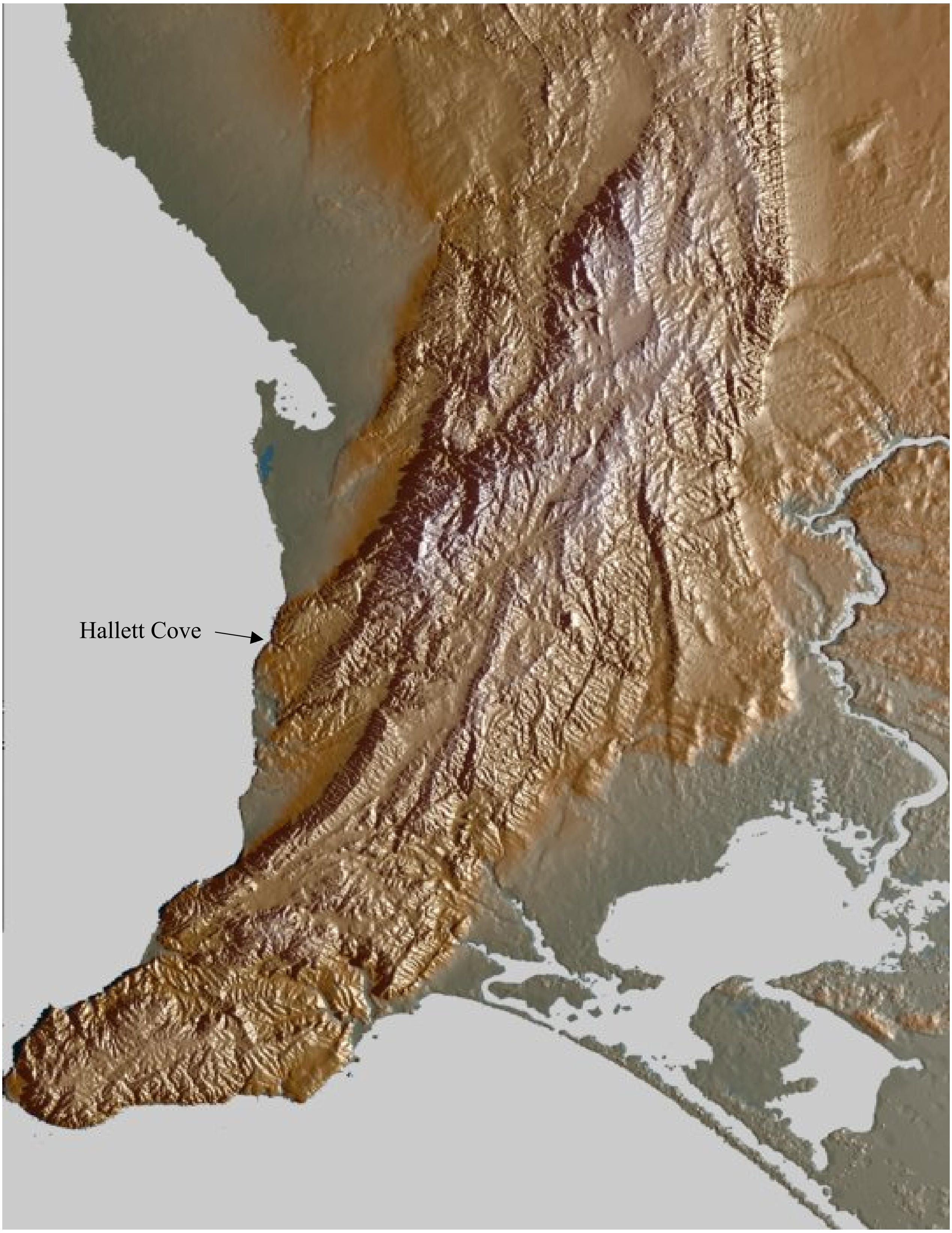
Your Name:____________________

University of Adelaide, School of Physics, Chemistry and Earth Sciences



The Mount Lofty Ranges and Fleurieu Peninsula Digital Elevation map (from jaeger.earthsci.unimelb.edu.au)

Introduction: Welcome

Geology is detective work. We study the rocks of the present-day earth, and based on this experience we learn to interpret more than 4 billion years' worth of prior Earth history. This is a dramatic story of tectonic, climatic, environmental and evolutionary change punctuated by occasional catastrophic earth-changing events. In geology we also use these skills to interpret the present and project to the future.

In this excursion we will show you how to develop and exercise these skills and introduce you to the main events that dominate the older geological history of the Adelaide region, the southern Mt Lofty ranges. Many of these events took place in the time interval from the Late Precambrian about 800 million years ago all the way through to the Cenozoic (about 5 million years ago). Many of you will have seen and learnt about man of the younger events in Building a Habitable Planet 1 in Semester 1, here we are focussing on the older history of region.

Adelaide is a great place from which to study geology. There are few Earth Science departments in the world that have such ready access to such fabulous geology right on the doorstep. We hope you enjoy your field trip. Don't forget to ask lots of questions.

A Simple Geological History:

Australia can be divided into:

1. Old basement (where rocks are older than 1000 million years);
2. Younger crustal growth or add-ons with ages of 800 million years or younger (in fact mostly younger than 500 million years).

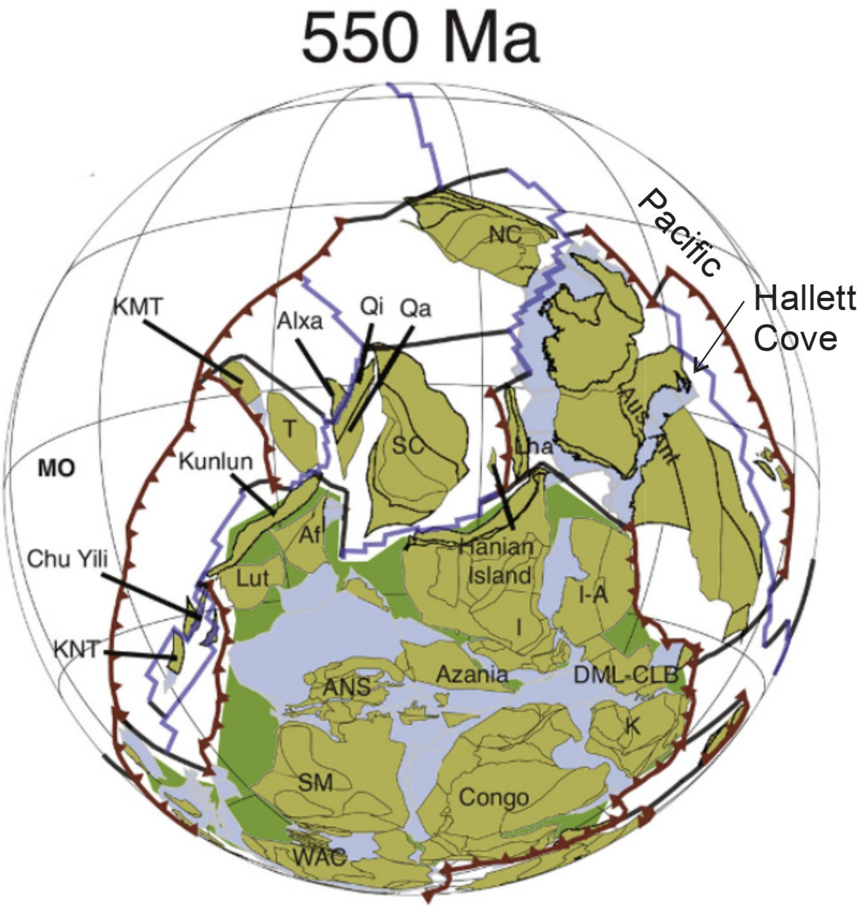
Western Australia, Northern Territory and much of South Australia (west of Adelaide) are composed of rocks that form the old basement. At about 700 million years ago Adelaide would have been on the eastern sea-board with a sea view to the east on the shores of the then newly formed prototype Pacific Ocean (initially smaller than the present ocean) having recently split off from North America, breaking up an earlier super continent called Rodinia. At that stage we together with Antarctica were part of the same continent (called eastern Gondwana). Together we were heading west, and were about to be involved in a nasty pile-up with India and eastern Africa. Africa had at that stage become recently joined to South America forming western Gondwana. Our collision with west Gondwana in the early part of the Cambrian created Gondwana.

