm a TCT source. To differentiate between the terranes of the TCT we developed a classification using linear discriminant analysis of immobile element ratios. We found that greywacke clasts were mostly locally derived in the Miocene–Pliocene, indicating localised areas of exhumation in the Marlborough Fault System (MFS) and on the Alpine Fault. In early Pleistocene strata, some greywacke clasts were derived from the more distal Rakaia Terrane, indicating major drainage reorganisation and significant exhumation on the Alpine Fault.

The DZ age spectra of sandstones are similar and indicate mixing of sediment derived from all terranes of the TCT. Variable proportions of Pahau Terrane-derived DZs are present in all samples, including non-marine sandstones from inland central Canterbury. These indicate exhumation highs within the MFS and fluvial transport to the southwest of up to 80–130 km during the Miocene.

Ultimately, the evolution of these inferred sediment transport pathways can be related to clockwise rotation of the Australian Plate and a transfer of significant exhumation from the MFS to the Alpine Fault since the early Pleistocene.

ORAL
Session 1c.

Fluid and heat flow in the Ōkataina Volcanic Centre and at Lake Rotomahana, New Zealand

<u>Sophie Pearson-Grant</u>[1], Warwick Kissling[1], Ted Bertrand[1], Cornel de Ronde[1], Lucy Carson[2], and Craig Miller[2]

[1] GNS Science, 1 Fairway Drive, Avalon, Lower Hutt 5010, New Zealand
[2] GNS Science, Wairakei Research Centre, 114 Karetoto Road, Taupo 3384, New Zealand.

s.pearson-grant@gns.cri.nz

The Ōkataina Volcanic Centre (OVC) in the Taupō Volcanic Zone is New Zealand's most recently active caldera complex, erupting 85km^3 (magma equivalent) in the past 21 ka. The OVC hosts numerous geothermal fields and surface features, predominantly around its margins. Successive caldera collapses over the past ~ 550 kyr have created a complex crustal structure through which fluids migrate. The fluid pathways and the factors that influence them can be explored using numerical models of heat and fluid flow. Here, we present two examples: investigating what controls the near-surface locations of hydrothermal systems in the OVC, and understanding the hydrothermal systems at Lake Rotomahana prior to the 1886 Tarawera eruption.

In the OVC, model results suggest that localised basal heat sources, as inferred by magnetotelluric (MT) resistivity models, are the largest influence on the locations of geothermal upflow. Near the surface, topographic loading effects also have a strong influence. Models are relatively insensitive to structural permeability variations, suggesting that deep fluid circulation is dominated by flow in fracture networks rather than individual mapped large-scale fault structures.

At Lake Rotomahana, TOUGH2 model results suggest that the source of hot hydrothermal upflow pre-1886 matches the northwest portion of a present-day MT anomaly. Further, the morphological boundary of the OVC was a major geological control on fluid circulation. If the permeability of this boundary is ~10^{-16} m^2 and lower than the surrounding material, separate upflows occur on each side which broadly match the locations and separation of the Pink and White Terraces and their respective hydrothermal systems. The simulations further suggest that the Terraces may have been only 3-4,000 years old at the time of the eruption of Mt Tarawera.

ORAL
Session 1e.

Re-defining the J hyperthermal event via paleoenvironmental analysis of early Eocene marl and limestone alternations from Mead Stream, New Zealand

Sonja Penafiel Bermudez[1, 2], **and Thomas Cooper** [2]

[1] *GNS Science, Wellington, New Zealand*
[2] *School of Geography, Environment and Earth Sciences, Victoria University, Wellington, New Zealand.*

s.bermudez@gns.cri.nz

This study integrates paleontology and geochemistry to provide a paleoclimatic analysis of cyclic sedimentation in the Lower Marl at Mead Stream in Marlborough, Aotearoa/New Zealand. Analysis of marine palynomorph and foraminifera assemblages from the alternating marls and limestones improves biostratigraphic resolution and further defines events during the Early Eocene Climatic Optimum (EECO; ~53–49 Ma) — a period characterised by the highest temperatures of the Paleogene.

A unique acetic acid leaching method was used to extract microfossils from the indurated limestones. The resulting paleontological assessment from the Lower Marl coupled with stable isotope analysis at the initiation of the EECO, indicates an earlier onset of the J hyperthermal event than previously recorded. Additionally, acmes of the foraminifera genus *Morozovella* and dinoflagellate cyst *Homotryblium tasmaniense* separated by an interval of low absolute abundances, implies that the J carbon isotopic excursion (CIE) may have been a two-stage event.

This increase in *Morozovella* coinciding with a sudden decrease in marine palynomorphs may indicate an expansion of warm waters to the mid– high latitudes in the southwest Pacific region within the J hyperthermal of the EECO.

POSTER
Session 2c.

In good shape? The impacts of variable fault geometries on synthetic earthquake catalogues from physics-based earthquake simulators

Camilla Penney[1], Andy Howell[1,2], Tim McLennan[3], Bill Fry[2] and Andy Nicol[1]

[1] *Te Whare Wānanga o Waitaha | University of Canterbury, Christchurch, Aotearoa New Zealand*
[2] *Te Pū Ao | GNS Science, Lower Hutt, Aotearoa New Zealand*
[3] *Seequent, a Bentley Systems, Incorporated company, 685 Stockton Drive, Exton, PA 19341, USA*

camilla.penney@canterbury.ac.nz

A well-known problem in understanding seismic hazard is the short duration of the historical record relative to the time between large earthquakes. This short record means that not all possible earthquakes have been observed, and that the statistics of earthquake recurrence intervals are poorly constrained. In particular, recent multifault ruptures, such as the 2010 El Mayor-Cucapah and 2016 Kaikōura earthquakes, have demonstrated the potentially complex interactions of faults in single earthquakes, contrasting with the typical assumption of characteristic fault ruptures in seismic hazard assessment.

Physics-based earthquake simulators, such as RSQsim (Dieterich & Richards-Dinger, 2010; Richards-Dinger & Dieterich, 2012), offer one approach to expanding our understanding of potential multifault earthquakes. Here we investigate the effects of fault geometry on the outputs of such simulators. We use the Canterbury and North Marlborough regions of the South Island of Aotearoa New Zealand – the epicentral region of the 2016 Kaikōura earthquake – as a case study. Using recently developed fault modelling tools (Howell et al., ibid), we create 3D fault networks spanning the range of uncertainty of fault geometries in the region, including the potential for missing faults and variable geometries at fault intersections. The different networks we develop are motivated by key observations from the Kaikōura earthquake, such as the high proportion of previously unmapped faults in the rupture (Litchfield et al., 2018), and by explicit uncertainties in the New Zealand Community Fault Model (Seebeck et al., 2022). We generate synthetic earthquake catalogues on these different fault networks and investigate their similarities and differences, both statistically and in terms of the generated multifault ruptures. By doing so, we are able to better understand the effects of uncertainties in fault geometry on earthquake simulator outputs, which is critical before synthetic earthquakes can be used as a starting point for seismic hazard assessment or scenario planning.

ORAL
Session 2a.

Properties of slow slip events explained by numerical model of rate-strengthening faults subject to periodic pore fluid pressure perturbations

Andrea Perez-Silva[1], Yoshihiro Kaneko[2], Martha Savage[1] and Laura Wallace[3,4]

[1]*School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand*
[2]*Department of Geophysics, Kyoto University, Kyoto, Japan.*
[3]*GNS Science, Lower Hutt, New Zealand*
[4]*Institute for Geophysics, University of Texas, Austin, Texas*

perezan@staff.vuw.ac.nz

Geophysical observations indicate that temporal pore fluid pressure changes correlate with slow slip events (SSEs) occurring along the shallow portion of the Hikurangi margin and in other subduction zones, such as Cascadia and Nankai. These fluctuations in pore fluid pressure are interpreted as due to fluid migration during and between SSE cycles, promoted by permeability changes during SSE's slip. These pore-pressure variations may modulate SSE occurrence. To examine the effect of pore fluid pressure changes on SSEs, we conduct numerical simulations in which we impose periodic pore-pressure perturbations on a rate-strengthening fault. We define two types of pore-pressure perturbations, assuming either fault-normal fluid flow (type I) or along-fault fluid diffusion (type II). Both perturbations induce SSEs, whose properties depend mainly on the characteristics of the pore-pressure change (amplitude, characteristic length, and period). By varying the perturbation characteristics, we find models that reproduce shallow Hikurangi SSE properties (duration, magnitude, slip, recurrence) and SSE moments and durations from other subduction zones. Our results indicate that large permeability values, in the range of ~10^{-14} to 10^{-10} m^2, are needed to reproduce the observed SSE properties. Such high values could be due to transient and localized increases in fault zone permeability that may result from the opening of fractures during SSE slip in the shear zone where they occur. Our model results suggest that a rate-strengthening fault subject to periodic pore-pressure perturbations may be a viable mechanism for SSE generation, which implies that fluids may play a more active role in SSE occurrence than previously assumed.

ORAL
Session 1d.

An automated approach to plume height estimation using infrasound from local to remote

Anna Perttu[1]

[1] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*

a.perttu@massey.ac.nz

Infrasound, sound below human hearing (> 20Hz) is a cloud cover and time of day independent tool that can be used to determine eruption source parameters. Infrasound is an ideal addition to remote sensing of remote volcanoes with little to no local infrastructure. Currently infrasound is generally used in a monitoring context to confirm eruptions, however this technology can also be used for ongoing eruption monitoring and eruption characterization. Eruption source parameters like eruption time, duration, and plume height are essential for dispersion models, which are used to inform hazard mitigation activities. During an eruption it can be difficult to obtain all these parameters in a time sensitive manner. Recent developments in the field of infrasound have shown that while full characterization of a signal requires consideration of many parameters, the results are similar to those obtained using relatively simple relationships that can easily be applied in a near-to-real-time manner. Based on these relationships infrasound can be used to calculate an exit velocity, and from there estimate a plume height (assuming low wind conditions). These results can be quickly obtained for both the local case (within 20 km of the vent), and have recently been extended to the regional to global scale. This method has potential to augment existing regional monitoring systems to reduce the lag time between an eruption and dispersion results based on measurements, not predefined scenarios.

ORAL
Session 4b.

Mt. Ruapehu lahars: past deposits, present modelling, and future hazards

Brian Perttu[1], Stuart Mead[1], Jonathan Procter[1], and Mark Bebbington[1]

[1] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*

bperttu@massey.ac.nz

Lahars, rapidly flowing mixtures of water and volcanic debris, are a frequent and destructive hazard at Mt. Ruapehu. Mt. Ruapehu's ring plain preserves a record of lahar formations spanning 22,600 years ago to the present day, with the youngest Onetapu Formation encompassing events from 2000 years to present day (roughly coeval with the present Crater Lake). The Onetapu Formation includes deposits that represent events showing volume, stage, and discharge measures that are orders of magnitude greater than the laharic events observed in the last 160 years.

To analyse the associated hazards, events represented in the Onetapu Formation have been grouped into 36 lahar sequences based on key lithological, textural, and grainsize changes. The volume, stage (at 40km from source) and four main triggering mechanisms: flank collapse, Crater Lake collapses, meltwater/rainfall remobilizing debris, and phreatic tephras mobilizing ice/meltwater have also been identified. This record was ordered and characterized by volume allowing for simple statistical analysis to determine the annual return period of different volumes for the first time. Lahar sequences with volumes >0.5×10^6 m^3 have a 100-year annual recurrence interval, and lahar sequences with volumes >10^3 m^3 have a 6.67-year annual recurrence interval, however changes to lahar typology would affect probabilities and require updated models. These data allow, for the first time, quantitative hazard determination for risk analysis from lahars at Mt. Ruapehu.

Advancing lahar hazard analysis needs to consider the difference in the resolution in the number of events identified over the last 160 years from direct observations in comparison to those identified from pre-historic deposits.

POSTER
Session 2a.

Spatiotemporal analysis of repeating earthquakes near Pōrangahau, Hikurangi Margin, New Zealand.

Olivia Pita-Sllim[1], **Calum Chamberlain**[1] **and John Townend**[1]

[1] *School of Geography Environment and Earth Sciences, Victoria University of Wellington*

olivia.pitasllim@vuw.ac.nz

Repeating earthquakes are thought to re-rupture the same fault-patch at different times, and thus have nearly identical waveforms, locations and magnitudes. Because repeating earthquakes represent cyclic loading, they can be used to detect temporal and spatial changes of slip-rate at depth and hence monitor how stress is transferred to seismogenic zones.

The Hikurangi subduction zone exhibits a variety of fault-slip related phenomena from large megathrust earthquakes to slow-slip. The northern Hikurangi margin hosts shallow slow-slip and is weakly coupled to shallow depths. In contrast, the southern Hikurangi margin is strongly coupled, with predominantly deep slow-slip events. The transition in coupling occurs beneath the township of Pōrangahau, making the surrounding area an exemplary focus region for studying how this along-strike change in behaviour is accommodated.

To examine slip processes near Pōrangahau, we have constructed and analysed a catalogue of repeating earthquakes that occurred since 2004. To build our catalogue, we first clustered GeoNet's extensive earthquake catalogue using a cross-correlation threshold of at least 0.95 normalised cross-correlation on two or more stations to identify repeating earthquakes. We then used a matched-filter to identify additional repeating events missing in the GeoNet earthquake catalogue.

Using precise locations and well-constrained focal mechanisms, we determined that the majority of the repeating earthquake families on the subduction interface are located at the transition from strong- to weak-coupling of the subduction interface. The majority of the repeating earthquakes we identify are located up-dip or down-dip of modeled slow slip patches, with few families correlating spatially with slow slip events. We infer that the spatial anti-correlation between repeating earthquakes and slow slip is the result of different frictional properties between these regions. The insights gained from this study lay the groundwork for future work constraining processes of strain accumulation at the creeping-to-locked transition zone near Pōrangahau.

ORAL
Session 1d.

Resolving past eruptive impacts from Taupō supervolcano using novel high resolution sampling techniques

Stephen Piva[1], Rewi Newnham[1], Simon Barker[1], Colin Wilson[1], Lionel Carter[2], and Nels Iverson[3]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand*
[2] *Antarctic Research Centre, Victoria University of Wellington, Wellington, New Zealand*
[3] *New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, Socorro, New Mexico, United States of America*

stephen.piva@vuw.ac.nz

In New Zealand, the nature, magnitude, and duration of past volcanically-induced environmental and climatic impacts often remain unresolved on ecological timescales due to incomplete geological records or coarse-resolution analysis of relevant proxies. Due to their widespread dispersal and often distinctive geochemical fingerprints, tephra deposits preserved in terrestrial, marine, and glacial archives are valuable time-plane markers. They not only provide high-precision chronological constraints and links between diverse sedimentary settings but can be integrated with high-resolution palaeoenvironmental and palaeoclimatic records to better understand the effects of volcanism on sub-decadal timescales. Although often undefined in tephropalaeoecological studies, recognition of eruptive sub-units provide critical insights into the mechanisms by which an eruption impacts vegetation, landscapes, and climate. Using continuous lacustrine sediment cores that preserve intact layers of tephra, stratigraphic milli-sampling techniques have been developed to analyse pollen and charcoal assemblages at both contiguous and discrete millimetric-intervals directly above and below tephra layers to assess immediate post-eruption vegetation and landscape responses. In addition, novel methods were established to concentrate, extract, and geochemically analyse microscopic volcanic glass from Antarctic ice core intervals associated with increased chemical anomalies (e.g., non-sea-salt sulfur), and particle counter measurements. Recognition of eruptive material and confirmation of the volcanic source can aid reconstructions of volcanic impacts on climate, constrain existing ice core chronologies, and provide insights into ash cloud extent, dispersal, and the long distance transport of tephra. In this study, millimetre-scale sampling of multiple North Island lake sites for high-resolution pollen and charcoal, and examination of Antarctic ice cores for microscopic volcanic glass shards were conducted to reconstruct the environmental and climatic impacts of the ~25.5 ka Ōruanui and 232 ± 10 CE Taupō eruptions. The results demonstrate the value of the high-resolution sampling techniques and practices developed in this study to resolve and assess past eruptive impacts on sub-decadal timescales.

ORAL
Session 1a.

Using Palaeomagnetic Techniques to Uncover the History of an Archaeological Site in Napier/Ahuriri, Hawkes Bay

Shefali Poojary and Gillian Turner

School of Chemical and Physical Sciences, Victoria University of Wellington – Te Herenga Waka, New Zealand

Gillian.Turner@vuw.ac.nz

Archaeomagnetic dating is a powerful technique to estimate the ages of fired archaeological features. Over the past millennium, the direction of the geomagnetic field over New Zealand has shifted from ca. 15° W to 20° E of N, gradually steepening at the same time. This characteristic palaeosecular variation is captured in the regional record NZPSV1k, providing a reference against which the direction of remanent magnetization of test features can be compared and hence, dated. During the 2020 demolition of early-mid 20th-century residential properties in central Napier/Ahuriri, an archaeological site was exposed. Features such as well-preserved hāngī, shallow fire-scoops, and stone-lined fireplaces were found on a buried surface covered with shells and pumice. Oriented fire-cracked stones were collected from four features: two hāngī (NP1 and NP2), two fire-scoops (NP4 and NP6). In addition, oriented samples were taken from the baked floor of a hearth (NP5), and a reddened pumice hearthstone (NP3) was, was also retrieved for palaeomagnetic study and potential dating. Directions of the remanent magnetization vector were calculated from progressive thermal and alternating demagnetization data on multiple specimens from each feature. Detailed analysis yielded palaeodirections with declinations between 10°W and 18°E and inclinations between –50° and -65° across the six sampled features. These correspond to archaeomagnetic ages between 1400 and 1900 AD. This suggests an extended period of occupation, when, prior to drainage and development ca. 1900 A.D., the area was predominantly wetland, and the site was surrounded by swamps and shallow tidal lagoons. The surface covering of pumice and its use as hearth-lining stones suggest that the fire-resistant stones, evidently recycled multiple times in the hāngī, were locally rare. Estimates of the intensity of the geomagnetic field show relatively little variation between 45 and 50 μT, consistent with previous estimates for the past 600 years.

POSTER
Session 1a.

Continental glaciation in New Zealand and West Antarctica during the Plenus Cold Event: relevance for modelling geoengineered CO_2 drawdown via ocean fertilisation

Nicholas G. Powell[1]

[1] *Forensic & Industrial Science Ltd, PO Box 67-087, Mt Eden, Auckland 1349, New Zealand*

research@forensicscience.co.nz

Ocean fertilisation has been proposed as a way to reduce atmospheric concentrations of CO_2, a long-lived greenhouse gas, by enhancing marine uptake of carbon via long-term sequestration into anoxic sediments in the form of biogenic high molecular weight organic compounds.

While considerable attention has been focussed on 'warming icehouse' climate transitions because of their relevance to global warming, 'cooling greenhouse' transitions also warrant careful study because of their potential utility as paleoanalogues for any future geoengineered efforts implemented to counteract climate forcing by anthropogenic emissions.

A 'cooling greenhouse' transition is evident near the Cenomanian-Turonian boundary (ca. 94 Ma), where Ocean Anoxic Event 2 is discernible as isotopic excursions and accumulations of organic-rich sediments. Ocean anoxia may be a biogeochemical response to fertilisation by large igneous province (LIP) basaltic volcanism. The concomitant Plenus Cold Event, which punctuated an otherwise-very-warm mid Cretaceous, is interpreted as a global climatic response to CO_2 drawdown.

The Waipounamu Erosion Surface, New Zealand, and the correlative West Antarctic Erosion Surface developed penecontemporaneously with Plenus cooling. While an origin involving marine erosion has been proposed by LeMasurier and Landis (1996), these enigmatic planar destructional surfaces can alternatively and preferably be interpreted as subglacial floors formed beneath extensive ($>10^6$ km^2) ephemeral continental interior ice sheets that nucleated during the Plenus Cold Event.

In principle, inferences about the extent and timing of mid Cretaceous glaciation could be integrated into models that interrogate the interplay of LIP ocean fertilisation, pCO_2, orbital forcing, global temperature, eustasy and ice volumes to quantitate how much ocean fertilisation is required to geoengineer CO_2 drawdown and mitigate the climatic effects of anthropogenic emissions.

The Plenus Cold Event 'cooling greenhouse' transition may constitute an informative paleoanalogue for any geoengineered initiatives involving ocean fertilisation and marine sequestration of carbon that might be needed to stabilise future Earth climates.

ORAL
Session 1c.

Induction Responses from Magnetotelluric Transfer Functions in Southland, New Zealand

K. Pratscher[1], M. Ingham[2] , W. Heise[3], T. Bertrand[4], Mikhail Kruglyakov[5], D. Mac Manus[6], C. Rodger[7], M. Dalzell[8], and T. Petersen[9]

[1]*Victoria University of Wellington, Wellington, New Zealand, Kristin.Pratscher@vuw.ac.nz*
[2]*Victoria University of Wellington, Wellington, New Zealand, Malcolm.Ingham@vuw.ac.nz*
[3]*GNS Science, Lower Hutt, New Zealand , W.Heise@gns.cri.nz*
[4]*GNS Science, Lower Hutt, New Zealand , T.Bertrand@gns.cri.nz*
[5]*University of Otago, Dunedin, New Zealand, mikhail.kruglyakov@otago.ac.nz*
[6]*University of Otago, Dunedin, New Zealand, macda381@student.otago.ac.nz*
[7]*University of Otago, Dunedin, New Zealand, craig.rodger@otago.ac.nz*
[8] *Transpower New Zealand, Wellington New Zealand, michael.dalzell@transpower.co.nz*
[9]*GNS Science, Lower Hutt, New Zealand ,*

T.Petersen@gns.cri.nz

The impact of geomagnetically induced currents (GIC) on the New Zealand power grid has previously been studied using a thin-sheet model of electrical conductance variations across the country. Due to its relative proximity to the auroral zone observed GIC are greatest in the south of the South Island in the Otago/Southland region. Recent acquisition of 62 long period magnetotelluric (MT) sites in this region provides the opportunity to better understand how GIC are related to the conductivity structure and tectonics. MT 1Hz impedance data in the period range between 10 and 10000 seconds have been combined with 1s resolution magnetic data to calculate the induced electric fields during the 2015 St. Patrick's Day Storm. Direct current measurements from sensors installed along the transmission network are compared with the induced electric fields to analyze the GIC and phases of the storm. Lastly, implications of multidimensional modeling of the geoelectric fields are explored to assess the role of complex conductivity structure on GIC.

POSTER
Session 2a.

Silicic volcanism at the dawn of the TVZ: Trends in geochemistry, mineralogy and magma storage, of the Tauranga Volcanic Centre, New Zealand

Marlena Prentice[1], Adrian Pittari[1], Geoff Kilgour[2] and David Lowe[1]

[1] School of Science/Te Aka Mātuatua, University of Waikato, Hamilton, New Zealand
[2] GNS Science, Taupō, New Zealand.

prenticelm@gmail.com

The Tauranga Volcanic Centre (TgaVC), in western Bay of Plenty, was active from ~2.95 to 1.90 Ma, around the time of Taupō Volcanic Zone initiation. Volcanic products of TgaVC include minor exposures of basalt (Matakana Basalt), an eroded andesitic stratovolcano (Otawa Formation), several dacite-rhyolite- lava dome/dome complexes (Minden Rhyolite Subgroup), and a pyroclastic succession comprising multiple ignimbrites and related fall deposits (Papamoa Formation) followed by the climactic eruption of the rhyodacite Waiteariki Ignimbrite. Silicic volcanism throughout the region was frequent yet episodic, with two key periods of activity occurring between ~2.5-2.3 and ~2.2-2.1 Ma. The NE alignment of domes is linked to regional extensional faulting where the western boundary coincides with that of the old Taupō Rift.

Magmas erupted from the TgaVC are typically crystal-rich (up to 40-50% phenocrysts) with a consistent mineral assemblage of plagioclase > hornblende ≥ orthopyroxene ± quartz ± biotite with olivine and sanidine present only in the Matakana basalt and Bowentown rhyolite, respectively. Whole-rock compositions span a continuous range between basalt (53.8 wt% SiO_2, 4.0 wt% MgO; Mg# 48) to rhyolite (76.7 wt% SiO_2) which in conjunction with trace element and isotopic compositions suggest a genesis involving fractionation, partial melting and assimilation of the surrounding crust and interaction with more primitive melts. Estimates of magmatic conditions for the Waiteariki Ignimbrite are modelled using multiple independent crystal-melt (plag-liq, opx-liq) or crystal-only (cpx; Al-in-hornblende) geothermobarometers to give pre-eruptive temperature ranges between 740-840°C and 900-990°C (ave. 790°C, and 950 °C, respectively) with a broader range observed for TgaVC lavas. Pressure estimates for all units range from < 50-150 MPa and indicative of multiple extraction zones and shallow, upper-crustal storage similar to models for rhyolites of the TVZ.

POSTER
Session 1b.

Pluton Map characterisation of Aotearoa New Zealand's intrusive rocks

Mark Rattenbury[1], **Rose Turnbull**[2], **Andy Tulloch**[2], **Matt Sagar**[1] **and Kevin Faure**[1]

[1] *GNS Science, Lower Hutt, New Zealand*
[2] *GNS Science, Dunedin, New Zealand.*

m.rattenbury@gns.cri.nz

The Pluton Map research project is characterising Aotearoa New Zealand's plutons in terms of their diverse geochemical and physical properties, emplacement age and other defining features within an improved geological map context. The pluton extents from geological map data are being linked to measured property data from representative key samples across each pluton. Additional characteristic attributes are also being compiled for every pluton, for example, petrogenetic suite affiliation, U–Pb intrusion age, emplacement depth, classifying element ratios and calculations such as Sr/Y and Zr+Ce+Y+Nb, and O-, Sr–Nd and Lu–Hf isotopes. Key samples have been identified for most plutons; those without key samples and new plutons will require field sampling or use of hand specimens in existing collections for further geochemical analysis and dating.

Pluton Map draws from two Nationally Significant Collections and Databases; the Regional Geological Map Archive and Datafile (RGMAD) and the National Petrology Reference Collection (NPRC) and Petlab database. The Petlab analytical data are accessed live and displayed in a GIS-based application and can thus accommodate future data acquisition. In turn, the project will add to the NPRC through new samples, Petlab through new analytical data and thorough QA/QC of existing data, and to RGMAD with improved geological map rendering of pluton geology.

Improved and validated Petlab data, including the compiled summary attributes, will be linked to the digital geological map to enable portrayal of colour-symbolised plutons based on different properties and defining features. Many of these will be summarized in an atlas of pluton properties. To date, 330 plutons have been identified both onshore and offshore, with 80% of these now having an established age and chemistry. However, additional plutons may yet be recognised in the West Coast and Tasman regions with further pluton-level differentiation of the existing suite-based geological map units.

ORAL
Session 1b.

Marine clay formation across the end-Permian mass extinction event.

Sofia Rauzi[1] **and Terry T. Isson**[1].

[1] *Te Aka Mātuatua, University of Waikato (Tauranga), BOP, Tauranga, New Zealand.*

sofiarauzi@gmail.com

The end-Permian mass extinction event is the largest mass extinction event in Earth's history, resulting in the demise of 85-95% of life on Earth. The climactic response following the end-Permian sets it apart from other mass extinction events; a prolonged period of high atmospheric CO_2 followed the event stifling the widespread recovery of life for around five million years. This protracted warm period defies the traditional framework of climate recovery after carbon injection events in which atmospheric CO_2 recovers to pre-event concentrations typically within less than 0.5 million years. It has been empirically demonstrated that, following the disappearance of siliceous organisms, higher marine authigenic clay formation (a process that recycles carbon within the ocean system) could have sustained the Early Triassic warm period. Here, we use lithium isotopes in shales (n=237) and cherts (n=111) to provide the first direct geochemical evidence of enhanced marine clay formation following the end-Permian mass extinction. Based on these results, we will discuss the role of marine clay formation in Earth's climate system and the novel use of lithium isotopes as a tracer of reverse weathering.

ORAL
Session 2c.

