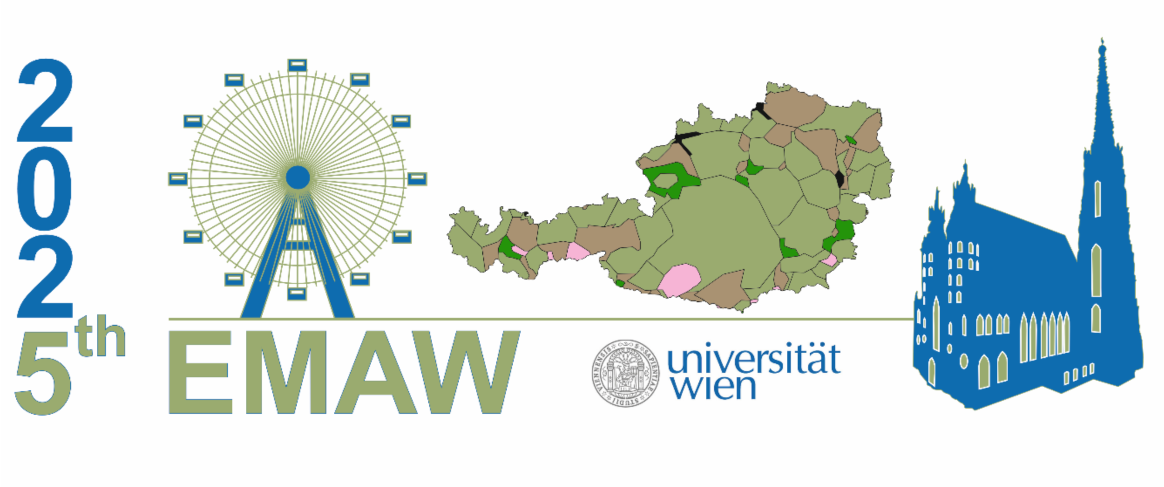
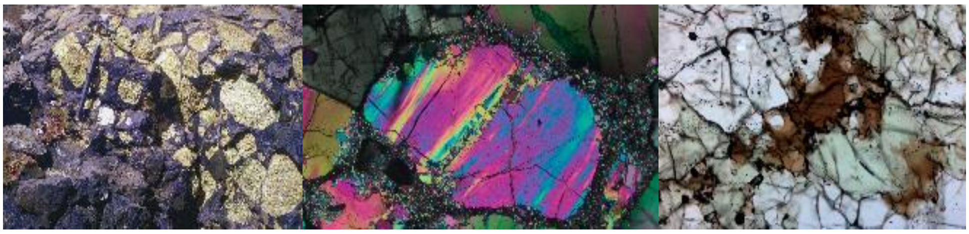
5th Earth Mantle Workshop

13 - 16 July 2025, Vienna, Austria





ABSTRACT BOOK

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MEETING DESTINATION VIENNA

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congress@univie.ac.at

VENUE

The **Earth Mantle Workshop 2025** will take place in the UZA II Building of the University of Vienna.

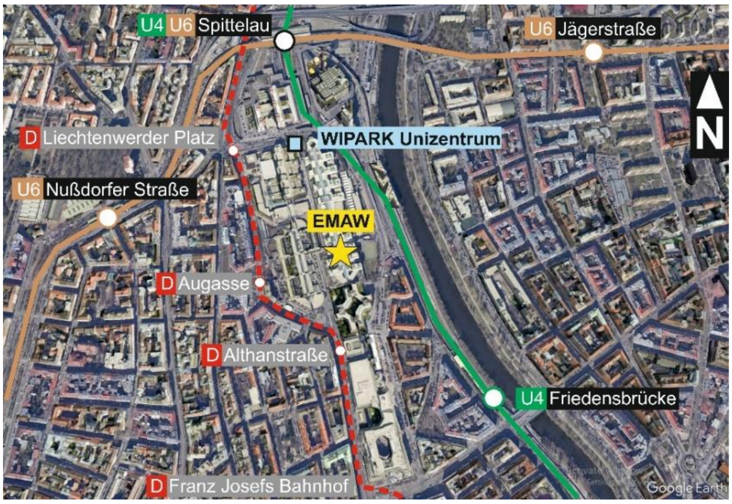
WORKSHOP LOCATION

ROOM: Lecture Hall (Hörsaal) 2
Faculty of Earth Sciences, Geography and Astronomy of the University of Vienna
Josef-Holaubek-Platz 2 (UZA II), 1090 Vienna

The UZA II (Universitätszentrum Althanstrasse) is located between the train stations "Spittelau" and "Franz-Josephs Bahnhof"

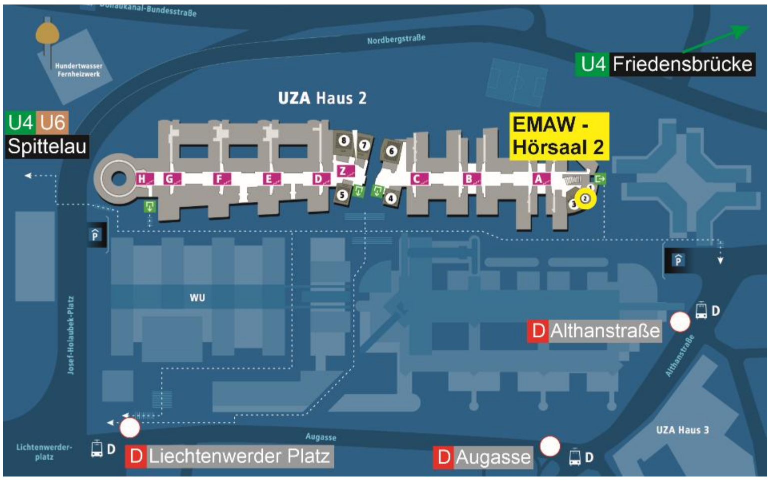
HOW TO REACH US:

1. Underground/Metro (U-BAHN): **line U4 Stop Spittelau or Friedensbrücke (N.B. Route Closure of U4 between Schottenring and Friedensbrücke → use tram E4 from Schottenring to EMAW)**
2. Underground/Metro (U-BAHN): **line-U6 Stop Spittelau**
3. Tram (Straßenbahn): **line D (or E4) Stop Augasse or Althanstraße or Liechtenwerder Platz**
4. Car: closest parking is **WIPARK Unizentrum Althanstraße Parkhaus**

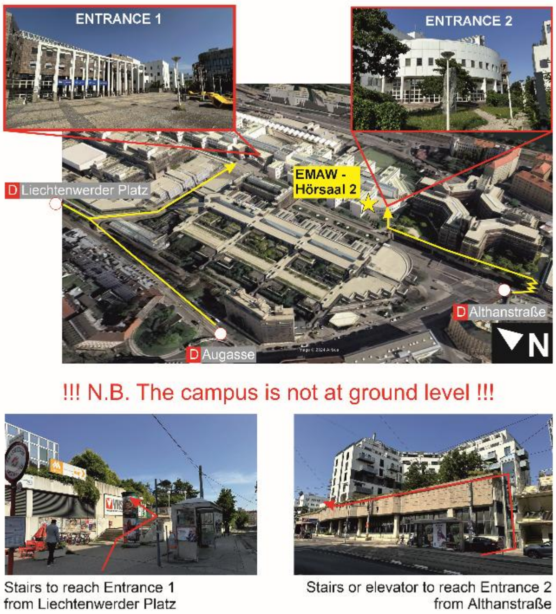


Location of the EMAW and how to reach the workshop site

U4 Route Closure



UZA II. Location and Lecture Hall (Hörsaal) 2



!!! N.B. The campus is not at ground level !!!

Stairs to reach Entrance 1 from Liechtenwerder Platz

Stairs or elevator to reach Entrance 2 from Althanstraße

Venue by tram line D (or E4)

!!! N.B. The campus is not at ground level !!!

Stairs to reach Entrance 1 from Spittelau

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Venue by U-Bahn

CATERING

Food and drinks provided by:

Gasthof Goldener Hirsch
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TIMETABLE

Sunday, 13.7.		**Monday, 14.7.**			**Tuesday, 15.7.**			**Wednesday, 16.7.**			**Thursday 17.7.**		
			8:00-9:00	Registration									
		A	9:00-9:20	Introduction	**E**	9:00-9:20	O13 - Woodland	**H**	9:00-9:20	O22 - Sauvalle		9:00-17:00	Field Trip
			9:20-9:40	O1 - Puziewicz		9:20-9:40	O14 - Wang		9:20-9:40	O23 - Szucs			
			9:40-10:00	O2 - Secchiari		9:40-10:00	O15 - Guarino		9:40-10:00	O24 - Seghedi			
			10:00-10:30	*Coffee break*		10:00-10:30	*Coffee break*		10:00-10:30	*Coffee break*			
		B	10:30-11:00	**INV1 - Giuliani**	**F**	10:30-11:00	**INV2 - Tilhac**	**I**	10:30-10:50	O25 - Matusiak-Malek			
			11:00-11:20	O3 - Fedortchouk		11:00-11:20	O16 - Nardini		10:50-11:10	O26 - Casetta			
			11:20-11:40	O4- Bonadiman		11:20-11:40	O17 - Zanetti		11:10-11:30	O27 - Niwa			
			11:40-12:00	O5 - Aulbach		11:40-12:00	O18 - Lopez Suarez		11:30-12:00	Open discussion			
			12:00-13:40	*Lunch break*		12:00-13:40	*Lunch break*		12:00-18:00				
		C	13:40-14:00	**SPO1 - Larmier (THERMO)**	**G**	13:40-14:00	**SPO2 - Sommer (ZEISS)**						
			14:00-14:20	O6 - Koutsovitis		14:00-14:20	O19 - Montanini						
			14:20-14:40	O7 - Mikrut		14:20-14:40	O20 - Eslami						
			14:40-15:00	O8 - Lavecchia		14:40-15:00	O21 - Ashchepkov						
15:00-18:00	Registration and ice-breaker		15:00-15:40	*Coffee break*		15:00-15:40	*Coffee break*						
		D	15:40-16:00	O9 - Dominique		15:40-18:00	Poster session						
			16:00-16:20	O10 - Rizzo									
			16:20-16:40	O11 - Sandoval									
			16:40-17:00	O12 - Forster									
			17:00-18:00	Drinks									
									18:00-21:00	Social dinner			

INDEX

SPONSOR PRESENTATIONS

INVITED PRESENTATIONS

ORAL AND POSTER PRESENTATIONS

SPONSOR PRESENTATIONS

Automated Mineralogical Mapping of Serpentinized Peridotites: Implications for H_2 Generation Potential

Larmier S.[1], Lefeuvre N.[2], Salazar Zambrano A.[1], Benedictus A.[1]

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[2] *UPPA - Equipe Caractérisation des Réservoirs Géologiques, PAU, France*

Serpentinization is a major geological process responsible for abiotic hydrogen (H_2) production via the oxidation of ferrous iron (Fe^{2+}) in olivine. This hydrothermal alteration yields serpentine, magnetite, and H_2 gas. Identifying and quantifying the mineralogical markers of this reaction is essential for evaluating the H_2 generation potential of ultramafic rocks.

This study applies advanced mineral mapping techniques to assess the semi-quantitative degree of serpentinization, the composition of serpentines (particularly Fe/Mg ratios). Particular attention is given to magnetite forming around Cr-rich spinels, whose role in facilitating or catalyzing hydrogen generation remains poorly constrained.

To conduct this analysis, we use Maps Min Software, a high-resolution, automated solution on an SEM-EDS platform designed for robust mineral characterization. This tool enables:

- Automated identification and quantification of minerals, even in fine-grained or complex textures, using integrated EDS and BSE/SE imaging.
- Deconvolution of mixed spectra at grain boundaries for accurate phase assignment at the micrometric and nanometric scale, crucial for distinguishing mineral intergrowths such as magnetite-spinel aggregates.
- True elemental bulk assay and mineral compositions determined using standards-based sum spectrum quantification per mineral, combined with grain-by-grain chemical analysis and quantitative compositional mapping to resolve solid solution chemistry (e.g., Fe/Mg in serpentines, Cr in spinels), enabling detailed evaluation of compositional variations and redox processes. Grain size analysis at multiple scales, to investigate hypotheses regarding serpentinization temperatures and kinetics.
- Data correlation, integrating optical microscopy and SEM datasets into a single petrographic workspace for in-depth comparative analysis.

This integrative approach not only enhances our capacity to interpret serpentinization-related mineral assemblages but also provides a reproducible workflow for screening the H_2 potential of peridotitic terrains in both modern and ancient geological contexts.

Get the big picture out of your rock section with your automated slidescanner

Sommer K.[1]

[1] *ZEISS Research Microscopy Solutions, Carl Zeiss Microscopy Deutschland GmbH, Oberkochen, Deutschland*

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INVITED PRESENTATIONS

The largest diamonds are hosted in iron-rich substrate accreted at the base of the lithosphere

Giuliani A.[1], Howarth G.[2], Tau M.[2], Cai R.[3], Liu J.[4]

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[2] *University of Cape Town, Rondebosch, South Africa*
[3] *Australian National University, Canberra, Australia*
[4] *China University of Geoscience, Beijing, China*

Diamonds larger than 100 carats are some of the most valuable gemstones ever unearthed. Beyond their large size and rarity, these diamonds exhibit distinctive attributes such as exceptional clarity and irregular shape, leading to the CLIPPIR acronym. The carbon isotopes of these diamonds indicate their origin from subducted slab material. While the formation of CLIPPIR diamonds in the mantle transition zone (MTZ) appears robustly constrained by the occurrence of majorite inclusions, the nature of the CLIPPIR diamond substrate remains obscure. Here we show that CLIPPIR diamonds are associated with kimberlites tapping vertically extensive, Fe-rich domains at the base of the lithosphere. Beyond enrichment in Fe, these domains exhibit light oxygen and heavy Fe isotopes, which indicate a major role of subducted basaltic material that experienced hydrothermal alteration at Earth's surface. The association of CLIPPIR and other sub-lithospheric diamonds with these anomalous Fe-rich domains that are rarely sampled by kimberlites and their similar isotopic anomalies point to a genetic relation. Considerations on kimberlite genesis in the upper convective mantle and partial retrogression of majorite inclusions suggest that the CLIPPIR substrate originally stalled in the MTZ, where the diamonds grew, before being accreted at the base of the lithosphere. The geographic overlap between CLIPPIR diamond locations and the loci of large igneous provinces points to accretion of subducted slab material including dense eclogitic crust via buoyant mantle upwellings. Beyond providing the largest diamonds, these Fe-rich, isotopically anomalous domains contribute to the isotopic heterogeneity of intraplate magmas globally.