The Hallett Cove area is the focus of our trip. It has undergone a number geologic events, which we can see in snapshots.

1. The ***Passive Margin*** phase: A passive margin with the western Pacific lasted from about 800 Ma to 515 Ma. A passive margin is where the continent and adjacent ocean are part of the same tectonic plate. Sedimentary basins form offshore at the edge of the continent. Whilst we had a Pacific view from 800 Ma to 515 Ma sediments poured eastwards off the eroding land into marine basins on the eastern margin. These deposits formed the sandstones, shales and occasional limestones that are now exposed to form the Flinders Ranges and extend south to be exposed as rocks of the prominent eastern "Hills Face" back-drop to Adelaide. These are the strata you see when you drive up the freeway and through the tunnel east from Adelaide (as far east as Mt Barker). These rocks form Black Cliff, the cliff faces to the north and also the shore platform at Hallett Cove.

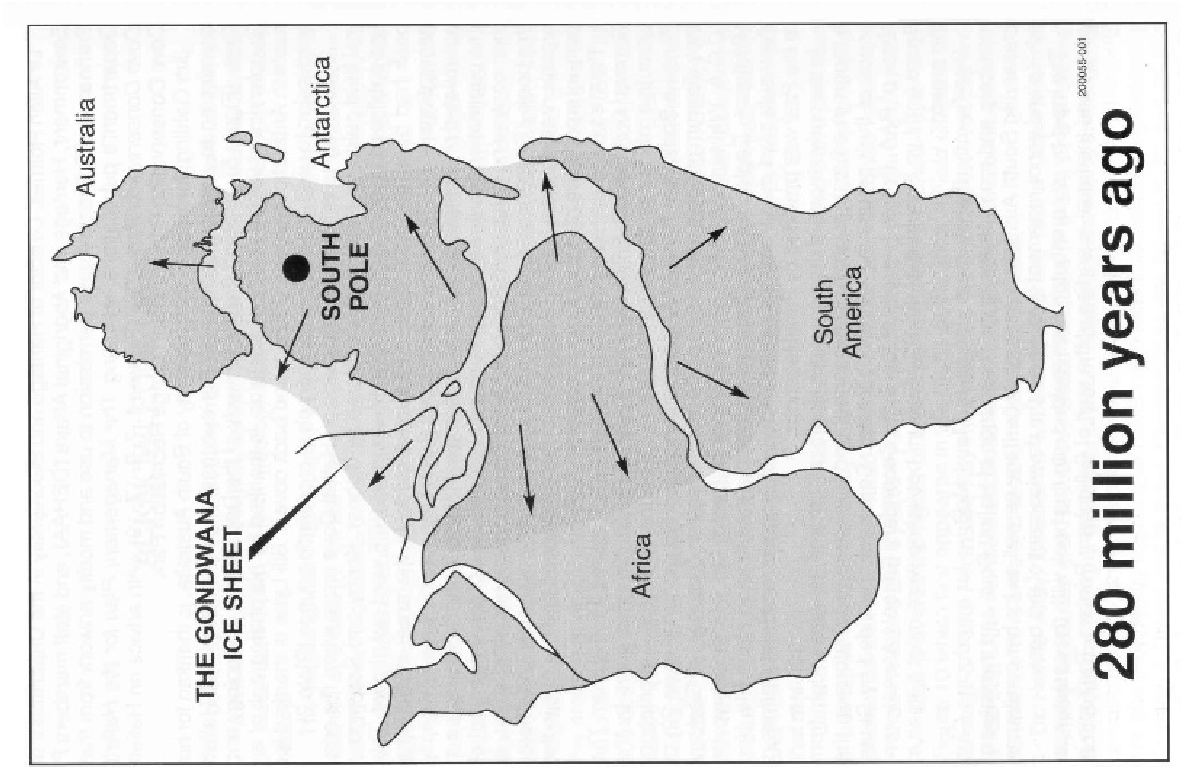
2. Mountain Building: From the start of the Middle Cambrian, the eastern Gondwana margin with the Pacific became a convergent/subduction margin (see figure next page). This continued until the present (note the active Pacific margin of Australia is now in New Zealand). This is a plate boundary where old oceanic lithosphere is thrust into the mantle. This geologic event resulted in the folding and faulting of the passive margin sedimentary rocks.

Below is a map of the formation of Gondwana shortly before the deformation that folded the rocks at Hallett Cove as the subduction zone around the Pacific Ocean advanced on the Australian margin causing compression (a bit like in the Andes today).



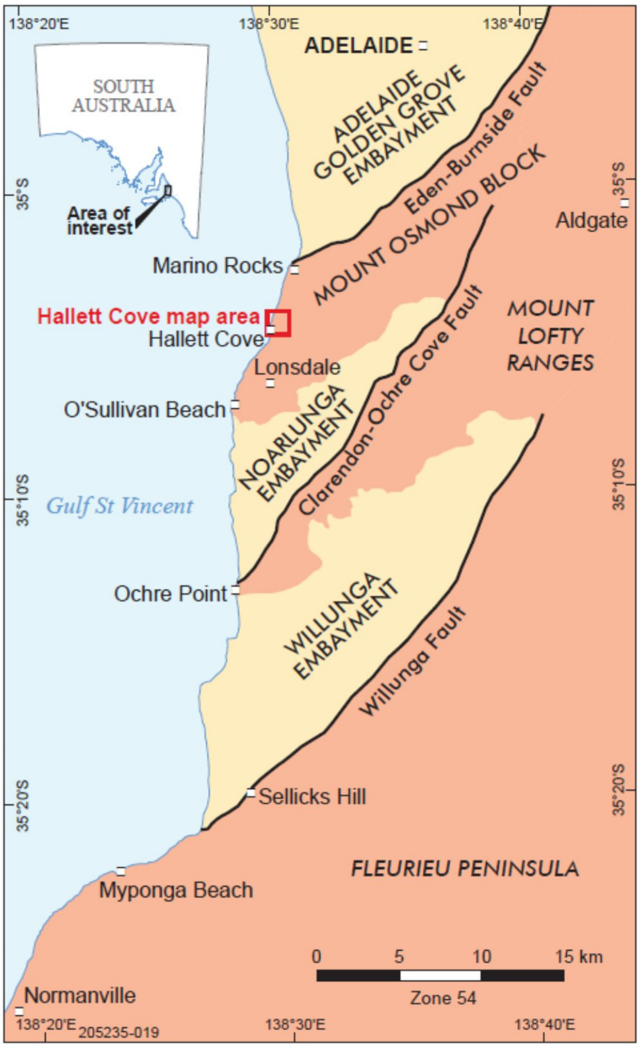
Merdith et al 2021 – Earth Science Reviews

3. Major glaciation: the Permian ice age. Australia was still part of Gondwana. Vast ice sheets covered Hallett Cove, much of Tasmania and Victoria, and part of South Australia. Ice sheets carried large 'erratic' rocks and dumped them. Melting ice deposited fine rock flour and coarser material. These Permian glacial sediments can be found throughout the locality. See the outcrop map of these deposits..



4. A shallow Pliocene sea (about 4 million years ago). A shallow sea covered low lying parts of the land on the Gulf St Vincent. Sandy sediments were deposited, forming the fossiliferous Hallett Cove Sandstone.