Mafic recharge in the lead-up to the world's youngest basaltic Plinian eruption: Ulawun volcano, Papua New Guinea

<u>Marco Rebecchi</u>[1], Cynthia Werner[1] and C. Ian Schipper[1]

[1] *School of Geographical, Environmental and Earth Sciences, Victoria University of Wellington, New Zealand*

marcomaria.rebecchi@vuw.ac.nz

The 2019 eruptive sequence at Ulawun volcano (5.05°S, 151.33°E, 2334m), which consisted of a Plinian eruption on June 26th and August 3rd (both VEI 4) and a Strombolian flank eruption on October 1st, includes the world's youngest Plinian eruptions of basaltic composition and represents the strongest and most mafic eruptions ever witnessed at Ulawun volcano since the start of monitoring. All three eruptions are characterized by only small seismic precursors and very quick eruptive onsets and cessations (<24h). Textural and crystal-melt equilibria analyses of samples from all three eruptions reveal eruption triggering by abrupt magma decompression leading to fast magma ascent and a large viscosity increase by disequilibrium crystallization of microlites (plagioclase >> olivine > clinopyroxene). Compositional zoning of plagioclase antecrysts further indicates a very mafic (An>90) and volatile rich (>4 wt.% H2O) initial magmatic intrusion with a rim-ward negative correlation between decreasing An-content and increasing mafic element concentrations (Mg, Fe, Ti) that perfectly mirror each other. The anorthite curve is interpreted as growth curve showing initial slow ascent and dehydration of the new magma while magnesium curves indicate diffusional re-equilibration of these mafic elements after disruption by mafic recharge. Increased magma decompression is assumed to have been triggered by volatile exsolution after this mafic recharge leading to a rapid, buoyant ascent of the magma and large undercooling of the magma causing disequilibrium microlite crystallisation. With plume heights of >19 km during peak Plinian activities it is further presumed that the erupted volatiles have reached Stratospheric altitudes. Despite their surprising rarity in the global geologic record, results from the 2019 Ulawun eruptive sequence confirm that basaltic Plinian eruptions have catastrophic hazard potential similar to their silicic equivalents, reinforcing initial ideas on their formation mechanism.

POSTER
Session1a.

Following the Waitapu Shell Conglomerate (0.9 Ma) across the Whanganui Basin

Callum Rees[1], Julie Palmer[1] and Alan Palmer[1]

[1] *Environmental Sciences Group, School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*

c.rees@massey.ac.nz

The Whanganui Basin in the lower North Island of New Zealand contains one of the most complete Quaternary records exposed onland anywhere in the world. Spectacular exposures occur in the Rangitīkei Valley, where regional uplift and deep fluvial incision has formed cliffs and gullies through the predominantly marine succession.

The basins Castlecliffian deposits (1.63 – 0.34 Ma) contain primary tephra and reworked volcaniclastics from the Taupo Volcanic Zone. Geochemical 'fingerprinting' of tephra and volcaniclastic deposits aids identification of chronostratigraphic horizons that are used to map the basin fill and correlate between sections. The units are often richly fossiliferous with fossil assemblages providing a basis for stratigraphic subdivision and contemporary counterparts from around New Zealand's coastline providing paleo-environmental analogues.

The Waitapu Shell Conglomerate is an important Castlecliffian marker horizon that contains the first influx of Kaukatea Pumice (c. 0.9 Ma) into the basin. Its fossil assemblage contains a mixture of estuarine to offshore species. Deposition is thought to have taken place seaward of a transgressive shoreline on a storm-dominated, muddy, innermost shelf, characterised by migrating subaqueous gravel dunes interfingering with deeper water heterolithic facies.

We follow the Waitapu Shell Conglomerate and its lateral equivalents across the Whanganui Basin, exploring differences in lithology, sedimentary structures and faunal content. A reduction in bioclastic material and an increase in greywacke and lignite deposits occurs towards the basins eastern margin.

Sedimentary response to ignimbrite emplacement appears to have involved inundation of river and coastal settings, causing valley aggradation, river avulsion, infilling and loading of the Whanganui coastal embayment and formation of a hydraulically active seafloor. Lateral changes in depositional style toward the basins eastern margin are considered to be related to relative position on the paleo-shelf, a reduction of accommodation space, intermittent preservation of low stand deposits and proximity to the uplifting paleo-axial range.

ORAL
Session 2b.

Developing indicators of volcanic induced coastal aggradation from lahars using satellite remotely sensed imagery; A case study from the 2018 Ambae Eruption, Vanuatu.

Hannah Reid[1], Stuart Mead[1] andJonathan Procter[1]

[1] Volcanic Risk Solutions, Massey Univeristy, Private Bag 11222, Palmerston North, New Zealand.

J.N.Procter@massey.ac.nz

Ambae (Aoba) Island in Vanuatu is one of the largest shield volcanoes in the Melanesian volcanic arc and is in the central part of the Vanuatu archipelago. The summit (1496 masl.) contains the active crater and lakes Manaro Lakua and Voui which is commonly known as the Manaro volcano. September 2017 marked the start of the last eruptive phase with significant eruptions occurring during November. Major eruptions and ash deposition occurred in March-April of 2018 with lahars being recorded on the 30-31st March.

Lahars resulting from tropical storms or intense rainfall is a significant hazard that can affect the distributed communities. The detection of areas susceptible to ash remobilisation and laharic activity can be difficult to determine due to dense jungle, limited access, and cloud cover. New remote sensing methods had to be developed to detect rapidly changing geomorphic conditions in immature catchments with weakly developed drainage networks and rivers that are obscured by dense jungle. The only observable changes from laharic activity were short-lived coastal aggradation around river outlets. Periods of prolonged cloud required the need to analyse multi-sensor, multispectral, multi-date satellite image data of high resolution. Data from Landsat 8 OLI/TIRS, Sentinel 2 (2A and 2B data) and Planet Cubesat imagery between July 2017 and April 2019 were mosaicked where needed and atmospherically corrected. The quantifiable measures of normalised difference water index (NDWI), modification of normalised difference water index (MNDWI), Automated Water Extraction Index (AWEI), and automated method for extracting rivers and lakes (AMERL) where all applied to calculate changes in coastal aggradation. A record of aggradation shows the relationship between laharic activity and the re-sedimentation of the ashfall over the last phase of activity at Manaro Volcano. Correlating rainfall and the volume of aggradation or minimum volume of lahars with each aggradational event is also being investigated.

POSTER
Session 1a.

Repeat Seabed Mapping: Understanding Complex Morphological Changes in seafloor Bedforms

Marta Ribó[1], Sally J Watson[2], Helen Macdonald[2], Lorna J Strachan[1], Arnaud Valcarcel[2], Craig Stevens[2], David Plew[2], and Kevin Mackay[2]

[1] School of Environment, Faculty of Science, The University of Auckland, New Zealand
[2] National Institute of Water and Atmospheric Research (NIWA), New Zealand.

m.ribo@auckland.ac.nz

Repeat, high-resolution, multibeam surveys are crucial to identify geomorphological changes on the seafloor, especially in the extremely dynamic shallow waters (< 200 m water depth). Timeseries bathymetric datasets allow us to measure and monitor spatial- and temporal changes in submarine bedforms and determine their evolution patterns. This is important for a better understanding of the sediment transport processes and the related hydrodynamics, but also to determine the settings for benthic ecosystems and identify changes in seafloor geomorphology to prevent potential damage of offshore infrastructure and maritime pathways.

We present three multibeam data sets acquired in 2017, 2020 and 2021 over a field of gravel-sand bedforms located in the high-energy Cook Strait / Te Moana-o-Raukawa, between Cape Koamaru and The Brothers / Ngāwhatu-kai-ponu. In this study we combine timeseries bathymetric data, ground-truth data (video footage and sediment samples) and oceanographic data (i.e., combining hydrodynamic modelling (RiCOM and ROMS) with in-situ observations from an Acoustic Doppler Current Profiler) to understand the sediment dynamics in the area. Results show that coarse sand and gravel field of dunes with superimposed megaripples have undergone intricate morphological changes. The ~100-m length and ~15-m height submarine dune crests bifurcate, becoming more complex between 2017-2020, followed by the reforming of dune crests between 2020-2021. Hydrodynamic data and modelling suggests there is an interaction between the tidal near-bottom currents and the sediment transport, creating a morphological positive feedback, which might be leading the complex bedform morphological changes observed in the repeated mapping surveys.

This study reveals the dynamic nature of the seabed over short time-scales (years) in highly dynamic areas, such as the tidally vigorous Cook Strait region. Our findings demonstrate the importance of repeat multibeam mapping in understanding of the rate and scale of changes on the seafloor.

POSTER
Session 2e.

Microplastics in Marine Sediments: Findings from the First Study around Aotearoa / New Zealand

Marta Ribó[1], Sally J Watson[2], Sarah Seabrook[1,2], Lorna J Strachan[1], Nina I Novikova[1] and Rachel Hale[2]

[1] School of Environment, Faculty of Science, The University of Auckland, New Zealand
[2] National Institute of Water and Atmospheric Research (NIWA), New Zealand.

m.ribo@auckland.ac.nz

Plastic pollution in the marine environment is a growing concern worldwide. However, little is known about the distribution and accumulation of microplastic particles (< 5mm) on the seafloor or the impact on benthic communities. Once in the ocean, microplastics behave like any other sediment particle and can become highly concentrated in specific environments with negative impacts on marine species and microbes.

In Aotearoa/New Zealand microplastics have been identified in sediments on land, in rivers, and in coastal zones; but the presence of microplastic particles in offshore marine sediments is less well-understood. Here we present the findings of the first study that have successfully identified plastic particles in offshore marine sediments around Aotearoa/New Zealand. We quantified the microplastic content in sediments collected from the Queen Charlotte Sound/Tōtaranui (QCS), using sediment cores from two sites: 1) high-human impact area, near the Picton coastal township; and 2) a low-human impact area, near the Kokomohua Marine Reserve (~30 km from the Picton township).

Results show different types of microplastic particles (e.g., fibres, fragments and foam), in several colours (e.g., blue, red, white and black), with different chemical composition, indicating a myriad of plastic pollution sources. We found an alarmingly widespread spatial distribution of plastic particles all over the QCS area. Microplastics were identified throughout the sediment cores, reaching depths of ~45 cm below the seabed. However, we observed variations in the abundance of microplastics across the sediment depth profiles across the two sites, suggesting there may be changes in the temporal distribution, sources and/or transport of microplastics within QCS.

This study provides crucial information for regional authorities to mitigate the source of plastic pollution in QCS. This research represents a proof of concept that can be used in future studies to identify the full extent of plastic pollution in Aotearoa/New Zealand's marine sediments.

ORAL
Session 2e.

Study of the formation and dynamics of secondary plumes through 2D experiments and models

<u>Geoffrey Robert[1]</u>, and Guillaume Carazzo[2]

[1] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*
[2] *Geological Fluid Dynamics Department, Institut de Physique du globe de Paris, Paris, France*

G.Robert@massey.ac.nz

Here we report the results of an experimental study elucidating the parameters that control the generation and dynamics of co-ignimbritic cloud generated by pyroclastic density currents. This series of experiments consisted in studying the involvement of water entrainment in an initially turbulent ethanol-ethylene glycol mixture in secondary plumes generation. We mainly studied the influence of flow rate and slope on the way the mixture entrained water within it and the consequences this had on the dynamics of a secondary plume. This series of experiments is comparable to the air ingestion required for a secondary plume to rise, except that our experiments are performed upside down. The water entrainment densifies the mixture which makes it heavier and allows it to fall to the bottom rather than rise as it does in nature, however the same physical properties are at play in both cases. Using the physical properties of our mixture we modelled our experiments, trying to predict the behaviour of secondary plumes and their influence on the overall flow (distance from which the plume rises, fraction of the flow that rises) by varying the flow rate and the slope. Thus, we highlighted the importance of the volcanic slope and of the initial flow rate in the generation of a co-ignimbritic cloud. We observed that both parameters have the same effect on the water entrainment within the flow. Indeed, by increasing both at a time we found that the water entrainment increased as well, generating more vigorous co-ignimbrite cloud and decreasing the lift-off distance of the flow but not at the same scale. Thus, the flow rate has a much bigger impact on the water ingestion than the slope. These observations led to the identification of three types of regimes: mainly dense flow, mainly lifted-off flow and fully lifted-off flow.

ORAL
Session 2a.

The global tsunami triggered by the Mw 8.1 South Sandwich Islands earthquake of the 12 August 2021: records and consequences in New Zealand

Jean Roger[1], Anthony Jamelot[2], Hélène Hébert[3], William Power[1], and Aditya Gusman[1]

[1] *Earth Structures and Processes, GNS Science, Lower Hutt, New Zealand*
[2] *Laboratoire de Géophysique de Pamatai, CEA/DASE, CPPT, Papeete, Tahiti*
[3] *CEA, DAM, DIF, 91297 Arpajon Cedex, France*

j.roger@gns.cri.nz

At 18:32:54 and 18:35:20 (UTC) on 12 August 2021 a doublet of reverse faulting earthquakes, with magnitudes M_w 7.5 and 8.1 respectively, occurred on the South Sandwich Islands (UK) Subduction Zone (SSSZ), on the eastern boundary of the Scotia Sea in the south Atlantic Ocean. The rupture mechanism was poorly understood during the first weeks after the earthquake, and the tsunami generated by this complex seismic event was significant, especially in nearby locations such as South Georgia Island. The tsunami was observed quite unexpectedly in all of the main ocean basins, particularly the Atlantic, Indian and Pacific oceans, including in New Zealand where it was recorded by at least two DART stations.

Numerical simulations of four different tsunami scenarios initialized by different source estimation methodologies (i.e., USGS, GCMT, SCARDEC and CALTECH) were computed to try and reproduce water-level records. This was done at a global scale and used a set of nested grids focusing onto specific areas. It shows that the tsunami source model built from the SCARDEC rapid-characterization model issued 45 minutes after the event provides the best fit between the recorded and the simulated signals. It also validates the global impact and propagation of the tsunami over the oceans, notably in the Pacific Ocean where the tsunami was unexpected.

The SSSZ is not considered as a potential threat in most national tsunami warning systems, including New Zealand's. An additional simulation of a magnitude M_w 9.0 maximum plausible scenario built using available tectonic and seismic knowledge of the SSSZ was performed to inform 1) the global impact of such an event in terms of affected regions/countries and expected tsunami wave amplitudes, 2) the integration of the SSSZ in several national tsunami hazard models and, 3) the potential impacts that such a tsunami might have on the Antarctic ice shelves.

ORAL
Session 2a.

The rates of moderate and large earthquakes in the New Zealand region, and their uncertainties

Chris Rollins[1], David Rhoades[1], Sepideh J Rastin[1], Annemarie Christophersen[1], Jesse Hutchinson[2], Kiran Kumar Thingbaijam[1], Matt Gerstenberger[1], Donna Eberhart-Phillips[3], Russ Van Dissen[1], Kenny Graham[1] and Jeff Fraser[1]

[1] *GNS Science, Lower Hutt, New Zealand*
[2] *Ocean Networks Canada, Victoria, British Columbia, Canada*
[3] *GNS Science, Dunedin, New Zealand*
[4] *WSP, Christchurch, New Zealand*

c.rollins@gns.cri.nz

For use in the Seismicity Rate Model (SRM) component of the 2022 New Zealand National Seismic Hazard Model, we estimate the total magnitude-frequency distribution (MFD) of earthquakes in the greater New Zealand region and along the Hikurangi–Kermadec and Puysegur subduction zones. The former is a key input into multiple components of the SRM in the onshore and near-shore regions, while the latter is a key input into models of earthquake rupture rates on the subduction zones.

Recent work (Christophersen et al., 2022) has greatly improved and homogenized the earthquake magnitudes in the New Zealand earthquake catalogue for use in the NZ NSHM 2022. Other parameters in the catalogue remain of mixed quality, however, in particular earthquake depths. Therefore, we develop an augmented New Zealand earthquake catalogue in which we import higher-quality depths and depth uncertainties, focal mechanisms, and some locations and magnitudes from several relocated and global catalogues. Next, we use event depths, focal mechanisms, 3D models of the Hikurangi and Puysegur subduction interfaces, and relative plate motion directions to classify earthquakes as upper-plate, interface or intraslab.

Using this augmented catalogue and adapting an approach used previously in California, we estimate the MFD of earthquakes in the near-shore region incorporating data back to 1843, balanced with the better data in the more recent part of the instrumental catalogue. This method estimates both the mean earthquake rate and its uncertainty, and we supplement it with an alternative estimate of the rate uncertainty that is based on the rate variability in the catalogue over a range of shorter timespans. We estimate the MFDs on the Hikurangi–Kermadec and Puysegur subduction zones using a simplified version of the method used in the near-shore region, with more recent data. Finally, we describe a globally based method to estimate the potential earthquake rate uncertainty on the Hikurangi–Kermadec subduction zone.

POSTER
Special Symposium

Tracking Magma-Crust-Fluid Interactions at High Temporal Resolution: Magmatic Oxygen Isotopes in the Central Taupō Volcanic Zone

Shane M. Rooyakkers[1], Kevin Faure[1], Isabelle Chambefort[2], Simon J. Barker[3], Hannah C. Elms[3], Colin J. N. Wilson[3] and Bruce L. A. Charlier[3]

[1] National Isotope Centre, GNS Science, Lower Hutt, New Zealand.
[2] Wairakei Research Centre, GNS Science, Taupo, New Zealand.
[3] School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand.

i.chambefort@gns.cri.nz

Oxygen isotopes are useful for tracing interactions between magmas, crustal rocks and surface-derived waters. We use them to consider the links between voluminous silicic volcanism and large-scale hydrothermal circulation in the central Taupō Volcanic Zone (TVZ). We present >350 laser fluorination $\delta^{18}O$ value measurements of plagioclase, quartz, hornblende and groundmass glass from products of 40 young ($\leq$54 ka) silicic eruptions, tapped from three discrete magmatic systems: Ōkataina and Taupō calderas, and the smaller Northeast Dome system. For each mineral phase, mean $\delta^{18}O$ values vary by <~1‰ ($\delta^{18}O_{plag}$ = +6.7–7.9‰, $\delta^{18}O_{qtz}$ = +7.7–+8.7‰, $\delta^{18}O_{hbl}$ = +5.4–+6.4‰, $\delta^{18}O_{glass}$ = +7.1–+8.0‰), and inter-mineral fractionations mostly reflect high-temperature equilibria. Rare outliers (e.g., ~+6‰ or >+10‰ plagioclase) represent contaminants incorporated on short-enough timescales to preserve disequilibrium (~10^2 yrs for plagioclase). Melt $\delta^{18}O$ values calculated from phenocrysts are ~+7.3–+8.0‰. Where multiple magmas were involved in the same eruption their melt $\delta^{18}O$ values are indistinguishable, implying that their parental mush systems were isotopically well-mixed and equilibrated with respect to oxygen. However, small (<0.5‰) but consistent $\delta^{18}O_{melt}$ value gradients occur over millennial timescales at Ōkataina and Taupō, with short-term ~0.4-0.5‰ decreases over successive post-caldera eruptions correlating with increases in $^{87}Sr/^{86}Sr$. These changes reflect tens of percent assimilation of a mixture of hydrothermally altered silicic plutonic material and higher-$^{87}Sr/^{86}Sr$ greywacke. These examples represent the first evidence for assimilation of altered crust into silicic TVZ magmas, indicating that its shallow silicic systems do at times spatially overlap and interact with their surrounding hydrothermal envelope. The subtle and short-lived isotopic signals of these interactions are only recognized through the high temporal resolution of the central TVZ eruptive record and complementary radiogenic isotope data. Similar interactions may have been easily overlooked or obscured in other nominally high- or normal-$\delta^{18}O$ magmatic systems where isotopic leverage is limited.

ORAL
Session 1a.

Strontium Isotope Ratios of New Zealand Kauri: An Indicator of Climate Conditions?

Michael C Rowe[1], Erik Mass1 Bruce LA Charlier[2], Gretel Boswijk[1], Luitgard and Schwendenmann[1]

[1] *School of Environment, University of Auckland, Auckland, New Zealand*
[2] *SGEES, Victoria University of Wellington, Wellington, New Zealand.*

michael.rowe@auckland.ac.nz

Dendrochronology in New Zealand provides an important source of climate data. Recent research on kauri (*Agathis australis*) has shown that ring width variability contains a signal of the El Nino-Southern Oscillation (ENSO). However, the chemical signal contained within tree growth rings is also a potentially useful source of environmental data. Here, we present investigative research on the dendrochemistry of kauri tree-rings, utilising archived kauri cores from Northland, Auckland, and Coromandel. Trace elements and strontium isotopes from individual tree rings were analyzed to look for correlations to indices such as age (dendrochronology), tree ring width, rainfall, or El Nino-La Nina cycles.

Tree ring strontium isotopic compositions ($^{87}Sr/^{86}Sr$) of core from kauri in Northland and Auckland regions indicate systematic variations through the lifespan of the trees with isotopic ratios becoming less radiogenic as the trees age. Although both cores show the same temporal trend, the absolute magnitude of isotopic variability is quite different, with a Northland kauri tree recording a large $^{87}Sr/^{86}Sr$ range from >0.7103 to <0.7092, while a contemporary core from an Auckland kauri is all < 0.7092. Interestingly, carbon-normalized Sr count rates show no significant change in composition despite the changing isotopic compositions, while Mg/C, Rb/C and Ba/C are all positively correlated to $^{87}Sr/^{86}Sr$ in the Northland kauri core.

Isotopic compositions in this study broadly correlate to long-term rainfall records. However, there are no obvious correlations between isotopic or trace element compositions and El Nino – La Nina years, despite clear temporal trends in dendrochemical results. Lack of obvious correlation between geochemical results and climate conditions may result from averaging of chemical components across rings in the outer sapwood, or from biological processing-buffering of chemical components.

ORAL
Session 4d.

Understanding flow localization using waxy fissures

Javiera Ruz-Ginouves[1], Rachael Baxter[1], James White[1], Hamish Bowman[1], Brent Pooley[1], and Rosie Cole[1,2]

[1] *Geology Department, University of Otago, Dunedin, New Zealand*
[2] *Institute of Earth Sciences, University of Iceland, Reykjavik, Iceland*

javiera.ruz@postgrad.otago.ac.nz

In the early stages of fissure eruptions, lava is extruded from elongated cracks in the surface that are several hundreds of meters long, forming a nearly continuous curtain of fire, that only a few hours later subsides and focuses into discrete vents. Modern examples of this eruptive behaviour include eruptions in Kilauea (2018), the Reykjanes peninsula (2021 and 2022) and La Palma (2021), yet can occur in any volcanic setting. Therefore, it is relevant to understand the processes that lead to localization to forecast the evolution of, and flow localization during, future fissure eruptions, including a potential eruption in Auckland Volcanic Field.

Many authors have proposed that focusing, or localization, is a thermally driven phenomenon. Using an Artificial volcanic fissure (Artfish), we aim to constrain and better understand the factors contributing to eruption localization. The ArtFish is a novel experimental apparatus that replicates a fissure segment using wax as a magma analogue. The device has a matrix of 70 independent panels that allow for individual changes in fissure width, temperature, and flow rate. Our first experimental series, currently in progress, intends to solve the relative influence of these parameters by varying them systematically using a simple panel matrix configuration. We hypothesize that a narrow fissure, high thermal contrast, and/or low flow rate, favours the localization of flow within the fissure. After this initial series, more complex settings can be tested, with varying geometries and wall temperatures. Potentially we will be able to apply our results to natural scenarios of fissure eruptions, and thus aid in improving our knowledge and forecasting of how fissure eruptions evolve in time.

POSTER
Session 1a.

Source-to-sink archives of vegetation change since the Last Glacial Maximum, Waipaoa Sedimentary System, New Zealand.

Matt Ryan[1], Kat Holt[2], Gavin Dunbar[3], Mike Marden[4], Brent Alloway[5], Dallas Mildenhall[6], Alan Palmer[2], and Helen Bostock[7]

[1] *Pattle Delamore Partners, Wellington, 6140, New Zealand;*
[2] *School of Agriculture and Environment, Massey University, Palmerston North, 4410, New Zealand.*
[3] *Victoria University Wellington, Te Herenga Waka, Wellington, New Zealand.*
[4] *Manaaki Whenua Landcare Research, Palmerston North, New Zealand.*
[5] *School of Environment, The University of Auckland, Private Bag 92019, Auckland, New Zealand*
[6] *GNS Science, Lower Hutt, 5040, New Zealand*
[7] *School of Earth and Environmental Sciences, University of Queensland, Brisbane, Queensland, Australia*

Matt.Ryan@pdp.co.nz

Records of terrestrial vegetation change capturing the last deglacial between ~18 and 6.5 ka from the Gisborne/East Coast region of the North Island, have been challenging to obtain. Arid conditions combined with the unstable landscape characteristic of the tectonically and volcanically active region precluded development and persistence of lake and bog sites suitable for preservation of long, continuous pollen records. However, lacustrine sediments preserved in abandoned meander channels on relict fluvial terraces provide a hitherto untapped source of pollen records.

Three such sites in the Waipaoa Sedimentary System (WSS) have been sampled to yield discontinuous pollen records; Redpath (16.3-14.1 ka); Linburn (18.3-8.5 ka); and Manders Rd (14-2 ka). These pollen data are further supported with a 18-7 ka pollen record from marine core MD06-3002, lower Poverty Bay continental slope, and a ~13-0 ka pollen record from the continental shelf (MD06-3006). Ages were constrained by radiocarbon dating and tephrochronology. For the early deglacial, both the onshore and offshore data imply cool climate conditions, with herbs and alpine trees and shrubs, and stands of beech or mixed beech/podocarp forest likely populating the exposed continental shelf. By ~15.5 cal ka BP much of the region was under forest.

At MD06-3006, the highest proportions of mangrove pollen (Avicennia marina) and the thermophilous shrub Ascarina lucida occur between 11-6.5 ka. This timing is consistent with evidence for a post-glacial rise in sea-level and inundation of the Waipaoa floodplain between 10-7 kyr. The presence of these taxa suggest climate was warm and humid during the early Holocene, with mangroves presently found further north (1°) in the Bay of Plenty. Ferns increase following frequent volcanic disturbances, with a 10x increase in *Pteridium* spores at ~~1312 AD consistent with Polynesian arrival.

ORAL
Session 2c.

An age model for the Tongaporutuan (Late Miocene) reference section, northern Taranaki

Matt Sagar[1], Malcom Arnot[1], Dominic Strogen[1], Greg Browne[1] and Diane Seward

[1] GNS Science, Lower Hutt, New Zealand

m.sagar@gns.cri.nz

We proposed a two-part linear age model for the northern Taranaki coastal section (Mohakatino, Mount Messenger and Urenui formations), integrating new laser ablation inductively-coupled plasma mass spectrometry (LA–ICP–MS) U–Pb zircon ages of tuffs with existing radiometric and biostratigraphic constraints (Sagar et al., 2019. DOI: 10.1080/00288306.2019.1600555). The lower and upper parts are characterised by relatively low and high undecompacted sedimentation rates, respectively. The linear model has a poor fit to the lower section age data and sedimentation rates are poorly constrained to between c. 100 and c. 300 m/Myr, depending on whether an unconformity (c. 0.7 ± 0.2 Myr) separates the two parts. In contrast, the linear model provides an excellent fit to age data from the upper part (MSWD = 1.32) and suggests a sedimentation rate of 1358 ± 144 m/Myr. The timing of Tongaporutuan bioevents (e.g., Tukemokihi Coiling Zone) are broadly consistent with the U–Pb zircons ages. However, their timing predicted using an upper section age model utilising only the new U–Pb zircon ages do not overlap the assigned bioevent ages. This discrepancy highlights the importance of propagating uncertainties into bioevent ages. Additional high-precision radiometric ages are needed to refine the age model, particularly for the lower part of the section, and may resolve this issue. A new U–Pb zircon age for an upper Mohakatino Formation tuff of 10.77 ± 0.16 Ma overlaps existing age constraints from the lower section. Recent analysis of zircon trace elements shows those from the Urenui Formation tuff sample have compositions distinct (e.g., high Ce/Lu) from those lower in the section. This indicates either a shift in Mohakatino Volcanic Centre magmas towards more evolved compositions, or sourcing of tephra from a different more evolved source. Analyses of zircon from additional tuffs are needed to distinguish these two possibilities.

ORAL
Session1c.