First Lu-Hf isotope data from the ultramafic-mafic Jijal Complex, Kohistan arc (Pakistan)

Tilhac R.[1], Garbet L.[2], König S.[2], Garrido C.[2]

[1] Géosciences Montpellier, CNRS, Université de Montpellier, Montpellier, France
[2] Instituto Andaluz de Ciencias de la Tierra (IACT), CSIC, Spain

We report the first whole-rock Lu-Hf isotope data from the ultramafic-mafic Jijal Complex, which represents the Moho transition zone of the Kohistan paleo-island arc in northern Pakistan. Data were acquired by isotope-dilution MC-ICP-MS on 19 samples with low, analytically challenging Hf concentrations (3 ng/g to 0.75 µg/g). Above the Moho, the gabbroic section displays homogeneous ^{176}Hf/^{177}Hf (0.2828-0.2836) yielding εHf-εNd comparable to oceanic basalts (Sm-Nd data from [1]), with notable exception of a hornblende gabbronorite with εHf of +245. Beneath the Moho, ultramafic rocks have more variable ^{176}Hf/^{177}Hf (0.2830-0.2852) yielding decoupled εHf-εNd (ΔεHf up to +75).

Hf-Nd isotope decoupling is commonly related to melt-peridotite interaction involving ancient, depleted components [2]. Yet, a lherzolite lens interpreted as pre-arc oceanic lithosphere, preserved within the Jijal mafic section, shows mantle-array-like compositions (ΔεHf=+5.6). Alternatively, radiogenic Hf may have been sourced from boninitic melts parental to the ultramafic section. A similar interpretation could apply to the hornblende gabbronorite with strongly decoupled εHf-εNd, which exhibits 87Sr/86Sr comparable to the ultramafics (0.704-0.705), markedly higher than those of the main garnet granulites.

The Jijal ultramafic websterites and clinopyroxenites, and some gabbronorites, which yield nearly identical Sm-Nd isochron ages (117-118 Ma; [3]), may thus share similar source characteristics. The genesis of boninitic melts with radiogenic Hf and Sr signatures - absent in most gabbroic protoliths of the garnet granulites - suggests that a depleted component was tapped only during subduction initiation and was subsequently absent or overprinted during the mature stages of arc magmatism.

Furthermore, if the Jijal pyroxenites are representative of ultramafic cumulates “missing” from the Kohistan arc root, the presence of such potentially delaminated material in the convective mantle could account for the Hf-isotope depleted component (“ReLish”) identified in the source of oceanic basalts.

[1] Dhuime et al., 2007 http://dx.doi.org/10.1016/j.epsl.2007.06.026
[2] Tilhac et al., 2022 https://doi.org/10.1016/j.chemgeo.2022.121039
[3] Dhuime et al., 2009 http://dx.doi.org/10.1093/petrology/egp010

ORAL AND POSTER PRESENTATIONS

Thermobarometry and geochemistry of mantle and lower crust xenoliths in Trans-Khamar-Daban Cenozoic volcanic zone

Ashchepkov I.[1], Ntaflos T.[2], Tsygankov A.[3], Burmakina G.[3]

[1] Sobolev Institute of Geology and Mineralogy SB RAS, Novosibirsk, Russian Federation
[2] University of Vienna, Department of Lithospheric Research, Vienna, Austria
[3] Dobretsov Geological Institute, SB RAS, Ulan-Ude, Russian Federation

Deep-seated xenoliths were met and investigated in several localities in 200 km N-S Trans-Khamar-Daban staring from Karierny volcano near Tunka valley to r.Margasan at r.Marta mouth then to Margasanskaya sopka and Tumusun volcano at the centre of K-D, and Bartoy volcanoes at the south. Karierny includes lherzolites with the rare garnet relics, abundant black pyroxenites and granulites. Lherzolites give several PT ascending branches below and near (pyroxenites upper) SEA geotherm 90 mwm^{-2}. Some pyroxenites and even amphiboles are heated to 1350 °C. In Fe- rich pyroxenites (granulites) are heated to 1200 °C Granulites tracing SEAG became more acid with rising Fe#~0.5. Margasan-Marta xenoliths include spinel-pseudo-garnet and black varieties. Lherzolites trase SEAG from the Gar-Sp transition to Moho. Pyroxenites ~ 150 °C upper. Lherzolites from v.Tumusun repeats previous PT estimates for Gar-varieties ~ to 2.2 GPa. Black pyroxenites heated to 1250 °C near Moho. In Bartoy volcanoes lherzolitic enstatites and Cr-diopsides with Cr- hornblendes and rare pyroxenitic garnets follow SEA geotherm with the small deviations in the spinels facie starting from near 1.9 GPa. The pyroxenitic branch starts at 1300 °C goes to 1000 °C at Moho. The pyroxenitic PT estimates at low crust continues the mantle branch, amphiboles are lower temperature. Cr-Di from Karierny reveal LREE-Th-U-rich patterns similar to garnet lherzolites but here suggest carbonatitic metasomatism. Black pyroxenites display rounded from La to Nd and inclined patterns Cr-Di from Lherzolites in K-D and Bartoy volcanoes are LREE depleted. The metasomatic lherzolites are LREE rich. Bartoy megapyroxenities REE patterns show asymmetric bell-like pattern with the peak in Sm. But spiderdiagrams show minima (Zr<<Hf) and Ta-Nb- peaks depressions in Th-U and strong peaks in Ba. The kaersutite reveals more LREE enriched nearly lineal REE patterns. It shows similar spiderdiagrams as clinopyroxene but Ta-Nb depressions

RSF grant 3-17-00030

Wehrlite formation and rift-related mantle-CO_2 degassing: News from the Eifel Volcanic Field

Aulbach S.[1], Hezel D.[1], Moser L.[2], Woodland A.[1]

[1] *Goethe University Frankfurt, Frankfurt Am Main, Germany*
[2] *Gutenberg University Mainz, Mainz, Germany*

Continental rifting has been linked to the thinning of cratonic lithosphere, and to the release of enough CO_2 to impact the global climate. During extension, small-volume carbonated melts interact with mantle peridotite to form wehrlite through the decarbonation reaction, which allows to calculate the mass and flux of CO_2 released during "wehrlitisation". For the Eifel Volcanic Field (EVF), a CO_2 flux of 1.7-1.1 Mt/yr had been estimated based on literature data (Aulbach et al. 2020 GPL). An in-depth survey of the literature on surface waters suggests a relatively low CO_2 flux of <<1 Mt/yr and provides additional constraints on the mantle contribution to this flux based on δ13C and $^3He/^4He$ (Rizzo et al. 2021 CG). Given various strands of evidence for continued magmatic activity and associated mantle-CO_2 degassing in the EVF, a fresh look at the underlying lithospheric mantle is warranted. We obtained X-ray maps from ~35 EVF spinel lherzolites and wehrlites, derived from ~30-60 km depth, to determine mineral modes. Preliminary results suggest that they contain enough hydrous minerals to generate a negative shear-wave velocity (VS) anomaly of a magnitude that has been reported for ~50-100 km depth (Dahm et al. 2020 G3). This suggests that at least some of the seismically detected VS reduction is located in the lithosphere rather than in the asthenosphere where it has been linked to plume activity. We are in the process of carrying out (1) high-precision olivine analyses in order to quantify Al and Ca abundances, allowing to estimate pressures and temperatures and understand the depth distribution of the various xenolith sources in the lithospheric mantle under the EVF, and (2) spinel analyses against Mössbauer-characterised standards in order to obtain high-precision oxygen fugacity estimates and understand whether wehrlitisation is accompanied by oxidation, with implications for the stabilisation and mobility of carbonated melts.

Characterization of an Anomalous Garnet Population from the Newlands Kimberlite, South Africa

Bonadiman C.[2], Milani L.[1], Tassinari R.[2], Lenhardt N.[1], Wessels E.[1], Delport P.[1], Rowe L.[1]

[1] Department of Geology, University of Pretoria, Pretoria, South Africa
[2] Department of Physics and Earth Sciences, University of Ferrara, Ferrara, Italy

In this study, we analysed separate grains of garnets of kimberlite samples from one of the diamantiferous blows of the Newlands kimberlite pipes, Northern Cape, South Africa. The kimberlite samples are homogeneous and lack mantle xenoliths [1]. Classified as a typical Group 2 kimberlite, Newlands has been dated at 144±12 Ma [2]. Despite the pipe's homogeneity, we found a wide variety of garnets; 135 out of 193 analyzed grains are pyropes (Prp 0.53–0.74; Alm 0.1-0.25; Kng <0.01-0.19; Grs 0.01–0.07). Among the pyrope group, those with the highest MgO and Cr2O3 (up to 12 wt%) are classified as Cr-pyropes. We also identified 53 almandine-rich garnets (Prp 0.26-0.42; Alm 0.38-0.66; Kng <0.01-0.19 Grs 0.0.3–0.16). Additionally, 5 relatively large (up to 3 mm-long) green crystals were classified as uvarovite-rich garnets (Prp 0.34–0.39; Uv 0.33-0.34 ; Alm 0.7-0.9; Grs 0.11–0.19; And 0.03-0.05). Green garnets are very rare in kimberlites [3]. Pyrope and Cr-pyrope grains record P-T equilibrium conditions of 776–1011°C and 2.8–4.6 GPa, respectively. This data points to a rather cold geotherm, between 37 and 40 mW/m^2. In contrast, the almandine-rich grains record crustal conditions (1.2-1.3 GPa). The composition of uvarovite-rich garnets doesn't allow for reliable pressure and temperature estimation. However, their presence can be explained as a replacement product from deep mantle metasomatic reactions with carbonatites, occurring at the expense of primary chromite- The coexistence of uvarovite-rich garnets and diamonds may indicate that these reactions occurred under low to very low oxidation conditions.

References

[1] Gurney, J.J., Menzies, A.H., 1998. Seventh International Kimberlite Conference, Cape Town. 40 pp.
[2] Stanley, J.R., Flowers, R.M, 2016. Geochem. Geophys. Geosyst., 17, 4517–4533.
[3] Gao, S., Campbell, K., Flemming, R.L., Armstrong, K., Kupsch, B., 2023. The Canadian Journal of Mineralogy and Petrology, 61, 767–785.

Olivine trace element chemistry in spinel to garnet peridotite xenoliths from Udachnaya-East (Siberia) and the chemical log of the sub-cratonic lithospheric mantle

Casetta F.[1], Ntaflos T.[1], Aulbach S.[2], Faccincani L.[3], Ashchepkov I.[4], Abart R.[1]

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Olivine chemistry is increasingly used to explore a wide range of processes within the Earth's mantle and volcanic plumbing systems, with particular focus on the evolution of kimberlitic melts and their associated diamond potential. Yet, the trace element-poor nature of olivine in mantle-derived peridotites is analytically challenging to acquire. The chemical characterization of olivine in mantle peridotites is often limited to low-current major element analyses by EPMA, while a fuller characterization of olivine trace element compositions allows tracing the T-P-fO_2 conditions, nature and metasomatic modification of the lithospheric mantle. Using routine, high-precision EPMA and LA-ICP-MS analyses and building on the pioneering work by De Hoog et al. (2010), we provide the first comprehensive dataset on olivine chemistry in spinel to garnet peridotite xenoliths from the Udachnaya-East kimberlite (Siberian craton). Combined with thermobarometry, bulk-rock composition and major element chemistry of coexisting minerals, we explore the utility of olivine as recorder of lithospheric mantle processes. Olivine trace element chemistry is controlled by a combination of T-P-fO_2, and melt-related enrichment, and discriminates between: i) refractory, coarse granular peridotites equilibrated at low-T-P, depleted in all trace elements; ii) fertile to refertilized garnet-bearing rocks equilibrated at high-T-P, enriched in all basaltic components, which record earlier significant addition of HFSE, Fe, Ca, Al and P at the base of the lithosphere; iii) metasomatically-derived wehrlites and dunites, which equilibrated at low-T but preserve selective trace element enrichment. In comparison to literature data, we discuss the applicability of discrimination diagrams used for spinel- vs. garnet-bearing peridotitic olivine, thus improving our knowledge of the nature and evolution of the lithospheric mantle and the provenance of the xenocryst cargo in kimberlites.

References

De Hoog J.C. et al. (2010) - Trace-element geochemistry of mantle olivine and application to mantle petrogenesis and geothermobarometry. Chemical Geology, 270(1-4), 196-215.

3D imaging of fluid inclusions in mantle xenoliths

Casetta F.[1], **Peres S.**[1], Lanzafame G.[2], Nardini N.[3], Di Muro A.[4], Faccini B.[3], Coltorti M.[3]

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Earth’s lithosphere is a transient reservoir of volatiles acting as a filter between the convective mantle and the atmosphere. Together with diamonds, peridotite xenoliths are the main direct source of information about the content of volatile elements (C-O-H-S species and halogens) that can be stored, or circulate, in Earth’s lithospheric mantle. These xenoliths can store significant amounts of volatiles into accessory minerals, nominally anhydrous minerals (NAMs), or small (1-50 µm) intra- and inter-granular fluid or glass phases associated to reaction zones.