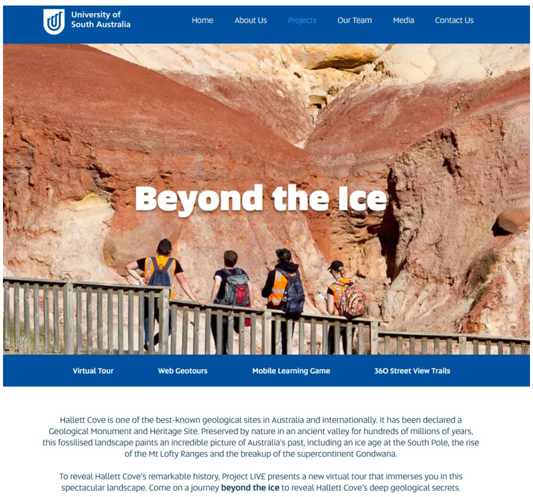
5. Since the Pliocene inversion of the earlier normal fault system that marks the Mount Lofty Ranges, the Adelaide/Golden Grove, Noarlunga and Willunga embayments has caused uplift of the Mount Lofty Ranges. This has occurred over the last 2 million years, and especially over the last 130,000 years and is ongoing today.



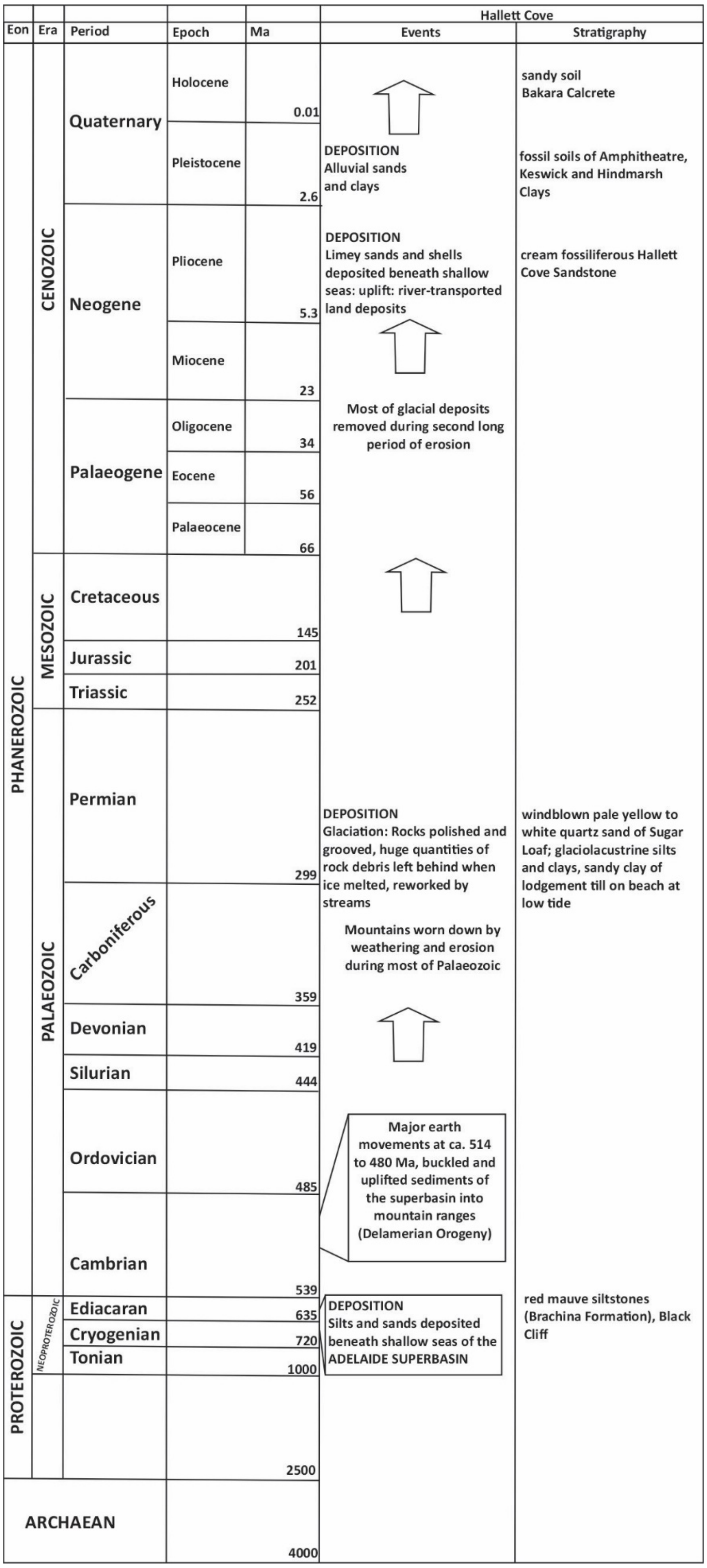
Simplified map of the geological structural location of Hallett Cover (Preiss 2019).

For some wonderful online resources about the geology of Hallett Cove, check this out…

https://www.projectlive.org.au/beyond-the-ice



This chart is a geologic time scale, **and showing the timing of all the geologic events that can be seen at Hallett Cove.**



Calcrete layer

Pleistocene silts and clays (fossil soils)

Hallett Cove Sandstone

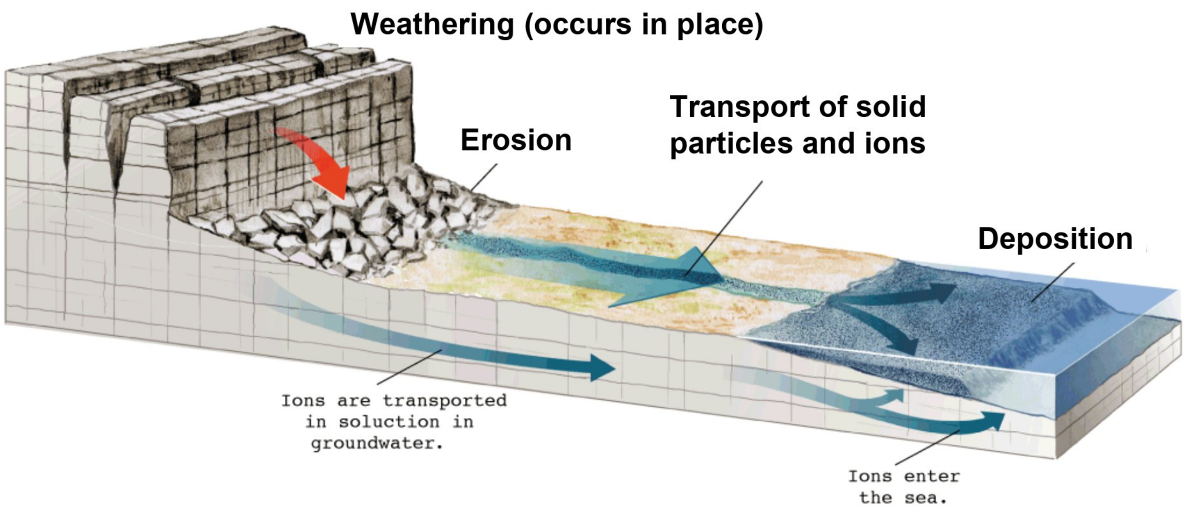
Windblown sands,
Red lake silts and clays

Black Cliff sedimentary rocks are folded and buckled

Black Cliff silt and sand is deposited in a shallow sea

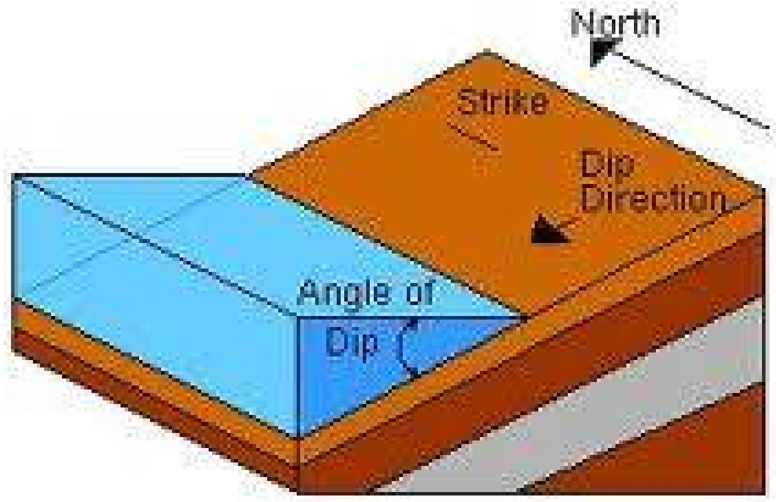
Some things you need to know, or remember:

1. **About sediments and sedimentary rocks:**
   - Sedimentary strata are deposited from surface water (sea, lake, river) and these strata form originally in approximately horizontal layers
   - Sediment is generated by weathering and erosion and the grains of sand and mud thus formed are transported by water (mostly) to the site of deposition (see figure below)

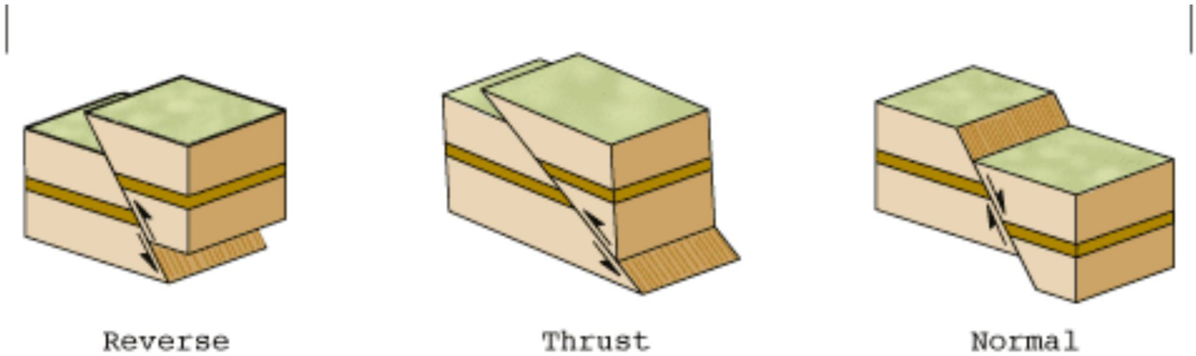


   - Faster currents suspend increasingly coarse particles and therefore fine (muddy) sediments = slower currents, coarser sediments (sand, gravels, pebbles and boulders) = faster currents.
   - When they are deposited, sedimentary strata are successively younger upwards and become finer grained the further away from the sediment source they are deposited.
   - Sedimentary structures such as ripples record information about the nature of the sedimentary processes, directions of tides and currents

2. **About structural geology (we'll revisit this after mid semester break)**
   - Tectonic forces drive tectonic plates and exert stresses (forces) on continents.
   - If these forces are large enough (or the rocks weak enough) then these forces may deform or break the rocks of the crust. We can measure the orientation of a sedimentary layer, called the "dip", the "dip direction" and the "strike" (see figure)

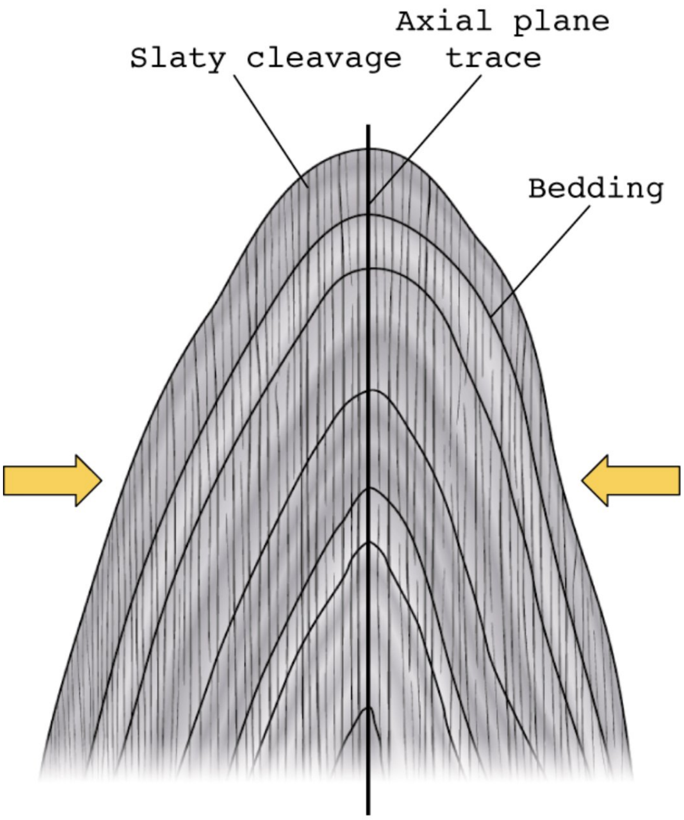


- Failure (breakage) is manifest by fault formation. Types are shown below.

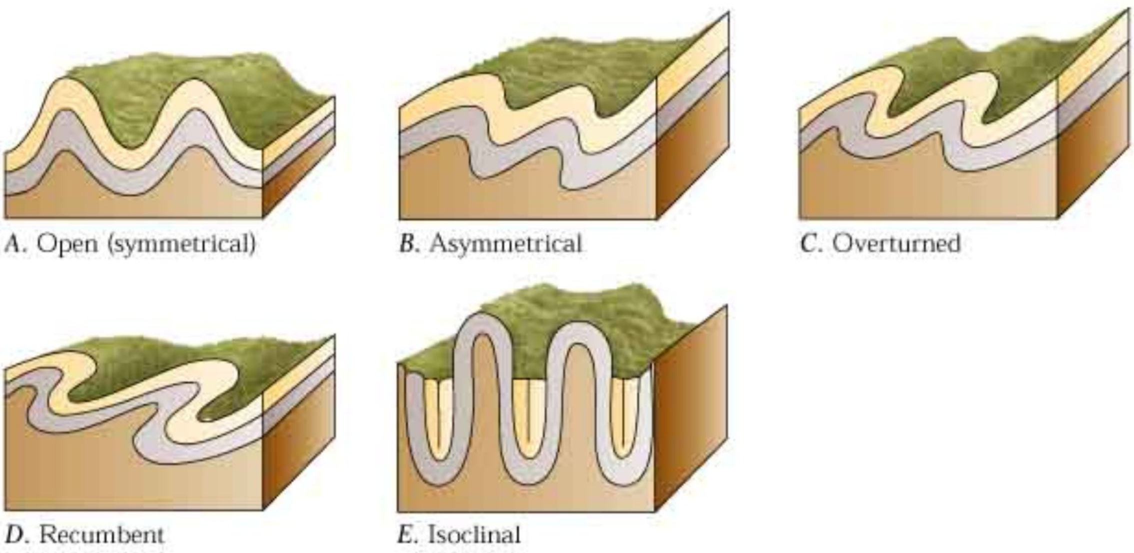


Deformation may result in folding.

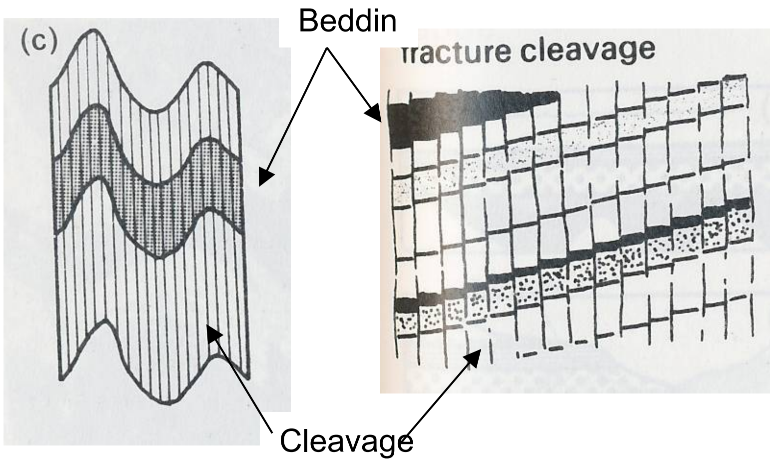
- Folds are generally (but not always) formed with their “crests” (like waves) perpendicular to the direction from which the tectonic force is directed. The picture to the right shows an upright fold with its “crest” perpendicular to the direction of the force.