Evolution of Cretaceous Normal Faulting in the Great South Basin

Tusar R. Sahoo[1, 2], Andy Nicol[1], Greg H. Browne[2] and Dominic P. Strogen[2]

[1] University of Canterbury, Private Bag 4800, Christchurch, New Zealand
[2] GNS Science, P O Box 30368, Lower Hutt, New Zealand.

t.sahoo@gns.cri.nz

Rift basins form due to extensional tectonics, with the history of growth faulting providing insights into continent-scale processes. Many global examples of rift basins have been uplifted and inverted, and in such cases, it is difficult to study the complete fault growth history. However, the Great South Basin is a continental rift basin which contains a thick Cretaceous rift succession that is largely unaffected by Neogene compressional tectonics and is imaged by good-quality seismic data. Interpretation of these data suggest three distinct stages of Cretaceous normal faulting, referred to here as: fault system initiation, fault system growth and fault system death. Each stage shows development of rift grabens filled with onlapping strata above a basal unconformity. The different stages of fault-system evolution comprise dominant NE-trending faults, and minor NW-trending faults. Fault system initiation (~105 to 101 Ma) primarily occurred in the central Great South Basin with rift depocentres mostly on, or close to, NW-trending basement terrane boundaries. These pre-existing basement boundaries represent zones of weakness that locally promoted early localisation of NW faults and retarded the propagation of NE faults. The fault system growth stage (~101 to 90 Ma) was characterised by widespread and more intense faulting with NE-trending faults increasing in length, number, displacement and spatial distribution. The influence of basement fabric gradually decreased during this stage. Finally, during the fault system death stage (~90 to 83 Ma) the number, length and displacement of faults decreased. Fault death coincided in time with the onset of Gondwana breakup and reflects the localisation of extension along spreading centres distal to the Great South Basin.

POSTER
Session 1c.

Changes in Seismic Velocity Accompanying Geodetically Detected Deformation at Taupō Volcano

Jessie Schuler[1], Finnigan Illsley-Kemp[1], John Townend[1], and Eleanor R H Mestel[1]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington*

jessieschuler2406@gmail.com

Taupō Volcano sits in the center of the North Island of New Zealand and is one of the most frequently active and productive rhyolite calderas in the world. Despite this, Taupō's periods of volcanic unrest are not well understood, and monitoring of the volcano is largely impeded by the overlying Lake Taupō. In the past, geodetically detectable deformation associated with volcanic unrest has often gone unnoticed until seismic activity was triggered. This was the case during the 2019 unrest period when inflation began beneath the Horomatangi reefs 6 months prior to a seismic swarm occurring beneath the lake.

This study takes advantage of GeoNet's continuous seismic data archives and ~2 years of data from the ECLIPSE seismic network (October 2019–May 2022), to gain a deeper understanding of Taupō's periods of unrest. This has the potential to help monitor, and potentially forecast, future activity. We use ambient noise to measure subsurface seismic velocity variations beneath Taupō over the past 7 years, focusing particularly on the 2019 unrest period. We also investigate local deformation likely caused by dyke intrusion in the Western Bay of Lake Taupō that occurred in the 2 weeks following the Kaikōura earthquake in 2016. By focusing on such periods, we hope to determine whether measurable seismic velocity variations are correlated with Taupō's deformation and to better understand potential causes of unrest at the supervolcano.

POSTER
Session 1a.

Development of a Bayesian Event Tree for Short-term Eruption Onset Forecasting at Taupō Volcano

Emmy Scott[1,2], Mark Bebbington[2], Thomas Wilson[1], Ben Kennedy[1] and Graham Leonard[3]

[1] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*
[2] *Volcanic Risk Solutions, Massey University, Palmerston North, New Zealand*
[3] *GNS Science, Wellington.*

emmy.scott@pg.canterbury.ac.nz; e.e.scott@massey.ac.nz

Taupō volcano, within the Central Taupō Volcanic Zone, is a silicic caldera volcano that has experienced both relatively small and very large eruptions. It is home to the world's most recent super-eruption, the 26.5ka Oruanui Eruption, and one of the most violent eruptions in the last 5000 years, the 232AD Taupō eruption. There have been at least 27 eruptions of VEI 3-6 at Taupō since 20.5ka, making Taupō volcano one of the most frequently active silicic volcanoes on earth. Considering there are 39,300 people living within 50km of Taupō volcano and 3.4 million within 250km, there is a high volcanic hazard exposure and a clear requirement to manage the volcanic risk. This is complicated by observations that Taupō volcano has experienced 17 recorded periods of unrest in the last 140 years, none which have led to eruption. A critical tool for volcanic risk management is eruption forecasting. The Bayesian Event Tree for Eruption Forecasting (BET_EF) is one probabilistic eruption forecasting tool that can be used to produce short-term eruption forecasts for any volcano worldwide.

A BET_EF model was developed for Taupō volcano, informed by geologic and historic data. Monitoring parameters for the model were obtained through a structured expert elicitation workshop with 30 of Aotearoa-New Zealand's volcanologists and volcano monitoring scientists. The probabilities of magmatic unrest, and the probabilities of eruption given magmatic unrest, output by the BET_EF model for Taupō volcano's 17 recorded unrest episodes (between 1877 and 2019) were examined.

POSTER
Session 2a.

Geologic, earthquake and tsunami modelling of the active Cape Egmont Fault Zone

Hannu Seebeck[1], Glenn Thrasher[1], Paul Viskovic[1], Suzanne Bull[1], Clarrie Macklin[1], Xiaoming Wang[1], Caroline Holden[1,*] and Yoshi Kaneko[1,2]

[1] GNS Science, PO Box 30368, Lower Hutt 5040, New Zealand
[2] Kyoto University, Yoshida-honmachi, Sakyo-ku, Kyoto 606-8501 Japan.
[*]now at SeismoCity Ltd., 16 Buckley Road, Wellington 6023, New Zealand and Victoria University of Wellington, PO Box 600, Wellington 6140, New Zealand

h.seebeck@gns.cri.nz

The active Cape Egmont Fault Zone in the southern Taranaki Basin, New Zealand, is a complex series of synthetic and antithetic dip-slip normal faults accommodating present-day extension. Located near nationally important energy infrastructure, the fault zone is well imaged on petroleum industry seismic reflection data with a number of previously studied faults on- and offshore. In this study we use basin analysis and structural modelling techniques to examine the influence of fault geometry on ground motions and tsunami wave heights derived from numerical simulations.

The largest and most mature normal fault in the region – the offshore Cape Egmont Fault – is at least 53 km long and, dependent on segment rupture, could generate an earthquake up to M_W 7.3.

Using a M_W 7.1 Cape Egmont Fault earthquake scenario, we test the sensitivity of predicted ground motions using numerical simulations on a range of fault geometries from simple to more complex representations developed from a three-dimensional structural model.

Our stochastic ground motion models result in higher Peak Ground Velocities than deterministic or Ground Motion Prediction Equation models, particularly within 10 km of the source. The stochastic model Peak Ground Accelerations are also comparable to observations from the 2010 Darfield earthquake, despite differences in fault source parameters. Predicted shaking intensities are strong to very strong across the southern Taranaki Peninsula in this earthquake scenario.

Due to its offshore location, a numerical tsunami model was generated for the same earthquake scenario. Results indicate that a significant east-directed tsunami could sweep the coastlines around the South Taranaki Bight with a focused maximum wave height of up to 2 m predicted at the coast to the northwest of Whanganui.

A report summarising this recently completed Endeavour Fund Smart Ideas project can be found at https://doi.org/10.21420/ED9K-EP20.

ORAL
Session 1d.

The New Zealand Community Fault Model version 1.0

H. Seebeck[1], R. Van Dissen[1], N. Litchfield[1], P. Barnes[2], A. Nicol[3], and M. Gerstenberger[1] on behalf of the New Zealand Community Fault Model team

[1] GNS Science, PO Box 30368, Lower Hutt 5040, New Zealand.
[2] NIWA, Private Bag 14901, Kilbirnie, Wellington 6241, New Zealand.
[2] University of Canterbury, Private Bag 4800, Christchurch 8140, New Zealand.

h.seebeck@gns.cri.nz

Community Fault Models (CFMs) developed by the scientific community aim to provide a consistent, largely complete and broadly agreed upon representation of active faults in a region. The kinematic and geometric properties of active faults are critical factors in many fundamental aspects of earthquake science including seismic and tsunami hazard assessment. In New Zealand, there has been a long-identified need for a community-developed, 3D active fault model that is publicly accessible and available to all.

The New Zealand Community Fault Model (NZ CFM) is a multi-organisational project led by GNS Science with the aim of developing a new nationwide 2D and 3D fault model capturing the current state of knowledge. The NZ CFM builds upon the Active Fault Model of New Zealand (Litchfield et al. 2014) through engagement and input from the geoscience community.

The first version of the NZ CFM (v1.0) has recently been completed and comprises 880 fault zones in two complementary datasets. The first dataset is a 2D map representation of active (or potentially active) fault zone traces with associated geometric and kinematic parameters. The second dataset is a 3D triangulated representation of the fault zone surfaces that extend from sea level to a maximum depth of fault rupture.

The NZ CFM v1.0 presently serves as a foundational resource for societally important applications such as the NZ National Seismic Hazard Model 2022, Resilience to Natures Challenges Earthquake and Tsunami programme physics-based fault systems modelling, earthquake ground-motion simulations, and tsunami hazard evaluation.

We present key aspects of design and build parameters of the NZ CFM v1.0, comparison with previous models, and current applications. The datasets and documentation associated with the NZ CFM v1.0 can be found at https://doi.org/10.21420/NMSX-WP67.

ORAL
Special Symposium

Using trace element and isotope geochemistry of central Taupō Volcanic Zone (New Zealand) granitoids to understand the processes contributing to silicic magmatism

Laura K. Seelig[1], Colin J.N. Wilson, [1], Isabelle Chambefort[2], and Bruce L.A. Charlier[1]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand.*
[2] *GNS Science, Wairakei Research Centre, Taupo, New Zealand.*

Laura.seelig@vuw.ac.nz

The central Taupō Volcanic Zone (TVZ) is an area of vigorous Quaternary silicic volcanism, with rhyolite output from caldera-forming events alone exceeding 6000 km^3 over the past 1.85 Myr. Our understanding of the geochemical evolution and magmatic processes operating within the modern TVZ rhyolitic systems (Taupō and Ōkataina) comes from the study of past eruptive products. Volcanic rocks provide a snapshot of the eruptible magma system during and immediately prior to eruption. Whereas their plutonic counterparts record magma accumulation over time, cooling and thus complementary insights into the processes in central TVZ magmatic systems.

Within the central TVZ, rare plutonic fragments have been erupted as lithic clasts in several silicic and mafic eruptions. This work focusses on erupted granitoid lithics from various central TVZ eruptions, with a specific interest in those erupted during the 54 ka caldera-forming Rotoiti event at Ōkataina, due to the large number erupted. Petrographic investigation (mineralogical and textural), geochemical, and isotopic analyses have been undertaken on these granitoids to better understand their environment of crystallisation and the magmatic processes contributing to their petrogenesis.

Trace element geochemistry suggests central TVZ granitoid compositions are controlled by plagioclase fractionation. Granitoid lithics show variations in Eu/Eu* that correlate with Rb/Sr ratios, both across the whole suite of central TVZ granitoids and within granitoids from the same eruptive unit. The central TVZ granitoids show a weak compositional gap in silica content (75 -77%), where granitoid groups either side of this divide correlate to distinct high Sr (112-215 ppm) and low Sr (8-50 ppm) compositional groups. The granitoids show a typically narrow range of $^{87}Sr/^{86}Sr$ isotope ratios (0.7050 – 0.7070) but with a weak bimodality. This bimodality between granitoids from different eruptions could reflect a link to two crustal domains that could tentatively be attributed to Waipapa- (lower $^{87}Sr/^{86}Sr$) versus Torlesse-influenced greywacke sources.

ORAL
Session 1b.

Active faults identified between the Taupō Rift and the North Island Dextral Fault Belt: kinematics and links with volcanism from the Taupō Volcanic Centre

Yaasameen Shalla[1], Pilar Villamor[2] and Colin J.N. Wilson[1]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand*
[2] *GNS Science, Lower Hutt, New Zealand*

yaas.shalla@vuw.ac.nz

Using the LiDAR-derived Digital Elevation Model (DEM), scarps have been identified between the Taupō Rift and North Island Dextral Fault Belt (NIDFB) and are interpreted as active normal-fault scarps, striking ~050°. This study carried out a remote kinematic analysis and paleoseismic study on these DEM inferred faults.

Remote mapping and kinematic analysis were carried out on the DEM with comparisons to the New Zealand Active Fault Database and GNSS-derived velocity vectors. As a result, this study highlights several possible kinematic controls of the DEM inferred faults, such as the Taupō Rift, NIDFB and possible reactivation of the inactive Kaingaroa Fault Zone.

To understand the activity of the DEM-derived scarps, a paleoseismic study was carried out through GPR surveying and trenching on one example in the western Taupō-Reporoa Basin. The newly named Parekarangi Fault demonstrates multiple Holocene events, as recently as during the 232 AD Taupō eruption. Recognition of the Parekarangi Fault rupturing during the 232 AD Taupō eruption (venting >55 km away) highlighted the spatial extent of stress changes during the eruption. Examples of volcanic-tectonic interactions such as syn-eruption fissuring, slumping and faulting during the Taupō eruption were collated to help further understand volcanic-tectonic interactions occurring during the eruption.

ORAL
Session 1c.

Sedimentary response to glacio-eustatic changes in the Northern Hikurangi subduction margin, New Zealand

Anthony Shorrock[1], Adam Woodhouse[2], Philip Barnes[3], Lorna Strachan[1], Martin Crundwell[4], Helen Bostock[5], Jenni Hopkins[6], Steffen Kutterolf[7], Katharina Pank[7], Erick Behrens[3], Annika Greve[8], Rebecca Bell[9], Ann Cook[10], Katerina Petronotis[11], Leah LeVay[11], Robert Jamieson[12], Tracy Aze[12], Laura Wallace[2, 4], Demian Saffer[2] and Ingo Pecher[13]

[1] School of Environment, University of Auckland, Auckland, New Zealand
[2] University of Texas Institute for Geophysics, University of Texas, Austin TX, USA
[3] National Institute of Water and Atmospheric Research, Wellington, New Zealand
[4] Surface Geosciences Department, GNS Science, Lower Hutt, New Zealand
[5] School of Earth and Environmental Sciences, University of Queensland, Brisbane, Australia
[6] School of Geography, Environment and Earth Science, Victoria University of Wellington, Wellington, New Zealand
[7] GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany
[8] Department of Earth Sciences, Utrecht University, Utrecht, The Netherlands
[9] Department of Earth Science & Engineering, Imperial College London, London, UK
[10] School of Earth Sciences, The Ohio State University, Columbus, OH, USA
[11] International Ocean Discovery Program, Texas A&M University, College Station, TX, USA
[12] School of Earth and Environment, University of Leeds, Leeds, UK
[13] College of Science and Engineering, Texas A&M University – Corpus Christi, Corpus Christi, TX, USA

asho465@aucklanduni.ac.nz

Gravity flows are one of the most significant drivers of sediment transport along the Hikurangi subduction margin (HSM). Despite this significance, few stratigraphic records from the region exist that reliably document how these processes respond to glacio-eustatic climate cycles. In 2018 a long (>500 m) sediment core was acquired from Site U1520 in the northern Hikurangi Trough as part of the International Ocean Discovery Program (IODP) Expedition 375. The upper ~110 m (Unit I) preserves a near-continuous, high-resolution turbidite succession composed of deposits associated with the last three Marine Isotope Stages (MIS). This represents the first opportunity to evaluate sedimentation in the Hikurangi Trough spanning the last glaciation and provides valuable insight into how sedimentary conditions in the region responded to changing environmental conditions associated with glacio-eustatic transitions.

An age-depth model has been produced for Unit I at Site U1520, integrating radiocarbon dates, tephrochronology, and $\delta^{18}O$ stratigraphy to evaluate the recurrence interval of sediment deposits and the rate of sedimentation at the study site. Analyses of this model have displayed pronounced variability in depositional conditions between glacial and interglacial stages. Mean event bed recurrence intervals vary from ~322 years in MIS1, ~49 years in MIS2 and ~231 years in MIS3. Sedimentation rate is <1 m/ka in the interglacial MIS1 and MIS3 but reaches as high as ~10 m/ka during MIS2. The sustained and significantly increased rates of sediment emplacement in the Hikurangi Trough during MIS2 is likely related to changes in regional sediment supply driven by climate-induced changes in terrestrial erosion and the activation of shelf-incising canyon systems as eustatic sea level reached a lowstand.

ORAL
Session 2c.

Trace Elements in Black Corals – Investigating Potential New Palaeoceanographic Proxies

Daniel Sinclair[1], Ashley Davis[1] Harry Parr[1] and Nicholas Hitt[2]

[1] School of Geography Environment and Earth Sciences, Victoria University of Wellington, New Zealand
[2] Tertiary Education Commission, Christchurch, New Zealand.

dan.sinclair@vuw.ac.nz

Little is known about the dynamics of the deep ocean because of the difficulty and expense of monitoring this marine environment. One way to circumvent this limitation is to reconstruct ocean dynamics using natural archives of marine information. Marine sediment cores are the archives most commonly used for palaeoceanographic reconstruction, but the temporal resolution of reconstructions can be limited by slow sedimentation rates and/or bioturbation of marine sediments.

Black corals are a new high-resolution archive, potentially allowing continuous sub-decadal reconstruction of ocean dynamics over thousands of years. These deep-sea corals grow for millennia, depositing layers of proteinaceous skeleton that capture a geochemical 'signature' of the surrounding ocean or their food source (phytoplankton debris). Here we present an investigation into trace elements in New Zealand black corals, which have the potential to act as proxies for marine micronutrients or changes to the ocean currents that mix subpolar with subtropical waters in this region.

We investigate both the spatial pattern of trace elements from multiple corals around New Zealand, as well as high-resolution time-series of trace elements within individual coral skeletons. While there is a high internal consistency of trace elements within coral skeletons, we do not find clear spatial patterns that match known gradients in trace element concentrations in the waters around New Zealand. However, a number of trace elements (e.g. V and U) show very strong correlations with each other both within and between specimens, hinting at underlying mechanisms of trace element uptake in the corals.

POSTER
Session 4d.

Fault zone contributions to the evolution of the Half Moon Bay landslide complex, Kaikōura

<u>Corinne Singeisen</u>[1], Chris Massey[2], Andrea Wolter[2], Colin Bloom[1], Richard Kellett[2], Zane Bruce[2], and Tim Stahl[1]

[1] School of Earth and Environment, University of Canterbury, Christchurch, New Zealand
[2] GNS Science, Lower Hutt, New Zealand.

corinne.singeisen@pg.canterbury.ac.nz

In this study, we present a detailed site investigation of the Half Moon Bay landslide complex located in a coastal slope above State Highway 1 north of Kaikōura. The landslide - located at a distance of c. 1 km from the Hope fault – is located between discrete structures within a broader fault zone and experienced significant ground deformation and partial failure as a rock avalanche during the 2016 M_w 7.8 Kaikōura earthquake. The site thus presents us with the opportunity to evaluate the controls of tectonic deformation on failure mechanism and coseismic slope stability. Using an integrated ground investigations concept comprising geomorphological analysis, coseismic landslide displacements, geophysical surveys and a 60 m deep borehole in the incipient portion of the landslide, we interpret the structure and mechanism of this landslide complex. Our results indicate the presence of sub-vertical structures, which appear in survey as resistivity contrasts and are morphologically expressed as counter-scarps. The drill core shows intense fracturing and weathering of the rock mass which gradually decreases with depth. In areas with large coseismic landslide displacement, close to the head scarp of the 2016 rock avalanche, the rock mass is particularly highly fractured and the geomorphology indicates that slope deformation predates the 2016 earthquake. Based on these results we interpret the landslide movement mechanisms to be a combination of flexural toppling along sub-vertical features, which are assumed to be tectonic structures in the Half Moon Bay area, and 'step-path' sliding along pre-existing, closely-spaced discontinuities within the rock mass. The evolution of this landslide complex is likely influenced by the deformation of inherited tectonic structures, cumulative rock mass damage, weathering and amplification of seismic ground motion. In future events, increasing landslide displacements will likely cause largely intact blocks to transition from sliding to avalanching – with potentially hazardous consequences for the transport corridor.

POSTER
Session 2b.

Mechanisms of rock slope failures triggered by the 2016 Kaikōura earthquake

Corinne Singeisen[1], Chris Massey[2], Andrea Wolter[2], Richard Kellett[2], Colin Bloom[1], Tim Stahl[1], Caleb Gasston[3], and Katie Jones[2,4]

[1] School of Earth and Environment, University of Canterbury, Christchurch, New Zealand
[2] GNS Science, Lower Hutt, New Zealand.
[3] School of Environment, University of Auckland, Auckland, New Zealand.
[4] School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand.

corinne.singeisen@pg.canterbury.ac.nz

Landslide failure mechanisms are influenced by topography, lithology, structure and rock mass damage - factors which also affect landslide susceptibility. With landslide hazard being a function of both susceptibility and failure mechanisms, understanding landslide failure mechanisms is crucial for hazard assessments. Here, we use 3D pixel tracking in pre- and post-earthquake aerial imagery, geomorphic mapping, rock mass characterisation, and geophysical ground investigations to develop conceptual models for earthquake-induced landslides triggered by the 2016 Mw 7.8 Kaikōura earthquake. While analysis of incipient landslides in Torlesse greywacke reveals the failure stages of a rock mass comprising multiple sets of closely-spaced and low persistence discontinuities, a landslide in Neogene massive siltstones demonstrates the role of high-persistence bedding planes in generating large translational rockslides. These two distinct mechanisms typify failures in basement and overlying massive sedimentary rocks respectively, and highlight the link between rock mass damage, failure mechanism, and initiation. In greywacke failures, the rupture plane initiated close to the ridgetop and propagated as a joint-step-path failure along pre-existing, but low-persistence joints whereas the landslide in Neogene siltstone initiated by sliding along weak, high persistence, bedding planes near the base of the slope where topographic stresses are highest. This highlights coseismic landslide susceptibility factors may vary fundamentally in different lithologies and geological settings. In greywacke rock mass, orientation of m-scale discontinuities, slope angle, rock mass strength and ground motion amplification effects determine landslide susceptibility, while the strength and stress conditions of bedding planes and bedding orientation relative to slope control landslide susceptibility in Neogene siltstone. Furthermore, we show that characteristic spatial landslide displacement patterns may be used to remotely identify relevant failure mechanisms and that the amount of displacement that can be accommodated before a failure transitions from sliding to avalanching is highly dependent on material characteristics and topography.

ORAL
Session 4c.

Slip rates on the eastern Hope Fault, New Zealand

Jan Sintenie[1], Andy Nicol[1], Andy Howell[12], Jade Humphrey[1], and Rob Langridge[2]

[1] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*
[2] *GNS Science, Lower Hutt*

jan.sintenie@pg.canterbury.ac.nz

The Hope Fault is a primary plate-boundary structure in the north-eastern South Island. Geological slip rates on the Conway and Seaward segments of the fault decrease eastwards from >20 mm/yr to ~3.5 mm/yr in offshore Marlborough (Langridge et al., 2003; Wallace et al., 2012). We present new data from displaced Late Quaternary landforms that constrain slip rates along the eastern 40 km of the onshore Hope Fault. Twelve strike-slip displacement measurements across 5 sites were determined using tape measure and displacement back-slipping of lidar-derived digital elevation models (to restore pre-faulting topography), while the ages of these landforms were estimated using Optically Stimulated Luminescence and radiocarbon dating. Strike-slip displacements of 3.5±0.5 to 410±20 m were measured and range in age from 250±50 yrs to 22.7±2 kyr, respectively. Slip rates at individual sites can range from ~10 to 25 mm/yr and over time intervals of >2 kyr decrease from an average of 16±3 mm/yr on the Conway Segment (Charwell River to Sawyers Creek) to a minimum of 3±0.7 mm/yr on the Seaward Segment. New estimates of slip rates on the eastern Conway segment are generally lower than the ~19-50 mm/yr previously documented from Late Quaternary landforms (see Langridge et al., 2003) and comparable to the ~16 mm/yr derived from GPS block models (Wallace et al., 2012). The eastward decrease of strike slip on the Hope Fault mainly reflects a gradual northward transfer of slip onto the Kekerengu Fault via a distributed network of structures including the Kowhai, Fyffe and Jordan faults.

ORAL
Session 1d.

A compiled historical volcanic hazards database for Tongariro National Park, New Zealand

Amilea Sork[1], and Ben Kennedy[1]

[1] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*

amilea.sork@pg.canterbury.ac.nz

A record of past volcanic hazards and hazard magnitudes is an essential component of risk management at volcanoes. Tongariro National Park (TgNP) is host to multiple volcanic vents and a popular tourist destination, necessitating risk management. Knowledge gaps in TgNP's eruption history have been a focus since the 1995 Ruapehu eruption episode. Few studies of the historical eruption record have been conducted, and even fewer have focused on the hazards associated with each eruption.

In this BSc Honours study, we produce a database which quantifies the known hazards associated with each known historical eruption at TgNP, building on past historical eruption record studies. Sources used for data included published scientific articles, unpublished theses from New Zealand universities, and volcanic alert bulletins. Verified and estimated hazards have been provided, along with magnitudes wherever possible. Hazards covered are ash, lahars, ballistics, pyroclastic density currents (PDCs), and lava. 169 eruption episodes, comprising 343 individual eruption events, 44 unrest events, and 11 non-eruptive lahars, have been identified. While Ngauruhoe and Ruapehu have had the same number of eruptive episodes (75 versus 76, respectively), Ruapehu has had far more individual eruptive events (232 versus 84). Ash is by far the most common recorded hazard. Ruapehu is the main producer of all studied hazards, both by volume and by number of events. The historical record for ash, lahars, and ballistics was found to be well-populated based on frequency comparisons before and after modern recording techniques. The database for PDCs is poorly populated. Lava has occurred in historical record very rarely at these sites.

POSTER
Session 2a.

Geomorphic time series reveals the constructive and destructive history of Havre volcano, Kermadec Arc

Erica Spain[1,2], Rebecca Carey[1], Jo Whittaker[1], Vanessa Lucieer[1], Jodi Fox[1], and Sally Watson[2]

[1] *National Institute of Water and Atmospheric Research, Wellington, New Zealand*
[2] *Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Tasmania, Australia*

Erica.Spain@niwa.co.nz

Change detection in the deep ocean is rare due to a paucity of data at appropriate scales. Monitoring of active seafloor processes requires repeat, comparable surveys. Here, we utilize an exceptional suite of bathymetric surveys across a spatio-temporal range at Havre volcano, Kermadec Arc, Southwest Pacific, over a period of 13 years. Surveyed in 2002 by the RV *Tangaroa*, the Havre caldera was resurveyed in 2012 (RV *Tangaroa*) and 2015 (RV *Roger Revelle*, AUV *Sentry*, and ROV *Jason*), following the largest observed deep-marine rhyolitic volcanic eruption.

These unprecedented datasets allow us to compare landforms across spatial and temporal scales and understand the constructive and destructive forces driving the evolution of Havre volcano. Multiple bathymetric datasets are used to parameterize geomorphological features and volcanic products over the caldera. We then interpret the volcanic, tectonic, erosional, and depositional processes driving the caldera's morphological evolution.

Four geomorphic groups at varying scales are interpreted: (i) large-scale tectonic features, e.g. faults, calderas; (ii) coherent volcanic products, e.g. lavas and domes; (iii) clastic volcanic products, e.g. ash, ash-lapilli-block, and giant pumice deposits; and (iv) mass-wasting features, e.g. debris flows and mega blocks. We use high-resolution AUV bathymetry to develop a fine-scale geomorphic map that reveals additional landforms and processes obscured in coarse resolution data. We integrate bathymetric data with sampling data and video footage from ROV Jason to refine geomorphic boundaries. We also integrate data from previous geological studies of Havre to inform the geomorphic interpretation.

Our work reveals additional growth on the primary dome emplacement (dome OP) between 2012 and 2015, which was not previously recognized. We also confirm voluminous shedding on the northern caldera wall and smaller scale shedding on the south-eastern wall. Our map reveals a variety of geomorphic forms reflecting a range of processes, highlighting the importance of repeat, high-resolution bathymetric surveys.

POSTER
Session 2e.

GeoNet's GNSS Data and Products: current state and future opportunities

Aleksandr Spesivtsev[1], **Elisabetta D'Anastasio**[1], **Megan Madley**[1], **and Jonathan Hanson**[1]

[1]*GNS Science, Lower Hutt, New Zealand*

a.spesivtsev@gns.cri.nz

The GeoNet GNSS (Global Navigation Satellite System) network was established more than 20 years ago, when GNS, EQC, and LINZ established a partnership to instate a backbone to understand deformation processes and realize the national datum of Aotearoa New Zealand. It currently consists of nearly 200 stations distributed around the country. GNSS techniques are an essential "instrument" to monitor and investigate geodynamics processes. The current network of GNSS stations can detect geophysical phenomena over a range of spatial and temporal scales with an accuracy of a few millimetres.