To observe and quantify the microstructural features linked to the potential storage of volatiles in mantle peridotites from the oceanic lithospheric mantle, we developed a 3D textural and volumetric characterization of fluid inclusions hosted in mantle xenoliths from the island of Mayotte (Comoros archipelago (Mozambique Channel, western Indian Ocean).

By using phase contrast Synchrotron X-Ray Computed Tomography (SR µCT) and a voxel size of 0.9 µm, we quantified the volume and spatial distribution of fluid inclusions hosted in each mineral phase constituent (olivine, orthopyroxene and clinopyroxene) of harzburgites and lherzolites from Mayotte. Our results revealed the presence, in considerable and variable amount, of fluid inclusions within all mineral phases in all the investigated samples. The size of fluid inclusions is highly variable, as it ranges between a few µm and 20-30 µm. Isolated fluid inclusions are rare, while fluid inclusions trails distributed along fractures and/or cleavage planes commonly occur in clinopyroxene and orthopyroxene minerals.

These findings will help in shedding light on the relationship between primary vs. secondary fluid inclusions and the geochemical features recorded by the host mineral phases. This information will be then used to model the volatiles’ storage capacity of mantle-derived peridotites and the circulation of fluids in the local lithospheric mantle and in the volcanic plumbing system.

Rodingitization (Ca-metasomatism) Induced by Fluid-Assisted Deformation: A Case Study from the Nain Ophiolite, Central Iran

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In the Nain ophiolitic massif, a 15 cm thick chromitite body is in close association with a boudinaged, isolated mafic dyke. Their contact is parallel to the foliation of the hosting serpentinized harzburgites, with an average dip of N135/57°NE, and is marked by a millimetric to centimetric alteration halo.

Detailed microstructural observations of 16 samples from this contact, combined with mineral chemical analyses and EBSD-based comparisons of crystallographic orientations among phenocrysts, inclusions, and matrix grains in three selected samples, reveal a multistage evolution:

(i) An initial high-temperature emplacement of chromite aggregates forming the massive body, indicated by their plurimillimetric size, rounded morphology and thier low intragranular misorientation with consistent crystallographic orientation across samples, stand-alone grains, and inclusions.

(ii) A subsequent high-temperature subsolidus intrusion of the mafic dyke, characterized by plurimillimetric, well-formed diopside phenocrysts with local augitic zoning and distinct shape-preferred orientations. This oriented crystallization is evidenced by coherent crystal lattice orientation distributions among clinopyroxenes (from augitic to diopsidic), plagioclases (from calcic to sodic), and rare orthopyroxenes (with [001] maxima), all showing negligible internal deformation.

(iii) Subsequent rodingitization affected some samples, with apparition of progressively smaller, milli to micrometric interstitial, sinuous grains of garnet, diopside, calcic amphiboles, chlorite, and acicular xonotlite with consistent lattice orientations.

This petrologic evolution occurred preferably at the contact with the chromitite body in semi-brittle conditions, suggested by the conjugated fractures, garnet-sealed within it. The parallelism between the hosting harzburgites, along with the magmatic then alteration structures, the consistency of the crystallographic orientation distribution and the remarkably low intragranular misorientation with absence of subgrain boundaries highlight the synkinematic conditions in which those fluid-leaded reactions succeed one another.

Tungsten composition and isotopes in Taishan komatiites: implications for alloy saturation

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We reports the first high precision W concentrations and ^{182}W isotopic compositions for the ~2.7 Ga Taishan komatiites in the North China Craton. Geochemical characteristics of these komatiites reveal an olivine fractionation as a major control, with minor crustal contamination. Their unusually high W contents, ranging from 1.0 to 15.2 ppm, exceed the W budget of all the known W-rich reservoirs. The overabundance in W also lead to highly elevated W/Th and relatively restricted Hf/W ratios that are rarely seen in ultramafic-mafic rocks closely affiliated with deep mantle. Another striking feature is that W is positively correlated with MgO and Ni, but inversely correlated with Na_2O, indicating a compatible behaviour of W during komatiitic magma differentiation. Therefore, the strong W overabundance must be a pristine feature of the Taishan komatiites. The Taishan komatiites have μ^{182}W values averaging at -2.3 ± 1.6 ppm (2 SD, n = 18), falling within the present upper mantle range, but distinct from the 182W excess found in the Archean TTG rocks from the Northeast North China Craton. The near-neutral 182W compositions of the Taishan komatiites indicate that by ~2.7 Ga, the regional mantle homogenization beneath the North China Craton has been achieved, but the global mantle heterogeneity persisted. Our data provide strong evidence for W being a compatible trace element, probably in the form of metal alloy, during the early-stage fractionation of komatiitic magma. The significance of the crystallization of non-silicate phases from the deep mantle lies in their extraordinary capability of scavenging siderophile elements, especially W, from the parental melt. The unique geochemical composition of the Taishan komatiites provides hints on the presence of the rarely seen but potentially widespread metal alloy phase segregation and, more importantly, its role in the W elemental and isotopic behavior during early melt extraction and subsequent magma differentiation.

Hydrogen speciation in ancient mantle

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Water, known as hydroxyl, is regarded as a key parameter for craton long-term stability as it may influence physical parameters such as viscosity and partial melting. It is already known that cratonic roots are drier than shallower parts of the cratonic mantle however this is based on OH studies which only show the “visible” hydrogen. Still, the origin and distribution of H in the cratonic mantle remain unclear. As such, this study proposes a thermodynamical model on the hydrogen distribution based on natural peridotites along a unique and entire log sampled through kimberlite eruption at Jagersfontein (Kaapvaal craton, South Africa). This work was focused on 17 highly refractory peridotites with none to poor metasomatism interaction in order to focus on the most ancient and representative part of the craton at its formation stage. Thermodynamical model parameters are supported by peridotites estimated pressure, temperature, oxygen fugacity and water content from Fourier-Transform infrared spectroscopy (FTIR). This study will present the evolution of hydrogen speciation in a C-H-O system under mantle water-undersaturated conditions.

Mineralogical and textural characterization of fluid-mediated alteration in chromitite–rodingite associations, Nain Ophiolite, Central Iran

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In the Nain ophiolitic massif of Central Iran, a deformed chromitite lense (15 cm thick and 3 m long) is spatially associated with boudinaged, isolated rodingite bodies hosted within highly sheared, NW-SE foliated and serpentinized harzburgite. The contact between the massive chromitite and the boudinaged rodingite is marked by a brecciated alteration selvage, referred to here as an alteration halo, varies in thickness from 2 mm to a maximum of 1 cm, and is characterized by distinct mineralogical and microstructural features. This zone comprises non-magmatic minerals such as zoned grossular surrounded by spherulitic Cr-rich andradite, diopside, xonotlite, carbonate, clinochlore and serpentine. Chromite in alteration halo is observed as stand-alone crystals and/or relics enclosed within grossular crystals. The composition of chromite ((Mg/(Mg+Fe2+): 0.64-0.70; Cr/(Cr+Al): 0.61-0.62; TiO2 0.14-0.33 wt.% and Fe3+/(Cr+Al+Fe3+): up to 0.23) in the alteration halo closely resembles that of chromite in the adjacent chromitite lense ((Mg/(Mg+Fe2+): 0.64-0.72; Cr/(Cr+Al): 0.59-0.71; TiO2 0.14-0.33 wt.% and Fe3+/(Cr+Al+Fe3+): up to 0.28). A multiphase solid inclusions are present in stand-alone chromite grains in alteration halo. These inclusions encompass clinopyroxene, pargasite, phlogopite, aspidolite, olivine, orthopyroxene, talc, garnets, apatite, and base-metal sulfides. Grossular displays oscillatory concentric zoning in Cr#: Cr/(Cr+Al), with Cr-spinel relics in the alteration halo. The replacement of chromite by Cr-rich garnet suggests that the Al, Cr, and Fe^{2+} were likely derived from the preexisting chromite. Our findings support a three-stage model for the evolution of the Nain chromitite–rodingite assemblage, involving: (i) High-T formation of chromitite and subsolidus recrystallization, leading to the development of polyphase silicate inclusions; (ii) syn-kinematic emplacement of mafic intrusions into the mantle under semi-ductile to brittle conditions; and (iii) fluid-assisted deformation followed by calcium metasomatism (rodingitization).

Calc-alkaline and alkaline metasomatism in the lithospheric mantle beneath New Zealand: clues from ultramafic xenoliths from Karioi volcano

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At convergent margins, the transition from alkaline to calc-alkaline magmatism typically marks the onset of slab retreatment inducing asthenosphere upwelling, and/or the formation of slab windows favoring the rise of deep, fertile mantle material. To date, it is still unclear if - and how - this succession of events can be preserved in the lithospheric mantle record. To address this question, we present the study of ultramafic xenoliths found in the Pliocene-Quaternary pyroclastic deposits of the Karioi stratovolcano (North Island, New Zealand), which are embedded within an eruptive sequence composed of randomly intercalated calc-alkaline and alkaline products (McLeod et al., 2022). The xenoliths suite is mainly constituted by olivine-clinopyroxenites, dunites and wehrlites with cumulate to mixed/protogranular texture, but also includes lherzolites and harzburgites, with protogranular, porphyroclastic and equigranular textures. Disseminated and vein amphibole is present in some olivine-clinopyroxenites and dunites. Reaction textures with formation of secondary phases and glass occur in all xenoliths, being predominant in olivine-clinopyroxenites and dunites. Lherzolites and harzburgites are mantle residua, and record low to medium partial melting degrees (5 to 15%). Samples showing the highest partial melting degree were overprinted by a metasomatic event after the interaction with calc-alkaline melts similar in composition to the erupted arc lavas, which caused the enrichment of LILE, LREE and MREE in orthopyroxene and clinopyroxene. Such calc-alkaline melts also produced the deep cumulate lithologies, i.e. olivine-clinopyroxenites and dunites. Afterwards, the infiltration of alkaline melts caused a further metasomatic modification in the xenoliths, generating Nb- rich amphiboles and providing the evidence for the passage of melts with different chemical affinity through the same mantle section.

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Evolution of diamond growth and dissolution environments at the base of cratons

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Lithospheric mantle underneath the cratons evolves through time due to percolation of metasomatic agents whose composition, mostly deduced from chemical zonation of mantle silicates and not yet well understood, controls precipitation vs. dissolution of diamonds. Diamonds travel to the Earth's surface within kimberlite magma and experience partial dissolution during the ascent. Some diamonds remain enclosed inside mantle xenoliths and preserve their pre-kimberlite surface features; however, such samples are extremely rare and mostly limited to eclogitic lithology. Diamond dissolution features acquired during mantle storage captures the conditions of diamond-destructive metasomatic events in the mantle. In this study we use diamonds with pre-kimberlitic surface features from eight kimberlite bodies from Botswana and Northwest Territories (Canada) to better understand the nature of mantle metasomatism.

From the 3256 studied diamonds (<1 to 4.5 mm size) 534 diamonds showed pre-kimberlite surface textures, divided into six types present in each diamond population which indicates similar metasomatism in the Zimbabwe and Slave cratons. Simultaneous study of diamond surface features, their growth patterns revealed in cathodoluminescence (CL) images, and the content of nitrogen defects in specific growth zones obtained using secondary ion mass spectrometry (SIMS) for 82 Ekati diamonds reveals a sequence of diamond growth and dissolution events. First, a spontaneous nucleation under supersaturation conditions produced aggregated diamond clusters, followed by a heterogenous growth of a uniform or slightly zoned and deformed layer, which alternates with oscillatory zoned layers and with dissolution events. These growth stages show different nitrogen content. The observed pre-kimberlite diamond resorption suggests interaction with asthenosphere-derived kimberlite melts percolating through diamondiferous lithospheric keel and cooling from ~1500°C to ~1400°C. If freeze, these melts release volatiles upon crossing the solidus precipitating a new growth layer on resorbed diamonds. Multiple growth - dissolution zones in diamonds indicate repetition of melting events over time.

Mapping the distribution of volatiles in mantle xenoliths at the nanoscale with Photo-induced Force Microscopy

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Photo-Induced Force Microscopy (PiFM) is a nanoscale analysis method that integrates atomic force microscopy (AFM) for surface imaging with infrared (IR) spectroscopy for phase determination. Unlike traditional IR techniques that limited by the optical diffraction limit to resoultion in the upper micrometer range, PiFM achieves much higher spatial resolution of around 5 nm by detecting attractive forces between a sharp AFM tip and the sample surface [1, 2].

In PiFM, a tunable IR laser is directed at a metal-coated AFM tip, inducing a photo-induced force (PiF) that corresponds to the sample's IR absorption properties. Scanning the laser over a range of wavenumbers generates a PiF-IR spectrum, which aligns closely with conventional FTIR spectra, allowing for reliable phase identification through FTIR reference libraries [2].

Here, we showcase the application of PiFM to mantle xenoliths that greatly benefits from nanoscale phase identification, particularly for investigating fluids at grain boundaries and identifying crystalline and amorphous (glass) phases at the nanoscale.

Furthermore, PiFM enables high-resolution analysis of chemical zonation in minerals and the detection of volatile species [3–5]. This capability is especially valuable in high-pressure experiments, where volatile-bearing melts rarely quench into glass. Instead, they typically crystallize into mats of nano- to microscale phases during cooling, complicating conventional analytical approaches. Thanks to its exceptional spatial resolution, PiFM can accurately identify these fine-grained quench phases, which are often undetectable using traditional spectroscopic techniques with larger spot sizes [6].