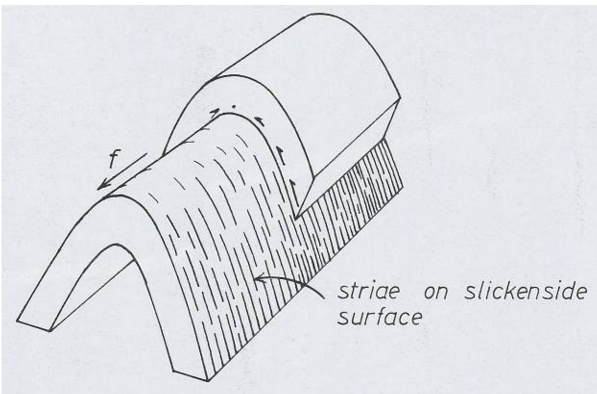
- Folds are often symmetrical and upright but may be “toppled over“ in the direction towards which the tectonic stress is being directed. This is called vergence. See this in examples below

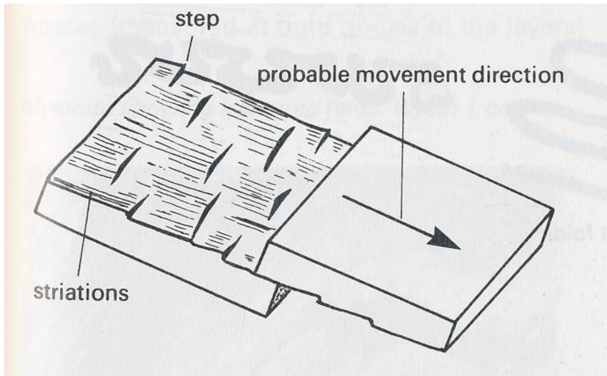


- Folding and faulting may be associated with new mineral growth and alignment to form cleavage or foliation (like the surface that slate splits along). Examples of cleavage within a fold are shown in the figures below.



Flexural slip during folding, or presence of faulting, may develop slickensides. The bedding surface in a fold may become polished to form slickensides which may have streaks parallet to the movement direction. The striations or streaks may show steps which allow the actual movement direction to be determined.



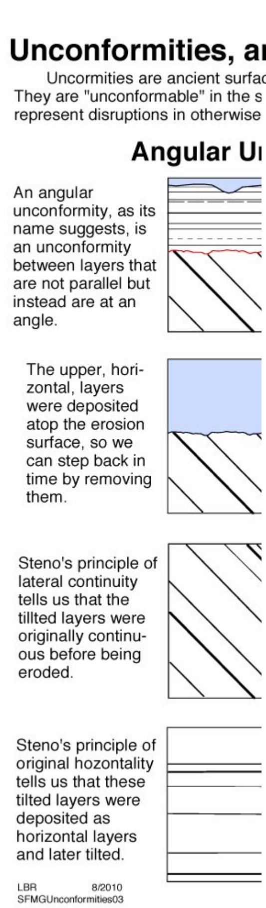


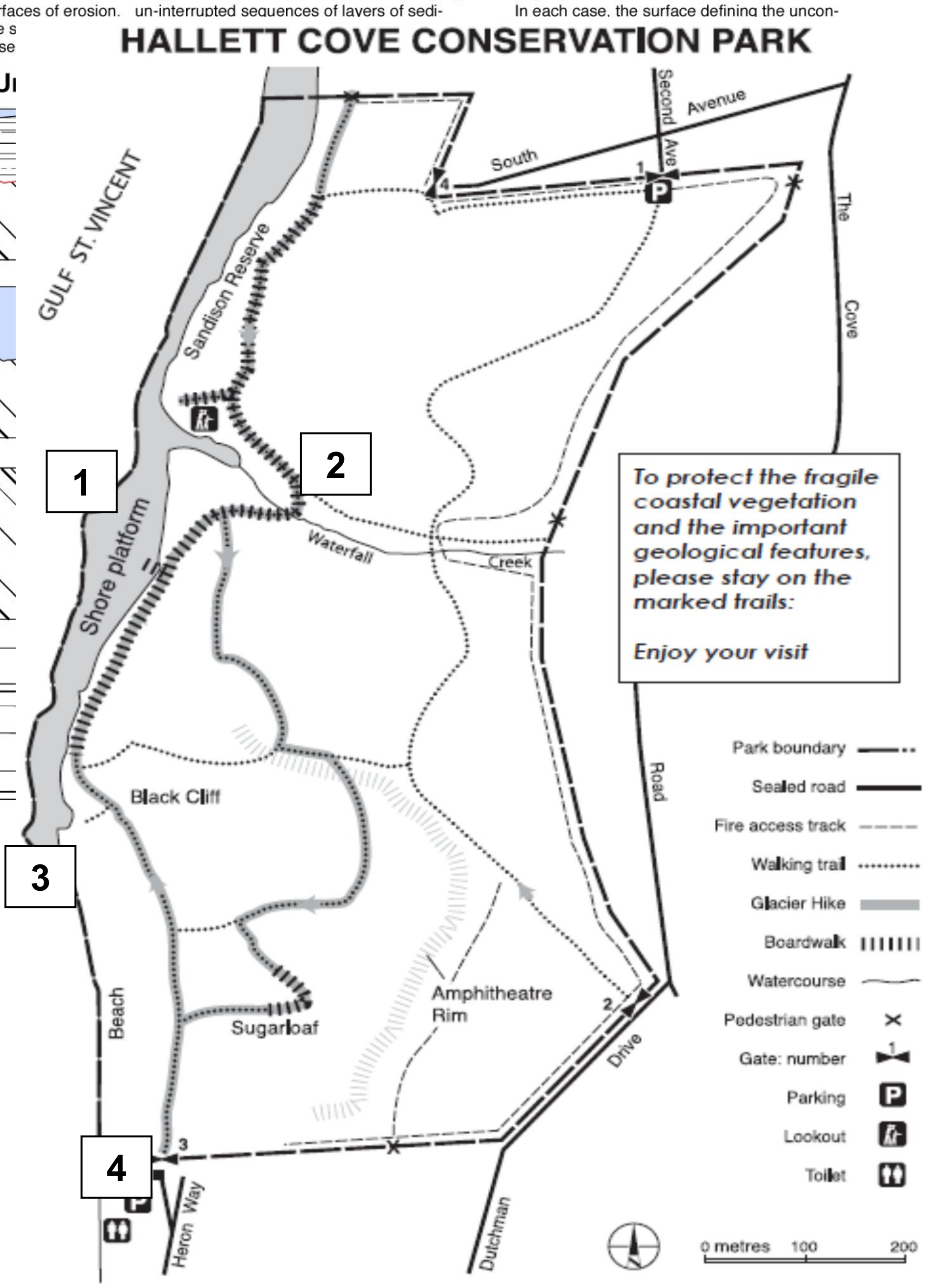
8.14 Slickensides on a fault plane. Slickensides alone indicate movement in one of two directions. If steps are present the movement direction is probably that indicated.