GeoNet ensures that data are continuously received, properly archived, curated, and generates products that are made accessible to the community. Raw GNSS data products include files in different formats: binary, hourly and daily RINEX (Receiver Independent Exchange) at 30 second sampling rate, and high sampling rate (1 Hz and 10 Hz) data for 23 major geological events.

Additionally, GeoNet processes raw GNSS data and provides access to daily time series at each site, which is a key geodetic product that represents temporal evolution of the 3D position of each station.

GeoNet is continually exploring opportunities to develop new analysis-ready geodetic GNSS products, that could be used as a basis for the future monitoring and research. These additional products will be easy to use, analyse and interpret by geodetic experts and other geoscientists. As part of looking at future geodetic opportunities, we will present some candidates for future services, and we would like to understand what type of geodetic GNSS products are of most interest to the Aotearoa geoscience community.

POSTER
Session 4b.

Automatic recognition of pre- and syn-eruptive tremor evolution patterns at andesitic, dome-building stratovolcanoes

Bastian Steinke[1], Roberto Carniel[2], David E. Dempsey[3], Nick Varley[4] and Shane J. Cronin[1]

[1] *School of Environment, University of Auckland, Auckland, New Zealand*
[2] *Dipartimento Politecnico de Ingeneria e Architettura, Università degli Studi di Udine, Udine, Italy*
[3] *College of Engineering, University of Canterbury, Christchurch, New Zealand*
[4] *Facultad de Ciencias, Universidad de Colima, Colima, México*

bastian.steinke@auckland.ac.nz

We apply a pattern recognition approach to continuous perennial tremor time-series recorded at Mt. Redoubt, Augustine volcano (both Alaska, US) and Volcán de Colima (México). We compare the 2006 eruption of Augustine volcano and the 2009 Mt. Redoubt eruption, both of which occurred after two decades of repose, with the 2013-2017 eruptive sequence of Volcán de Colima. This sequence represents Colima's most recent phase of major explosive and effusive activity during a near-continuous eruptive period (since 1998) with few repose intervals. All three volcanic cases are characterised by Vulcanian explosions and Pyroclastic Density Currents, as well as episodes of recurrent growth and collapse of lava domes. We investigate how the seismic precursors compare for multi-phase eruptions of this type and scale (Vulcanian to sub-plinian). We use an automatic classifier based on Self-Organising Maps (SOM) and k-means clustering. The approach is extendable to a variety of volcanic settings through systematic tuning of the classifier. We apply a Kernel Density Estimation approach to automatically detect changes within the observed seismicity. These changes reveal a sequence of distinct seismo-volcanic regimes representing different states of the respective volcanic system during multiple eruptive phases. Preliminary results emphasise the strength of the classifier to detect the onset of different eruptive phases. Feature analysis further indicates separation between pressurisation and depressurisation regimes through the course of individual eruption sequences. These results suggest that the SOM classifier could be a useful tool to help track the course of a long eruption sequence, and with more fine-tuning, to detect short-term precursors of heightened eruptive phases that pose greatest hazard.

ORAL
Session 4a.

Refining the Early Geochronological Record for the Dunedin Volcano, New Zealand

Ayla Stenning[1], James D.L. White[1], Marco Brenna[1], Sidney Hemming[2], J. Michael Palin[1] and Rachael Baxter[1,3]

[1] Department of Geology, University of Otago, Dunedin, New Zealand.
[2] Lamont-Doherty Earth Observatory, Columbia University, New York, USA.
[3] Department of Earth Sciences, University of Cambridge, Cambridge, UK.

ayla.stenning@postgrad.otago.ac.nz

The composite Dunedin Volcano (DV) (South Island, New Zealand) is the single largest centre represented in the Dunedin Volcanic Group, lying within the monogenetic Waipiata Volcanic Field. This alkaline intraplate volcano (16-11 Ma) grew through submarine and subaerial volcanism. Compositionally diverse lavas, pyroclastic deposits and subvolcanic intrusions, linked to numerous vents, preserve the record of a complex eruptive history.

Current understanding of DV age relationships is inconsistent. Published radiometric dates (41) are dominated by samples collected from the mainland with ages obtained via K-Ar methods. Various dates incur debate, particularly where volcanic units and specific samples have been re-analysed with varied resultant ages. This, alongside a stratigraphic framework divided by “floodplain conglomerates” that are often pyroclastics of questionable age significance, rather than widespread fluvial deposits, has led to an incomplete and skewed understanding of the volcanic timeline.

Here we present new radiometric dates for DV. Alongside refining and expanding the known geochronology, new dates for the stratigraphically earliest, basal eruptive deposits at different sites elucidate temporal relationships at the onset of volcanism, particularly for Otago Peninsula. New $^{40}Ar/^{39}Ar$ dates have not yet replicated the 16.0 Ma age, as no newly dated rocks are older than ~14.4 Ma; additional dating is underway to investigate this further. New U-Pb zircon dates (~13 Ma), a first for DV, provide opportunity to examine results obtained via different radiometric techniques applied to the same samples within this study.

By improving the geochronological record, we aim to determine how DV became established. Was there a single absolute age for the onset of volcanism? Or a staged onset across the volcanic footprint, perhaps an intensification and localisation of the wider volcanic field? A new comprehensive radiometric dataset with corresponding geochemistry will aid identifying any temporal and spatial controls to the silica saturated and undersaturated suites of DV.

POSTER
Session 1b.

New insights into one of the largest submarine caldera eruptions of the last 2000 years in the South Pacific, the ~AD1450 Kuwae eruption, Vanuatu

Sönke Stern[1], Shane J. Cronin[1], Stuart Bedford[2], Chris Ballard[2], Robert Henderson[2], Salkon Yona[3], Dan Tari[4], Ingrid Ukstins[1]

[1] *School of Environment, University of Auckland, New Zealand*
[2] *College of Asia and the Pacific, Australian National University, Canberra, Australia*
[3] *Vanuatu Kultural Senta, Government of Vanuatu, Port Vila, Vanuatu*
[4] *Department of Geohazards, Government of Vanuatu, Port Vila, Vanuatu*

s.stern@auckland.ac.nz

Around AD1453 one of the largest climate-forcing eruptions of the last 2000 years world-wide took place, with an impact similar to the "year without a summer" caused by the 1815 Tambora eruption. The AD1450's event was sourced at the currently submarine Kuwae caldera (~50 km^2), located between the islands of Epi and Tongoa in central Vanuatu. Locally, this eruption caused a mass exodus of people and re-arranged the social structures. We examined new coastal outcrops on islands around the caldera caused by cyclone erosion. Now we establish the first complete stratigraphy of this event sequence. The eruption began with fine ash fall deposition from small explosive events, accompanied by faulting of paleosols and earlier volcanic deposits. This corresponds with oral traditions describing precursory earthquakes that fore-warned people. The climactic event(s) began with a long-lived, stable plinian eruption column, depositing subaerial lapilli fall of up to 4 m-thick on northern Tongoa Island, dominated by low-density andesitic-dacitic pumice. This evidences a subaerial source, corresponding with local legends of how the islands of Tongoa and Epi were joined before the eruption. The next eruption stage of collapsing columns is represented by widespread set of surge deposits showing antidunes. This passes up to a massive lithic lag breccia of 10-50 m-thick, containing megaclasts (>10 m-diameter) recording caldera collapse and destruction of an earlier andesitic stratovolcano. Following pumice-rich pyroclastic flow deposits (5-50 m-tthick) were emplaced on all surrounding islalnds by a series of explosions, with increasingly diverse textures of chilled, glassy bombs and lapilli reflecting an overal increasing role of magma-water interaction. The pyroclasts evidence mixed and mingled magmas were involved in this event ranging from 62-72 wt% silica. The largely sub-aerial nature of the climactic phase of this large eruption likely led to its huge global atmospheric impact.

ORAL
Session 1a.

Do tide gauge records from New Zealand provide a reliable picture of relative sea level change over the past 100 years?

Tim Stern[1], Paul Denys[2], Simon Lamb[1]

[1] *Earth Sciences, Victoria University, Wellington, New Zealand*
[2] *School of Surveying, University of Otago, Dunedin, New Zealand.*

tim.stern@vuw.ac.nz

Much effort is now being expended on trying to develop a predictive model for relative sea level rise over the next 30-100 years. A key part of predicting relative sea level in New Zealand is determining the local vertical land movement (VLM). Continuous GNSS (cGNSS) and INSAR (radar methods) measurements have been widely used to determine VLM, but their time series typically go back only a decade or two, and they only give one component of relative sea level change. Tide gauge (TG) measurements, on the other hand, span up to the last 120 years and show the full relative sea level change, potentially providing a better way to predict the next 100 years. In addition, the tide gauge sees all the effects of oceanographic behaviour, such as El Nino events and the Southern Oscillation, which will also contribute to relative sea level change. A test of the veracity of New Zealand TG records is provided by a comparison with a eustatic sea level (GSC) curve, based on an average from global records. There is an almost perfect fit between the GSC over the past 120 years and the trends in the TG record for Auckland and Dunedin. In other words, on this time scale, there appears to be no tectonic component, either of subsidence or uplift, for Auckland and Dunedin, so that both locations appear tectonically stable. Wellington TG record indicates a small additional component of tectonic subsidence between 0.5 and 1 mm/yr. We therefore conclude that on multi-decadal timescales, there has been minimal (<<0.5 mm/yr) vertical tectonic land movement in Auckland and Dunedin, and only small (<1 mm/yr) subsidence in Wellington. This result does not, however, preclude periods of more rapid subsidence or uplift (up to 2 mm/yr) on sub-decadal timescales at any of these localities.

POSTER
Session 2b.

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Crustal structure, mantle melt zones and processes beneath the Taupo Volcanic Zone, New Zealand: evidence from active-source seismic exploration and GPS data

Tim Stern[1], Wanda Stratford[2], Simon Lamb[1], Adrian Benson[2]

[1] *Earth Sciences, Victoria University, Wellington, New Zealand*
[2] *GNS Science, Lower Hutt.*

tim.stern@vuw.ac.nz

Reprocessed seismic data from the MORC active-source seismic survey (2005) images an 80-km-wide pillow-shaped structure beneath the Taupo Volcanic Zone (TVZ). This "rift-pillow" has a thickness of ~11 km and is emplaced between depths of 15 and 26 km. Seismic P-wave speeds of 6.7 -7 km/s are observed suggesting the rift-pillow comprises underplated new crust of a mafic composition.

A deeper reflector (R3 reflector), which extends laterally for about 20 km, is found at a depth of ~32 km beneath the eastern margin of the TVZ. This has previously been interpreted as a Moho reflector, but our new analysis of the seismic attributes of R3 clearly shows it to have a negative polarity and therefore the top of a low velocity zone. This rules R3 out as the Moho. Our interpretation is that it is the top of an extensive zone of melt in the upper mantle.

A combination of campaign and continuous GPS data show a remarkable down-warp of the crust in the Rotorua-Taupo region, with a maximum subsidence rate of ~15 mm/yr. The region of high subsidence rates is ringed by zones of uplift where vertical motion is in the range of 2-5 mm/yr. One possible mechanism, which explains both the magnitude of the subsidence and the flanking uplifts, is a 3D flexural model with an elastic plate thickness of ~3 km and a source for the load deeper than 15 km. The driving source is interpreted to be episodic vertical forces, generated by flow in the molten parts of the upper mantle, being coupled into the more viscous, underplated lower crust. This proposal of basal forces along the axis of an upwelling mantle flow is adapted from that used to explain the distinctive axial grabens of mid-oceanic ridges.

ORAL
Session 1d.

A synthesis of volcanic edifice evolution based on a 3D lithological reconstruction of Heyward Promontory, East Otago, New Zealand

Thomas Stevenson[1] **and Marco Brenna**[1]

[1] *Department of Geology, University of Otago, Dunedin, New Zealand*

tom.stevenson@otago.ac.nz

This study applies novel technologies to interpret key volcanic sequences of Dunedin Volcano/Rakiriri, an extinct intraplate shield volcano. Rakiriri experienced a prolonged eruptive history between 16-11 Ma and achieved a diameter of ~25 km.[1,2] Part of this history is preserved in cliffs along Heyward Promontory, northeast of Dunedin City. The cliffs contain distinctive outcrops of alkaline basalt, trachyte, kaiwekite[3] and phonolite ~13 Ma in age. Numerous dikes, domes and other structures suggest a complex development of the edifice and its internal plumbing.[4] Many aspects remain unclear, such as the locations of vents, for how long they erupted, and how much material they erupted. The excellent exposures at Heyward Promontory present an opportunity to answer such questions and inform studies of shield volcanoes worldwide.

We have photographed key outcrops at Aramoana, Murdering Beach and Long Beach using an aerial drone. These sites were chosen for their quality and variety of rock exposure. Photogrammetry software has been used to assemble the photographs into a 3D digital model. Geochemical data derived from whole rock, XRF and SEM analyses have been used to correlate volcanic strata between sites. They have been integrated with pre-existing spatial and geochronological data in ArcGIS, as well as estimated volumes of post-volcanic erosion, to construct a lithological model of Heyward Promontory as it appeared at the height of volcanism ~13 Ma.

It is recommended that the model be refined and expanded upon to encompass all of Rakiriri. Such a model would bear considerable research and educational value, as it would allow learners to more easily visualise the edifice and understand its evolution. It would also illuminate processes that shape currently active volcanoes, such as Kīlauea in Hawaii[5] and Cumbre Vieja in the Canary Islands, which present significant risks to human life.

POSTER
Session 4b.

Finding NZ's next meteorite with the Fireballs Aotearoa meteor-tracking camera network: conception, results, outreach

Thomas Stevenson[1], Mia Boothroyd[1], Marshall Palmer[1], Nadine Cooper[1] and James Scott[1]

[1] *Department of Geology, University of Otago, Dunedin, New Zealand*

tom.stevenson@otago.ac.nz

Only nine meteorites have been discovered in NZ, and only the 1908 Mokoia and 2004 Auckland meteorites were seen to fall. Our goal is to recover the tenth NZ meteorite. With support from Fireballs Aotearoa (www.fireballs.nz) and funding from a Curious Minds Participatory Science Fund, we have built and installed a network of ~20 night-sky meteor cameras in primary and high schools from Stewart Island to Oamaru. These cameras record amazing scenes from the night-sky, including meteors and their source regions, as well as constellations and other planets. Our data are uploaded to the freely accessible Global Meteor Network (http://istrastream.com/rms-gmn/?country=NZ).

The Fireballs Aotearoa network is globally important because it is the world's southernmost meteor network, and one of only two in the Southern Hemisphere. Therefore, it observes meteors that other networks miss. The cameras have already revealed just how busy the night sky is, with our current record being 409 meteors in one exceptional evening. Several bright, shallow meteors travelling over Canterbury have potentially dropped meteorites. No new meteorites have yet been recovered, although the July 7th fireball over Wellington, which was the fifth largest global explosion in the sky in over a year, likely dropped some in Cook Strait.

Our project has led to novel collaborations, such as with meteorological groups for radar data that might aid in tracking a fireball, and GNS Science for the sonic booms recorded on seismometers when a meteor explodes. An underpinning aim of the project has been to engage school students in geology, astronomy and planetary science. Students can download and analyse their own camera datasets, and we have developed a teacher kit of fun experiments and classroom tasks.

Oral
Session 4b.

Biogeochemical cycling of trace metals and their isotopes: Links to past and present climate change

Claudine Stirling[1,2]

[1] *Department of Geology, University of Otago, Dunedin, New Zealand.*
[2] *Centre for Trace Element Analysis, University of Otago, Dunedin, New Zealand.*

claudine.stirling@otago.ac.nz

Trace metals play many important roles in the biogeochemistry of the oceans, and via connections with the atmosphere, as well as carbon and sulfur cycles, are intrinsically linked to global climate. The oceanic distributions of trace metals are significantly influenced by the concentration of dissolved oxygen, as well as the intensity and efficiency of the ocean's biological pump that helps regulate atmospheric CO_2 levels. Therefore, metal stable isotope systems have recently emerged as powerful tracers of the redox evolution and productivity status of the past and present oceans. A growing inventory of data provide (1) important boundary conditions for modelling future climate scenarios, and (2) reconstructions of the evolution of the ocean-atmosphere system throughout Earth's history, as recorded in marine sediments. However, both applications rely on robust calibration of metal isotope cycling in the modern marine environment, and in-depth understanding of how the dissolved isotopic signatures are transferred to the sedimentary record.

To help address this knowledge gap, we have investigated the biogeochemical cycling of the iron, zinc, cadmium, and uranium isotope systems, together with a wide range of trace element distributions, in under-constrained regions of the world's oceans that are representative of past global ocean regimes. These studies have been aided by the large-scale sampling voyages of the international *GEOTRACES* and *IODP* programmes, as well as smaller, targeted expeditions within and outside of New Zealand. The datasets obtained improve the calibration of these metal isotope systems in the modern ocean and facilitate their robust application to sedimentary records to aid environmental reconstructions throughout Earth's history. Our reconstruction efforts are focused on the glacial-interglacial climate transitions of the Quaternary through to 'deep time' ocean-atmosphere reorganisations, such as the super-greenhouse '*Ocean Anoxic Events*' of the Mesozoic and the Paleoproterozoic '*Great Oxidation Event*'.

KEYNOTE
Session 4d.

Earthquake source characterisation in southern New Zealand: an update

Mark Stirling[1], Jack Williams[1], and Jonathan Griffin[2]

[1]Department of Geology, University of Otago, PO Box 56, Dunedin, 9054
[2]Community Safety Branch, Geoscience Australia, 101 Jerrabomberra Ave, Symonston, ACT

mark.stirling@otago.ac.nz

Until recently, identification and characterisation of earthquake sources in the low-seismicity Otago and Southland regions were largely limited to the efforts of QMAP, and to hydroelectric investigations in the 1980s. The latter were leading efforts of the time, but were data-poor due to the absence of applicable dating techniques. More recently, GNS Science has led major regional and national-scale compilations of earthquake sources. Our efforts are primarily focused on data acquisition and interpretation. Paleoseismic investigations have been carried out on seven active faults in Otago, and late Quaternary slip rates have been determined for two of the faults, providing a longer-term context for interpreting the paleoseismic record. The Otago studies provide insights into the space-time behaviour of active faults in low seismicity regions. Our Southland efforts are focused on going beyond geomorphic-based methods of active fault identification, as faults may be hidden due to surficial process being faster than tectonic processes. Specifically, we are: (1) establishing a regional seismic deployment to investigate if range- and/or terrane-bounding faults are currently hosting microseismicity, and whether hidden faults exist beneath the Southland Plains; and (2) interpreting existing geophysical data. These efforts are justified by the occurrence of a number of major New Zealand historical earthquakes on sources with no prior geomorphic expression.

ORAL
Session 1d.

Crust and subduction architecture in Southland-Solander Basin.

Wanda Stratford[1], Calum Chamberlain[2] and Rupert Sutherland[2], Tim Stern[2] and the SISIE team

[1] GNS Science, Lower Hutt, New Zealand
[2] Victoria University of Wellington, Wellington, New Zealand.

w.stratford@gns.cri.nz

We present a new crustal thickness map for Southland and a geometric model for the offshore Fiordland-Puysegur subduction zone beneath Solander Basin constrained by onshore-offshore multichannel seismic data. The data provide evidence for a crustal thickness that increases from ~30 km at the southern Southland coast northward and eastward into the Murihiku terrain of the Takitimu mountains and the Catlins, where thicknesses are 40 +/- 2 km. These crustal thicknesses are 10 km greater than in Torlesse terrain to the north in Canterbury and similar in thickness to crust shortened in the central Southern Alps. Preliminary analysis of bright upper mantle reflections observed from beneath northern Solander Bain are interpreted as arrivals from the top of the subducting slab of the Australian plate and indicate it is relatively shallow, ~45 km deep, and possibly dipping to the northeast here. Because of lower earthquake frequency and poor locations in this isolated region, previous models have lacked constraint on the shape, depth-extent, and seismic hazard potential of the subducted slab here and the nature of the crust beneath southland. We use new active source seismic data from the Southland Seismic project, an offshore multichannel seismic survey in Solander Basin that recorded seismic energy onshore on seismographs in Southland and Fiordland, to model crust and mantle structures. Seismographs were deployed in two arrays in line with the offshore shots, enabling the construction of two onshore-offshore crustal structure models for the region. In addition, stations on offshore islands provide fan-shot images of the subducted slab at depth. The project piggy-backed off a 2018-19, NZ-USA, international project across the Puysegur subduction zone.

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POSTER
Session 1c.

Palaeogeographic evolution of Zealandia: mid-Cretaceous to present

Dominic P. Strogen[1], Hannu Seebeck[1], Benjamin R. Hines[2], Kyle J. Bland[1], and James S. Crampton[2]

[1] GNS Science, PO Box 30368, Lower Hutt 5040, New Zealand
[2]School of Environment, Geography and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand.

d.strogen@gns.cri.nz

We present a recently published suite of 15 palaeogeographic maps illustrating the geological evolution of the entirety of Zealandia, from mid-Cretaceous to present, highlighting major tectonic phases, from initial Gondwana rifting through to development of the Neogene plate boundary. They illustrate palaeobathymetric and palaeofacies interpretations along with supporting geological datasets and a synthesis of regional tectonics. The maps are underpinned by a geologically constrained and structurally-based rigid retro-deformation block model. This model, tied to the global plate circuit, is relatively simple for the main regions of Northern and Southern Zealandia, but breaks central Zealandia into numerous fault-bounded blocks, reflecting complex Neogene deformation associated with the modern plate boundary. Production of maps using GPlates and GIS allows for simple alteration or refinement of the block model and reconstruction of any geological dataset at any time. Reconstructions are within a palaeomagnetic reference frame, allowing assessment of palaeo-latitude, critical for palaeo-climatic and palaeo-biogeographic studies.

Map inputs include recent (unreconstructed) regional palaeogeographic studies focusing on New Zealand's major sedimentary basins, new reviews of NZ biostratigraphic data, and numerous detailed studies in onshore/nearshore New Zealand. In data-poor frontier regions such as the Campbell Plateau, Bounty Trough and Chatham Rise and much of northern Zealandia, we rely on regional studies based on limited seismic datasets, dredge data and DSDP/IODP wells, as well as recent reassessments of the onshore geology of New Caledonia. Future iterative refinements to tectonic models and palaeogeographic maps are expected with improved modelling of extensional and contractional deformation, and integration of further regional datasets, as available.

ORAL & POSTER
Session 1c.

A New Basin-Depth Map of the Fault-Bound Wellington CBD Based on Residual Gravity Anomalies

Alistair Stronach[1] **and Tim Stern**[1]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand*

alistair@stronach.co.nz

A new basin-depth map for the Wellington Central Business District is presented, showing a maximum depth of 540 m near the Wellington Stadium. This is twice that previously proposed (Semmens 2010, Kaiser et al. 2019). Our new basin geometry constraints are from a residual gravity anomaly map, the first since Hatherton & Sibson (1969), based on ~600 new gravity observations and funded by the EQC. Residual gravity anomalies are as large as -6.2 mGal with uncertainties <0.1 mGal. Two-dimensional gravity models constrained by boreholes that intersect basement are used to generate the basin depth map. In the deepest areas of the city (Thorndon, Pipitea and CentrePort) previous depth maps have been hindered by a lack of deep boreholes, whereas the residual gravity anomaly map has allowed more detailed interpretations to be made in these areas.

The gravity models also indicate the location of a possible onshore extension of the recently discovered Aotea Fault (Barnes et al. 2019) on the western side of Mt Victoria. A maximum basement offset of up to 130 m and gravity anomaly gradients up to 8 mGal/km are observed across the fault. A secondary splay off the main Aotea fault trace is identified in the NW corner of Mt Victoria, and a possible extension of the Lambton fault is identified beneath the Wellington Railway Station. The Terrace Fault is also apparent in the gravity models. This new basin depth and fault trace data provide valuable constraints to models of seismic hazard assessment for Wellington City, as the sharp impedance contrasts across faults and greater sediment depths will both act to amplify earthquake shaking and hazard through reverberation and basin-edge effects.

ORAL
Session 4c.

Comparison of hydrothermal fluids and fields of the northern Okataina Volcanic Centre: fifty years ago to present time

Valerie Stucker[1], Jay Curtis[1] and Karen Britten[2]

[1] Labs and Collections, GNS Science, Lower Hutt, New Zealand
[2] Volcanology, GNS Science, Wairakei, New Zealand.

v.stucker@gns.cri.nz

Hydrothermal features in the Okataina Volcanic Centre, North Island, New Zealand, are found predominantly along the northern and southern boundaries of the centre. Very little work has been done studying the northern fluids, although yearly samples are collected from a handful of locations for monitoring purposes. In this study, we examine fluids from Tikitere and Waitangi Soda Springs, located along the northern OVC boundary near Lakes Rotoiti, Rotoma and Rotoehu and compare them to published, historical data from the region. Samples taken from the lakeshores indicate bicarbonate-chloride rich fluids that show minimal changes since 1970. Alkali geothermometer temperatures estimating reservoir temperatures range from around 220 to 290°C. In contrast, slightly further south and higher in elevation, the Hells Gate geothermal tourist location has a wider range of hotter geothermometer temperatures and features acid-sulfate fluids. There have been noticeable changes here since 1970, with new pools formed, and an evident enrichment in stable water isotopes, indicating greater water rock interactions and evaporation have occurred over time. Overall, hydrothermal fluids from the northern Okataina Volcanic Centre show good stability and low eruption risk.

ORAL
Session1e.

Mineral Recorders of Ascent Processes in Explosive Eruptions at Mt. Taranaki, New Zealand

Jordan Swann[1], Michael Rowe[1] and Richard Hervig[2]

[1] *School of Environment, University of Auckland, Auckland, New Zealand*
[2] *School of Earth and Space Exploration, Arizona State University, Tempe, Arizona, United States.*

jswa555@aucklanduni.ac.nz

Eruption styles and magnitudes of intermediate composition volcanoes can vary significantly from one eruption to the next. Processes which influence the eruption style are numerous and include both magmatic and external forcings. Mt. Taranaki, New Zealand, is one such volcano demonstrating a range of eruption styles, from dome building to plinian. Here we attempt to analyse ascent processes and crystallisation histories to compare their relative impact on eruption style. Because of their rapid diffusive properties, H and Li concentrations, and their isotopic compositions are compared here from a single eruptive formation, including a plinian, sub-plinian, and block and ash flow deposit.

Minerals extracted from pumice samples were analysed for H and Li isotopes and concentrations using secondary ion mass spectrometry. Concentrations differ from core to rim in plagioclase minerals across all eruption styles, with inconsistent core-to-rim trends in H, Li, and their isotopic ratios from grain to grain within the same eruption deposit. Generally, H concentrations are higher in plagioclase cores from the sub-plinian and block and ash flow deposit, compared to the plinian sample. Li concentrations, which have previously been used to argue for volatile enrichments in shallow magmatic systems show little change from core to rim in the sub-plinian and block and ash flow deposits. Li shows a slight increase in plagioclase rims of the plinian deposit compared to core values. Results indicate that multiple factors likely influence the concentration of Li and H in mineral rims and support the trend that the Taranaki magmatic system contains a mixture of grains with different crystallisation and thermal histories.

POSTER
Session 1b.

Stress field in the northwestern part of the South Island, New Zealand, and its relationship with faults of recent earthquakes

Ayaka Tagami[1], Miu Matsuno[1], Tomomi Okada[1], Satoshi Matsumoto[2], Yuta Kawamura[2], Yoshihisa Iio[3], Tadashi Sato[1], Satoshi Hirahara[1], Shuutoku Kimura[1], Stephen Bannister[4], John Ristau[4], John Townend[5], Martha Savage[5], Clifford Thurber[6], and Richard Sibson[7]

[1] *Research Center for Prediction of Earthquakes and Volcanic Eruptions, Graduate School of Science, Tohoku University, Sendai, Japan.*
[2] *Institute of Seismology and Volcanology, Faculty of Science, Kyushu University, Shimabara, Japan.*
[3] *Disaster Prevention Research Institute, Kyoto University, Uji, Japan.*
[4] *GNS Science, New Zealand.*
[5] *Victoria University of Wellington, New Zealand.*
[6] *University of Wisconsin - Madison, United States of America.*
[7] *University of Otago, New Zealand.*

ayaka.tagami.p6@dc.tohoku.ac.jp

In the northwestern part of the South Island, many old normal faults that developed due to extensional stress fields associated with the formation of the Tasman Sea and the Emerald Basin are widely distributed. Currently, tectonic inversion under compressional stress, in which the normal faults have been re-activated as reverse faults, has been confirmed (Ghisetti et al., 2014).