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New insights into the APIP petrogenesis from xenoliths and xenocrysts entrained in the Limeira I kimberlite

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The Limeira I kimberlite (91±6 Ma), emplaced in the Alto Paranaíba Igneous Province (APIP) along the southern part of the São Francisco craton, is formed by olivine, phlogopite/tetraferriflogopite, Al-free magnetite, magnesian ilmenite, rutile, perovskite, monticellite, apatite, and carbonate, and by a remarkable suite of xenoliths and xenocrysts (wehrlite, phlogopite-ilmenite- websterite, olivine-ilmenite- glimmerite, clinopyroxenite with potassic-richterite, chromite-monticellite-kalsilite xenoliths, rutile with either priderite or perovskite reaction rims, magnesian chromian ilmenite with perovskite rims). The wehrlite has high-Mg olivine (Mg# = 91-92), Cr-rich phlogopite (Cr_2O_3= ~1 wt%; Mg# = 93-94), potassic richterite (Mg# = 93) and Cr-rich, Al-poor clinopyroxene (Cr_2O_3= 1.3-3.7 wt%; Mg# = 93-96). The phlogopite-ilmenite-websterite has orthopyroxene (Mg#=86), clinopyroxene (Mg# = 94), phlogopite (Cr_2O_3<0.4 wt%; Mg# = 84-85) and chromian magnesian ilmenite (Cr_2O_3= 5.1-5.4 wt%; MgO 8-19 wt%). All clinopyroxene xenocrysts have a Mg# <90, low Cr_2O_3 concentrations (<0.8 wt%) and (Sc/V)N ratios <1. This suggests their magmatic nature. Some clinopyroxene xenocrysts (Mg# = 90) have Cr_2O_3 1.0-1.4 wt% and $(Sc/V)_N$ ratios of ~1.

Trace element concentrations of perovskite indicate variable Zr (700-1800 ppm) and Nb (3300-15000 ppm), high and variable LREE enrichment (ΣREE= 55000-94000 ppm) and strongly fractionated patterns [$(La/Yb)_N$=38-54)]. An oxidized crystallization environment is indicated by magnetite-ilmenite pairs, which plot along with a temperature range between 1000 and 800 °C and along or slightly above the NNO buffer. The presence of xenoliths containing clinopyroxene, potassic-richterite and even kalsilite, which are not stable phases in a kimberlitic magma, suggests that some stage, kamafugitic magmas or intrusions associated with kamafugites were sampled and entrained in the kimberlite feeder system. Since our samples lack garnet xenocrysts, as found at Três Ranchos, the final entrainment occurred at a shallower depth, and from the spinel facies to the crust.

Thermal structure and chemical composition of the subcontinental lithospheric mantle beneath the Alto Paranaíba Igneous Province: insights from xenocrysts and xenoliths trapped in the Três Ranchos kimberlite (APIP, Brazil)

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Valuable insights have been provided into the subcontinental lithospheric mantle (SCLM) beneath the Alto Paranaíba Igneous Province (APIP; Brazil) by the petrographic and geochemical characteristics (major and trace elements) of garnet and clinopyroxene xenocrysts, as well as of mantle peridotite xenoliths, entrapped in the Três Ranchos kimberlite.

This study sheds light on the thermal structure and heat flow, the pristine petrochemical mantle composition after partial melting and the metasomatic events undergone by the lower SCLM sector of the São Francisco Craton reworked by the APIP geodynamic evolution.

The following mantle sectors have been identified:

- A very deep mantle portion (160 km), as documented by a lherzolite xenolith (5 GPa and 1200 °C), underwent pervasive interstitial melt percolation by an ultra-alkaline silicate melt and by late injection of small silicate-carbonate melt fractions.
- A shallower sector extends from 124 to 100 km in depth (3.9-3.1 GPa and ~940-810 °C). This is characterized by metasomatized (±phlogopite) lherzolite with sinusoidal REE garnet compositions.
- Strongly depleted peridotites also occur at depths of 120-110 km (3.7-3.3 GPa and ~850 °C), as recorded by garnet and clinopyroxene compositions that are extremely impoverished in moderately incompatible elements (e.g., HREE) due to extensive, ancient melt extraction.
- A fertile lherzolite layer at a depth of 100 km is identified by garnet xenocrysts with "normal", HREE-enriched/LREE-depleted steadily fractionated patterns. Analogous fertile lherzolites are found in the uppermost sectors of the Siberian and Kaapvaal SCLM, suggesting that they may be primary, ubiquitous features possibly related to the stabilization of Archean cratons.

Estimated temperatures and pressures indicate that the typical cratonic geotherm was preserved in the SCLM beneath Três Ranchos. Surface heat flow is estimated at ~40 mW/m^2, which is only slightly higher than that at the São Francisco Craton margin (35-36 mW/m^2).

Neogene two-stage metasomatism of the subcontinental lithosphere beneath Southeast Asia – evidence from P-REE enriched peridotite xenoliths from central Vietnam and southern Laos

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The volcanic history of Southeast Asia is characterized by widespread Miocene to Pleistocene basaltic volcanism, specifically in Vietnam, Thailand, Laos, Cambodia and Southern China. This area is encircled by multiple elongated subduction zones which likely triggered mantle upwelling resulting in the Southeastern Asian Basalt Province. Alkaline volcanic eruption centers extracted a variety of xenocrysts (augite, zircon, corundum) as well as mantle xenoliths, the latter documenting a complex metasomatic history within the subcontinental lithospheric mantle. Here we present two examples from southern Laos and central Vietnam.

Spinel-lherzolite xenoliths from southern Laos show protogranular textures with grain sizes of ca. 0.1-5 mm. Two successive metasomatic events formed apatite, whitlockite, phlogopite, calcic amphibole, calcite and orthopyroxene. Phase compositions and textures indicate that the first event was triggered by a P-alkali element-rich mixed H_2O-CO_2 fluid, whereas the second was caused by infiltration of a Si-undersaturated alkali basaltic melt. Diffusion modelling using phosphorus zoning in olivine indicates that both events took place less than ~100 years before the xenoliths were transported to the surface.

In Central Vietnam, Pliocene to Pleistocene mantle metasomatism is documented by a wehrlite xenolith containing extremely REE-rich apatite and monazite, associated with globular patches of calcite and pools of quenched silicate melt. Textures and phase compositions observed in this wehrlite xenolith are attributed to a successive and nearly simultaneous interaction of depleted mantle with cogenetic silicate and carbonatite melts formed by fractionation-driven immiscibility within a parental SiO_2-undersaturated melt characterized by high P, CO_2, and REE contents. This immiscibility occurred at ~700-800 °C and a depth of ~30 km in the shallow subcontinental lithospheric mantle. The carbonatite melt was likely P-REE rich with low aH_2O whereas the silicate melt was alkali-basaltic in composition.

Occurrence of Tithonian to Early Cretaceous ophiolite mélanges in southern Albania

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The Middle Jurassic Mirdita ophiolite forms a NW – SE elongated belt within the Albanide mountain range representing remnant Tethyan oceanic lithosphere. Parts of these ophiolites have supra-subduction zone (SSZ) affinities, whereas some parts show mid ocean ridge basalt (MORB) characteristics.

Within this ophiolitic sequence, ophiolitic mélanges of Tithonian to Early Cretaceous age occur in the Southeastern Albanides. They lie transgressively or normally on top of radiolarian cherts of Kimmeridgian-Tithonian age, or on top of Middle Liassic to Malmian pelagic carbonate sequences along the periphery of the ophiolites. The ophiolitic mélanges consist of conglomerates or breccias with centimeter to meter sized clasts/blocks of (serpentinized) ultrabasites, gabbros, leucogabbros, troctolites, basalts, marl with calpionellids, sandstone, radiolarite, limestone embedded within a serpentinite matrix. Less commonly, "exotic" components such as amphibolite occur, most likely representing the metamorphic sole of the ophiolite.

The volcanic components recovered from mélange outcrops in the vicinity of Korçë comprise basalt, alkali-basalt and phonolite as well as dacite. The basalt has a MORB, alkali-basalt/phonolite a within plate affinity and the dacite belongs to an island arc setting. The plutonic suite within the mélange consists of fine and coarse grained gabbro, partly sheared leucogabbro and troctolite. Part of the clasts have an ultrabasic composition representing cumulates and fall into the peridotite gabbro field, all others plot within the gabbro field. The few clasts representing "normal" gabbro (micro gabbro, dark medium grained gabbro) fall into a mid ocean ridge setting. Out of the five recovered "exotic" amphibolite samples four have typical MORB and one alkali-basalt composition.

The polymictic mélanges containing clasts of peridotites, basalts, dacites, amphibolite, etc., being covered by pelagic sediments, might be a good candidate to represent one of the rather rare fossil remnants of serpentinite seamounts bearing potential additional evidence for a SSZ forearc setting during their formation.

Caught in the act: Interaction of MARID metasome with peridotite wall rock preserved in a xenolith from Kimberley (Kaapvaal craton)

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Mica-Amphibole-Rutile-Ilmenite-Diopside (MARID) xenoliths are representatives of volatile and alkali-rich, highly metasomatized/magmatic rocks of the cratonic, lithospheric mantle. Here we present major and trace elements of silicates and sulfides of a unique xenolith from Kimberley (Kaapvaal craton). The xenolith gives direct evidence of an interaction of a MARID-like metasome with the peridotite wall rock.

The xenolith consists of olivine, K-richterite, phlogopite, clinopyroxene, ilmenite, Fe-rich spinel, zircon and is enriched in sulfides (~0.5 vol%). Different petrographic areas are present: (A) coarse grained olivine, (B) an assemblage of coarse-grained phlogopite, K-richterite, clinopyroxene ± olivine and (C) an assemblage of coarse and fine-grained K-richterite (>50 vol%), olivine and phlogopite. Coarse-grained ilmenite, zircon, sulfide (up to >500 µm) and Fe-rich spinel are limited to the areas B and C. In contrast, fine-grained sulfide veins infiltrated the peridotite wall rock along olivine grain boundaries.

The xenolith derives from the shallow lithospheric mantle (2.5 GPa, 700 °C) and is geochemically enriched with Mg# in olivine of 87 with high concentrations in Ti (80 µg/g), Zn (110 µg/g) and Mn (1400 µg/g). Trace element systematics of phlogopite and clinopyroxene indicate that the newly formed magmatic/metasomatic minerals crystallized from a MARID-like agent.

We propose that the rock represents a reaction front of a MARID-like metasome with the peridotite wall rock. During the reaction, the metasomatic agent reached sulfur saturation (drop in fO_2/redox freezing? Liquid immiscibility?), causing crystallization of large amounts of sulfides. The event resulted in strong enrichment of volatiles, alkalis, Fe, Ti, Zn, Mn, sulfur (± related elements). Due to the fine-grained nature of area C, this event must have happened shortly before the entrainment of the rock by the host kimberlite. This indicates either that MARID agents were active or became re-activated during the high kimberlite activity beneath the Kaapvaal craton at 90 Ma ago.

The origin of the chromitite-bearing dunites from Tropoja ultramafic massif, northern Albania

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Tropoja is part of the Mirdita ophiolitic complex in Northern Albania, which is separated into a western and eastern unit. The eastern unit consists of SSZ and the western of MORB ophiolites. The ultramafic part in both units consists of harzburgites and depleted lherzolites that experienced various degrees of serpentinization. Chabra is a 1.0 × 2.5 km outcrop in the SSZ unit containing exceptional fresh dunites and podiform chromitite deposits that are embedded in strongly serpentinized peridotites.

The western part of the Chabra dunitic outcrop is characterized by the presence of podiform chromitites with Cr# varying between 0.6 and 0.8 whereas the Fo content is as high as 94.3 and the NiO = 0.56 wt%, is the highest measured in this outcrop. In contrast, in the eastern part chromitites are entirely absent; the Cr# of the spinel ranges from 0.50 to 0.60 and the Fo and NiO contents vary between 90-93 and 0.38-0.42 wt%, respectively. A remarkable feature of the dunites, mainly in the eastern part, is the presence of, up to 0.8 cm in diameter, enclaves consisting of harzburgites and/or pyroxenites. The frequency of the enclaves is increasing towards serpentinized peridotites. Detailed BSE images confirm the incongruent dissolution of orthopyroxene from harzburgites to form olivine. Because both, dunites and serpentinized peridotites have the same deformation features, a tectonic contact could be excluded. Apparently the serpentinized peridotites in the area of Chabra have been partly dehydrated due to an upwelling SiO_2-undersaturated basaltic magma to form harzburgites that subsequently interacted with fluid rich melts resulting in the formation of Fo-rich dunites and chromitites. Estimated equilibration temperatures using opx-cpx pairs ranging from 796 to 853 °C reveal the conditions under which the dehydration event took place. Further study of the peridotites is required to understand the origin of the dunites and the chromitites.

The origin and evolution of ultra-refractory peridotites in the Kamuikotan belt, Hokkaido, Japan constrained from Re-Os isotope and highly siderophile element systematics

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There has been considerable debate as to whether the high degree of melting associated with Archean craton formation was achieved by deep plume melting or by shallow melting under hydrous conditions. Ultra-refractory peridotites with supra-subduction zone affinities have been reported in circum-Pacific regions, and may serve as an analogue for elucidating the geodynamic setting for the craton formation. The Kamuikotan belt in Hokkaido is known to host ultramafic bodies originated from highly depleted harzburgites and dunites that occur sporadically along the north-south trending belt. Since the entire region is extensively serpentinized, a comprehensive study of the whole-rock chemistry has not yet been undertaken. In this work, we have carried out whole-rock analyses including major, trace, highly siderophile (HSE) and chalcophile element concentrations and Re-Os isotopes, of ultramafic rocks in Pinneshiri, Horokanai, Takadomari, and Iwanai-dake.

Despite varying degrees of serpentinization, little effect on immobile trace elements, HSEs, or Os isotope ratios, is inferred from the lack of correlations with loss on ignition (LOI) values. The most striking feature of their whole-rock abundance variations is that highly depleted harzburgites and dunites tend to show greater variations in Os and Ir (Os = 0.001-24 ng/g; Ir = 0.004-17 ng/g). Since strongly fractionated Os, Ir, and Pt patterns are commonly observed in highly refractory residues from circum-Pacific regions such as Papua New Guinea and New Caledonia, we consider that the generation of a boninitic melt in supra-subduction zone settings is related to the Os-Ir alloy dissolution. In contrast, their $^{187}Os/^{188}Os$ ratios are relatively homogeneous with a peak value of ~0.121, and show no correlation with Os abundances. From these, we propose that the Kamuikotan ultramafic rocks are derived from a mantle domain that underwent partial melting at ~1.0 Ga and subsequently acquired highly refractory compositions with unique HSE patterns via recent subduction processes.