Unconformities are gaps in the geologic record that may indicate episodes of crustal deformation, erosion, and sea level variations. They are a feature of stratified rocks, and are therefore usually found in sediments (but may also occur in stratified volcanic rocks). They are surfaces between two rock bodies that constitute a substantial break (hiatus) in the geologic record (sometimes people say inaccurately that "time" is missing). Unconformities represent times when deposition stopped, an interval of erosion removed some of the previously deposited rock, and finally deposition was resumed.
Commonly three types of unconformities are distinguished by geologists: Angular unconformities, disconformities and nonconformities. You will see examples of some of these on the excursion.

You will see several important features of South Australian geology on this excursion:

a) Neoproterozoic sedimentary rocks (ca 620 million years old).
b) that are folded and deformed.
c) Records of the Gondwana glaciations, which took place about 290 million years ago
d) Excellent unconformities (time gaps in the rock record) between the rock units





You have 4 stations at which you have tasks to complete.

Half of the group will immediately descend down the stairs north of Waterfall Creek to the shore platform (station 1 on map). This station will take all morning/ or all afternoon.

The other 3 stations together will also take ½ of the day.
It's best if some groups head for station 2, and the others to 3 and 4 to start off.

Note that it does not matter what order you go through these tasks, but stations 1 and 3 are best at low tide

LOW TIDE Saturday 7th = 06.21am, Sunday 8th = 11.31am

All groups will return to the parking lot at the south end for lunch/toilet access.

Station 1: shore platform.

Task A: Walk carefully down onto the shore platform and describe the variety of rock types exposed. Include texture and composition. You should be able to identify and name at two types of sedimentary rocks.

<table>
<tr><th colspan="4">Sample location:</th><th colspan="3">Rock Name:</th></tr>
<tr><td colspan="7">Circle only one rock type below. Next, answer and/or circle as many as apply beneath the subheadings (only for the correct rock type!)</td></tr>
<tr><th colspan="2">Igneous</th><th colspan="3">Sedimentary</th><th colspan="2">Metamorphic</th></tr>
<tr><th rowspan="2">texture</th><th rowspan="2">crystal size</th><th colspan="3">if clastic:</th><th rowspan="2">texture</th><th rowspan="2">crystal size</th></tr>
<tr><th>grain sizes</th><th>grain sorting</th><th>grain shape</th></tr>
<tr><td rowspan="5">phaneritic
aphanitic
porphyritic-phaneritic
porphyritic-aphanitic
pyroclastic
vesicular
glassy
pegmatitic</td><td>coarse-grained
medium-grained
fine-grained</td><td>gravel
sand
silt
mud</td><td>poorly sorted
moderately sorted
well sorted</td><td>angular
in-between
rounded
unknown</td><td rowspan="5">slaty
phyllitic
schistose
gneissic
non-foliated
lineated
granoblastic
porphyroblastic</td><td>coarse-grained
medium-grained
fine-grained</td></tr>
<tr><th>if 2 or more grain sizes, give size info on coarsest:</th><th colspan="3">describe any bedding/layering present:</th><th>if 2 or more grain sizes, give size info on coarsest:</th></tr>
<tr><td rowspan="3"></td><td colspan="3"></td><td rowspan="3"></td></tr>
<tr><th colspan="3">if chemical:</th></tr>
<tr><td colspan="3">biochemical chemical</td></tr>
</table>

Composition & Abundance (in %). (Make sure it adds up to 100%)

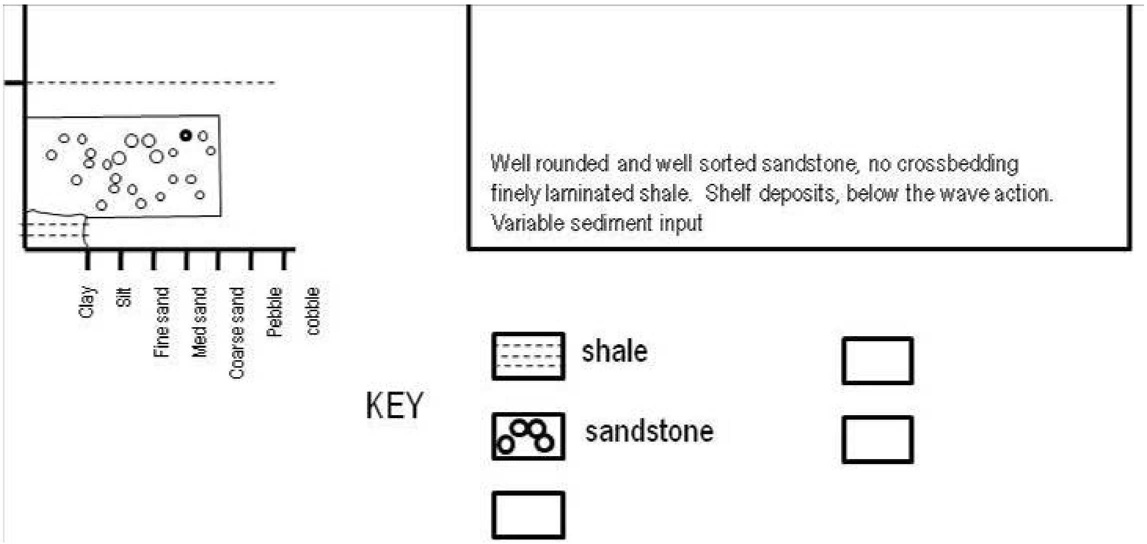
Rock type 2

<table>
<tr><td colspan="4">Sample location:</td><td colspan="4">Rock Name:</td></tr>
<tr><td colspan="8">Circle only one rock type below. Next, answer and/or circle as many as apply beneath the subheadings (only for the correct rock type!)</td></tr>
<tr><td colspan="2">Igneous</td><td colspan="4">Sedimentary</td><td colspan="2">Metamorphic</td></tr>
<tr><td rowspan="2">texture</td><td rowspan="2">crystal size</td><td colspan="4">if clastic:</td><td rowspan="2">texture</td><td rowspan="2">crystal size</td></tr>
<tr><td>grain sizes</td><td>grain sorting</td><td colspan="2">grain shape</td></tr>
<tr><td rowspan="5">phaneritic
aphanitic
porphyritic-phaneritic
porphyritic-aphanitic
pyroclastic
vesicular
glassy
pegmatitic</td><td>coarse-grained
medium-grained
fine-grained</td><td>gravel
sand
silt
mud</td><td>poorly sorted
moderately sorted
well sorted</td><td colspan="2">angular
in-between
rounded
unknown</td><td rowspan="5">slaty
phyllitic
schistose
gneissic
non-foliated
lineated
granoblastic
porphyroblastic</td><td>coarse-grained
medium-grained
fine-grained</td></tr>
<tr><td rowspan="2">if 2 or more grain sizes, give size info on coarsest:</td><td colspan="4">describe any bedding/layering present:</td><td rowspan="2">if 2 or more grain sizes, give size info on coarsest:</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td rowspan="2"></td><td colspan="4">if chemical:</td><td rowspan="2"></td></tr>
<tr><td colspan="2">biochemical</td><td colspan="2">chemical</td></tr>
</table>

Composition & Abundance (in %). (Make sure it adds up to 100%)