Our previous studies focused on several large earthquakes (e.g., the 1929 Buller earthquake Mw 7.3, and the 1991 Hawks Crag earthquake Mw 6.0), and confirmed that the eastward-dipping planes are likely to have slipped (e.g., Tagami et al., JpGU Meeting 2022). This study focused on two other large earthquakes (the Inangahua earthquake Mw 7.1 and the Maruia Springs earthquake Mw 5.7) to investigate the relationship between the stress fields and the fault planes.

First, we estimated the current stress field using the focal mechanisms obtained by temporary and permanent stations (Okada et al., 2019; Matsuno et al., 2022) and the GeoNet moment tensor solutions. Then, we evaluated the likelihood of slip by the Slip Tendency analysis (Morris et al., 1996).

1968 Inangahua earthquake (INA). The westward-dipping plane has a high ST value (>0.7) and is more likely to slip under the stress field. Our result is consistent with previous studies (e.g., Anderson et al., 1994).

1971 Maruia Springs earthquake (MAR). Both nodal planes have ST values less than 0.7 and are unlikely to slip.

We examined that INA possibly triggered MAR by static stress change, and found a positive Coulomb stress change for MAR.

POSTER
Session 1d.

A Quantitative Investigation into Pyroclast Properties Across the Transitional Stratigraphy of the Taupo 232 CE Y4/Y5 Eruption Phases

Sarah Tapscott[1], Gert Lube[1], Colin J.N. Wilson[2], Anja Moebis[1], Hannah Walters[1], and James Ardo[1]

[1] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*
[2] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand.*

s.tapscott@massey.ac.nz

Successive units Y4 and Y5 of the Taupo 232 CE eruption are individually well-studied examples of phreatoplinian and large plinian eruption deposits, respectively. An in-depth quantitative investigation into the physical properties of pyroclasts across the stratigraphical transition between the two contrasting eruptions is, however, necessary to further the understanding of transitional vent behaviour and the mechanisms that influence a change in eruptive style during such large-scale events. Here we present a comprehensive analysis of the variation in pyroclast properties in proximal stratigraphical profiles from the upper Y4 deposit and lower Y5 deposit through granulometry, componentry and textural investigation.

Four juvenile component classes are defined: J1) microvesicular pumice; J2) macrovesicular pumice; J3) fibrous pumice; and G) glass/obsidian. Pumice classes J1–J3 within the Y5 exhibit mean vesicularities of 78% ± 3 – 4% and show significant variations in internal clast textures, whereas pumices in the upper Y4 have a lower mean vesicularity. Lithic component classes were defined according to estimates of their likely depth of origin in the crust: F1) shallow lavas and hydrothermally altered material; F2) intermediate lacustrine sediments; and F3) deep microcrystalline intrusives. G and F2 clasts are most notable in the transition from Y4 to Y5, with F2 showing a sudden ~18wt% increase in overall abundance at the onset of Y5 from a steady ~5wt% in the below Y4 layers, and G showing a sudden ~23wt% decrease from Y4 to <1wt% within Y5.

Using the above data, we here reconstruct the spatiotemporal evolution of vents as well as changes in magma fragmentation conditions during the transition from the phreatoplinian Y4 to large plinian Y5 phase, providing insights into potential vent synchronicity or migration and further adding to the understanding of the Taupo 232 CE eruption.

POSTER
Session 1a.

Seismicity and its implications for fluid movement in the northern and central Hikurangi subduction zone

Kazuya Tateiwa[1], **Calum Chamberlain**[2], **Martha Savage**[2] **and Tomomi Okada**[1]

[1] *Graduate School of Science, Tohoku University, Sendai, Japan*
[2] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand*

kazuya.tateiwa.r7@dc.tohoku.ac.jp

Beneath the North Island of New Zealand, the Pacific plate is subducting under the Australian plate along the Hikurangi Trough, forming the Hikurangi subduction zone. In the Hikurangi subduction zone, some recent studies suggest that fluid movement from the oceanic crust to the plate boundary or into the Australian plate impacts various seismic activities such as SSEs (slow slip events), tremors, and earthquake swarms. In this study, we classified earthquakes in the northern and central Hikurangi into earthquakes occurring within the Australian plate (AUS), within the Pacific plate (PAC), or on the interplate interface (INT) based on their relocated hypocenters, focal mechanisms, and waveform correlations. Then we investigated the relationship between earthquake source parameters, their inferred tectonic setting, and SSEs.

PAC earthquakes were distributed widely, while AUS and INT occur only in focused regions. Many AUS earthquakes in the northern Hikurangi occurred where extensional areal strain was observed (Dimitrova et al., 2016), and we infer that earthquakes here may be related to extensionally enhanced permeability. INT earthquakes cluster at the periphery of SSE source regions. Within and surrounding the shallow SSE source region, AUS earthquakes were active during the post-SSE period, INT earthquakes were active during the co-SSE period, and PAC earthquakes were slightly active during the pre- and co-SSE period. The activated period of these earthquakes were emphasized when only the earthquake swarms were analysed. This characteristic temporal relation with SSE related to earthquake locations can be explained by fluid movement. That is, fluid movement from the oceanic crust to the plate boundary or upper plate, as proposed by Nishikawa et al. (2021), may have triggered SSEs, tremors, and AUS or INT earthquakes.

POSTER
Session 1d.

The Story of a Seismic Network: the RCET Te Tai Tokerau Northland Array

<u>Sam Taylor-Offord</u>[1], and Tim McDougall[1]

[1]*GNS Science, Lower Hutt, New Zealand*

s.taylor-offord@gns.cri.nz

To support the enterprising efforts of the Rapid Characterisation of Earthquakes and Tsunami (RCET) programme, an array of 15 broadband seismic sensors is being built in Te Tai Tokerau Northland with sites peppered through the Auckland and Waikato Regions. Site selection and network construction in the array has followed the GeoNet standard and progressed through a partnership between regular GeoNet staff and researchers involved in the RCET programme. Built through to 2025 but with long-term prospects in mind, the array has potential to become a mainstay of the permanent New Zealand seismic network. The array – while powerful in its own right – fits within a regional set of arrays whose collective capability aims at characterising large, potentially tsunamigenic earthquakes in the South Pacific. This presentation covers the story of the array from the perspective of those selecting its sites, with a focus on the site selection and array design process, and with ample reflection on the successes and the challenges experienced throughout this journey.

ORAL
Session 3c.

GeoNet Sensor Network Capability; Estimates of the Earthquake Detectability in New Zealand

Sam Taylor-Offord[1], Mark Chadwick[1], Holly J. Godfrey[1], Jonathan Hanson[1], Tim McDougall[1], Jerome Salichon[1], Steve Sherburn[1], Daniel Whitaker[1], and Clinton Zirk[1]

[1]GNS Science, Lower Hutt, New Zealand

s.taylor-offord@gns.cri.nz

Here we present a simple approach for assessing seismic sensor network capability using estimates of the minimum detectable earthquake magnitude. We implement the SN-CAST algorithm to simulate the first stage of GeoNet's earthquake detection routine using a simple but effective combination of average seismic station noise values and the local magnitude scale. Empirical comparisons shows that our estimates of minimum detectable magnitude are akin to average magnitudes of completeness values, proving their utility as first-order measures of network capability. The SN-CAST algorithm offers benefits over catalogue-based measures due to its catalogue-independence and the tunability of its input. Applications include near-real-time network capability monitoring, decision-support in network development and earthquake detection system modifications, prioritisation of network management, and more.

POSTER
Session 1d.

The 2022 NZ-NSHM Workflow for the Distributed Seismicity and Slab Source Models

K.K.S. Thingbaijam[1], M.C. Gerstenberger[1], C. Rollins[1], R.J. Van Dissen[1], S. J. Rastin[1], D.A. Rhoades[1], P. Iturrieta Rebolledo[2], S.S. Bora[1], and C. DiCaprio[1]

[1] *GNS Science, Lower Hutt, New Zealand*
[2] *GFZ, Helmholtz Centre Potsdam, Germany*

k.thingbaijam@gns.cri.nz

The distributed seismicity and slab source models for the 2022 New Zealand National Seismic Hazard Model (NZ NSHM) provide earthquake forecasts, complementary to fault-based models, for hazard computations. The distributed seismicity model describes not only shallow crustal (hypocenter depth ≤ 40 km) earthquakes, but also lower magnitude (*Mw* 5.0 - *Mw* 7.0/7.5) interface events in the Puysegur and Hikurangi subduction zones. On the other hand, the slab model accounts for intraslab earthquakes in these subduction zones. The workflow for these source models primarily comprises two parts. The first part assembles the essential components, which include models of spatial distributions, frequency-magnitude distributions, hypocentral depth distributions, and faulting patterns (focal mechanisms, including definitions for finite-fault ruptures). The second part optimises these source models to achieve computational efficiency in hazard calculations. We analyse the sensitivity of the mean hazard (that is, peak ground acceleration, pseudo-spectral acceleration at different periods for the different probability of exceedance) to the epistemic uncertainties within each component; branches which have little effect on the hazard are trimmed from the logic tree of epistemic uncertainties. The optimised source models are subsequently applied in the NZ NSHM computations.

POSTER
Special Symposium

Largest-known fossil penguin moves peak body size closer to first appearance of Sphenisciformes in Zealandia

Daniel B. Thomas[1], Daniel T. Ksepka[2], Simone Giovanardi[1], and Alan J.D. Tennyson[3]

[1] School of Natural Sciences, Massey University, Auckland, New Zealand
[2] Bruce Museum, Greenwich, CT, USA
[3] Museum of New Zealand Te Papa Tongarewa, Wellington, New Zealand

d.b.thomas@massey.ac.nz

Zealandia is a centre of extant penguin diversity (Sphenisciformes) and was important for the early origin of these diving seabirds. The oldest and most stemward fossil penguin so far described was uncovered from early Paleocene sediments in Aotearoa and was within the size range of extant penguins. The giant body sizes for which fossil penguins are famous were first demonstrated relatively soon thereafter, with slightly younger penguins from the late Paleocene Moeraki Formation demonstrating body sizes far larger than living penguins. New discoveries from Moeraki Formation push our knowledge of early penguin diversity even further and now reveal the largest species of penguin yet reported. The massive size and placement of one of these new species close to the root of the penguin phylogeny supports a scenario in which penguins reached the upper limit of sphenisciform body size very early in their evolutionary history, while still retaining numerous plesiomorphic features of the flipper. The race to become giant ahead of optimising for movement in water is instructive about the drivers that have shaped the evolutionary history of penguins, and can also help us understand drivers in other lineages that have transited across dramatically different biomes. With these new contributions from Moeraki Formation, the fossil penguin record of Zealandia is steadily becoming one of the best resources for studying the early history of a tetrapod group that has secondarily returned to life in water.

ORAL
Session 1c.

Interaction of Taranaki Maunga and the Cape Egmont Fault Zone

<u>Glenn Thrasher</u>[1], Matthew Sager[1], Paul Viskovic[1] and Hannu Seebeck[1]

[1] GNS Science, PO Box 30368, Lower Hutt 5040, New Zealand

g.thrasher@gns.cri.nz

Igneous centres within and adjacent to the Taranaki Peninsula represent the southwestern-most extent of arc volcanism associated with the Tonga-Kermadec-Hikurangi subduction system. Across the peninsula, Taranaki Maunga and associated ring plain, along with predecessors, lie on a west-dipping angular unconformity cut into Pliocene marine strata. Many petroleum exploration wells have penetrated these surficial igneous rocks, which rarely extend more than a few hundred metres below sea level. In addition, the active Cape Egmont Fault Zone intersects these igneous units across the southwestern portion of the peninsula.

Here we combine existing seismic reflection data (Seebeck et al, 2021) with new radiometric dating to better constrain the fault system and its relationship to igneous activity. Pliocene to recent normal faulting along the Cape Egmont Fault Zone has formed a series of grabens underlying the western portion of the peninsula and its offshore region. This extensional system offsets the base of the igneous sequence by hundreds of metres across individual faults.

Seismic reflection mapping reveals several subsurface igneous features in close association to the fault zone. Offshore, immediately west of the peninsula, there are three small buried volcanic cones. Each of these features appears to have been active for a few hundred thousand years, with overall activity ranging from c. 2.5 Ma to c. 0.5 Ma. Onshore, at least two small cones underly the ring plain, resting on the unconformity.

Hornblende from six igneous samples from onshore petroleum exploration wells have yielded $^{40}Ar/^{39}Ar$ plateau ages ranging from c. 2.3 Ma to 150 ka. These data suggest that surficial volcanism, including Taranaki Maunga, initiated at 500 to 400 ka under most of the western side of the peninsula. These surface units overlie older igneous rocks deposited about c. 2.5 to c. 1.5 Ma, possibly associated with the offshore cones.

ORAL
Session 1a.

A multidisciplinary source to sink approach in mapping erosion ‘hot-spots’ and sediment pathways in a harbour subcatchment of Te Whakaraupō/Lyttelton, Banks Peninsula

Michael Thwaites[1], Catherine Reid[1], Darren Gravley[2] and Deirdre Hart[3]

School of Earth and Environment, University of Canterbury, Christchurch, New Zealand

michael.thwaites@pg.canterbury.ac.nz

Governor’s Bay is one of three major bays in the upper harbour of Te Whakaraupō/Lyttelton, Banks Peninsula, that contains an extensive intertidal mudflat. While natural features of the landscape, these mudflats are thought to be accumulating sediment at an enhanced rate as a result of intensive land use within the harbour catchment. This poses risks for native marine ecologies, recreational use of the harbour, mahinga kai opportunities and shipping/dredging operations at Lyttelton port.

We identify key erosion hotspots and sediment deposition patterns in the upper harbour using differential aerial LiDAR and imagery, sediment grainsize analysis, x-ray fluorescence for geochemical fingerprinting of sediment provenance, simple hydrological modelling and interpolated bathymetric mapping from single-beam echo sounding surveys. Data collected will be analysed and processed using GIS software (ArcGIS) producing a complete upper harbour map that highlights areas of hillslope erosion and identifies the geochemical nature of sediment in the Governor’s Bay catchment. Using the combined methodology will hopefully yield a detailed description of hillslope erosion pathways and sediment circulation patterns within the intertidal and subtidal areas of the upper harbour. If successful, this could be a very useful multidisciplinary approach to assessing catchment-scale sedimentation processes. Our results will provide a baseline for decision-making by stakeholders in the Whaka-Ora Healthy Harbour district plan in prioritising remediation and restorative efforts.

ORAL
Session 4b.

2016 Kaikōura earthquake turbidite shows that a single core could be representative of the seismic history of a submarine distributary system

Stephanie Tickle[1], Jamie Howarth[1], Alan Orpin[2], Katherine L. Maier[2], Lorna J. Strachan[3] and Scott D. Nodder[2]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, P.O. Box 600, Wellington 6012, New Zealand*
[2] *National Institute of Water and Atmospheric Research, Private Bag 14901, Wellington 6241, New Zealand*
[3]*School of Environment, University of Auckland, Private Bag 92019, Auckland 1142, New Zealand*

stephanie.tickle@vuw.ac.nz

Subduction zones are the source of the largest seismic and tsunami hazard on earth, yet our understanding of past earthquakes and how they are represented in the geological record is limited. Submarine turbidite paleoseismology provides an avenue by which the history of subduction zone earthquakes can be examined quantitatively, using turbidites emplaced following earthquake shaking as a 'natural seismometer'. As terrestrial paleoseismic evidence can be discontinuous and localised, continuous sedimentary records preserved in offshore continental slopes and sedimentary basins offer a viable alternative. However, the marine realm is not without its own complexities. Studies of ancient channel and canyon systems highlight that the number of turbidites preserved in such environments, and their character, can vary with height above the channel or canyon thalweg. This could be problematic for submarine turbidite paleoseismology studies that are often limited to scattered single cores across discrete distributary systems to accurately determine the presence or absence of turbidites along portions of a subduction margin.

The 2016 M_w 7.8 Kaikōura earthquake provides an unprecedented opportunity to examine the detailed distribution of co-seismic turbidites preserved in the southeastern Cook Strait region of the Hikurangi subduction margin. We present results from a dense array of sediment cores recovered from cross-sections of the Opouawe, Campbell and Hikurangi canyon/channel systems. The Kaikōura event bed is preserved ubiquitously across the channel-levee transect, but is most complex in the channel, particularly within the Hikurangi Channel. However, on the canyon walls the sedimentary structure of the Kaikōura event bed is remarkably consistent. Based on our observations, for the first time we can infer that a single, well-placed sediment core above the channel, may indeed be representative of the earthquake history of the entire distributary system. This result provides significant confidence for turbidite paleoseismology approaches applied globally.

ORAL
Session 2e.

The Southern Alps Long Skinny Array (SALSA): Virtual Earthquake Analysis of Future Alpine Fault Earthquakes and Ground-Shaking

John Townend[1], Caroline Holden[1,2], Calum Chamberlain[1], Emily Warren-Smith[3], Ilma del Carmen Juarez-Garfias[1], Olivia Pita-Sllim[1], Marine Denolle[5], Finnigan Illsley-Kemp[1], Olivia Mark[1], Ashleigh Matheson[1], Ross McGregor[1], Jessie Schuler[1], Kasper van Wijk[5], Andrew Curtis[6], and Hiroe Miyake[7]

[1] *School of Geography., Environment, and Earth Sciences, Victoria University of Wellington*
[2] *SeismoCity Ltd., Wellington*
[3] *GNS Science, Lower Hutt*
[4] *Earth and Planetary Sciences, University of Washington, Seattle, Washington, USA*
[5] *Department of Physics, University of Auckland, Auckland, New Zealand*
[6] *School of Geosciences, University of Edinburgh, Edinburgh, UK*
[7] *Earthquake Research Institute, University of Tokyo, Tokyo, Japan*

john.townend@vuw.ac.nz

Ground motions of societal concern are controlled by a combination of near-source conditions—the distribution, direction, and speed of rupture—and by the effects of three-dimensional variations in elastic and anelastic structures further afield. A key component, and challenge, of seismic hazard forecasting is to construct a comprehensive suite of geologically- and geophysically-plausible but as-yet unobserved rupture scenarios, and to evaluate the shaking from each one. This is a particularly pressing question in the case of the Alpine Fault, which is recognised as being late in the typical interseismic phase of its earthquake cycle with the likelihood of a M_w>7 earthquake occurring in the coming 50 years estimated to be 75% (29–99%; 95% confidence interval).

Here, we review recent results from field and modelling studies of the Alpine Fault and discuss how they can be incorporated in assessments of large-earthquake ground motions via "virtual earthquake" methods. Using data from the Southern Alps Long Skinny Array (SALSA), consisting of broadband sensors spaced 10–12 km apart along a ~450 km length of the Alpine Fault, and from seismometers and high-rate geodetic sensors throughout southern New Zealand, we can synthesize seismograms ("Green's functions") representing the farfield response to incremental slip anywhere on the fault surface. By convolving these Green's functions with kinematic rupture models incorporating observational constraints on along-strike and down-dip heterogeneity, present-day seismicity, and fault zone properties, we can compute ground motions at locations of interest in response to large numbers (millions) of plausible ruptures. This will enable us to comprehensively explore how the Alpine Fault's structure, heterogeneity, and present-day state will affect earthquake slip and ground-shaking in future large earthquakes.

ORAL
Session 1d.

Comprehensive update of marine reservoir values for New Zealand coastal waters to inform coastal hazard research

Jocelyn C Turnbull[1,2], Kate J Clark[1], Bruce A Marshall[3], Taylor Ferrick[2], and Jamie D Howarth[4]

[1] GNS Science, Lower Hutt, New Zealand
[2] University of Colorado at Boulder, USA
[3]Te Papa Tongarewa, Wellington, New Zealand
[4]Victoria University of Wellington, New Zealand

j.turnbull@gns.cri.nz

Accurate dating of coastal hazard events such as earthquakes and tsunamis typically hinges upon marine radiocarbon ages, and a well-constrained marine reservoir correction is vital to evaluating the size and frequency of large to great subduction earthquakes and tsunamis. Yet in New Zealand, we have relied on only 31 ΔR values from four locations to estimate ΔR for the entire coastline. Here we add 170 new measurements to the marine reservoir correction dataset for the mainland New Zealand and evaluated the influence of location, feeding method, living depth, environmental preference and species on the variance in ΔR values. We find there are no significant differences between ΔR values from suspension-feeding organisms compared to browsing/scavenger/carnivore-feeding organisms, and we find little variability between species that prefer estuarine environments to open coastal environments. This means that when dating shells from geological records, we do not need to take particular care to avoid certain species that may have anomalies of carbon precipitation in their shells. Importantly, location is the dominant control on ΔR variability and we recommend the subdivision of New Zealand into five large regions, each with a different ΔR value.

POSTER
Session 4d.

Plate boundary intracontinental transfer across the developing Marlborough Fault System, New Zealand

Phaedra Upton[1], Andy J. Tulloch[2], James S. Crampton[3], Alison Duvall[4], Matt Sagar[1], Donna Eberhart-Phillips[2], Susan Ellis[1], Rob Langridge[1], and Dougal Townsend[1]

[1] GNS Science – Te Pū Ao, PO Box 30368, Lower Hutt 5010, New Zealand
[2] GNS Science – Te Pū Ao, Private Bag 1930, Dunedin, New Zealand
[3] School of Geography, Environment and Earth Sciences, Victoria University of Wellington Te Herenga Waka, Wellington, New Zealand
[4] Department of Earth and Space Sciences, University of Washington, Seattle, WA 98195, USA

p.upton@gns.cri.nz

Here we review, synthesise, and add new data to understand the tectonics of the Marlborough region with emphasis on variations along and across strike, with depth and in time. We consider tectonic history with constraints from thermochronology, structural geology, and landscape processes. To understand the active deformation occurring under the present tectonic regime, as manifested by recent complex faulting during the 2016 Mw 7.8 Kaikōura earthquake, we focus on understanding the 3D structure of the region as well as the development of, and control by, inherited structures.

Cretaceous restoration of eastern Marlborough suggests that the major faults formed during extension of Te Riu-a-Māui Zealandia preceding breakaway from Gondwana. Overall, given the uncertainties of the reconstruction, the Cretaceous structural similarity of paleo-Marlborough with wider South Zealandia seems a remarkably clear and consistent match. How much of that distinctive landscape is due to the constraints of the current plate boundary versus the influence of tectonic inheritance? Relative motion along and surface processes associated with faulting have contributed to the development of the distinctive landscape of the northern South Island. We argue that structural inheritance has played a significant role in determining fault development and evolution.

The boundary conditions impacting Marlborough have changed significantly over at least the past ca. 10 Ma due to the rapidly evolving nature of the plate boundary. The present-day brittle upper and underlying ductile crust of Marlborough is being transferred from the Pacific to the Australian Plate. Shear between Marlborough lower crust and the underlying Pacific oceanic crust is localised within the lowermost ductile lower crust above the underplated mafic crust. Southeast of the Hope Fault, the change in the nature of the lower crust from weak ductile to strong brittle rocks will fundamentally alter the future dynamics of the leading edge of the evolving plate boundary.

ORAL
Session 1c.

NZ NSHM 2022: Geologic and Subduction Interface Deformation Models

Russ Van Dissen[1], Hannu Seebeck[1], Laura M Wallace[1,2], Chris Rollins[1], Matt C Gerstenberger[1], Andy Howell[1,3], Chris DiCaprio[1], and Charles A Williams[1]

[1] GNS Science, 1 Fairway Drive, Avalon, Lower Hutt, New Zealand
[2] University of Texas, Institute for Geophysics, Austin, Texas, USA
[3] University of Canterbury, School of Earth and Environment, Christchurch, New Zealand

r.vandissen@gns.cri.nz

Following the UCERF3 workflow (Field et al. 2014), deformation models provide the locations, geometries and slip rates of the earthquake-producing faults explicitly modelled within the NZ NSHM 2022. Within that model, the two main deformation model classes are upper plate, and subduction interface.

With only slight amendments, the upper plate geologic deformation model is derived directly from the fault geometries and slip rates characterized in the NZ Community Fault Model version 1.0 (NZ CFM v1.0) (Seebeck et al.2022).

The geometry and slip deficit rates for the Hikurangi–Kermadec subduction interface deformation model are blends of different data, constraints and interpretations that are available for the Hikurangi and Kermadec portions of the interface. The geometry of the Hikurangi–Kermadec subduction interface deformation model is a linear blend of the Hikurangi interface geometry of Williams et al. (2013) and the Slab 2.0 Kermadec interface geometry of Hayes et al. (2018), and extends north from the Chatham Rise to the Louisville Ridge. Derivation of slip deficit rates on the Hikurangi portion of the deformation model are founded on the well-established block modelling methods described in Wallace et al. (2004, 2012) with “locked to trench” and “creeping at trench” slip deficit rate renditions defined. Slip deficit rate for the Kermadec portion of the Hikurangi–Kermadec subduction interface deformation model is based on convergence rate and locking (coupling coefficient) considerations. The two Hikurangi slip deficit rate renditions (‘locked to trench’ and ‘creeping at trench’) are smoothly combined with the single Kermadec slip deficit portrayal to yield two alternative slip deficit rate characterisations for the Hikurangi–Kermadec interface.

The geometry of the Puysegur subduction interface is taken directly from the NZ CFM v1.0. adopting a “cut by the Alpine Fault” rendition, and the slip deficit rate is derived from plate convergence rate and interface coupling considerations.

POSTER
Special Symposium

Seismic methods for three-dimensional imaging to depth of the crust under the Auckland Volcanic Field

Kasper van Wijk, Josiah Ensing, Bernhard Spörli, Gugi Ganefianto, and Simon Barter

The active, monogenetic, and intraplate Auckland Volcanic Field (AVF) poses a considerable risk to the largest city of New Zealand. A full understanding of the mechanisms driving AVF volcanism is hampered by a lack of detailed structural information on the deeper crust and lithosphere.

We present an overview of seismic studies that probe crustal properties under the AVF, to complement an extensive body of geologic and geochemical studies. A 3D image of the AVF crust emerges from these studies with features that align with the NNW-SSE trend also presented by the Junction Magnetic Anomaly (JMA) in the Dun Mountain/Matai Terrane and from geological mapping of basement features. Beneath and east of the AVF, in the Waipapa Terrane, a mid-crustal wedge with low seismic speed thins towards the east, while west of the AVF a crust with higher seismic speed consists of thickened crust composed of the Dun Mountain/Matai Terrane, overlain by Murihiku Terrane. Most intriguingly, the 3D model from ambient seismic noise shows a sharp, vertical, NNW-SSE striking seismic discontinuity extending at least 15 km in depth, positioned under Rangitoto, the youngest and largest volcano of the AVF and lying within a major long-lived fault zone that upthrows basement to the East. Preliminary work with seismic travel time anomalies from teleseismic body waves agrees with such a discontinuity, and seismic body waves from local earthquakes and quarry blasts may also require such a strong near-surface seismic speed contrast to fit the data. Additional acquisition of such seismic data could improve knowledge of the deeper structure below the AVF so much that the volcanic processes can even be explored with geodynamic modelling.

POSTER
Session 1d.

Novel techniques for reconstructing relative changes in past UV-B flux

Bert Verleijsdonk[1], Timothy Anane[1], Katherine A. Holt[1], Barry H. Lomax[2], Phillip E. Jardine[3], and Marcus J. Vandergoes[4]

[1] School of Agriculture and Environment, Massey University, Palmerston North, New Zealand
[2] School of Biosciences, University of Nottingham, Sutton Bonington, United Kingdom
[3] Institute of Geology and Palaeontology, University of Münster, Münster, Germany
[4] Palaeontology department, GNS Science, Lower Hutt, New Zealand

B.Verleijsdonk@massey.ac.nz

Many climate and environmental parameters can now be reconstructed over geological timeframes via biological, geochemical, biogeochemical and sedimentological proxies. However, reconstructions of past variations in UV-B radiation are comparatively limited, due to a lack of suitable proxies. Given the threat that UV-B radiation poses to both human and ecosystem health and ecosystem processes; there is a need for a better understanding of past UV-B flux to appreciate the challenges further elevated surface UV-B levels could pose in the long-term.