Petrogenetic constraints from the refertilized Krrabi massif lherzolites in the Mirdita ophiolite complex, Albania

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A peridotitic massif in the Mirdita ophiolite in Albania (Krabbi), comprises mostly of variably refertilized lherzolites. Ultramafics are fine to medium grained, displaying secondary mosaic porphyroclastic and locally equigranular textures. Despite their apparent primitive nature, their calculated pyroxene abundances (modal cpx+opx = ~30.0 vol.%) are lower than those of typical primitive mantle lherzolites. They additionally contain variable amounts of amphibole (modal amph = ~0.6 vol.%) and plagioclase (modal pl = ~5.0 vol.%). Lherzolites comprise of olivine (Fo 88.6-90.9, NiO 0.3-0.4 wt.%, CaO ≤0.05 wt.%), orthopyroxene (Mg# 88.9-90.5), clinopyroxene (Mg# 89.4-92.9), plagioclase (bytownite), amphibole (kaersutite, pargasite) and spinel (Cr# 0.42-0.54; Mg# 0.38-0.50).

Petrographic observations support the refertilization scenario via basaltic melt infiltration upon highly depleted ultramafics. This led to partial replacement of olivine and subsequent formation of clinopyroxene, amphibole, plagioclase but also accessory Al-enriched spinel in equilibrium with ilmenite. The latter appear as microintergrowths along with exsolved ilmenite. These rocks were previously depleted spinel- plagioclase peridotites that later experienced refertilization modeling through addition of trapped tholeiitic basalt melt, followed by equilibrium element distribution. Clinopyroxenes display a clear positive correlation between Ti and Cr ($R^2 = 0.91$), signifying that they are associated with refertilization. Further evidence of refertilization can also be deduced from the non-equilibrium coexistence of most pyroxene crystals, shown by the tie-lines between the clinopyroxene-orthopyroxene pairs in the Cr vs. Al binary plots.

Geochemically, they are comparable with Primitive Mantle lherzolites. Mg# values range between 89.6 to 90.8, whereas their CaO and Al_2O_3 contents correlate negatively with MgO, varying between 2.6-3.8 wt.% and 3.0-4.3 wt.% respectively. HREE are close to those of PM [HREE = 0.77–1.04 × PM]. The results obtained from the Na, Nd, Sr and Zr refertilization modeling, point to addition and entrapment of up to 8% of basaltic melt increments in the plagioclase stability field, to interpret the formation of these significantly refertilized lherzolites.

(withdrawn) ~~The evidence of deep melting processes in xenolith bearing mafic rocks in Southern Thrace region: The new insights for peridotite and the pyroxenite source melting~~

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~~Xenolith bearing mafic rocks with late Miocene age are widely distributed in southern Thrace region. Primitive mantle - normalised multi-element diagrams of these mafic rocks display OIB signature and specific incompatible element ratios such as Nb/La (1.65-2.05) Nb/U (37.81-48.74), Zr/Ba (0.45-0.72) further indicate that mafic rocks were originated from the OIB-like component. Re content of xenoliths range between 0.09-0.44 similar with fertile mantle values (0.26 ppb) suggested by Morgan (1986). Xenoliths (0.1191-0.1379) and the host rocks (0.1279-0.1439) have the similar 187Os/188Os isotopic compositions.~~

~~Geothermobarometric analyses of clinopyroxene (Putirka, 2008) from host basalts express that the melting source resides at an estimated depth of around 85 km. In addition, Gd/Yb ratios span between 0.97-3.3 in xenoliths and also span between 3.92-5.24 in basaltic rocks, suggest melting from a deep source. The mafic lavas of Thrace region with high Tb/Yb$_{(N)}$ values (2.33-3.16) seem to be derived from garnet bearing peridotite (Tb/Yb$_{(N)}$ >1.8 Wang et al., 2002). These ratios also gain significant support from Dy/Yb values that range between 2-2.43 for xenoliths and 1.98-3.27 for host basalts.~~

~~High Nb/U, Gd/Yb ratios, Re-Os isotopic compositions, and the REE-based melting model starting from the primitive xenoliths (study region) and pyroxenite source (Van Nostrand, 2015) reveal that single source melting is not capable of producing the mafic lavas, instead, these rocks appear to be originated from the melting of the deeper part of the mantle, contributed from both of the sources, rather than shallow asthenosphere .~~

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On the Role of the Mid-Lithosphere Discontinuity in Craton Delamination

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Here we show the results of a 2D, thermo-mechanical numerical model investigating the interactions between mantle plumes and cratonic lithosphere, where a mid-lithosphere discontinuity (MLD) is included. In this model, we assume that vertically oriented, deep-seated weak regions may occur between the MLD and the lithosphere-asthenosphere boundary (LAB). In addition, we test the effect of different characteristics of plumes and MLD thickness on the evolution of cratons during plume upwelling and impingement. Our results suggest that mantle plumes can constitute a key factor in destabilizing and delaminating a cold and thick cratonic lithosphere. However, a region of weakness (either inherited from preceding tectonic phases or induced by melt and/or volatiles presence) is necessary for enhancing thermal-mechanical erosion by the plume at the LAB and triggering delamination of the lithospheric mantle along the MLD. Our findings support the long-term stability of cratons, by implying that their destabilization may happen under exceptional conditions.

Subduction initiation at an attenuated continental margin: Geochemical evidence from the Timor peridotites and boninites

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Field and geochemical evidence suggest that many supra-subduction zone (SSZ) ophiolites formed during sea-floor spreading triggered by subduction initiation. Current models of intra-oceanic subduction initiation are largely based on Eocene forearc sequences from the Western Pacific, where subduction is interpreted to have initiated along oceanic transforms. In contrast, we present new mineralogical and geochemical data from the Miocene Timor ophiolite, part of the Banda arc–basin system, which reveal a different tectonic context: subduction initiation at an attenuated continental margin. The Timor peridotites include fertile lherzolites with LREE-depleted patterns, chromian spinels with low Cr# and oxygen fugacities near the QFM buffer, and trace element compositions consistent with a mildly depleted subcontinental lithospheric mantle origin. These are juxtaposed with more refractory harzburgites displaying LREE-depleted to U-shaped REE patterns, spinels with higher Cr#, elevated oxygen fugacities, and enhanced fluid–melt reaction signatures. On discriminant diagrams such as Cr# vs. $\Delta\log fO_2$ and Ti/Fe^{3+} vs. Ga/Fe^{3+}, the Timor peridotites define coherent trends reflecting progressive interaction between pre-existing continental margin lithosphere and subduction initiation melts. These trends differ markedly from those observed in the Western Pacific, where abyssal peridotites interacted with boninitic melts during intra-oceanic subduction initiation. This emphasizes that the precise location of subduction initiation can significantly influence the petrology and geochemistry of SSZ ophiolites.

Nature of the mantle-crust transition in the Finero complex (Ivrea-Verbano Zone, Southern Alps)

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Finero Complex (Ivrea-Verbano Zone, Southern Alps) exposes mantle–crust sections recording geodynamic evolution from the Late Palaeozoic to Early Mesozoic. Early Mesozoic dykes mark a transition from orogenic to anorogenic-alkaline magmatism, reflecting post-Variscan collision to Alpine Tethys rifting. This study examines the mantle-crust transition at the Rio Cannobino–Rio Creves outcrop to constrain tectono-magmatic processes and timing of mantle accretion to Moho levels. Data includes petrography, mineral chemistry (phlogopite, amphibole, orthopyroxene, garnet), and Sr-Nd-Pb isotopes from amphiboles. The outcrop exposes the contact between Finero-Phlogopite Peridotite (FPP) and the crustal Layered Internal Zone (LIZ). The mantle unit is harzburgite with phlogopite and amphibole elongated parallel to the mantle-crust contact. A 1-m amphibole-biotite orthopyroxenite marks in places the mantle side; the crustal side has layered garnet-amphibole gabbro and hornblendites. The FPP shows chemical heterogeneity, evidencing migration of LILE-enriched melts. Mantle amphiboles away from the contact is characterized by high Mg#, Ba, Rb, Cr, Sc, V contents, fractionated LREE, and low Nb-Ta. Amphiboles in orthopyroxenite and adjacent harzburgite are enriched in Th, U, Fe, Al, LREE and depleted in Cr, Sc, V. On the LIZ side, the garnet-amphibole gabbro shows LREE-depleted amphibole and clinopyroxene, and garnet with a strong positive Eu anomaly. Hornblendites, dominated by titanium-pargasites, are richer in Fe, Al, and Ti, with convex-up L-MREE patterns and Nb-Ta enrichment. Geochemical features (LILE/LREE enrichment, Nb, Ta, HREE-depletion) of harzburgite and orthopyroxenite at the contact, document Palaeozoic melt migration, facilitating FPP deformation and migration at mantle depths. The garnet-amphibole gabbro exhibits hybrid compositions from LILE/LREE-depleted mantle melts assimilating earlier plagioclase-bearing cumulates after mantle emplacement at Moho depths. Later, alkaline mantle melts migrated through hornblendites, reflecting Upper Triassic–Lower Jurassic events in the Southern Alps. Therefore, the FPP-LIZ transition acted as a multistage lithospheric discontinuity, channeling mantle melts from the end of the Variscan Orogeny to the Lower Jurassic.

The composition and origin of sulfides in lherzolite xenoliths from Befang (Cameroon Volcanic Line, W Africa)

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Eocene alkaline volcanic rocks from the continental part of the Cameroon Volcanic Line (CVL) (W Africa) are rich in peridotitic xenoliths hosting sulfides, which provide insight into metal migration through the upper lithospheric mantle (LM) beneath the Central African Orogenic Belt (CAOB). A Befang xenolith suite from the CVL is dominated by lherzolites, subdivided into two main lithological groups. Group I features clinopyroxene with a depletion in LREEs relative to MREEs/HREEs. This clinopyroxene recrystallized during the percolation of a metasomatic melt. Group II contains LREE-enriched clinopyroxene with a crystallographic preferred orientation representing deformation preceding melt percolation [1]. Group I lherzolites are interpreted as metasomatized by MORB-like melts coming from the Depleted MORB Mantle (DMM). Group II peridotites are interpreted as the protoliths of those in group I.

Sulfides occur as inclusions in olivine, orthopyroxene, and clinopyroxene. They form either globular to oval or elongated grains composed of monosulfide solid solution (MSS) with pentlandite (Pn) and chalcopyrite (Ccp) exsolutions. Group I lherzolites are more enriched in sulfides (up to 0.031 ‰) with larger grains (range: 14–250 μm, average: 57 μm), compared to group II (up to 0.002 ‰, range: 12–45 μm, average: 27 μm). Sulfides from group I are Ccp-rich and Pn-poor ($MSS_{66}Pn_{23}Ccp_{11}$) in contrast to group II ($MSS_{62}Pn_{13}Ccp_{25}$). Ni/(Ni+Fe) in MSS from group I (0.14–0.43) shows a broader range than in group II (0.20–0.37).

Higher sulfide contents and larger sizes of sulfide grains in Befang group I lherzolites suggest a significant role of metasomatic melts in transporting sulfur along with metals. The observed refertilization by DMM-derived melts might affect the budget of chalcophile and highly siderophile elements in LM beneath the CAOB.

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Southern Sweden's peridotitic xenoliths record the structure and evolution of Earth's mantle beneath the East European Craton margin

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Peridotitic xenoliths sampled by Jurassic alkaline basanites from S Sweden provide key insights into the lithospheric mantle evolution at the SW margin of the East European Craton (EEC). The xenoliths include high- and low-temperature peridotites. High-temperature peridotites show hypidiomorphic granular and granular textures and contain chemically homogeneous clinopyroxene with a convex-upward REE pattern ($(La/Lu)_N$ = 1.70-14.55). The low-temperature peridotites comprise rocks of protogranular and porphyroclastic textures. The protogranular ones contain chemically homogeneous clinopyroxene with a convex-downward rare earth elements (REE) pattern ($(La/Lu)_N$ = 3.40-17.30), while in the porphyroclastic peridotites the clinopyroxene is usually heterogeneous and incompatible element-enriched ($(La/Lu)_N$ = 5.68-58.69).
Application of various geothermobarometers suggests that high-temperature peridotites (e.g. T(Ca-in-Opx) = 1050-1180 °C; Brey and Köhler 1990) formed through reaction between shallow peridotites (33 and 42-44 km) and melts similar to alkaline mafic rocks of various ages from S Sweden. Low-temperature (T(Ca-in-Opx) = 835 °C) protogranular peridotites derive from ~50-60 km, while porphyroclastic types (T(Ca-in-Opx) = 883-1002 °C) represent deeper levels (~60–65 km, estimations based on 3D geothermal model of Čermák and Bodri (Tectonophysics, 1995) with correction for lithosphere cooling since Jurassic) affected by cooling followed by reheating. This thermal evolution is recorded by heterogeneous, zonal chemical composition of pyroxenes. The textures, modal and chemical compositions of the low- and high-temperature peridotites suggest their evolution involved reactions with mafic melt (protogranular) and metasomatism by variable fractions of carbonatitic melt (porphyroclastic). This complex and intense multi-stage metasomatic process may have contributed to the modification or loss of cratonic features in the lithospheric mantle beneath the southwestern margin of the EEC.