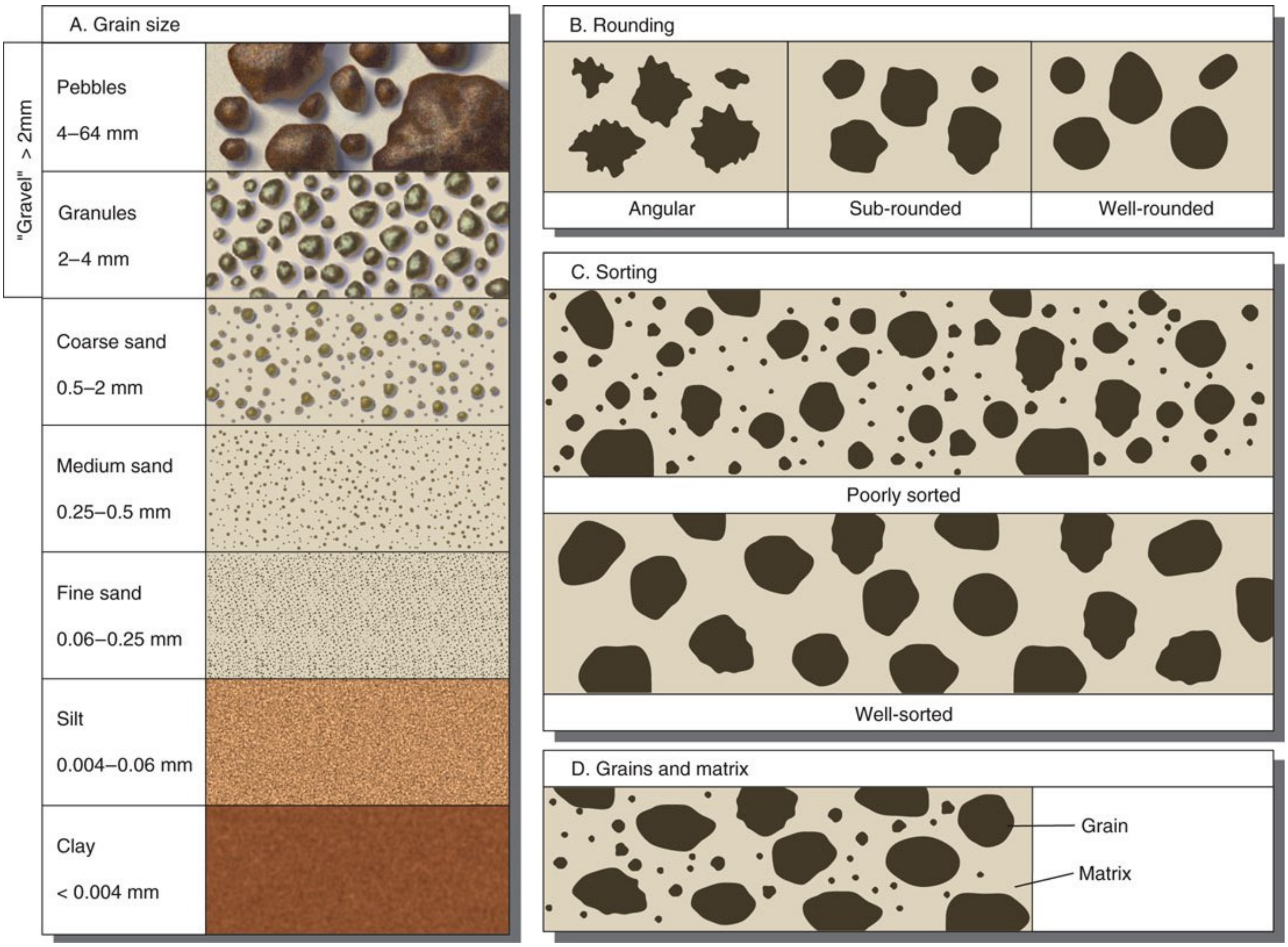
Task B: The variation in sedimentary rock type can give us information about the sedimentary environment. A stratigraphic log allows us to visualise the changes in rock type that can provide information about changes in depositional environment. Along the shore platform, your demonstrator will lay out a 2 metre section of the stratigraphy with some sort of measuring device. Your job is to carefully plot the thicknesses of individual rock types on your stratigraphic log (next page), describe the change in texture and composition along this tape measure length, and then make some observations about the depositional environment.

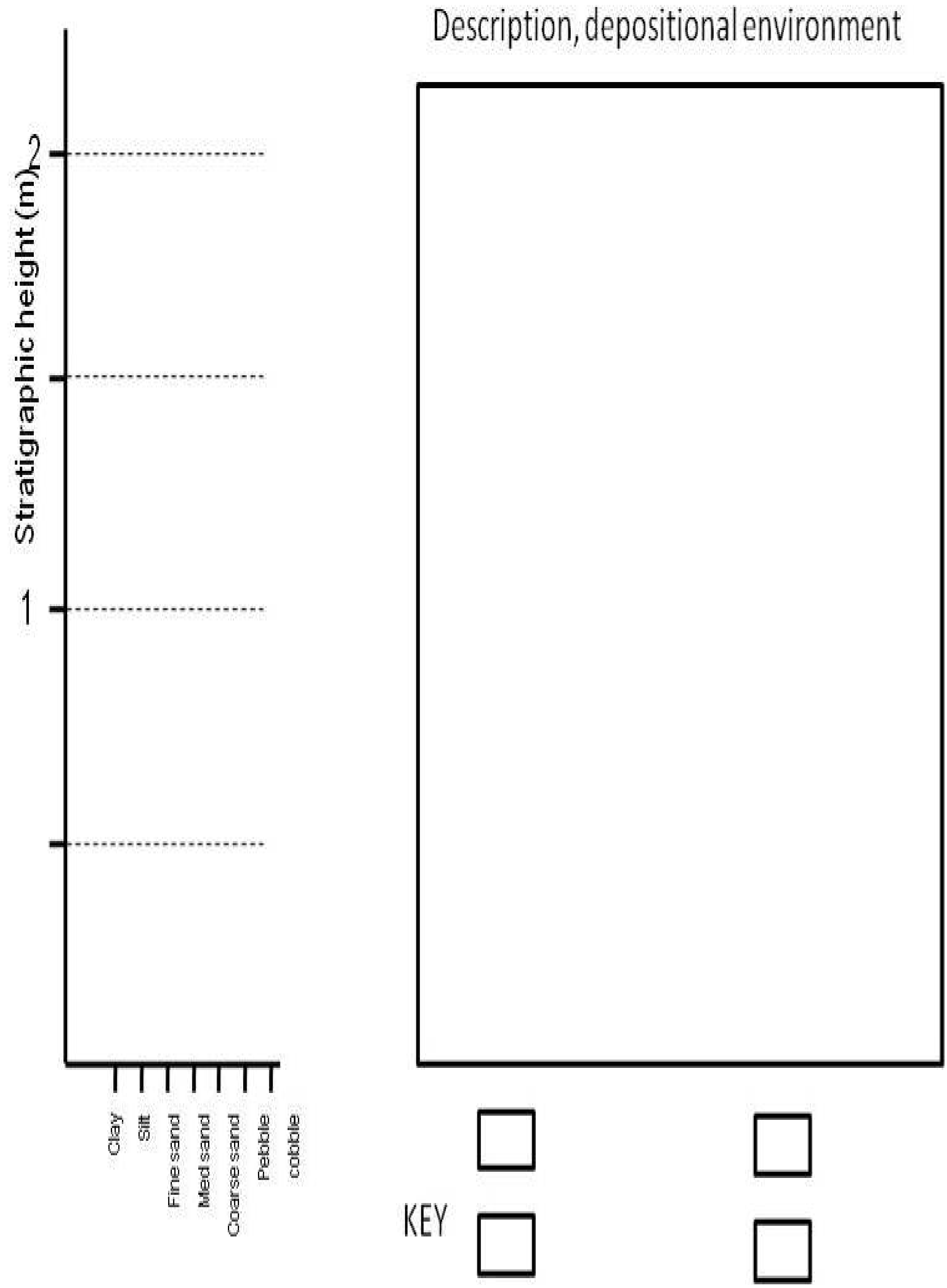
Here is a sample of what your stratigraphic log may look like, and some useful information for making your log.



SAMPLE STRATIGRAPHIC LOG. Note the detail in the description section, and the comment about deposition environment (shelf deposit, below the wave action). The section on the left provides information about the grain size of the material you are looking at.

Information on grain size, rounding and sorting, which you have learned in your prac work.





Task C: These sedimentary rocks are no longer horizontal. What is the orientation of the layering along the cliff walls and on the shore platform? (Your demonstrator is going to demonstrate the use of a compass clinometer. This is something you will use extensively if you go on in geology to the 2nd year Structural Geology course. There should be plenty of extras for you all to try your own measurements)

DIP AMOUNT:_________________________

DIP DIRECTION:______________________

TASK D: Along the cliff wall, look for evidence of flexural slip. Your demonstrator will help you find slickensides.