Sporomorphs (pollen and spores) contain UV-B absorbing compounds (UACs) in the sporopollenin biomacromolecule which forms their outer walls. UACs function as a natural ‘sunscreen’, protecting the gametes within the sporomorph from damage caused by exposure to UV-B radiation. Empirical and experimental studies have determined that UACs are ubiquitous in sporopollenin, and that the quantity increases with increased exposure of the parent plant to UV-B. Because sporopollenin is highly resistant to decay, sporomorphs are abundant in the fossil record, and their UAC content stays stable over time, sporomorphs offer an avenue for the reconstruction of surface UV-B flux through time.

We present preliminary results from our project in which we are using Fourier Transform infrared (FTIR) microspectroscopy to measure UACs within sporomorphs from two lake sediment records: Lake Ohau (New Zealand) and Nar Gölü (Türkiye). One of our project aims is to produce the first sporomorph-based UAC record from the Southern Hemisphere. To deliver this, we will target at least two taxa native to New Zealand within the Ohau record, to produce a high-resolution (biennial) record for the Maunder Minimum, and a low-resolution record for the entire Holocene. A further aim is to deliver a complimentary dataset using a similar sampling strategy from Nar Gölü, (Türkiye) in order to undertake an interhemispheric comparison of UAC records of UV-B variation through time.

ORAL
Session 2c.

Modelling outgassing through channelling in vulcanian eruption.

Juliette Vicente[1], Marielle Collombet[2] and Alain Burgisser[2]

[1] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*
[2] *Institute of Earth Sciences (ISTerre), Université Savoie Mont Blanc, Le Bourget-du-Lac, France*

jvicente@massey.ac.nz

An andesitic magma, although very viscous, can degas through efficient percolation mechanisms. Among them, the ability of gas bubbles to connect to form permeable networks is the most studied mechanism and was assumed to be dominant until now. However, recent studies on Vulcanian eruptions products have shown that the volcanic conduits considered were filled, for the most part, with magma of low porosity (<10 % vol). In comparison with models of degassing in a closed system, these observed porosities are much lower, suggesting a more efficient degassing mechanism depleting the magma of volatiles as it ascends the column. Relying on the studies of Parmigiani et al. [2017] and Degruyter et al. [2019], we hypothesize a channelling mechanism for this efficient degassing at a high crystal content (between 40 and 70 % of the volume). Using COMSOL Multiphysics software, we simulated the gas fluxes, through the conduit/atmosphere and conduit/surrounding rocks interfaces, associated with the permeability of channelling in an immobile magma column. Porosity and crystallinity data (Collombet et al. [2021]) from three recent Vulcanian eruptions of Merapi (Indonesia), Soufriere Hills (Montserrat), and Tungurahua (Ecuador) were used. The fluxes modelled for the three eruptions are very high because they are associated with channelling permeabilities 2 to 5 orders of magnitude higher than other degassing mechanisms commonly considered. The Tungurahua eruption caught our attention, because the presence of an impermeable "lid" (in which the conditions of channelling are not fulfilled), leads to a pressurization of the system and to quite important lateral flows which are not able to compensate the absence of surface flows. Moreover, an increase in the initial pressure of the system leads in this case to a decrease in the gas flows.

POSTER
Session 1b.

Fault Ruptures Triggered by Large Rhyolitic Eruptions at the Boundary Between Tectonic and Magmatic Rift Segments: The Manawahe Fault, Taupō Rift, New Zealand

Pilar Villamor[1,] Nicola J. Litchfield[1], David Gomez[2], Fidel Martin-González[2], Brent Alloway[3,4], Kelvin Berryman[1,5], Kate Clark[1], William Ries[6], Andrew Howell[1,7], and India A. Ansell[8]

[1] GNS Science, PO Box 30-368, Lower Hutt 5040, New Zealand
[2] ESCET- Area de Geologia, Universidad Rey Juan Carlos, C/Tulipan s/n, 28933 Madrid, Spain
[3] School of Environment, University of Auckland, Private Bag 92019, Auckland 1142, New Zealand
[4] Instituto de Geografía, Pontificia Universidad Católica de Chile, Santiago, Chile
[5] Berryman Research and Consulting, 18 Cluny Road, Plimmerton, Porirua 5026, New Zealand
[6] Prae Doc, Department of Geography and Regional Research, University of Vienna, Universitätsstraße 7, A-1010 Vienna, Austria
[7] Department of Geological Sciences, University of Canterbury, Christchurch, New Zealand
[8] 8 Talavera Tce, Kelburn, Wellington 6012, New Zealand

p.villamor@gns.cri.nz

The Manawahe Fault is located at the boundary between the tectonic Whakatane and the magmatic Okataina segments of the Taupō Rift. We investigate prehistoric ground surface fault ruptures and their timing in association with volcanic eruptions of the Okataina Volcanic Centre (OVC), using geomorphic fault mapping, paleoseismic trenching, ground penetrating radar and shallow drillcores. Paleoseismic trench data across the major strand shows that the Manawahe Fault ruptured at least seven times in the last c. 9.5 cal. ka (with a possible rupture 8 just prior to c. 9.5 cal. ka). At least four of these surface fault ruptures occurred during, or immediately prior to, volcanic eruptions. These eruptions, named Whakatane (c. 5.5 ka – 1 fault rupture), Mamaku c. 8 cal. ka -1 fault rupture), and the Rotoma (c. 9.5 cal. ka - 2-3 fault ruptures), were all sourced from the nearby Haroharo Volcanic Complex nested within the OVC, one of the 2 currently active volcanic lineaments within the OVC. Ground penetrating radar and drillcore data show that the Manawahe Fault has a slip rate of c. 3 mm/yr and that it only formed recently (< 26.5 ka ago), much more recently than the last caldera forming eruption, the c. 61 ka Rotoiti eruption. Fault rupture recurrence is 1580-2000 years. We discuss possible modes of ruptures of the Manawahe Fault in association with modes of volcanic unrest and magmatic processes; whether these prehistoric ruptures were seismogenic or not, and what the implications are for volcanic and seismic hazard.

ORAL
Session 1e.

Influences on lahar preparedness in Mount Rainier, USA, communities

Lauren Vinnell[1], Emma Hudson-Doyle[1], David Johnston[1], Julia Becker[1], Lucy Kaiser[1], Michael Lindell[2], Ann Bostrom[2], Chris Gregg[3], Maximilian Dixon[4] and Brian Terbush[4]

[1] *Joint Centre for Disaster Research, Massey University, New Zealand*
[2] *University of Washington, Seattle WA, USA*
[3] *East Tennessee State University, Johnson TN, USA*
[4] *Washington State Emergency Management Division, Camp Murray WA, USA*

l.vinnell@massey.ac.nz

Communities living near snow-capped volcanoes are often at a high risk of lahar and other debris flow impacts, with several devastating events in recent global history such as the loss of over 23,000 lives in Colombia in 1985. One such volcano which poses a significant lahar risk is Mount Rainier, Washington, United States which has a large amount of glacial ice and snow. Over 150,000 people live near this volcano and are at risk from potential impacts. In order to reduce the likelihood of negative outcomes for these communities, it is important to understand how they perceive and prepare for this risk. An online survey (*N* = 830) found differences based on demographic, social, and behavioural factors which could have implications for communication and engagement with these communities. For example, men saw themselves as more prepared and had weaker intentions to prepare, self-perceptions of preparedness as well as likelihood of having an emergency kit were highest among those who neither live nor work in a lahar hazard zone, and self-efficacy and intentions to evacuate appropriately were better among those who had practised drills and evacuation. These findings demonstrate the importance of considering and understanding the particular context of communities at risk of volcanic impacts when determining how to communicate that risk and how to encourage preparedness actions.

POSTER
Session 3a.

Digitising and Vectorising Paper Seismograms in the National Earthquake Information Database

Paul Viskovic[1], Clark Williams[1], Annemarie Christophersen[1], and Jonathan Hanson[1]

[1] GNS Science, Avalon, Lower Hutt, New Zealand

p.viskovic@gns.cri.nz

As part of the nationally significant Earthquake Information Database, GNS Science maintains a unique, non-repeatable record of New Zealand seismicity dating back over 100 years. These original paper seismograms were recorded from 1900 to 2005, cover all of mainland New Zealand, as well as extending from the Pacific Islands to Antarctica.

The history of instrumental seismology is short and collections of digital recordings even shorter especially in comparison to geological hazard cycles, which results in a relative scarcity of records for large historical earthquakes. This limits our ability to re-analyse historical events using modern analytical techniques. GNS Science is undergoing a process to digitise and vectorise this collection, to help encourage collaboration with external researchers and ensure that this unique dataset is available at a time of significant advances in seismology and data science.

We will highlight recent efforts in collating and scanning a collection of significant earthquakes, digitising and making available all Annual NZ Seismological Reports, and publishing records of instrument metadata and deployment dates. Also, we will share our findings from testing vectorising tools to increase the utility of the paper seismogram collection.

ORAL
Session 2a.

Geodetic deformation model for the 2022 New Zealand National Seismic Hazard Model

Laura Wallace[1,2], Kaj Johnson[3] Jeremy Maurer[4], Ian Hamling[1] Charles Williams[1], Chris Rollins[1], Matt Gerstenberger[1] and Russ van Dissen[1]

[1] GNS Science, Lower Hutt, New Zealand
[2] University of Texas Institute for Geophysics, Austin, Texas, USA
[3] Indiana University, Bloomington, Indiana, USA
[4] Missouri University of Science and Technology, Rolla, Missouri, USA

lwallace@utexas.edu

Geodetic measurements of crustal deformation in plate boundary zones enable quantification of the modern-day distribution and rate of tectonic strain accumulation, and contain important information about future earthquake rates. Such measurements have been undertaken in New Zealand since the early to mid-1990's. One of the major new components of the 2022 update of the New Zealand National Seismic Hazard Model (NSHM) is incorporation of a fault source model based on geodetic data. Previous versions of the NSHM contained some basic information from geodetic studies, such as informing fault slip rates on some faults in the NSHM where geologic slip rate constraints were not available, and utilizing geodetic coupling studies to inform the Hikurangi subduction interface fault source. However, the degree to which geodetic data were utilized in the earlier versions of the NSHM was limited.

To incorporate geodetic measurements of contemporary deformation into the NSHM, we utilize strain rate and fault slip deficit rate models derived from New Zealand's interseismic campaign GPS velocity field spanning 1995-2013. The strain rate maps (derived from the GNSS velocity field using four very different methods) are used to underpin "backslip models" that invert the suite of strain rate models for slip deficit rates on all of the crustal fault sources to derive a geodetically-based fault source model. Most of the fault slip rates agree well with those estimated geologically, with a few exceptions where the geodetic data suggest higher fault slip rates (such as northern Canterbury), and in some cases lower slip rates (e.g., parts of the Wellington fault). This source model has been incorporated into the NSHM in a similar way that the geologically based fault source models are used, and the two models are weighted equally in the Seismicity Rate Model. The geodetic strain rate models we have developed are also being used in a multiplicative hybrid model inform the background seismicity model.

POSTER
Session 3b.

Run for the Hills! - Co-Design of Games for Geological Disaster Risk Communication

Kieron Wall[1], Ben Kennedy[2], Simon Hoermann[3], Heide Lukosch[1], Kirke Sawrey[4] and Mereana Wilson-Rooy[5]

[1] HIT Lab NZ, University of Canterbury, New Zealand
[2] School of Earth and Environment, University of Canterbury, New Zealand
[3] School of Product Design, University of Canterbury, New Zealand
[4] Te Kura O Te Paroa, Whakatane, New Zealand
[5] GNS, Wellington, New Zealand

kieron.wall@pg.canterbury.ac.nz

In this research, we will present how serious games, games that support learning, can be designed to communicate volcanic-tsunami risks to New Zealand school children educated in a bi-cultural environment. Appropriately designed risk communication resources for children can reduce societal vulnerability to natural hazards.

Serious games can be an effective pedagogy for children to learn, yet the research gaps are extensive. This research presents data from working with a Māori language kura to co-design a serious game for tamariki about tsunami risk communication and evacuation strategies. Our methods use data collected from children and teacher's feedback and observations from a workshop during a week-long GNS science led Geocamp learning activity. The results suggest a hybrid, locally situated game with 3D elements as a viable design approach. Hybrid games are games that combine physical elements like a board and tokens, with digital content such as a mobile application. Further game ideas collected include, but are not limited to, playable avatars, the use of te reo Māori, and voices heard.

In addition to observing and reflecting on the children's game ideas, interviews with kura māhita and geoscience experts will be conducted. These will help focus ideas for the game within constraints of the school and science research. Once results are collected, children will be able to vote for the final design of a game they would like to play.

The game will be designed in a way that east coast Aotearoa locals will be able to connect to the game whilst playing and learning about tsunami risk and evacuation strategies.

We will present our insights in the co-design process, first game design concepts and the overall value of games in earth ako at the GeoScience conference.

POSTER
Session 3b.

COMCOT tsunami simulation model – features and recent applications

Xiaoming Wang[1], **William Power**[1], **Aditya Gusman**[1], **and Philip L.-F. Liu**[2,3]

[1] *GNS Science, Lower Hutt, New Zealand*
[2] *National University of Singapore, Singapore*
[3] *Cornell University, Ithaca, USA*

x.wang@gns.cri.nz

COMCOT (Cornell Multi-Grid Coupled Tsunami) is a numerical model to simulate tsunami processes, including its generation, propagation, run-up, and inundation. Initially born at Cornell University, USA, this modelling tool has been under development at GNS Science, New Zealand since 2009. Multiple source mechanisms, such as earthquakes, landslides, ground-motions, inflow conditions, and air-pressure anomalies, have been developed and dynamically coupled with tsunami simulations.

The model uses modified staggered leap-frog finite difference schemes to solve conservative forms of governing equations describing tsunami, floods and river flows, together with shock-capturing upwind schemes and breaking algorithms for improved accuracy, stability and extended range of validity, e.g., across shocks or hydraulic jumps. It supports both Spherical and Cartesian coordinates and their combinations, providing flexibilities to tsunami investigations ranging from global-scale tsunami hazard analyses to local-scale coastal impact assessments. A flexible two-way nested grid system is implemented in the model to balance computational efficiency and spatial accuracy and to meet spatial resolution requirements as tsunami evolves from its source to coast areas. It uses a relatively large grid spacing to efficiently calculate transoceanic tsunami propagation in deep ocean and telescopes to refined grid spacing in coastal areas of interest to resolve highly detailed spatial and temporal evolution of tsunami.

This model has been widely used by researchers to study various aspects of tsunami, including source mechanisms, transoceanic behaviours, coastal impacts, as well as effects of rivers, tides and sea level rises on tsunami hazard risk assessments. We will present major features and functionalities of this model and some of its recent applications, including the 2018 earthquake and landslide triggered tsunami in Palu Bay of Indonesian, landslide tsunami and ground-motion induced seiching in Lake Tekapo of New Zealand and the tsunami waves excited by air pressure waves from the 2022 Hunga Tonga Hunga Ha'apai eruption.

ORAL
Special Symposium

High-resolution images of paleo-pockmarks on the Chatham Rise using densely spaced echosounder profiles

Fynn Warnke[1], Ingo A. Pecher[1,2], Jess I.T. Hillman[3], Bryan Davy[3] and Lorna J. Strachan[1]

[1] School of Environment, University of Auckland, Auckland, Aotearoa New Zealand
[2] Texas A&M University - Corpus Christi, Corpus Christi, Texas, United States
[3] GNS Science, Avalon, Lower Hutt, Aotearoa New Zealand

fynn.warnke@auckland.ac.nz

Seafloor depressions, known as pockmarks, are commonly observed features on the ocean floor. Their shape and size can range from small, circular indentations (10s m) up to large, often irregularly shaped depressions (several kms in diameter). The origin of pockmarks is often attributed to focused fluid or gas seepage at the seafloor, but their formation mechanisms (e.g., gas/fluid composition, timing, physical processes) remain ambiguous in many cases. Seismo-acoustic imaging allows the investigation of potential fluid-flow pathways and buried paleo-pockmarks. 3D multi-channel seismic surveys provide comprehensive insights of the imaged subsurface; however, the acquisition of 2D profiles is far more common. The lower frequencies (~20-1000 Hz) of traditional marine seismic sources (e.g., air gun or sparker) provide deeper subsurface penetration at the expense of vertical resolution. In contrast, high-resolution imaging of shallow subsurface features can be conducted using hull-mounted, parametric subbottom profilers that are available on most larger research vessels. Higher frequencies (>1 kHz) and narrow acoustic beams provide very high vertical resolution (decimetre range) and small lateral footprints capable of resolving smaller structures than using conventional seismic. A recent voyage in 2020 acquired an extensive grid of closely spaced (~25 m) 2D sub-bottom profiles over a dense pockmark field on the Chatham Rise, offshore New Zealand's South Island.

Here we present a novel approach to create a comprehensive pseudo-3D cube from high-resolution 2D echosounder profiles using a custom-developed processing workflow. This cube allows us to perform a preliminary analysis of seafloor pockmarks and the paleo-pockmark field underneath. Our analysis includes insights into the recurrence of pockmark formation at different geological times and an assessment of morphological changes and varying spatial locations. Additionally, we illustrate a potential polygonal fault network beneath the lowermost layer of paleo-pockmarks that might channel upward fluid migration in the area.

ORAL
Session 4a.

Is this the real life? Is this just fantasea? Caught in a landslide: Megablocks from the Deepwater Taranaki Basin.

Georgia Warren[1], Lorna Strachan[1] Suzanne Bull[2], Jess Hillman[2], Sally Watson[3,1], Malcolm Arnot[2] and the TAN2205 scientific party[2,3]

[1] School of Environment, The University of Auckland, Auckland, New Zealand, [2] GNS Science, [3] NIWA.

gwar900@aucklanduni.ac.nz

“Megablocks” are large (kilometre scale) volumes of relatively undeformed strata transported and preserved within major slope instability events. These events may have catastrophic effects on marine habitats, seafloor infrastructure, and can also generate tsunami. Megablocks are a feature of the Deepwater Taranaki Basin, located in the eastern Tasman Sea off the West Coast of the North Island, New Zealand. These blocks are found within a submarine landslide deposit which occurred an estimated 1.5 million years ago. First identified using seismic reflection data, the megablocks within the landslide deposit are up to 300 m high and 1.8 km across. However, due to their partial burial beneath the modern seafloor, these estimates may be conservative. Moreover, the megablocks form positive relief features that can focus fluid flow and create localised oases of abundant marine habitats in deep marine environments. This study explores one of the megablocks located proximal to the continental shelf, using datasets obtained on two recent marine voyages on RV Tangaroa. These voyages were led by GNS Science and NIWA in their Te Tai-o-Rēhua - Silent Tsunami project. Multibeam bathymetry data collected during the first voyage revealed the presence of numerous megablocks visible on the modern seafloor, despite partial burial by younger covering sediments. We present the results of sedimentological analysis of long cores collected from on top of one megablock, and from the adjacent moat feature surrounding it. Results yield insights into the impact of megablocks on seafloor topography and on the evolution of subsequent deepwater sedimentation.

POSTER
Session 2.e

Evidence for Spatially Heterogeneous Megathrust Fluid Valving in the Northern Hikurangi Subduction System

Emily Warren-Smith[1]

[1]*GNS Science, Lower Hutt, New Zealand*

e.warren-smith@gns.cri.nz

Recent studies observe a temporal link between fluid pressure and slow slip event (SSE) cycles in subduction zones via a 'valving' model. However, it remains unclear if this is a spatially distributed process or whether discrete sites are responsible for valving fluid, and over what length scale this occurs. Spatial localisation of valving would enable specialised, targeted experiments to be designed to monitor temporal changes in physical properties occurring in these zones, and better relate their occurrence with slow earthquake cycles.

Here we consider microseismicity datasets alongside geophysical observations from New Zealand's Northern Hikurangi Margin to identify spatially heterogeneous hydrological coupling between the two plates. We identify patches of co-located, differing seismic behaviour, including: interface micro-seismicity, pre-SSE swarms, lower plate strike-slip earthquakes, upper plate swarms and elevated Vp/Vs zones. These patches correlate well with conductive interface regions constrained by magnetotelluric studies and thermal springs exhibiting mantle chemical signatures. We propose these patches represent 'valve' sites at the 10s of kilometre scale, where hydrological coupling between the plates is transiently increased, facilitating episodic fluid valving which may be linked to SSE timing.

We propose these 'valve' sites may be physically related to heterogeneities in permeability along the plate interface, most likely from entrained oceanic mafic fragments, including seamounts, or from localised fluid reservoirs linked to bending related fracturing within the lower plate. These observations contribute to a growing consensus that subduction megathrust faults are inherently heterogeneous, and these heteronegeneities in frictional and fluid related properties may play a role in their ability to host a spectrum of deformation modes.

POSTER
Session 1d.

Using microearthquakes to probe the structure and mechanics of Alpine Fault segment boundaries and quantify implications for future rupture

Emily Warren-Smith[1], John Townend[2], Calum John Chamberlain[2], Carolyn Boulton[2], Julian Lozos[3] and Konstantinos Michailos[2,4]

[1] GNS Science, Lower Hutt, New Zealand
[2] School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand
[3] California State University – Northridge, Northridge, California, United States
[4] University of Lausanne, Lausanne, Switzerland

e.warren-smith@gns.cri.nz

Paleoseismic evidence from the late-interseismic Alpine Fault suggests key section boundaries (near Haast and Inchbonnie) conditionally inhibit rupture, but it remains unclear what physical processes control this segmentation. We use data from a two-part seismometer network (DWARFS) to characterise ~7500 earthquakes and ~800 focal mechanisms, producing high-resolution structural images of these boundaries to study the effects of material and structural heterogeneities on mode-switching rupture behaviour.

We find that lithologically controlled frictional behaviour and crustal strength appear to influence lateral and vertical on-fault seismicity distributions. Specifically, ultramafic hanging-wall serpentinite and related fault core minerals along the South Westland (SW) boundary may result in abundant on-fault microseismicity and a localised 30-50% shallowing in seismogenic depths (to ~8km), reducing the fault width available for rupture. Furthermore, we show that a 40º dip change at the SW boundary may be accommodated by either a single through-going fault plane – a difficult geometry across which to obtain multi-segment earthquakes when considering rupture dynamics – or by a deeper vertical fault strand truncated by a shallower listric plane. Despite complex along-strike geometrical variations, we show that rotations in the maximum horizontal compressive stress near boundaries, coupled with spatially variable fault frictional properties are more important than geometry alone in controlling Sections' relative frictional stability. Whereas the SW and Central Sections are well-oriented for failure, the North Westland Section is severely misoriented compared with faults of the Marlborough Fault Zone, which are favourably oriented and possibly facilitate a preferred rupture route.

Finally, we use our high-resolution observations to inform and construct a range of plausible 3D fault geometries on which we perform fully dynamic single earthquake rupture simulations. We present preliminary results from parametric testing designed to ascertain the role geometrical complexities and stress distributions play in influencing rupture segmentation and compare our results to multi-cycle rate-and-state dependent modelling.

ORAL
Session 1d.

Using local infrasound arrays to detect plunging snow avalanches along the Milford Road, New Zealand | Aotearoa

Leighton Watson[1], Brad Carpenter[2], Kevin Thompson[2], Jeffrey Johnson[3], Scott Havens[4] and Jonathan Arthur[2]

[1] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*
[2] *Milford Road Alliance, Te Anau, New Zealand*
[3] *Department of Geoscience, Boise State University, Boise, Idaho, United States of America*
[4] *Snowbound Solutions, Boise, Idaho, United States of America*

leighton.watson@canterbury.ac.nz

Snow avalanches pose a hazard in alpine environments endangering people and property. Observations of snow conditions are combined with weather data to forecast avalanche hazard. Avalanches are predominantly detected by visual observations of the flows in motion or of their deposits. There is a need to improve monitoring capabilities in order to reliably detect and locate avalanche activity, which will help validate avalanche hazard assessments. Recent work has demonstrated the utility of infrasound (low frequency sound waves below human hearing i.e., < 20 Hz) for snow avalanche detection as it can provide continuous monitoring (during the night and periods of low visibility) and broad geographic coverage.

The Milford Road in Fiordland, New Zealand | Aotearoa is the only highway with a permanent avalanche monitoring programme. Size 4 (or larger) plunging avalanches frequently occur the glacial-carved valley where steep cliffs (slope angles can exceed 50^{O}) can reach over 1000 m tall. During 2020, nearly 250 natural and triggered avalanches occurred with one particularly large event transporting 167,000 tonnes of snow!

Here, we present the first use of infrasound to monitor snow avalanche activity in a maritime climate along the Milford Road in Fiordland, New Zealand | Aotearoa. During a month-long pilot study, we deployed two infrasound arrays on the eastern side of the Homer Tunnel and recorded triggered and natural avalanches. We use array processing to identify avalanche signals, calculate back-azimuths, and triangulate source locations. The infrasound amplitudes are substantially (>10x) larger than previously recorded at other locations with a maximum peak-to-peak amplitude of 37 Pa detected for a large triggered avalanche. This reflects that massive scale and unique physics of the plunging avalanches that occur along the Milford Road. This study demonstrates the utility of infrasound for snow avalanche monitoring in maritime climates.

POSTER
Session 1a.

Tracking a pyroclastic density current with seismic signals at Mt. Etna (Italy)

Leighton Watson[1] and Andrea Cannata[2]

[1] School of Earth and Environment, University of Canterbury, Christchurch, New Zealand
[2] Università degli Studi di Catania, Dipartimento di Scienze Biologiche, Geologiche e Ambientali - Sezione di Scienze della Terra, Catania, Italy.
[3] Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo – Sezione di Catania, Catania, Italy.

leighton.watson@canterbury.ac.nz

Pyroclastic density currents (PDCs) are dangerous flows of volcanic rock and gas that are the deadliest proximal volcano hazard. There is significant interest in better understanding PDC dynamics, however, they are challenging to study due to their extreme hazard, infrequent occurrence, and because the complex internal dynamics are obscured by clouds of ash.

Here, we use seismic data recorded by the permanent monitoring network at Mt. Etna (Italy) to track a PDC at second-scale temporal resolution and calculate a mean velocity of 35 m/s (126 km/hr). We identify multiple pulses and show that while the late-stage source locations correspond with the mapped PDC deposits, the PDC initially travelled further to the south. High temporal and spatial resolution measurements of PDC movement from seismic data can be used to inform numerical modelling of PDC dynamics and aid in hazard assessment by improving our understanding of PDC flow paths. This work illustrates how seismic signals can be used to track other surficial mass movements such as lahars, landslides, and debris avalanches.

ORAL
Session 2b.

The underwater landslide archives of Aotearoa/New Zealand: Documenting occurrence or preservation bias?

Sally J. Watson[1, 2], Sam Davidson,[1,3] Jess I.T. Hillman[4], Susi Woelz[1], Suzanne Bull[4], Joshu Mountjoy[1], and Gareth Crutchley[5]

[1] National Institute of Water & Atmospheric Research (NIWA), Aotearoa New Zealand
[2] University of Auckland, Aotearoa New Zealand
[3] Ministry of Primary Industries, Aotearoa New Zealand
[4] GNS Science, Lower Hutt, Aotearoa New Zealand
[5] GEOMAR Helmholtz Centre for Ocean Research, Kiel, Germany

Sally.watson@niwa.co.nz

Documenting and characterising ancient submarine landslide features is fundamental to understanding their distribution and frequency through time. Such information is critical to assess modern hazard potential of submarine landslides. The availability of marine geophysical data spanning ~1,200 km along the eastern Aotearoa/New Zealand provides an excellent basis to map regional trends in landslide occurrence, and better constrain the causes of submarine landslides. Expansive and high-quality bathymetry data have already been used to catalogue >2,200 submarine landslides to understand potential geomorphic and tectonic controls on their emplacement. Of those landslides mapped in bathymetry data, only 1% showed evidence of a preserved Mass Transport Deposit (MTD), and most (68%) landslide scars occur within submarine canyon systems. This suggests that the preservation of MTD in the geological record is rare, and that submarine canyons may be more prone to failure. We present and compare surface landslides with the complementary subsurface database that documents MTD in all available seismic reflection data. Data were collated from >30 marine surveys, encompassing >43,000 km of seismic lines. The subsurface dataset reveals >700 individual observations of MTD, with initial results showing preferential preservation within basin structures and on open continental slopes. The disconnect between the distribution of surface and subsurface MTD suggests the number of MTD preserved in the subsurface likely represents a gross underestimate of landslide occurrence in the geological record. Furthermore, we pose the question: do regional observations of submarine landslide occurrence reflect true tendencies of slopes to fail, or does preservation bias muddy the waters?