Boninitic and FAB Magmatism in the Kukes Massif (Mirdita Ophiolite, Albania): Evidence for a Jurassic Forearc Segment in the Tethyan Realm

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Due to its limited tectonic overprint and alteration, the Mirdita Ophiolite (N Albania) offers one of the best-preserved sections of oceanic lithosphere worldwide. It exhibits notable internal variation: the western domain comprises lherzolitic and harzburgitic mantle domes with MORB-type magmatism, whereas the eastern Mirdita Ophiolite (EMO) displays a complete Penrose-type sequence with SSZ chemistry. Our study focuses on ultramafic and mafic rocks from the Kukes massif, located in the easternmost EMO. These rocks form a continuous lithological sequence from east to west, transitioning from depleted mantle harzburgites through thick (1.5-2.5 km) dunites and pyroxenites to layered gabbros. Mineral compositions indicate a high degree of partial melting in harzburgites (orthopyroxene Mg#=90.3-91.5, Al_2O_3= 0.8-2.2 wt%) and of reaction melting in dunites (olivine Fo=87-92.5, NiO = 0.15-0.42 wt%). Clinopyroxenes in wehrlites and pyroxenites exhibit homogeneous, depleted major (Mg#=87-92) and trace element compositions (LuNC1=0.8-2.3), suggesting crystallization from a single magma type. We interpret the Kukes rocks as products of melt–rock interaction (mantle wehrlites and dunites) and crystallization (crustal pyroxenites and wehrlites) from boninitic and foreac basalt-like (FAB) magma. Their geochemical features resemble cumulate sequences from the Bonin Ridge forearc slope [Loocke, Snow, J Petrol 2024] and the New Caledonia ophiolite [Marchesi et al., Chem Geol 2009]. In both settings, boninitic magmas played key roles in crust formation and lithosphere evolution, in Bonin the role of FAB is also emphasized. The lithological and chemical architecture of the Kukes massif mirrors that of the Bonin inner trench, suggesting that the EMO represents a Jurassic forearc segment. Combined with the presence of FAB-like sheeted dikes [Phillips-Lander, Dilek, Lithos 2009], we propose that this ophiolite records the early evolution of a west-dipping subduction zone. If this inference is correct, it has important implications for understanding igneous processes in subduction zones and for reconstructing the geotectonic evolution of the Balkans.

From crustal protoliths to mantle garnet pyroxenites: insights from Os isotopes and highly siderophile elements

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Recycled pyroxenites are key components of mantle heterogeneity, influencing magma generation and contributing to the radiogenic Os signature of oceanic basalts. However, natural examples of pyroxenites recording crustal recycling are rare, and the mechanisms behind their formation remain debated. This study presents data on HSE, chalcogens (S, Se, Te), and Os isotopes from garnet clinopyroxenites and websterites enclosed in fertile peridotites from the Jurassic Northern Apennine ophiolites. The pyroxenites show fractionated HSE patterns, depleted in Os and Ir and enriched in Pt, Pd, and Re relative to host lherzolites. Present-day ^{187}Os/^{188}Os ratios range from moderately to highly radiogenic (0.154–2.475). Garnet clinopyroxenites exhibit lower Os, higher Pd/Ir, and more radiogenic Os than websterites. Model calculations based on bulk HSE data indicate the garnet clinopyroxenites reflect sulfur saturation and base metal sulfide (BMS) crystallization from partial melts of eclogites derived from MORB-type gabbroic protoliths. Their Os isotope signature indicates long-term Re/Os enrichment and derivation from ancient protoliths (>1.0 Ga). The HSE distribution and Os isotopic signature of the websterites, along with their sulfide mineralogy, support a hybrid origin with contributions from both peridotite- and eclogite-derived components. The websterites may represent natural analogs of the second-stage pyroxenites involved in OIB magma genesis. Host lherzolites exhibit flat CI chondrite-normalized HSE patterns and near-chondritic Se/Te and Pd/Ir ratios, implying initial depletion of incompatible HSE, followed by BMS addition during melt percolation that also affected some pyroxenites. Se (78–539 ppb) and Te (13–44 ppb), the first reported data for recycled mantle pyroxenites, are significantly enriched in the pyroxenites. The low Se/Te ratios (6–15) in garnet clinopyroxenites could explain the Se–Te signature of plume-influenced E-MORB. The HSE and Os isotope variability of the pyroxenites reflects heterogeneity of crustal protoliths, melt-peridotite interactions and melt percolation, offering insights into crustal recycling in the mantle.

Diving into the roots of plumbing systems: ultramafic xenoliths from a Triassic diatreme in the Dolomites (Southern Alps, Italy)

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Ultramafic cumulate xenoliths are one of the most useful tools to achieve information about the deepest portions of magmatic plumbing systems. Here, we report new textural and geochemical data on ultramafic xenoliths hosted in Middle–Late Triassic volcanic diatremes intruding the Latemar carbonate platform (Dolomites, Southern Alps, Italy). The xenoliths, mainly clinopyroxenites with minor wehrlites and websterites, display equigranular to inequigranular textures. Pristine samples (wehrlites and some clinopyroxenites) contain diopsidic clinopyroxene with Mg# 90-93, CaO 22-25 wt%, and Cr_2O_3 0.2-0.7 wt%. In contrast, clinopyroxenes (in clinopyroxenites and websterites) modified by host interaction show Mg# 82-87. Clinopyroxene in the host lava is normally zoned, showing primitive cores (Mg# 81-95; Cr_2O_3 0.1-1.1 wt%) and evolved rims (Mg# 62-77; Cr_2O_3 < 0.1). Olivine crystals in xenoliths ($Fo_{84–89}$, NiO 0.10-0.15 wt%) are less primitive than those in the host lava (Fo_{92}, NiO up to 0.4 wt%). Orthopyroxene in websterites is relatively Mg-poor (Mg# 77-82) with 1.1-1.8 wt% Al_2O_3. Spinels occur as chromite, magnetite, and Ti-magnetite, with Cr_2O_3 ranging from 0.1 to 45.5 wt%. Chondrite-normalised trace element patterns in clinopyroxene reveal general depletion (0.01–10 chondritic), negative Rb, Ba, and HFSE anomalies, and positive Th–U anomalies. REE patterns are convex-upward, with La/Yb_N ratios of 1.5-8.2 and negative Eu anomalies in Mg-poorer crystals (Mg# 82-83). Thermobarometry indicates clinopyroxene in xenoliths crystallised at 1077-1100 °C and 300-500 MPa, while crystals in host lava formed across a broader range (1030-1170 °C; 170-900 MPa).

These results help to reconstruct the deepest portion of the plumbing system of Middle Triassic volcanoes in the Dolomites. Equilibrium melt calculations with clinopyroxene will be used to trace the magmatic liquid line of descent and evaluate the Triassic melt compositional evolution in this section of the Southern Alps.

Osmium isotope signatures in petit-spot mantle xenoliths from the northwestern Pacific reveal the presence of ancient, depleted mantle components

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Studies of oceanic peridotites such as abyssal peridotites and mantle xenoliths from ocean island basalt have shown that the present-day Earth's mantle preserves chemical heterogenity that were created during ancient partial melting events. Here we focused on peridotite xenoliths from small intra-plate volcano called “petit-spot” found on the deep seafloor near the subduction zone. These petit-spot volcanoes are not associated with mantle plumes or other large-scale mantle upwellings, and therefore, the peridotite xenoliths from these volcanoes provide rare and direct samples of the old oceanic lithosphere just before it is subducted. This information helps complement data from abyssal peridotites, which mostly represent shallower and younger parts of the oceanic lithosphere.

The peridotite samples including garnet-bearing lherzolites from two petit-spot localities in the northwestern Pacific: Site-A (~130 Ma seafloor age) and Site-B (~135 Ma seafloor age) were obtained using the submersible Shinkai 6500 during research cruises: YK05-06, YK20-14S, YK21-07S, and YK24-10S, by R/V Yokosuka. We conducted analyses of Re-Os isotope ratios and highly siderophile element concentrations on selected harzburgite and lherzolite samples. Most of the samples showed 187Os/188Os values that match the range reported for abyssal peridotites (~0.122 to 0.132). However, one sample had a notably low ratio of about 0.118, suggesting that part of the lithospheric mantle beneath the petit-spot volcanoes had undergone melt depletion in Proterozoic.

Previous studies have shown that basaltic lavas from petit-spot volcanoes are enriched in incompatible elements and exhibit isotopic signatures similar to the EM-1 mantle component, which is believed to originate from ancient recycled materials. In this presentation, we will discuss whether the unradiogenic Os isotopic ratios observed in petit-spot mantle xenoliths are genetically related to the magma source of the petit-spot volcanoes or reflect a common heterogeneity within the shallow lithospheric mantle.

Volatile Element and B, Sr, O Isotope Systematics of the Serpentinized Oceanic Mantle Lithosphere: New Constraints from Recent Deep Drilling at the Atlantis Massif (IODP Exp. 399)

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The volatile element makeup and isotopic systematics of serpentine minerals provide a critical record of the process of hydration of mantle rocks exhumed on Earth's mid ocean ridge system. These geochemical tracers can also be employed to track devolatilization in subduction zones and associated fluid-mediated subduction zone processes. Dredging and shallow (<200 m bsf) drilling in abyssal serpentinite has provided critical insight into the nature of oceanic serpentinization but does not provide the spatial context necessary to interrogate km-scale geochemical variability.

We present bulk rock B and Sr measurements on a deep (1268 m) core in abyssal serpentinite and subordinate gabbroic rocks recovered at the Atlantis Massif oceanic core complex during IODP Expedition 399. Serpentinite B contents decrease by an order of magnitude downcore reflecting distillation of alteration fluid and lower integrated fluid flux away from a crustal-scale detachment fault. Substantial variation in serpentinite B isotopic values primarily reflect spatial and temporal variability in temperature and pH conditions during the serpentinization process. Conversely, the Sr systematics of serpentinite is almost entirely controlled by the late precipitation of carbonate during late-stage seawater ingress and localised carbonation along the margins of gabbroic intrusions. Our results imply a more limited role for the hydrated lithospheric mantle in the long-term cycling of B and Sr than previously thought.

We also present plans for upcoming in situ B, O isotopic and trace element analysis on selected U1601C serpentinites. This work will form part of a detailed study on the temporal evolution of alteration conditions that facilitate serpentinization in oceanic environments.

Redox evolution of the lithospheric mantle beneath the Nógrád-Gömör Volcanic Field (Northern Pannonian Basin)

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The oxidation state of polyvalent elements determines the redox state of the Earth's mantle, which in turn influences the location of the mantle solidus and melt/fluid-rock interactions, causing elemental fractionation in space and time. Iron is the most abundant redox-sensitive major element in the mantle, and therefore largely controls the redox state of a given mantle volume, but it may nevertheless undergo redox interactions with other polyvalent elements, such as carbon and sulfur. If the $Fe^{3+}/\Sigma Fe$ of spinel is known, the assemblage olivine, orthopyroxene and spinel can be used as an oxybarometer, providing crucial insights into the speciation and mobility of volatile elements. Wehrlites are orthopyroxene-free to -poor rocks which are key indicators for interaction of peridotite with small-volume, carbonated melts. Their formation involves formation of olivine and clinopyroxene via consumption of orthopyroxene and dolomite, accompanied by release of CO_2 vapour, which may ultimately be released to the atmosphere. The Nógrád–Gömör Volcanic Field (NGVF) is one of the locations in the Carpathian–Pannonian Region where Neogene alkali basalts brought abundant upper mantle xenoliths to the surface. Detailed previous studies on the geochemical evolution of the NGVF suggest that initial mantle depletion was followed by enrichment associated with a poorly characterized subduction event and subsequent basaltic melt migration and related melt-rock interactions. This later event led to the formation first of orthopyroxene-poor lherzolite and ultimately wehrlite and was plausibly accompanied lithospheric mantle oxidation, but such a trend remains to be unambiguously documented. With this in mind, we are in the process of reducing high-precision spinel data acquired by electron probe microanalyzer (EPMA) in 30 xenoliths ranging from lherzolite to orthopyroxene-poor lherzolite and wehrlite, whereby the $Fe^{3+}/\Sigma Fe$ ratio of the spinels is calculated based on mineral stoichiometry and a set of Mössbauer-characterized secondary spinel standards.

Inhomogeneous mantle lithosphere underneath Central Vietnam: petrological and geochemical aspects

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Cenozoic intraplate volcanic centers are widely dispersed along the continental margin of East Asia. Mantle-xenolith-bearing basalts of the most recent volcanic activity mainly consist of alkali basalts and basanites. A collection of 24 mantle xenoliths from Central Vietnam (Pleiku-area), predominantly spinel-lherzolites (17), spinel-harzburgites (3), wehrlites/dunites (2) and garnet-pyroxenites (2) has been studied in detail. With exception of the garnet-pyroxenites where amphibole has been identified, no other hydrous phases have been so far identified in the studied rocks. It is remarkable that one third of spinel-peridotites are strongly enriched in opx, suggesting metasomatic interaction with Si-rich melts. The major and trace element analyses display a wide compositional range indicating a common mantle source having experienced variable degrees of partial melting between 2 % and 20 %. The REE are divided into two groups: group A with $(La/Yb)_N$ <1 and group B with $(La/Yb)_N$ >1. In group 1 there is a slight LREE enrichment $(La/Nd)_N$ between 2 and 9. In group B the samples with the highest up to 43 $(La/Yb)_N$ ratio are dunites and wehrlites. Chondrite normalized highly siderophile element (HSE) patterns show melt depletion combined with metasomatism by sulphur-undersaturated melts. The Os T_{RD} age shows that the Lithospheric Mantle underneath Central Vietnam has been stabilized before 1.9 Gy, which is consistent with the Meso-Palaeoproterozoic age of the crustal formation in this region. Estimates of P-T conditions yield an unusual wide range of equilibration temperatures from 710 to 1020 °C and source depths of about 36 to 50 km. The mantle lithosphere underneath the studied area experienced carbonatitic and silicate metasomatism. Samples with high CaO/Al_2O_3-ratios together with high Eu/Ti-ratios and CO_2-inclusions in clinopyroxenes indicate carbonatitic metasomatism whereas samples with strongly enriched LREE and MREE suggest interaction with Si-rich melts.