POSTER
Session 2e.

The Footprint of Anchoring on the Seafloor

<u>Sally J. Watson</u>[1,2], Marta Ribó[3], Sarah Seabrook[1], Lorna J. Strachan[2], Rachel Hale[1] and Geoffroy Lamarche[2]

[1] National Institute of Water & Atmospheric Research (NIWA), New Zealand.
2 The University of Auckland, New Zealand.
3 Auckland University of Technology, New Zealand

Sally.watson@niwa.co.nz

With the SARS-CoV-2 coronavirus came what media has deemed the "port congestion pandemic". Since it began, thousands of ships have been reported waiting outside heavily congested ports relying on anchoring gear to hold fast. While the shipping industry is known to contribute to air, water and noise pollution, the physical impact of shipping practices, such as anchor use on the seafloor, has received much less attention. With a regional survey using high-resolution (1 m) bathymetry data of a comparatively low congestion port in New Zealand-Aotearoa, we demonstrate that high-tonnage ship anchors excavate the seabed by up to 80 cm and the associated impacts are preserved for at least 4 years. This is the first characterisation of the intensity and extent of damage to the seafloor and benthic environment caused by high-tonnage ship anchoring. We demonstrate that the observed seabed damage is attributed to high-tonnage passenger and cargo vessels. Anchor use in port regions has significantly changed the structure of the seafloor, with downstream impacts on benthic habitats and ecosystem functions. Extrapolating these findings to a global scale, we estimate that between 6,000 and 20,000 km2 of coastal seafloor is adversely affected. With the predicted increase in global marine traffic, a less destructive method of managing high-tonnage vessels awaiting port calls is necessary to mitigate the impact of maritime activities on chemically and biologically important shallow marine environments.

ORAL
Session 2e.

Tsunami Early Warning System: a study case of the North of New Zealand

Emeline Wavelet1, Bill Fry[2], Andrew Gorman[1], and Sarah-Jane McCurrah[3]

[1], Department of Geology, University of Otago, New Zealand.
[2] GNS, Lower Hutt, New Zealand.
[3] EQC, Wellington, Nez Zealand

New Zealand's (NZ) entire coastline is at risk of tsunami from local, regional and distant sources. With more than 75% of New Zealanders living or working within 10 km of the coast, our tsunami risk is significant. Numerous research programmes are being undertaken to better understand, mitigate and respond to tsunami events. One of these research programmes is the Rapid Characterization of Earthquakes and Tsunamis (RCET).

One project within the RCET programme focuses on two main objectives: 1) improving tsunami forecast and the resultant inundation on New Zealand's coasts by analysing seismic and Deep-ocean Assessment and Reporting of Tsunamis (DART®) buoys 2) improving the communication and reducing uncertainty of forecasts to improve advice for emergency response to tsunami events.

Routine tsunami early warning (TEW) forecasts in NZ currently provide limited or no information about wave arrival times and no information about threat duration. By using improved methods based on seismic W-phase and DART analysis, we will provide TEW forecasts that contain estimates of threat duration. For example, within 30 minutes of a significant Kermadec tsunami, we aim to deliver threat maps containing likely maximum coastal amplitudes and duration of coastal tsunami threat for each coastal zone.

New TEW products will be developed in close consultation with relevant stakeholders, specifically Civil Defence Emergency Management (CDEM), NEMA, NZ lifelines and the Māori sector. Ultimately, New Zealand will benefit from increased certainty in inundation, reduced warning times and improved evacuation planning.

POSTER
Session 3a.

Wild Fire Geochemistry: Lessons for Managing Future Impacts on Water Quality

Jenny Webster-Brown[1,2], John Revell[2] and Cassandra Irvine[2]

[1] Our Land and Water National Science Challenge, Lincoln, New Zealand
[2] Waterways Centre for Freshwater Management, University of Canterbury, Christchurch, New Zealand.

Jenny.webster-brown@agresearch.co.nz

Research into the impacts of two major forest wildfires on freshwater in their respective catchments has recently concluded, providing an unprecedented geochemical record of the immediate to short term effects of such fires on water quality. The first of these wildfires occurred in February 2017 in the Port Hill of Christchurch, and the second in the Waimea catchment in Nelson in February 2019. Both were in areas dominated by pine forest, on surficial loess and other fine sediment deposits. The loss of vegetative cover was predicted to increase the erosion of these fine sediments, increasing the sediment load in the receiving water bodies; spring-fed streams draining into the Ōpāwaho/Heathcote River in Christchurch, and the Wai-iti River, a Waimea River tributary, in Nelson.

Immediately following the fire, a stream monitoring programme commenced to detect changes in water systems draining the burnt areas, using an unburnt catchment as a control. Monitoring of stream discharge, and of suspended sediment (TSS), trace element (Fe, Mn, Cu, Pb, Zn, Co, Ni, Cr, As, Cd, Sb, Ge, U and V), major ion, nutrient and organic carbon concentrations continued for over 3 years. Fire-related effects on stream geochemistry included the immediate changes in nutrient concentrations, as reported following forest fires in Australia, but also very high TSS concentrations in Port Hills streams (up to 1900 mg/L) due to loess erosion. Suspended sediment geochemistry was consistent with a direct derivation from local loess deposits for many trace elements, but Cu, Pb, Zn and As were elevated well above the concentrations present in the source loess. Higher fine sediment and attendant trace element loads following such fires, signal the importance of adequately managing suspended sediments during high flow events, as both forest fires and extreme rain events are predicted to become more frequent as a consequence of climate change.

ORAL
Session 4d.

Is Taranaki Exhaling? Detecting Volatile Emissions from a Dormant Volcano

Cynthia Werner[1], C. Ian Schipper[2], Shane J. Cronin[3], Peter H. Barry[4], Michael K. Stewart[5]

[1] *University of Auckland (contractor), New Plymouth, New Zealand*
[2] *Victoria University, Wellington, New Zealand*
[3] *University of Auckland, Auckland, New Zealand*
[4] *Woods Hole Oceanographic Institution, MA, USA*
[5] *Aquifer Dynamics and GNS Science, Wellington, New Zealand*

cwerner@volcanogeochemistry.com

Indicators of volatile emission from subsurface magmas are often subtle at dormant volcanoes. As a result, carbon dioxide (CO_2) emissions from deep magmatic sources can easily go undetected. CO_2 reacts with cold groundwaters in the subsurface, providing a long-term mechanism for deep CO_2 transfer to the surface. While rarely used as a monitoring tool, understanding how dissolved volatiles vary in time could provide important insight into the reawakening of dormant volcanic systems.

Here we provide an update on a geochemical survey of mineral springs and associated degassing at Mount Taranaki volcano, New Zealand. Cold mineral springs (kōkōwai) emerge on flanks between 1.5 to 5 km from the summit, and warm springs are found in a zone ~13 km from the summit on the ring plain. Springs were sampled in 2020 and show little change in their chemistry since the last sampling ~40 years ago. The cold springs degas CO_2 and sometimes hydrogen sulphide (H_2S) as they emerge at the surface. Concentrations of CO_2 and H_2S in the air downwind of some springs have been observed up to 3000 and 0.3 ppmv, respectively. The $\delta^{13}C$ of the dissolved inorganic carbon (DIC) in the Kōkōwai springs is -5.2, suggesting a magmatic source. The correlation of the $\delta^{13}C$ with DIC concentrations in the warm springs point to a Kōkōwai-type primary source water and form a trend that is different to trends observed in waters from sedimentary source rocks that lie directly beneath the volcanics, suggesting a relatively shallow flow path from the summit. Modelling of tritium data suggests a mean residence time of only 7.8 years at the Kōkōwai spring. This young age combined with elevated magmatic DIC suggests present-day degassing of magmatic CO_2 into the upper edifice of Mount Taranaki, and possible steady state degassing over the last 40 years.

ORAL
Session 1b.

Do cyanobacterial blooms occur naturally in dune lakes?

Caitlin Wheeler[1], Susie Wood[2], Katherine Holt[3], Steve Trewick[1], Marcus Vandergoes[4], Xun Li[4], Claire Shepherd[4], John Pearman[2], Jamie Howarth[5], and Chris Moy[6]

[1]*School of Natural Science, Massey University, Palmerston North, New Zealand*
[2]*Cawthron Institute, Nelson, New Zealand*
[3]*School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*
[4]*GNS Science, Lower Hutt, New Zealand*
[5]*Victoria University*
[6]*Otago University*

wheelecait@gmail.com

Cyanobacterial blooms are a major challenge for lake management, as their ecological impact and toxicity can affect a lake's ecosystem functioning and affect social and cultural values. Paleolimnology offers a method to guide restoration and management plans. This field has been enhanced recently by the analysis of environmental DNA that provides greater information on soft-body organisms such as cyanobacteria.

In this study we explored changes in the cyanobacteria community to compare timelines of eutrophication between two contrasting lakes: shallow Lake Alice (3 m) and the deeper Lake Wiritoa (20 m), both in the Whanganui region. Sediment cores collected through the Lakes380 programme were systematically sampled and analysed for a number of proxies including pollen, trace metals, hyperspectral imagery, ITRAX and environmental DNA.

Palynology clearly captured transitions between Māori and European eras in the lakes. Prior to human arrival, the landscape was forested. Lake productivity was stable. After European arrival, vegetation becomes dominated by exotic taxa and grasses. Levels of cadmium (Cd) and lead (Pb) increase markedly. Manganese:Iron shifts suggest that destabilisation of the lakes' oxygen regime, either through erosion and/or increasing biological oxygen demand, is associated with the European era. Increases in chlorophyll-a imply higher lake productivity. Digital droplet PCR (ddPCR) indicates an increase in cyanobacterial biomass beginning in the late Māori to European era. Metabarcoding detected a shift in community composition from picocyanobacterial genera such as *Cyanobium* towards bloom-forming taxa such as *Dolichospermum* and *Microcystis*.

Despite similar trajectories of change, the cyanobacterial communities of both lakes differ. While Lake Alice is dominated by *Dolichospermum*, Wiritoa is primarily affected by *Microcystis*. In both lakes the onset of cyanobacterial blooms correlated with an increase in cadmium, suggesting that the initiation of fertilisation in the catchment played a significant role in the eutrophication of both lakes.

ORAL
Session 2c.

Evolution of geology and groundwater-geothermal systems in the Okataina caldera groundwater catchment

Paul White[1] **and Graham Leonard**[2]

[1] *GNS Science, Private Bag 2000, Taupo, New Zealand.*
[2] *GNS Science, P.O. Box 30-368, Lower Hutt, New Zealand.*

p.white@gns.cri.nz

The Okataina groundwater catchment (OGC), with its large caldera structures and rhyolite domes, 11 lakes, numerous cold groundwater systems and 14 geothermal fields, is a spectacular part of the Taupō Volcanic Zone (TVZ). The 4D evolution of geology and groundwater-geothermal systems in the OGC was described in four phases with models representing: TVZ structure underlying the OGC, i.e. the Kapenga-Whakatane graben (KWG); major volcanic units sourced from within, and outside of, the OGC; estimated paleotopography, caldera lakes, surface drainage (e.g., the paleo-Tarawera River) and the paleo-coastline. Groundwater-geothermal systems were assessed with estimates of paleo-groundwater elevation and of geothermal field age using a hot-spring chloride mixing-model assuming progressive mixing of 'shallow' (cold) and 'deep' (hot) groundwaters over time.

The early-TVZ 'proto- KWG Phase' saw development of the KWG graben, the proto-Tarawera River, and catchment, ending with deposition of Whakamaru Group ignimbrites, sourced south of the OGC. Then, the 'Matahina Phase' included Matahina Formation ignimbrite, deposited over a large area within, and beyond, the OGC. The Matahina caldera, filled or partilly-filled by Lake Matahina, received outflow from the OGC groundwater system and was the location of multiple geothermal fields, probably mostly located on the shores of the lake.

Thirdly, the 'Penultimate Phase' saw development of the Rotoiti caldera, Lake Haroharo, and two large OGC ignimbrite-forming eruptions including Rotoiti Formation sourced from the caldera. Groundwater flowed into Lake Haroharo and geothermal fields developed on the lake shores, including the more-active current geothermal fields, i.e., Waimangu/Pink Terraces. Lastly, the 'Infill Phase' produced today's major OGC landforms, e.g., Mt Tarawera and Haroharo dome complex and separated Lake Haroharo into multiple lakes.

Paleo-lake sediments buried within OGC caldera are an important control on vertical groundwater flow but the location, and properties of these sediments are unknown; deep drilling is recommended to address this knowledge gap.

ORAL
Session 1e.

Short-Term Eruption Forecasting in New Zealand

Melody Whitehead[1], Mark Bebbington[1], Jonathan Procter[1], Matthew Irwin[1], and G. Paul Viskovic[2]

[1] School of Agriculture and Environment, Massey University, Palmerston North, New Zealand
[2] GNS Science, Avalon, Lower Hutt, New Zealand

m.whitehead@massey.ac.nz

We need reliable short-term forecasts for accurate and timely information on the evolving state of our volcanoes. This information directly impacts crisis management from evacuations to exclusion zones, and decisions on when it is safe to return. Eruption forecasting is thus not purely an academic exercise, nor is now the time for 'we-told-you-so' hindcasting demonstrations. To produce a short-term eruption forecast, a method should be selected via a systematic evaluation of options, including a critical assessment of outstanding issues and assumption validity.

There are currently no quantitative short-term eruption forecasts based on peer-reviewed and validated models that are operational for New Zealand's volcanoes. Specific forecasts produced for work-risk assessments are not generally publicised. During a volcanic crisis, eruption forecasts are demanded under high stress and time-restricted conditions. Many forecasting options exist but none are proven as universally viable, with testing and calibration limited to the hindcasting of specific events.

Here, we compare the requirements of six methods with currently available data and monitoring capabilities at each of New Zealand's volcanoes to determine which methods are currently feasible, as well as those options that may be implemented with additional effort or equipment. In New Zealand, the major limiting factor in method selection is the low number of past instrumentally monitored eruptions. This data gap may be filled by carefully selected analogue data from a global volcano set and expert knowledge. Event trees and the failure forecasting method may be set up at most volcanoes with minimal effort, but the latter can only forecast eruption onset time. Expert interpretation is the only method available in New Zealand for any forecast output type. This work addresses the matter of method feasibility; however, questions remain about which methods are most accurate, and which are more likely to be trusted during a volcanic crisis.

POSTER
Session 2a.

The Ghost Uranium Deposit of Niue Island

Neil Whitehead[1] and **Paul Aharon[2]**

[1] Whitehead Associates, 54 Redvers Drive, Lower Hutt, New Zealand, 5010
[2] University of Alabama, 201 7th Ave, Tuscaloosa, AL 35487, USA

neil@chchquake.co.nz

This paper explains the implications of the "ghost" uranium deposit in soils on the raised atoll, Niue Island, in the South Pacific. Niue has soils with anomalously high natural radioactivity rather than fallout, however no economically significant uranium deposit has been found on drilling underlying rock. This type of deceptive geology will occur particularly for uranium. From new interpretation mostly of existing data, the major soil elements probably originated from weathering a mat of floating pumice, either basaltic or andesitic. Uranium however, was concentrated in anoxic sediments and/or below the water lens (a) from seawater (b) from weathered coral aragonite/calcite and dolomite. New interpretation of isotopic evidence shows that after accumulation of radioactive daughter products the uranium was mostly leached away in oxic conditions as the island rose tectonically, and with various sea-level changes.

The geological type-environment of this occurrence is a raised, previously suboxic, atoll, and other new examples discussed in this paper are Lifou (Loyalty Islands), Bellona and Rennell (Solomon Islands) and north Guam. A model of the accumulation conditions may exist in the sediments of the sea-level brackish Lake Tegano (Rennell).

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POSTER
Session 4f.

How and when earthquakes create light

Neil Whitehead[1]

[1] *Whitehead Associates, 54 Redvers Drive, Lower Hutt, New Zealand, 5010*

neil@chchquake.co.nz

The New Zealand Kaikoura earthquake (M_W 7.8, 14.11.2016) resulted in co-seismic flashes of predominantly pale blue earthquake light near the ground in various places, and the sky briefly appeared blue and as bright as midday. This is usually called “earthquake light”. Mostly there was a white hemisphere on the ground, up to 250 m radius, the color becoming increasingly blue further out from the centre, as described in the literature. Fifteen videos were available for analysis from valleys near Wellington, 230 km north of the epicentre. The talk will present the Lower Hutt videos, one of which is unique internationally, and other selected international examples The best geophysical explanation seems to be seismically induced temporary charge separation on silicates, some tens of meters underground and a wave of positive charge reaching the surface and interacting with the air. Colours result from Raleigh Scattering and disappear in a median of 0.6 sec. The Hutt/Wellington data show that the production of light does not depend on being at the epicentre, near a fault, above subsurface seismic-created cracks, or on any particular rock type. It appears to require local forces of about Mercalli scale VII. In spite of its rather apocalyptic appearance the light has not been reported to cause physical harm or damage.

POSTER
Session 1d.

Nature vs Nurture – Quantifying Evolutionary Rate and Ecophenotypic Variation in *Pelicaria vermis*

Callum Whitten[1], **James Crampton**[1] **and Cliff Atkins**[1]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, New Zealand*

ckmwhitten@gmail.com

The fossil record provides the only direct evidence we have for the rate and nature of morphological evolution within lineages of complex animals or plants. Well preserved lineages, with high resolution phenotypic trait data, provide the best opportunity to investigate fine-scale evolutionary trends. The Late Neogene-Quaternary, endemic marine gastropod genus *Pelicaria* is such a lineage. *Pelicaria* are common within the New Zealand fossil record and display rich morphological diversity. This high morphological variability has been interpreted as high species diversity[1], and high plasticity in phenotypic expression[2].

In this study we quantify seven arithmetically independent morphological parameters, which include two coiling rate estimates, namely the rate of anterior aperture translation and rate of whorl expansion[3], two measures of exterior whorl profile, two measures of aperture shape, and the centroid size of the final adult aperture. We use a variety of methods to capture the nature of morphological variation in a biologically meaningful way; each morphological parameter relates directly to how the animal grew and interacted with its environment. To the best of our knowledge this study provides the most thorough quantitative description of gastropod shell morphology ever undertaken.

We quantify these parameters in 296 Plio-Pleistocene *Pelicaria* specimens and analyse the evolutionary modes of each parameter within two geographically separate locations in the Wairarapa. A sedimentary facies-based approach is used to model environmental change throughout each sequence and used to investigate correlations between morphology and environmental variability.

We will present our key findings relating to the roles of evolution and environment on morphological variability within *P.vermis*. The species is shown to evolve following stasis and random walk with little apparent response to environmental trends through time; however it does show short-term population specific variations in several shell characters that are correlated to local changes in environmental factors related to water depth.

POSTER
Session 2e.

Short-Term Eruption Forecasting For the Auckland Volcanic Field Using a Bayesian Event Tree

Alec Wild[1], Mark Bebbington[2] and Jan Lindsay[1]

[1] *School of Environment, University of Auckland, Auckland, New Zealand*
[2] *Volcanic Risk Solutions, Massey University, Palmerston North, New Zealand*

awil302@aucklanduni.ac.nz

Auckland's metropolitan area is situated upon the monogenetic Auckland Volcanic Field (AVF), posing a significant risk to the population. The probability of eruption using monitoring data will provide imperative information for crisis support to make critical decisions, such as when and where to call an evacuation. An approach gaining prominence in eruption forecasting is the use of statistical frameworks, such as the Bayesian Event Tree for Eruption Forecasting (BET_EF). A BET_EF can assess short- and long-term probabilities, depending on the input at each node, which are connected by branches to evaluate an overall state, such as eruption probability. For short-term forecasting, the probability of each branch is controlled by monitoring parameters (e.g. number of seismic events) with associated thresholds and weights.

A previous BET_EF was developed for the AVF as part of the 2008 Exercise Rūaumoko. However, since then there have been significant improvements in the scientific understanding of the AVF, which include constraining the field's geographic extent, spatial vent likelihood, eruptive style, and the age of past eruptions as well as the increased seismic network in Auckland to support monitoring in the field. Hence, as part of developing an AVF evacuation crisis decision-support model, it was evident that the previous AVF BET_EF required revisiting. To inform the monitoring parameters for the AVF BET_EF, an expert opinion workshop was held with 25 monitoring scientists and volcanologists, who were asked to review, update and add to the original inputs. The eight AVF scenarios were used to test the performance of the revised AVF BET_EF. The updated BET_EF for the AVF will assess the eruption probability and likely vent location, and subsequently applied within an evacuation decision-support tool.

ORAL
Session 2a.

Slow Slip Events at the Hikurangi Subduction Margin, New Zealand, from 2006 to 2017

Charles A. Williams[1], Laura M. Wallace[1,2], Noel M. Bartlow[3] and John Haines[1]

[1] GNS Science, Avalon, Lower Hutt, New Zealand.
[2]University of Texas Institute for Geophysics, Austin, Texas, USA.
[3] University of Kansas, Lawrence, Kansas, USA.

c.williams@gns.cri.nz

Slow slip events (SSEs) are frequent along the Hikurangi Margin and understanding them is critical to our understanding of interseismic coupling, plate motion budgets, and the potential for damaging earthquakes. Deeper and less frequent SSEs are observed on the southern margin, while shallower and more frequent events are observed along the northern section. We are compiling a catalogue of Hikurangi SSEs covering the period from 2006 to 2017 to help us understand the spatial and temporal patterns of slip. Using this catalogue, we can begin the process of characterising the behaviour of Hikurangi SSEs, looking at properties such as depth, peak slip rate, total slip, and recurrence interval. It will also allow us to explore possible scaling relationships, such as that between moment release and event duration.

We use the Network Inversion Filter (NIF) [Segall and Matthews,1997; McGuire and Segall, 2003; Miyazaki et al., 2006] to perform our time-dependent slip inversions. We generate Green's functions using the PyLith finite element code [Aagaard et al., 2013] to include elastic property variations provided by the New Zealand-wide seismic velocity model [Eberhart-Phillips et al., 2010]. Previous results [Williams and Wallace, 2015; 2018] showed that SSE inversions that consider elastic heterogeneity provide significantly different results compared to elastic half-space solutions. Incorporating these effects significantly improves the accuracy and reliability of our time-dependent inversions. Our inversions also include recent absolute pressure gauge (APG) data to constrain offshore vertical movement during a recent SSE observed in 2014. Most recently, we have used the VDoHS technique [Haines et al., 2015] to provide much cleaner time series to use with the NIF. The catalogue represents the most comprehensive to date for the Hikurangi Margin, and the usage of APG data and consideration of elastic heterogeneity effects will provide the best possible constraints on the predicted slip distributions.

ORAL
Session

Along-strike extent of ruptures on geometrically complex reverse faults; insights from paleoseismic investigations and physics-based earthquake simulations of the Nevis-Cardrona Fault system

Jack Williams[1], Mark Stirling[1], Govinda Niroula[1], Ashleigh Vause[1], James Stewart[2], Andy Nicol[3] and Robert Langridge[4]

[1]Department of Geology, University of Otago, PO Box 56, Dunedin, 9054
[2]GeoSolve Ltd, 8 Pinot Noir Drive, Cromwell, 9342
[3]Department of Geological Sciences, University of Canterbury, Private Bag 4800, Christchurch, 8140
[4]GNS Science, PO Box 30368, Lower Hutt, 5040

jack.williams@otago.ac.nz

The Nevis Cardrona Fault System (NCFS) consists of a geometrically complex array of fault traces that extends for 130 km from Wānaka southwards to the Mataura River. Empirical scaling implies that the system can produce M_W 7-7.5 earthquakes, and such events would generate significant damage in the nearby towns of Queenstown, Wānaka, and Cromwell. Herein, we present the results of two trenches excavated across a ~1.8 m high NCFS scarp in the Upper Nevis Valley, and place them in the context of: (1) trenches previously excavated along the NCFS in the Kawarau Gorge and Branch Creek; and (2) simulations of NCFS seismicity from the Rate-and State Earthquake Simulator (RSQSim). Deformation in the Upper Nevis Valley trenches is accommodated by a combination of folding and small (<0.5 m) offsets across four faults that presumably represent near-surface splays of an underlying master fault. The offsets of a top silt layer and underlying gravel unit, and formation of a colluvial wedge in the lee of two faults, provide stratigraphic evidence for the most recent NCFS event in the Upper Nevis Valley, and equivocal evidence for a penultimate event. Optically Stimulated Luminesce dates collected from these trenches are forthcoming. Nevertheless, it is noticeable that the NCFS scarp in the Upper Nevis Valley is considerably smaller and more degraded than the ~3-5 m high NCFS scarp in the Kawarau Gorge and Branch Creek. OxCal modelling also indicates that the penultimate event in the Kawarau Gorge trench is not recorded at Branch Creek. This is evidence for variability in the along-strike extent of NCFS earthquakes, a behaviour also noticeable in the RSQSim simulations.

POSTER
Session 1d.

From Geological evidence to tsunami impact forecasting in the Southwest Pacific Islands

S. Williams[1], C. Bosserelle[1], E.M. Lane[1], O. Fa'anunu[2], S. Mulitalo[3], T. Kula[4], L. Talia[3], B. Miville[1], F. Mendez[5], H. Damlamian[6], A. Rueda[5], A. Ricondo[5], L. Cagigal[5], B. Perez[5], S. Castanedo[5], N. Ripoll[5], R. Paulik[1], R. Welsh[1], J. Powell[1] and J. Borrero[7]

[1] NIWA Taihoro Nukurangi, PO Box 8602, Christchurch, Aotearoa New Zealand
[2] Tonga Meteorological Service, MEIDECC, Nukualofa, Tonga
[3] Meteorology Division, Ministry of Natural Resources and Environment, Private Bag, Apia, Samoa
[4] Tonga Geological Service, Ministry of Lands and Natural Resources, Nukualofa, Tonga
[5] GeoOceans Group, University of Cantabria, Spain
[6] Pacific Community – Geoscience, Energy and Maritime Division, Suva, Fiji
[7] eCoast Marine Consulting and Research, Raglan, Aotearoa New Zealand

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Natural hazard risk forecasting provides a soft adaptation intervention which can help strengthen resilience to geohazards through preparation for imminent events that in turn, can assist with strengthening capacity to respond to, or recover from, associated disaster impacts. In this talk we discuss the geological evidence-base for tsunamis in the central southwest Pacific with a focus on Samoa and Tonga, and how our understanding of long-term tsunami hazards and risks have culminated in the establishment of a prototype tsunami inundation impacts operational forecasting system in this region. We explore the approximate 1,000-year record of tsunamis preserved in sedimentary and geomorphological records in these islands, including localised events (e.g., 1905–1911 Mt Matavanu volcanic-generated tsunamis in Samoa), and enigmatic events which likely resulted in the deposition of massive tsunami boulders weighing up to more than several tonnes each deposited at Fahefa as well as Haveluliku on Tongatapu Island.

We then discuss the development of a tsunami metamodel database comprising several thousand pre-computed earthquake-generated tsunami inundation scenarios simulated using the BG-Flood software for Tongatapu Island and the whole of Samoa. In addition, volcanic-generated tsunami inundation scenarios were simulated for selected submarine volcanoes along the Tofua Ridge as well as Vailulu'u hotspot volcano using the January 2022 Hunga Tonga-Hunga Ha'apai eruption source mechanism as a base analogy. The database has been semi-automated to run on NIWA's supercomputer, with forecast maps of inundation and on-the-fly, exposure and damage metrics produced using risk evaluation software, RiskScape, and displayed in an online web information portal (i.e., CliDEsc Portal). The tsunami forecast products are only created if a tsunamigenic earthquake affecting the Samoa/Tonga region is detected by the Pacific Tsunami Warning Centre. The system checks for tsunamigenic earthquakes or volcanoes every 3 minutes and if one is detected, then corresponding precomputed inundation and impacts products are created and automatically pushed to the CliDEsc Portal for duty operator interaction and response. In addition to presenting an overview of the current system, we discuss the operational challenges as well as areas for ongoing testing and improvement.