Xenolithic comment on the evolution of the Variscan orogenic mantle root in Europe

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The European Variscan Orogen (EVO) originated through tectonic accretion of some continental ribbons followed by collision of Gondwana and Laurussia. During growth of the orogen, slices of its mantle were tectonically incorporated into the crust and now they form "orogenic peridotites", which usually belong to the garnet peridotite facies. The partially molten orogenic root (Moho depth ca 55-60 km) was affected by gravity-driven lateral flow. This process occurred to different degrees throughout the Variscan belt concomitantly with slab retreat and led to gravitational collapse, resulting in a relatively flat Moho at ca 30-32 km depth. The peridotites of lithospheric mantle of the EVO were sampled – as xenoliths – by numerous Cenozoic alkaline lavas of the Central European Volcanic Province. Despite locally strong Cenozoic metasomatic overprint, these xenoliths offer the opportunity to decipher the evolution of lithospheric mantle from which they come. The peridotite xenoliths occurring in Cenozoic lavas are almost exclusively spinel peridotites, showing that large part of lithospheric mantle underlying EVO was exhumed from garnet- to spinel-facies P-T conditions. This decompression is recorded by spinel-pyroxene symplectites after garnet in some xenoliths. The xenoliths containing those symplectites usually are harzburgites depleted in major melt-mobile elements, suggesting that they represent lithospheric mantle fragments tectonically attached to the orogenic root ("Variscan orogenic mantle" of Puziewicz et al. 2020). Their occurrence documents decompression caused by significant crustal thinning which indicates that large parts of the EVO lithospheric root escaped wholesale delamination and replacement by asthenospheric mantle. Orogen-scale analysis of mantle xenoliths, combined with models of crust evolution, allow thus to propose more precise tectonic-geodynamic models of the EVO.

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Petrology and geochemistry of mantle xenoliths from Lanzarote (Canary Islands, Spain)

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Mantle-derived xenoliths from the Macaronesian archipelagos (North East Atlantic) can provide useful insight on the structure and geodynamic evolution of the oceanic lithospheric mantle.
A petrological and geochemical study of mantle-derived xenoliths from Lanzarote was conducted to reconstruct the depletion and subsequent metasomatism experienced by the oceanic lithospheric mantle beneath the Canary Islands, and its relation to the Canary Island volcanism. The studied n. 17 samples are spinel-bearing and mostly harzburgites, with subordinated dunites and orthopyroxene–rich harzburgites. The harzburgites have protogranular texture and are composed of Fo_{90-92} olivine, orthopyroxene with Mg# = 90-92, clinopyroxene with Mg# = 90-93, and spinel with Cr# of 40-60. Dunites have protogranular to slightly porphyroclastic texture, and are composed of Fo91-91.5 olivine and spinel with Cr# of ~40. All samples fall within the OSMA (Olivine-Spinel Mantle Array), and plot within the abyssal peridotite field. Partial melting models suggest that the harzburgites represent a refractory mantle which has experienced 20-30% partial melting, which is consistent with what is reported by other authors (Siena et al., 1991; Neumann et al., 1995). In harzburgites, reaction zones around spinel and orthopyroxene include secondary Mg-rich olivine, clinopyroxene, Cr-rich spinel and Si-rich andesitic glass. In the dunites, reaction zones are constituted by secondary olivine and spinel and by trachybasaltic glass. Corroborated by thermobarometric data, our results will be used to reconstruct the sequence of events which shaped the oceanic lithospheric mantle beneath the easternmost portion of the Canary archipelago.

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Light noble gases and carbon in ultramafic xenoliths provide information of mantle processes

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In mantle studies, noble gases and carbon are typically measured in fluid inclusions (FIs) within minerals from ultramafic rocks. Light noble gases are key tracers for assessing the composition and dynamics of the Earth's mantle. Among them, helium isotopes (^{3}He and ^{4}He) are particularly informative due to their distinct origins: ^{3}He is primordial, while ^{4}He is generated by the radioactive decay of U and Th. Variations in the ^{3}He/^{4}He ratio reflect the heterogeneity of mantle reservoirs and are widely used to identify deep mantle (plume) contributions as well as the recycling of crustal materials linked to geodynamic processes. In contrast, neon and argon isotopes are more susceptible to atmospheric contamination, as Ne and Ar are several orders of magnitude more abundant in the atmosphere than in mantle-derived fluids. Nonetheless, their isotopic compositions provide insights into the presence of atmosphere-derived components in the mantle. Additionally, ratios such as He/Ar are also useful for constraining partial melting and metasomatic processes.

Carbon is typically present in FIs as CO_2, which is the dominant fluid phase in mantle xenoliths. The CO_2 content, combined with the carbon isotopic composition (δ^{13}C), provides additional constraints on the type and extent of metasomatism and on crustal recycling into the mantle.

In this contribution, I will present selected case studies from European and global localities that highlight the application of noble gas and CO_2 systematics in FIs for investigating mantle processes. Special attention will be given to the integration with mineral chemistry, which allows a better understanding of how:

- degrees of partial melting are mirrored in volatile ratios within FIs;
- CO_2 abundances in FIs can reveal carbonate/carbonatitic metasomatism in the sampled mantle domains.

Fluid Inclusions in Mantle Xenoliths: A Key to Understanding the Deep Carbon Cycle

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Carbon ingass into the Earth's mantle is driven by recycling of subducted carbonate and organic materials in sediments, altered oceanic crust, and mantle layers attached to the oceanic slab (Plank and Manning, 2019). While some subducted carbon returns to the exosphere via volcanic arcs, most is transferred into the deep mantle. The chemical reactions and new carbon phases in the mantle influence the formation of various isotopic reservoirs, offering critical insights into crustal recycling and deep carbon cycling. Fluid inclusions in mantle xenoliths are primarily composed of CO_2, along with other carbon species such as CH_4, CO, and carbonates. This makes them ideal objects for studying the carbon isotopic signature of the mantle and the metasomatic fluids that modify its composition. Isotopic analyses of mantle xenoliths show a wide $\delta^{13}C$ range from -30‰ to +1‰, attributed to three endmembers: mantle carbon (~-5‰; Deines, 2002), organic carbon (-30‰ to -10‰; Faure, 1987), and carbonate carbon (-1‰ to +1‰; Sano and Marty, 1995). Our research on fluid inclusions in mantle xenoliths, sourced from ocean island basalt (OIB) and continental rift regions, integrates the analysis of carbon isotopes. We show that the isotopic composition of the upper mantle is variable and closely tied to the geodynamic history of each study area, as well as metasomatic and refertilization processes. By examining mantle xenoliths from the Canary Islands, Mexico, French Polynesia, Cape Verde, and Tanzania, we provide insights into the characteristics and evolution of the lithospheric mantle across different geodynamic settings. We also investigate the roles of partial melting, mantle metasomatism, and refertilization. Key aspects we aim to address include the influence of mantle plumes on recent magmatism in OIB regions, and the way carbon - either from recent or fossil subduction systems - is recycled into the mantle.

Constraints on the neon isotopic composition of the lower mantle by single vesicle analyses in Icelandic glasses

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The origin of volatile elements on Earth is still debated. Noble gases, due to their chemical inertness, can serve as powerful proxies to study planetary formation processes and mantle evolution. Neon is particularly relevant for tracing the source of volatile elements of our planet as its isotopic composition varies greatly between reservoirs in the Solar System. The existence of a preserved (over 4.45 Ga), relatively undegassed, reservoir in the mantle has been inferred from noble gas isotopic systematics [1]. This reservoir is tapped by deeply rooted mantle plumes, namely Galapagos, Hawaii and Iceland plumes. Analysis of quenched glass, preserving magmatic gases, from these locations, revealed that the neon isotopic composition of the lower mantle is different to that of the upper mantle (source of the MORBs), particularly for the ^{21}Ne/^{22}Ne ratio. In both cases however, neon has a ^{20}Ne/^{22}Ne ratio over 12, akin to a solar, primitive source, distinct from the atmospheric ratio of 9.8. The exact neon isotopic compositions of the lower mantle is still unclear, however. Indeed, the step-heating or step-crushing analytical techniques leads to a mixing curve for neon isotopic ratios between air contained in cracks and open vesicles (^{20}Ne/^{22}Ne = 9.8) and the mantellic value, contained in closed vesicles. To address this, we analyzed single vesicles from undegassed Icelandic subglacial lavas and developed a statistical approach to determine the ^{20}Ne/^{22}Ne of the Icelandic source. This technique has been shown to be efficient to obtain the neon isotopic composition devoid of shallow atmospheric contamination. Our findings support solar wind irradiation of protoplanetary disk dust as the mechanism for Earth's light volatile accretion, aligning with Péron et al. [2] for the Galapagos mantle source.

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Tracking mantle heterogeneity across the Iberia-Newfoundland conjugate margin: new insights from PGE and Re-Os isotopes

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The Iberia-Newfoundland conjugate margins are among the few sites on Earth where the mantle exposed at an ocean-continent transition has been accessed through scientific drilling. Despite their relevance, the comprehensive characterization of these mantle rocks was long hampered by pervasive serpentinization, leaving their origin and evolution poorly constrained. Recently, renewed attention has provided new insights into these mantle sections (e.g. Secchiari et al., 2025). Peridotites from the West Iberian margin (WIM) show striking petrological and geochemical heterogeneity, reflecting ancient melt depletion overprinted by rifting-related melt–rock interaction. In contrast, Newfoundland margin (NFM) peridotites are more homogeneous, displaying highly depleted geochemical signatures (Müntener & Manatschal, 2006). Here, we present new platinum-group element (PGE) abundances and Re-Os isotope data from a suite of well-characterized peridotites drilled at the WIM (ODP Hole 899B, 1068A, 1070A) and the NFM (ODP Hole 1277A). PGE concentrations fall within the range of abyssal peridotites, showing strong correlations among IPGE (Ir, Os, Ru) and more scattered trends for PPGE (Pt, Pd). NFM peridotites display greater variability and generally higher PGE contents. PM-normalized PGE patterns are flat to gently sloping (Pd_N/Ir_N =0.77-0.87) for WIM samples, except for Hole 1070A, which shows fractionated IPGE-PPGE profiles (Pd_N/Ru_N= 0.07-0.6) and Pd negative anomalies. In contrast, NFM peridotites exhibit flat IPGE patterns with pronounced Pt-Pd anomalies. Initial $^{187}Os/^{188}Os$ recalculated at 120 Ma range from sub-chondritic to chondritic (0.1135-0.1292), with variable $^{187}Re/^{188}Os$ (0.05-2.31). Re-depletion ages (TRD) for low Re/Os peridotites (mainly WIM) mostly fall between 0.4 and 0.7 Ga, with some samples yielding notably older ages well beyond 1 Ga. These results highlight distinct geochemical and isotopic signatures between the mantle domains exposed at the Iberia - Newfoundland conjugate margin, supporting asymmetric rifting and exhumation of long-lived, heterogeneous mantle domains with contrasting evolutionary histories.

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Source and evolution of post-subduction, potassic magmatism, NE Papua-New-Guinea

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Potassic magmatism hosting economic gold deposits occurs within the Tabar-Lihir-Tanga-Feni island chain, NE Papua-New-Guinea. The island chain is situated within a former forearc basin, and melts are characterized by the geochemical fingerprint of mantle metasomatism. Current models attribute the formation of primitive K-rich magma to preferential melting of hydrous phases in the metasomatized mantle source as a response to incipient rifting. The conditions of melting and magma evolution at crustal depths, resulting in a wide range of melt compositions erupting in volcanic edifices of variable types, are yet unknown. This study focuses on primitive K-rich basalts, previously unknown in the region, and more Si-rich absarokites sampled at a volcanic ridge south of Tabar Island. The samples were recovered during cruise SO299-DYNAMET (June-July 2023). K-rich basalts include olivine phenocrysts and xenocrysts, augite phenocrysts and chromite microphenocrysts in a glassy groundmass. Absarokites include augite and plagioclase phenocrysts and olivine and magnetite microphenocrysts in a glassy groundmass. Major element composition and mineral textures of basalts and absarokites from the South Tabar Ridge shed light on their diverging evolutionary pathways. Compositions of olivine-hosted melt inclusions and volcanic glasses in basalts and absarokites plot along a common line of descent, indicating formation of intermediate lava from mantle-derived melt via fractional crystallization of mafic phases. Gradual normal zoning of phenocrysts in absarokites provides further evidence for extensive fractional crystallization. Superposed on the general fractionation trend is (a) late crystal settling of sub-ophitic augite-plagioclase in absarokites, also reflected by P_2O_5 and K_2O depletion; (b) early wall rock incorporation in basalts, evident by the occurrence of dunite xenoliths, olivine xenocrysts and Fe-rich augite antecrysts, which may be responsible for depletion in P_2O_5 and alkali elements.

Neoproterozoic superchondritic OIB-like magmatism in Eastern Moesia: Cocoşu basalts

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We are presenting here petrological interpretations on Neoproterozoic basaltic volcanism (Cocoşu Group) found in the Precambrian basement of South Dobrogea - a sunken block of the Moesian Platform. The Cocoşu basalts form the lower succession of the Cocoşu Group formation established in borehole 5051 Cocoşu for a 400 m thickness. The succession consists of basalt flows interbedded with coarse to fine-grained volcaniclastics and epiclastic deposits. The rocks are variably vesiculated, showing massive intersertal to porphyritic textures, with variably altered primary magmatic minerals. Abundance of large limestone clasts in the epiclastic beds suggests a shallow marine depositional environment. According to geochemical data the rocks are SiO_2-undersaturated alkaline basalts. Trace multielemental pattern show an enriched light REE relative to chondrite source, very similar with average OIB values. OIB-like characteristics are also attested by the plot of Nb/Yb vs. Th/Yb diagram. Sm_n/Yb_n (3.2-4.5) and Dy_n/Yb_n (1.28-1.73) proposes variable residual garnet implication in the source of Cocoşu basalts, but also a low degree of partial melting of the source as relatively high La_n/Sm_n ratio. All the samples show high Zr/Hf (>37) and Nb/Ta (>19) ratios that are superchondritic suggesting to be derived, at least partially, from a residual (refractory) eclogite reservoir. Since eclogite is fertile, and has a lower melting point than peridotitic mantle could create spots with low melting point, in this way eliminating the need for excess temperature to explain melting anomalies. It is most probably that the source of the Cocoşu basalts is mixture of eclogite and enriched peridotite melting according to Zr/Nb vs La/Yb modeling. The rock geochemistry suggests continental intraplate affinities and a transtensional rift setting. The extensional tectonic event that affected the (edges of) Moesia region could have created conditions that promoted low degree adiabatic decompression melting of a complex asthenospheric magma suggesting a superchondritic garnet peridotitic-eclogitic source.

Chromitite petrogenesis and mantle geodynamics: insights from the Chalkidiki mantle section, Greece

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The PGE-poor chromitite occurrences of west Chalkidiki ophiolites are solely hosted within dunite bodies. These bodies have developed within a highly depleted harzburgite mantle section subdivided into ‘primitive’ and ‘transitional to dunite’ types, correlated with decreasing orthopyroxene porphyroclasts and clinopyroxene concentrations. Clinopyroxene grains are either relict or neoblastic, generally less than 500 μm in length, typically located at grain boundaries or in contact with chromite. Olivine forsterite (Fo) contents record a compositional gap between the relatively low-Fo of ‘primitive’ and high-Fo ‘transitional’ harzburgite. Magmatic and low-pressure Ca-amphibole is included within chromite grains, evidencing hydrous melt interaction. Mineral geothermometry is in line with re-equilibration temperatures, with typical mosaic texture. Detailed mineral chemical analysis revealed compositional differences between the two harzburgite types with respect to their silicate minerals and chromite, yet their chemistry is typical for forearc peridotites, with few analyses resembling abyssal counterparts. The partial melting degrees are estimated to be above 20%. Mineral and whole-rock REE concentrations are considerably below Primitive Mantle (PM) concentrations. In their majority, whole-rock REE profiles are U-shaped typical trait of boninite-rock interaction, being the major controlling mechanism for depletion (constant Yb concentrations and increasing Zr/Hf ratios). The aforementioned interaction between an already depleted harzburgite and boninite led to the formation of dunite and chromitite assemblages. The latter forms confined bodies with low PGE concentrations. The mode of occurrence and PGE geochemistry are controlled by the nature of the mantle section, which was in turn shaped by the local geotectonic settings, i.e. forearc above a subduction zone.

Noble gas isotopic composition in olivine phenocrysts from Miocene to Pliocene basaltic rocks of the Pannonian basin

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Neogene to Quaternary alkaline basalt volcanism in the Pannonian Basin is enigmatic, as it occurred during a phase of thermal relaxation following major continental lithospheric extension. Petrogenetic modeling suggests that the majority of magmas formed in the asthenosphere at depths of 80-120 km. Therefore, a crucial question is why melting was possible at such depths. In this study, for the first time, a noble gas isotope analysis complemented by textural and geochemical investigations was conducted on high-Mg olivine crystals from selected basalt volcanoes in western Hungary, which erupted between 8 and 2.5 million years ago. These results provide insights into the nature of the asthenospheric mantle, and we compared them with noble gas isotope data from olivine in peridotite xenoliths representing the local lithosphere.

The helium isotope ratios, expressed relative to the atmospheric 3He/4He ratio (Ra), ranged from 5.9 to 5.3 Ra in samples from Hegyestű and Ság. In these locations, basaltic magmas likely ascended rapidly, minimizing modification of trapped fluids in olivine, preserving the original isotopic signature. Thus, these values may reflect the nature of the asthenospheric source region. In contrast, relatively lower R/Ra values were observed in basalts from Badacsony and Haláp, where magmas likely resided longer in crustal magma reservoirs before eruption. These R/Ra values are lower than those typical in global asthenospheric mantle and are even below the values measured in the local lithospheric xenoliths (6.5–6.9 Ra).

The relatively low noble gas isotope ratios can be explained by a mantle source, potentially influenced by previous subduction-related contamination and/or the presence of recycled crustal material such as pyroxenite/eclogite. The minor element composition of olivine from Hegyestű and Ság supports a mixed mantle source consisting of peridotite with an eclogite/pyroxenite component, which could lower the solidus and enabled mantle melting at the inferred depths.

Fabric transition of olivine as the cause for an anisotropic seismic discontinuity in the mantle of the northern Slave craton, Canada

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The linkage between olivine fabrics and seismic anisotropy of peridotites is the basis to trace mantle flow and plate tectonics from seismic observations. Here we present an integrated study of 27 peridotite xenoliths from the adjacent Jericho and Muskox kimberlite pipes in the northern Slave craton to correlate the olivine fabric with the seismic architecture of the lithospheric mantle. Olivine H_2O concentrations increase with depth, correlating with a decrease in the olivine Mg# (molar Mg/(Mg+Fe)) and elevated clinopyroxene modes. In the Northern Slave mantle, the dominant axial [010] olivine fabric coexists with two distinct fabrics above and below 120 km. The transition from the [100]-slip dominant (A and AG-type) to [001]-slip dominant (B- and AG-type) fabrics was likely driven by increased pressure and the metasomatically-controlled high water content. The calculated seismic properties of peridotite xenoliths could explain an anisotropic seismic discontinuity observed at 120 km in the Northern Slave. The upper layer is defined by the preferred alignment of the fast [100] olivine axes along the N-S direction of the subhorizontal foliation plane, whereas in the lower layer the olivine [100] axes align parallel to the NE-SW direction. The discontinuity reflects the long, incremental formation process of the cratonic lithosphere that juxtaposes segments with distinct fossil flow directions, as evidenced by distinct fabric orientations. The upper layer may represent the older, depleted peridotites formed during the Mesoarchean craton stabilization, concurrently with the overlying crust. The deeper Proterozoic layer may have been added through accretion, subduction, plume-related melting, and modified by metasomatic events. Below 170 km, the B-type fabric disappears. The olivine AG-type fabric near the lithosphere-asthenosphere boundary results in the present-day asthenospheric mantle flow direction parallel to the polarization direction of SKS waves.

The nature of the upper mantle beneath the Vogelsberg volcanic field (Germany) as revealed by xenoliths from Ober Widdersheim

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Vogelsberg is the largest volcanic field in central Europe. Peridotite xenoliths occur at some localities, offering a glimpse into the geochemical processes in the uppermost lithospheric mantle under the European continent in Miocene times. However, they are restricted to primitive late-stage lavas [1]. A capping basanite flow at the Nickel quarry in Ober Widdersheim (WSW part of field) contains abundant xenoliths. Unfortunately, they are strongly altered, but some are coherent at least in their inner portions, preserving textures and minerals. Eight samples were investigated by EPMA, LA-ICP-MS and Mössbauer spectroscopy (spinel $Fe^{3+}/\sum Fe$). Most are lherzolites, with one harzburgite and one transitional sample. Major element mineral characteristics for the lherzolites are: Opx: Mg# = 0.905-0.91, Al_2O_3 = 3.3-4.0 wt%; Cpx: Mg# = 0.905-0.915, Al_2O_3 = 4.4-5.8 wt%; Sp: Mg# = 0.72-0.76, Cr# = 0.11-0.16. And for the harzburgite: Opx: Mg# = 0.918, Al_2O_3 = 1.8-2.1 wt%; Cpx: Mg# = 0.915, Al_2O_3 = ~3 wt%; Sp: Mg# = 0.61, Cr# = 0.44. Assuming an equilibration pressure of 1.5 GPa, calculated "BKN" temperatures are 940-1000 °C. All samples are oxidised, with $\Delta \log fO_2 >$ FMQ.

Trace element signatures of Cpx and Opx vary between samples. All indicate variable degrees of metasomatic enrichment, with the harzburgite exhibiting the strongest effects, similar to xenoliths from the SCLM beneath the Massif Central [2]. Normalised signatures of Opx indicate depletion going from HREE to MREE, but enrichments in the LREEs. There is more scatter in LREE enrichment within a sample compared with Cpx. Equilibrium Opx/Cpx partitioning [3] is indicated for MREE and HREE, but less so for LREE. Cpx in the harzburgite has low Ti/Eu, elevated Nd/Yb and a stronger negative Hf anomaly compared to Zr, which point to carbonatitic metasomatism. Cpxs in the other samples have flat or slightly depleted chondrite-normalised patterns with variable LREE enrichment, reflecting interaction with silicate melts or fluids coupled with chromatographic effects.

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Post-orogenic K-metasomatism demonstrates lower continental crust recycling in the Earth’s mantle

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Sediment recycling via subduction is widely recognized as a key process for introducing incompatible elements into the Earth’s mantle. However, recent geodynamic models suggest that during the peak of major orogenic cycles, large sections of continental crust can also be subducted and delaminated to mantle depths, where they are stored and remobilized. In this contribution, we document the formation of an enriched domain in the subcontinental lithospheric mantle by the migration of melts produced by partial melting of delaminated Lower Continental Crust (LCC) flowing at mantle depths during the post-collisional phase of the Variscan orogeny. This process triggered pervasive K-metasomatism, resulting in the formation of abundant phlogopite and K-rich pargasite. Trace element and isotopic Nd–Hf–Sr–Pb–O composition of the metasomatized lithospheric mantle reveals a strong affinity with Variscan post-collisional lamprophyres, as well as with African and Australian K-rich cratonic lamproites. We propose that such an LCC-contaminated lithospheric mantle may serve as source for K-rich magmatism, or, if recycled into the deeper mantle, contribute to geochemically Enriched Mantle reservoirs sampled by hotspots and ocean floor basalts.

The evolution of the Oceanic Lithospheric Mantle beneath Madeira Island: evidence from petrology and geochemistry of ultramafic xenoliths

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Ultramafic xenoliths brought to the surface by primitive magmas in the Macaronesian archipelagos (Canary, Cape Verde, Madeira and Azores islands) can provide important constraints on the structure and chemical composition of the oceanic lithospheric mantle, its record of geodynamic processes, and the evolution of deeper portions of plumbing systems beneath active volcanic areas (Munha et al., 1990).

Here we present a detailed study of 16 ultramafic xenoliths brought to the surface by basaltic to basanitic magmas in the Madeira Island (Portugal). The xenoliths are mostly protogranular to porphyroclastic spinel harzburgites and dunites, with subordinate cumulate-textured wehrlites and olivine clinopyroxenites.

Two groups are recognized based on the mineral major element composition. The first group is represented by harzburgites, which are composed of highly forsteritic (90-92) olivine, high Mg# (90-93) pyroxene and high Cr# (0.3-0.7) spinel, suggesting their derivation from a refractory mantle which experienced a high extent (20-25%) of melt extraction. The second group is represented by dunites, wehrlites and olivine clinopyroxenites, comprising low forsterite (82-86) olivine, low Mg# (82-86) pyroxene and low Cr# (0.2-0.4) spinel, which fall out of the peridotite field, pointing towards a cumulate origin related to alkaline magmas (Munha et al., 1990) or to formation by extensive mantle metasomatism. The equilibration temperatures obtained from the two-pyroxene geothermometer and the spinel-olivine geothermometer are 1009-1073 °C for harzburgites and 896-1056 °C for the cumulates, considering a pressure of 11 kbar. The oxygen fugacity was between +0.94 and +1.90 $\Delta\log fO_2$ [FMQ].

Our data provides evidence for the lithospheric mantle beneath Madeira having a refractory composition, and for infiltration by alkaline magmas causing metasomatic modification of the mantle lithotypes and the genesis of cumulate rocks.

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Lithospheric mantle of the Cenozoic Upper Rhine Rift (Europe): the record in xenoliths from the Vogelsberg (Central Germany)

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The 18-14.7 Ma Vogelsberg volcanic field, located at the northern end of the Upper Rhine Rift, belongs to the Cenozoic Central European Volcanic Province. The Vogelsberg overlies the boundary between the Rheno-Hercynian and Saxo-Thuringian zones of the Variscan basement. We studied two xenolith suites (Breitenborn and Nidda) from the Vogelsberg lavas. The xenoliths are spinel peridotites (lherzolites and harzburgites) and sparse clinopyroxenites. Peridotites are protogranular or porphyroclastic, and could display a foliation development. Crystallographic preferred orientation (CPO) of minerals shows that in granular peridotites all three main minerals were deformed together, whereas other peridotites with a well-developed foliation consist of an olivine framework with later addition of pyroxenes. Minerals are chemically homogenous at the grain and xenolith scale (olivine Fo 89.3-91.6%, orthopyroxene Mg# 0.895-0.923 and 0.05-0.24 atoms of Al per formula unit (pfu), clinopyroxene Mg# 0.890-0.931 and 0.10-0.27 atoms of Al pfu). Spinel Cr# ranges from 0.14 to 0.51. Clinopyroxenites are protogranular, contain cpx with Mg# 0.750-0.863 and 0.25-0.36 atoms of Al pfu. The majority of peridotite clinopyroxene REE patterns show different degrees of LREE enrichment. Less common are spoon-shaped, flat or LREE-depleted REE patterns. Clinopyroxene exhibits 87Sr/86Sr ratios from 0.703149 to 0.703413. Temperatures calculated using REE exchange (TREE) range between 860 and 1130 °C and show that the majority of pyroxenes are in REE equilibrium. Temperatures calculated on the basis of pyroxene major element contents are ~40-140 °C lower than TREE, suggesting pre-entrainment cooling from a heating event that is still recorded by the slower-diffusing REE. The lithospheric mantle beneath the Vogelsberg is highly heterogeneous. This may be a result of lithologically variable lithospheric mantle slices docked to the growing Variscan orogen, and modification during late/post orogenic Variscan orogen flattening and subsequent Cenozoic rifting and volcanism.

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