ORAL
Session 2a.

Characterisation of the anomalous sub-alkaline Maniototo Basalts in the alkaline Dunedin Volcanic Group; Sources and Mechanisms

L. J. E. Wilson[1], J. M. Scott[1] and P. J. le Roux[2]

[1]Department of Geology, University of Otago, Dunedin, New Zealand
[2]Department of Geological Sciences, University of Cape Town, Rondebosch, South Africa

wilsonla321@gmail.com

The Maniototo area in the north-western corner of the Dunedin Volcanic Group (DVG) (Oligocene-Miocene) is geochemically anomalous within the established context of the DVG. This is due to the presence of a series of subalkaline flows, in addition to alkaline basalts typical for the DVG. These flows originate from three principal eruptive centres: Swinburn South, Waipiata and Haughton Hill. The Maniototo basalts are primitive, geochemically unfractionated but are distinguished by subtle differences in trace element abundance between the subalkaline and equivalent alkaline lava, best observed in the high field strength and light rare earth elements. These subalkaline lavas are unusual and clearly distinguishable from typical DVG alkaline rocks through their geochemistry and isotopic compositions. Isotopically these subalkaline lavas have more radiogenic $^{87}Sr/^{86}Sr$ ratios with equivalent $^{143}Nd/^{144}Nd$ values compared to the alkaline lavas and both the $^{206}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$ are elevated. These elevated lead ratios are especially noteworthy as they form distinct clusters above both the measured DVG and mantle array values.

A notable feature of the Maniototo area is that these subalkaline rocks occur often within areas that also contain alkaline volcanism. For example, alkaline units have been identified in the north-eastern edge of the Waipiata flow and proximal alkaline intrusions at Swinburn. Trace element ratios and non-modal melt modelling indicates that the range of alkalinities is cause by a combination of differing melting conditions and sources, with the Maniototo (subalkaline) basalts have a distinct mantle reservoir to that of the alkaline basalts that characterise the rest of the volcanic field.

POSTER
Session 1b.

Reconstructing Landscape Change from Earthquakes and Storm Events in Lake Gunn, Fiordland

Inez Wilson-Harding[1], Sean Fitzsimons[1] and Jamie Howarth[2]

[1] School of Geography, University of Otago, Dunedin, New Zealand
[2] School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand

wilin507@student.otago.ac.nz

The role high magnitude, low-frequency landscape perturbations such as earthquakes and storm events, play in the erosion and evolution of mountain belts is strongly contested. One approach to this issue is to develop millennial to decadal records of landscape change in order to move beyond the limitations of relatively short instrumental records. Many turn to natural archives such as lacustrine sediment to understand landscape change over these longer timescales because they offer well-preserved, potentially, continuous sedimentary records of seismic and storm-driven perturbations. In this presentation, we describe an investigation of the sedimentary record of Lake Gunn in Fiordland to understand how earthquakes and storm events drive landscape change within the area. Three 6 m cores and eight 1.5 m cores together with seismic surveys provide a record of perturbations that interrupt continuous sedimentation over the last ~4100 cal BP. The cores have been used to develop a facies model based on physical sedimentology and geochemistry for the reconstruction of landscape disturbance events. Nine sedimentary facies combine to form five facies associations. Depositional processes include Type 1, 2 and 3 Rapidly Deposited Layers similar to those identified in the literature within New Zealand and globally. The collected cores capture significant spatial variability in deposits that may be a result of the complex multi-basin bathymetry, the direct supply of sediment from landslides on the surrounding steep slopes and the complex sediment transport dynamics that often impede the preservation of environmental signals. As deposits are not consistently recorded in all cored locations across Lake Gunn, this creates a challenge for the development of a coherent reconstruction of the catchment's environmental history.

ORAL
Session 2b

A National Landslide Dam Database for New Zealand

Andrea Wolter[1], Regine Morgenstern[1], Biljana Lukovic[1] and Akansha Sirohi[2]

[1] *GNS Science, Avalon, New Zealand*
[2] *WelTech, Petone, New Zealand.*

a.wolter@gns.cri.nz

Landslide dams are a critical component of multi-hazard cascading systems around the world and in Aotearoa New Zealand, linking slope and fluvial processes. They form when landslides block a watercourse, and can result in catastrophic flooding if they fail rapidly. Nonetheless, they are under-researched given the potentially high consequences of sudden dam breach and failure. Their formation, longevity, and breaching behaviour are not well understood, which is critical information needed for effective risk management.

As part of a larger programme on earthquake-induced landscape dynamics focussing on the 2016 Kaikōura earthquake sequence, we present a nation-wide database of landslide dams, spanning pre-historic to historic natural dams and compiling several existing datasets. The database includes more than 700 landslide dams, as well as information for each dam such as catchment properties, landslide and dam dimensions, dam type, and dam composition where available. Where possible, quantitative attributes have been calculated automatically using arcpy (a Python site package that utilises ArcGIS processing tools), which allows consistency and repeatability in the database. A data quality ranking scheme has also been developed to assess the reliability of each dataset and case study.

Several case studies, including the Hapuku, Stanton, Leader, Linton, and Conway landslide dams that formed during the 2016 Kaikōura earthquake, have been analysed in detail. Multiple field and remote sensing campaigns completed since 2016 – including field mapping, RTK surveying, drone photogrammetry, and LiDAR – show the evolution of the landslide deposits and dams, providing high-resolution spatiotemporal data on the formation and breaching characteristics of various landslide dams.

The database is currently being analysed to improve our understanding of dam formation potential and longevity, as well as breaching behaviour. These analyses will ultimately contribute to filling the information gap on this important hazard.

POSTER
Session 4c.

New windows on the world: Applications of extended reality in the geoscience classroom

Matthew Wood[1], Dene Carroll[1], Jacob Young[2], Cliff Atkins[1], Nadia Pantidi[3], James Crampton[1] and Jamey Stutz[4]

[1] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, New Zealand*
[2] *School of Engineering and Computer Science, Victoria University of Wellington, New Zealand.*
[3] *School of Design Innovation, Victoria University of Wellington, New Zealand.*
[4] *Antarctic Research Centre, Victoria University of Wellington, New Zealand.*

matthew.wood@vuw.ac.nz

In recent years a radical democratisation of immersive computing technologies has occurred. This has allowed the development of virtual and augmented reality (VR/AR) educational tools within university departments using 'prosumer'-grade equipment. As big tech establishes and expands the metaverse – and the requisite hardware becomes increasingly mainstream – there will be both incentives and imperatives for innovation in geoscience teaching, research, and outreach. Through app development and user testing, this project aims to implement and refine VR/AR (collectively, 'extended reality') experiences in a tertiary Earth science curriculum.

Extended reality begins with the generation of high-resolution 3D assets and 360° imagery. Geological hand samples and outcrops are digitally replicated using both iPad-based LiDAR and photogrammetry (via Apple's Object Capture API). Blender facilitates the modelling of 3D meshes and the creation of digital terrain models with draped aerial photography. 360° video is captured using specialised cameras and 360° Google Earth imagery can be animated and rendered using Earth Studio. Stationary 360° 'photo spheres' can be captured via the Google Street View mobile app. Traditional 2D video content from handheld cameras and drones can be transformed and incorporated into 360° video projects in Final Cut Pro X. Final executable experiences are developed in the Unity game engine for VR and Apple's Reality Composer for AR.

Importantly, the current work does not seek to replace the existing classroom experience, but to complement and enhance it. Virtual and augmented experiences can act as primers for upcoming work or as revisions of completed exercises. Extended reality models have been deployed in 100-level Earth science laboratory sessions to supplement existing in-house teaching. Animated and narrated structural geology models are examined by students individually, using mobile VR headsets, or collaboratively, using shared iPads. These explanatory tools have been especially useful to those students for whom 3D visualisation poses a challenge.

POSTER
Session 3b.

Geological setting and Early Oligocene invertebrate fauna at McDonald's Quarry, Kakanui, New Zealand

Yutong Wu[1], Jeffrey Robinson[1], Daphne Lee[1] and Marco Brenna[1]

[1] Department of Geology, University of Otago, Dunedin, New Zealand.

wumi5629@student.otago.ac.nz

McDonald's Quarry is a limestone quarry about 1 km north of Kakanui township, North Otago and was the type locality for the McDonald Limestone, which is now regarded as the upper unit of the Ototara Limestone. Two major lithologies are recognized at McDonald's Quarry, namely, the Kakanui Lapillistone (Kl) and the McDonald Limestone (Ml). Non-welded basaltic grains of lapilli size cemented by calcium carbonate are the dominant component of Kakanui Lapillistone, with less abundant crustal fragments (schist and sedimentary), mantle xenolith fragments also present (olivine (Fo > 90), diopsidic clinopyroxene, and orthopyroxene). Foraminiferal dating indicates that the McDonald Limestone has an age of Lower Whaingaroan (Lwh). The major constituents of the limestone are bryozoans (~80%), benthic foraminifera including *Amphistegina*, ostracods, echinoderm, brachiopod and molluscan bioclasts in a sparite matrix so it is classified as a bryozoan-rich biosparite. Sedimentary structures are very rare in the limestone. The brachiopod fauna is dominated by large and smooth *Liothyrella gravida* (Suess, 1864). A simple morphometric analysis (N = 108) of *L. gravida* compared with *Liothyrella* species proposed by R.S. Allan (1932) suggests that some of the species that he named may be synonyms. Other brachiopods present within the fauna include: *Aetheia gualteri*, *Tegulorhynchia squamosa*, *Tegulorhynchia sublaevis, Terebratulina suessi*, *Waltonia (?) oamarutica,* and *Stethothyris uttleyi*. The molluscan fauna is sparse and dominated by *Serripecten sp.*, with rare specimens of *Limatula cf. trulla*. Ostracod fossils (Order: Podocopida) are uncommon but well-preserved, and include two superfamilies, Bairdioidea and Cytheroidea. Bryozoan fossils (order: Cheilostomatida) are ubiquitous throughout the entire quarry, with bryozoan diversity possibly exceeding 100 species. Paleoecological information of all fauna at McDonald's Quarry implies that the McDonald Limestone was deposited in a warm and shallow marine environment (possibly middle to outer shelf), on a volcanic high, and intercalated with periods of monogenetic volcanism.

POSTER
Session 1c.

Understanding caldera degassing from a detailed investigation at Lake Rotoiti, Okataina Volcanic Centre, New Zealand

Tsung-Han Jimmy Yang[1,2], Isabelle Chambefort[1], Agnes Mazot[1], Michael C. Rowe[2], Brad Scott[1], Nick MacDonald[1], Cynthia Werner[3], Tobias P. Fischer[4], and Cornel E.J. de Ronde[5]

[1] GNS Science, Wairakei research Centre, New Zealand
[2] School of Environment, University of Auckland, New Zealand
[3] Research Geologist (under GNS Science contract), New Plymouth, New Zealand.
[4] Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, U.S.A.
[5] GNS Science, Lower Hutt, New Zealand

tyan870@aucklanduni.ac.nz

Volcanic lakes in large silicic caldera volcanoes are an important source of CO_2 emissions. However, quantifying CO_2 output is challenging due to the lack of observed historical CO_2 flux records and the large size of the volcanic and hydrothermal systems. Twenty percent of the surface area of Okataina Caldera (caldera size 450 km^2) is covered with lakes. Geothermal expressions, predominantly on the Okataina caldera margin, occur in at least six different locations, with surface expressions both on land and under water. Lake Rotoiti is located at the northwest edge of the Okataina Caldera, spans across the Tikitere and Taheke geothermal fields, and has inputs from on-land thermal springs, lake floor hydrothermal vents, and from Lake Rotorua. CO_2 flux from Lake Rotoiti was assessed using the accumulation chamber method and three techniques are used to process the data for total CO_2 emission of the lakes: (1) sequential Gaussian simulation (sGs) method allow quantification of CO_2 emission with spatial control, (2) graphical statistical approach (GSA) allows the quantification of CO_2 emission from different degassing regimes, and (3) a method based on water chemistry of the lake. We find CO_2 is mostly emitting at Tumoana Bay and Central Basin, and the emission rate is 271± 38 t d^{-1} of CO_2 (based on sGs) We then added this estimated emission data to the existing CO_2 data for individual geothermal systems distributed around the active Okataina volcanic centre and calculate that the entire caldera is emitting at least 1856 t d^{-1} of CO_2. The total emission is dominated by the lakes, where the topography is lower. We discuss the implications of this study in terms of preferential degassing locations and the amount of degassing, in particular for CO_2, in an active caldera setting.

ORAL
Session 1e.

CO_2 Emissions of the Tauhara Geothermal Systems, Taupo Volcanic Zone, New Zealand

Tsung-Han Jimmy Yang[1,2], Isabelle Chambefort[1], Agnes Mazot[1], Michael Rowe[2], Cynthia Werner[3], Tobias Fischer[4], Naoto Takahata[5], Jun Seastres[6], Thomas Brakenrig[1], Nick Macdonald[1], and Lauren Coup[1]

[1] GNS Science, Wairakei research Centre, New Zealand.
[2] School of Environment, University of Auckland, New Zealand.
[3] U.S. Geological Survey, David A Johnston Cascades Volcano Observatory, Vancouver, U.S.A.
[4] Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, U.S.A.
[5] Atmosphere and Ocean Research Institute, The University of Tokyo, Japan.
[6] Contact Energy, Wairakei Power Station, Taupo, New Zealand.

tyan870@aucklanduni.ac.nz

In a volcanic geothermal area, greenhouse gases are naturally emitted through steaming ground, fumaroles, and mud pools, as well as from industrial power generation processes. Tauhara geothermal field is the newest geothermal development in the Taupo Volcanic Zone, New Zealand. The geothermal field's chemical behavior and geology are relatively well understood concerning resource sustainability. However, Governmental regulations to reduce carbon emission are leading field operators to consider to future reinjection of CO_2 and other non-condensable gas. But to monitor efficiently in the future, the present-day surface gas emission needs to be understood to obtain a proper base line budget for future field operations.

Here we present a CO_2 emission map of the Tauhara geothermal field, including the Ring of Fire, Crown Park, Craters of the Moon, Taupo City, and Aratiatia farm, that show the variation of emission rates in different areas of the field. To provide a temporal control of the flux, we repeatedly monitored the CO_2 flux at Crown Park and Craters of the Moon over the last 2 years. Together with fluid geochemistry and isotopic data from production wells, we aim to understand large-scale gas emission based on geothermal and volcanic carbon output of the Tauhara geothermal field.

POSTER
Session 4e.

Petrophysical properties and reservoir potential of rhyolitic lava domes

Edward Yates[1], Darren Gravley[1], Ludmila Adam[2], Alan Bischoff[3] and Paul Ashwell[4]

[1] *School of Earth and Environment, University of Canterbury, Canterbury, New Zealand*
[2] *School of Environment, The University of Auckland, Auckland, New Zealand*
[3] *Geological Survey of Finland (GTK), P.O. Box 96, FI-02151 Espoo, Finland*
[4] *Department of Chemical and Physical Sciences, University of Toronto, Mississauga, Canada.*

eya16@uclive.ac.nz

Volcanic rocks often have sufficient porosity and permeability to provide suitable reservoirs for fluid storage, carbon sequestration and geothermal production. Presently, physical properties of lava domes are mostly discussed in the context of their formation where highly permeable lava domes are more efficient at degassing and thus less likely to experience explosive eruptions. Here we present petrophysical properties of three coeval lava domes within the Taupō Volcanic Zone. We compile data from the literature, measure new parameters (porosity, permeability and ultrasonic wave speeds) and investigate the reservoir potential of diverse lava dome lithofacies.

Lava domes are typically divided into four facies: *(i) interior core facies*; *(ii) basal breccia facies*; *(iii) a carapace facies*, and *(iv) a spine*. Measurements across 41 core samples show the core facies are of variable porosity (5-25%) and permeability (0.3-1475 mD), basal breccia is of moderate porosity (14-22%) and permeability (8-1475 mD), carapace facies is of high porosity (23-38%) and permeability (21-5703 mD) while the spine facies is of low porosity (3-9%) and moderate permeability (4-1650 mD).

Understanding the movement of fluids in the subsurface requires monitoring. Seismic waves are commonly used to monitor reservoirs due to their high sensitivity to fluids and can also be used to estimate the elastic stiffness of rocks. Here, a dataset of P- and S-wave velocities is presented at atmospheric pressure with experimental results showing that lava dome facies can be partially distinguished based on their velocity-porosity clustering.

In addition, five samples are experimentally tested for P- and S-wave velocities for a range of saturating fluids at in-situ effective pressures (i.e. depths). Our study suggests that intra-dome porosity and permeability is sufficient to perform as a fluid reservoir. Based on experimental data, we show that seismic methods are capable of monitoring liquid-CO_2 replacing water in porous and fractured dome facies.

ORAL
Session 4e.

A Cretaceous ichthyosaur from North Canterbury

George Young[1], Paul Scofield[2], Catherine Reid[1], Al Mannering[2], and James Crampton[3]

[1] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*
[2] *Canterbury Museum, Christchurch, New Zealand.*
[3] *School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand*

george.young@pg.canterbury.ac.nz

Ichthyosaurs are a group of secondarily aquatic tetrapods that invaded the Mesozoic seas from the Early Triassic. These reptiles converged on the body morphologies seen in today's fish, and developed a suite of characters for aquatic living, such as endothermy and viviparity. Ichthyosaurs were important members of Mesozoic marine ecosystems until their extinction in the end of the Cenomanian (~94Ma). Ichthyosaur fossils have been found throughout New Zealand; however, these remains are fragmentary, and none have been confidently described to valid taxa. A partial ichthyosaur skeleton, GS15687, encased within a concretion from the Swale Member the of Split Rock Formation (99-97Ma) in North Canterbury provides an opportunity to describe a New Zealand taxon to a species level. The concretionary blocks were CT scanned, and segmentation of the CT data allowed the digital reconstruction and rendering of the concretion and the fossils within. The fossil material preserved includes elements from the cranium, pectoral and pelvic girdles, an articulated partial hindfin, and a disarticulated forefin. The digitally reassembled concretion allows far visualisation of the 3D relationships between the fossil elements of GS15687, and also provides evidence for different taphonomic impacts on the ichthyosaur carcass. Additionally, there are abundant ribs and elements from the dorsal spinal column. GS15687 has several features suggesting its inclusion in the most advanced ichthyosaur group, the Platypterygiinae. There are also several characters that differentiate GS15687 from the other derived ichthyosaurs and suggest its recognition as a separate taxon. GS15687 has provided an opportunity to describe the first endemic Zealandian ichthyosaur and understand its relations with the globally distributed Late Cretaceous ichthyosaur taxa. GS15687 also represents one of the more complete specimens from the Cenomanian ichthyosaur fauna and so also expands our knowledge of the diversity of ichthyosaurs shortly before their extinction.

ORAL
Session 1c.

From Picks to Pixels: Developing eXtended Reality Tools for Geoscience Education and Outreach

Jacob Young[1], **Matthew Wood**[2], **Nadia Pantidi**[3], **Cliff Atkins**[2], **James Crampton**[2], **Dene Carroll**[2] **and Jamey Stutz**[4]

[1] School of Engineering and Computer Science, Victoria University of Wellington, New Zealand.
[2] School of Geography, Environment and Earth Sciences, Victoria University of Wellington, New Zealand
[3] School of Design Innovation, Victoria University of Wellington, New Zealand.
[4] Antarctic Research Centre, Victoria University of Wellington, New Zealand.

jacob.young@vuw.ac.nz

The best geologist is the one who has seen the most rocks. For students this experience comes in the form of field trips, however accessibility concerns prevent some students from participating. Furthermore, the infrequent nature of these field trips limit the potential for repeated exposure and practice of vital skills learned during the outing which could lead to poorer outcomes for many students. This is exacerbated in times of pandemic or poor weather, during which these trips might not even be possible, and students are often left without a suitable alternative for learning these skills.

Virtual reality has long been proposed as an enabling technology for increasing the accessibility of education, particularly for environments or situations which may be dangerous or difficult to replicate in the real world. Virtual reality can also act as a strong intrinsic motivator for students and can result in higher knowledge retention when used for training. Through virtual reality, one could faithfully recreate an outcrop that could be visited and measured without regard for accessibility, weather, lockdowns, or logistics.

We have developed a virtual reality tool that replicates the field trip experience, allowing students to revisit locations and lessons at any time and practice their geological skills "in the field". Several locations are recreated through a combination of 360° video and photogrammetric 3D models of real geological formations that can be freely explored, with the scope to include many common tools through which the environment can be interacted with. Current lessons focus on teaching students how to measure the strike and dip of a bedding plane using a virtual compass, with plans to include other concepts such as younging direction, overturned bedding, and macro- to meso-scale structure in the future.

POSTER
Session 3b.

Australian Granite Database: a case study for large scale database development

Elham Yousef Zadeh[1], **and Katie Peters**[1]

[1]Kenex Pty Ltd., Wellington, New Zealand

Eli@Kenex.co.nz

Easy access to large amounts of data in one place is one of the most significant advantages of designing and using a database. Unfortunately, having easy access to good quality data over a large area is not always possible and geodata are no exception. Geo-databases nowadays are gradually improving and are widely used by governments, industries, and academic centres. By using available databases many companies, active in mining, oil exploration, engineering geology and environmental sectors have been able to gain a better understanding of their projects and therefore make more informed decisions. However, there is still a lot of improvement to be made including cleaning and integrating existing datasets to make them useful on a large scale.

Kenex have identified a need for a spatial database of felsic and intermediate intrusive rocks for Australia. The database will be critical for targeting granite related mineral systems including tin and lithium. Currently the available granite mapping is variable between states and is not well attributed with information relevant to identifying these mineral systems. Kenex are in the process of developing this database, combining data from geology mapping undertaken by each state into a single country wide dataset. The database is being attributed with information from the original survey mapping, the Australian Stratigraphic Database and other spatial data including relevant geochemistry and mineral occurrence information.

Continuous improvements to available geospatial datasets are needed to make them fit-for-purpose. The development of the Australian Granite Database is an example of how we can improve geospatial data on a large scale to aid project generation for critical mineral deposits needed for green technologies.

POSTER
Session 4a.

The influence of geomorphological models on geosite recognition utilizing qualitative-quantitative assessment of geodiversity

Vladyslav Zakharovskyi[1], **and Karoly Nemeth**[1, 2, 3]

[1] *School of Agriculture and Environment, Massey University, Palmerston North, New Zealand*
[2] *Saudi Geological Survey, Jeddah, Saudi Arabia*
[3] *Institute of Earth Physics and Space Science, Sopron, Hungary*

v.zakharovskyi@massey.ac.nz

Geosites are specific locations of geodiversity containing an important information about history of Earth's evolution. Their recognition is the first step for geoparks establishment. However, the manual search for these places can be inefficient, as researcher must study acceptable literature and maps, then directly observe area of research for its description. Hence, to avoid the first step and specify the second one, we are utilizing simple methodology of qualitative-quantitative assessment of geodiversity for geosite recognition. It requires only simple geological and geomorphological data accessible for territory of research. Even though geomorphological data is the most acceptable, its assessment strongly dependable on the type and scale of research. Currently, researchers are utilizing Digital Elevation Model (DEM) and/or their analogues analyzing it with Geographical Information Systems (GIS). Here, we compared three different models (Slope angle, Raggedness and Roughness) of geomorphology and their influence on qualitative-quantitative geodiversity assessment for geosites recognition. Slope angle is the most standard type of surface analyzes as it is showing slope degree of assessed area. Then, roughness is other model which demonstrate relief irregularity. Then, Terrain Raggedness Index (TRI) is expression of mean differences between central pixel and its neighboring ones'. As an example of assessment, we utilized the data of Coromandel Peninsula. Its territory has been calculated through the square grid with area in 6.25 km2 to avoid low quality of SRTM and simplify a large are of the territory. Three geomorphological models have been evaluated with 7-point evaluation system, based on their range values specifically for the Peninsula, while geological evaluation system is based on the rareness of rock types on the Earth's surface. The result of analyzes have been compared to show the differences between models and their matching with known possible geosites recognized through the previous field observations.

ORAL
Session 3b.

The origin, preservation and prehistoric human use of ocean-rafted pumice found in raised beach ridges and archaeological sites in Northern Norway

<u>Anke Verena Zernack</u>[1], Erlend Kirkeng Jørgensen[2], Anders Romundset[3], Anthony Newton[4], and Felix Riede[5]

[1] Volcanic Risk Solutions, Massey University, Palmerston North, New Zealand
[2] Norwegian Institute of Cultural Heritage Research, Tromsø, Norway
[3] Norwegian Geological Survey, Trondheim, Norway
[4] School of Geosciences, University of Edinburgh, Edinburgh, United Kingdom
[5] Department of Archaeology and Heritage Studies, Aarhus University, Aarhus, Denmark

a.v.zernack@massey.ac.nz

Ocean-rafted pumice is found globally on modern and fossil beaches from the North Atlantic and Mediterranean to the South Pacific. Ocean-rafting events preserved in volcanic and non-volcanic areas can be correlated to their source and used to date sedimentary records and landforms, including raised shorelines. In addition, geochemical fingerprinting of artefacts made from ocean-rafted pumice can provide additional age constraints for pumice-bearing archaeological sites.

Our study explores links between spatiotemporal patterns of pumice redeposition along the northern Norwegian coastline and prehistoric human use of this versatile resource. Use-wear analysis of pumice from spatially diverse Mesolithic to Norse-medieval sites showed that most pieces were being used as abrasive tools. Their geochemical composition allowed to Holocene groups of tephras or individual eruptions from the Katla Volcanic System in Iceland. Our data showed that the estimated eruption dates typically predate the archaeological contexts by several hundred and up to 2-3,000 years, probably reflecting abundance and availability of certain pumice types at the time.

To investigate how geological processes such as eruption frequency, ocean-currents, and deposition/preservation of rafted pumice influenced distal resource availability, we focused field efforts on the Varanger Peninsula. Here, strong Holocene uplift rates and sea-level changes have built a unique record of raised shorelines that provide insights into fossil beach ridges up to the marine limit, covered in little vegetation. We found that pumice was abundant on certain paleo-shorelines and in specific geomorphic settings but absent from older beach ridges. The distinct mid-Holocene transgression high stand accumulated the largest variety of pumice types and clast sizes. Correlating the pumice sample suite to eruptive origin will contribute to a better understanding of the nature and frequency of Holocene silicic eruptions from Katla while also improving age control for existing relative sea-level curves.

ORAL
Session 1a.

Volcanology, geochemistry and age of Pigroot Hill Volcanic Complex, Waipiata Volcanic Field, New Zealand

Rong Zhang[1], and Marco Brenna[1]

[1] Department of Geology, University of Otago, Dunedin, New Zealand

zharo178@student.otago.ac.nz

Pigroot Hill Volcanic Complex (PHVC) is the remnants of Miocene monogenetic volcanoes in Waipiata Volcanic Field, Otago, New Zealand. The PHVC consists of four small hills namely Red Cutting Summit (771 m asl), Trig 634 (634 m asl), Pigroot Hill (758 m asl) and Round Hill (743 m asl). Red Cutting Summit has been frequently mentioned and studied due to its lherzolite-bearing phonolite. However, the PHVC also contains other kinds of rocks and relatively complex and overlapping volcanic vents indicative of the deviation from a simple monogenetic plumbing architecture. The PHVC therefore deserve further in-depth study and exploration. Compared with Phonotephrite, Tephriphonolite and Phonolite at Red Cutting Summit, the lava flow group at Pigroot Hill is mainly composed of Basanite and Basalt with a small amount of Phonotephrite. There is no mantle xenoliths observed in the samples of Pigroot Hill. The new ^{40}Ar-^{39}Ar age of Phonotephrite at Red Cutting Summit is 18.67 Ma, which is similar to the age of 18.5 Ma for Phonolite here shown by previous studies. However, Basanite and Basalt at Pigroot Hill showed ^{40}Ar-^{39}Ar ages of 14.77 Ma and 15.41 Ma, respectively. In addition, the main and trace elements of Pigroot Hill samples showed a different pattern from that of Red Cutting Summit. This indicates that at least three volcanic eruptions were recorded by the PHVC as well as the heterogeneity of the local magma source in the area. Detailed field surveys and sampling, as well as petro-geochemical and chronological studies, provide more detailed information on the PHVC and improve the understanding of its plumbing development, eruption history and relationship to the broader monogenetic volcanic system.

POSTER
Session 1a.