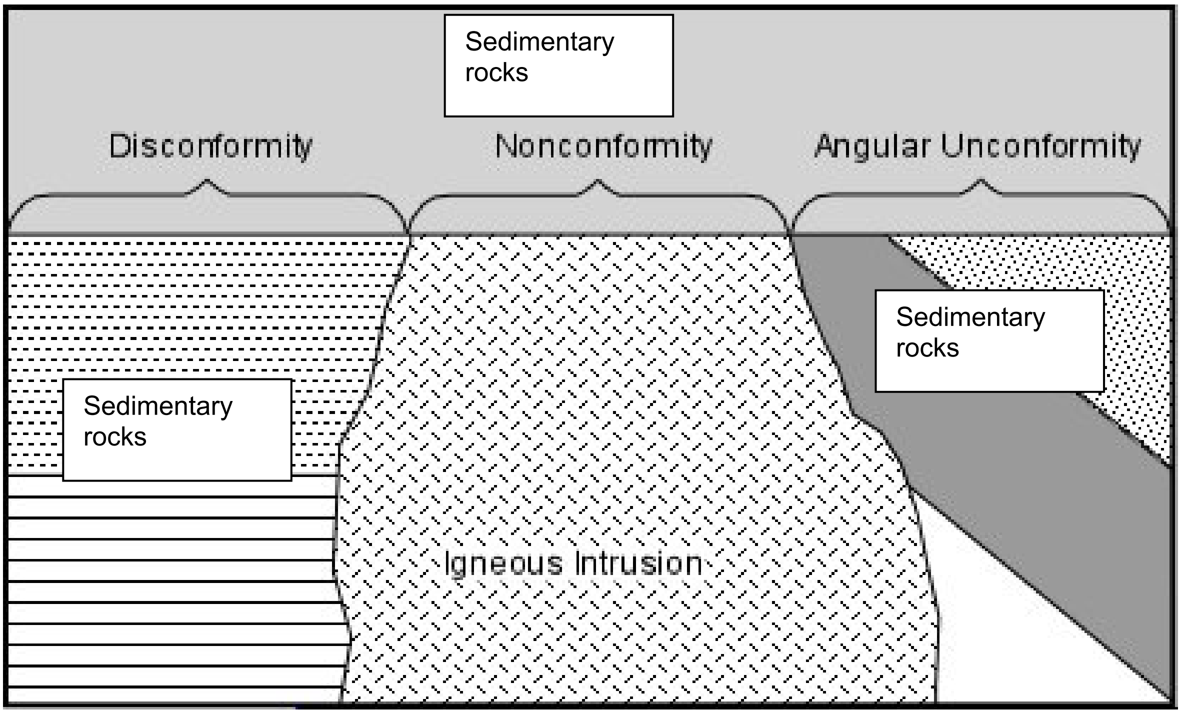
Look for ‘steps’ in the slickensides (see the figures on page 8). What do the steps tell you about the direction of slip along this plane? (answer below)

Draw a field sketch of the outcrop, highlighting the main structural features.

Station 2: Unconformities and the big picture in cross-section

Find Station 2 on the location map on page 9 and go there. This is the Waterfall Creek area. There are two major unconformities visible here. The lower one represents a large gap in time between the vertically dipping Neoproterozoic sedimentary rocks and the nearly horizontal ca 270 million year old Permian glacial sediments.

Task A:
Use the cartoon below to work out what type of unconformity this 'older' one is.

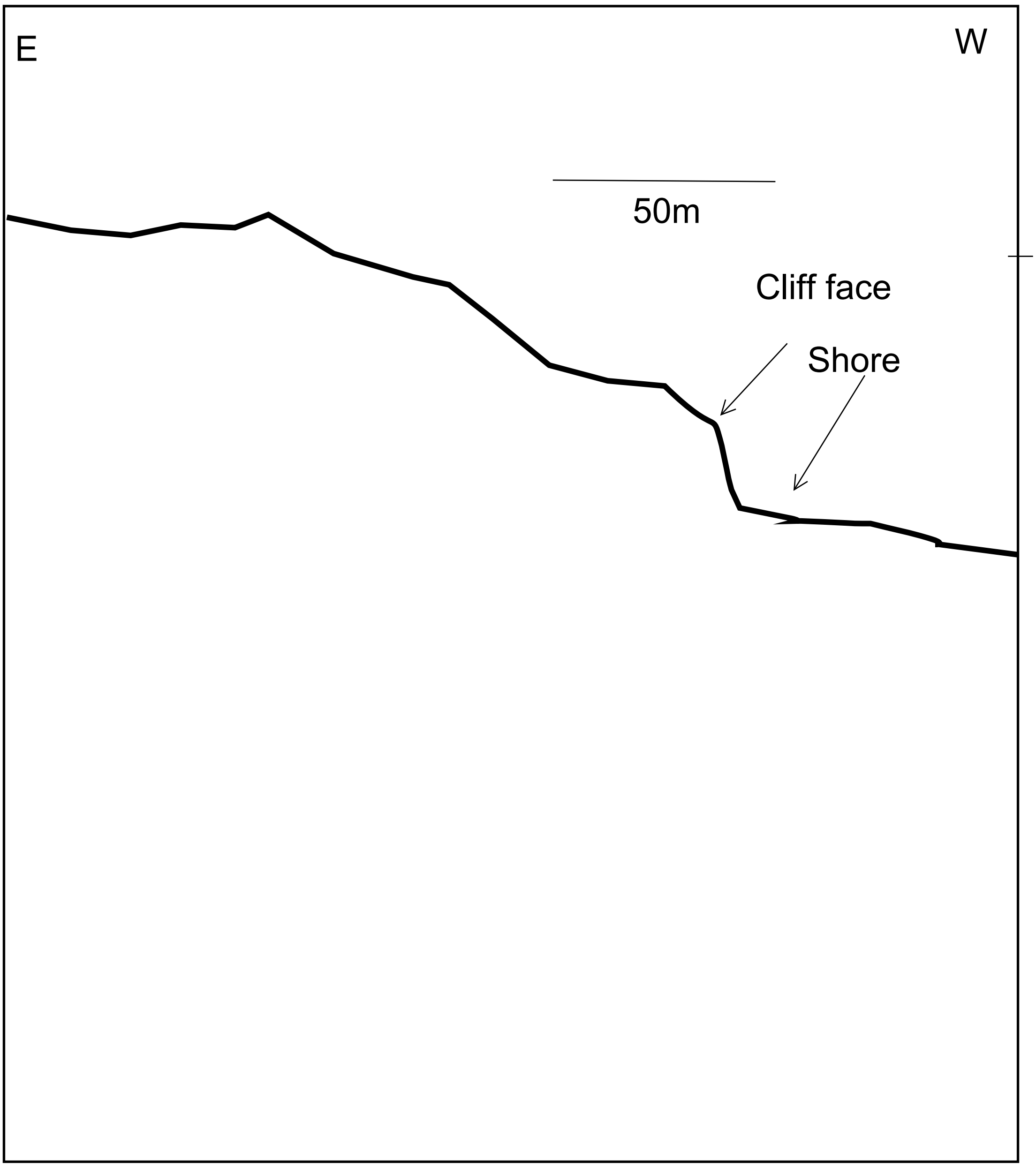


Can you see a structure in the sequence of Neoproterozoic rocks? Ask you demonstrator (and list below) what information you can get from these structure.

From this vantage point you can also see a lens or layer of hard grey to whitish sandstone lying on top of the softer glacial sediments. This is the Pliocene Hallett Cove Sandstone. It is about 4 million years old. The gap between the Permian ca 270 Ma glacial sediments and the 4 Ma Hallett Cove Sandstone is also an unconformity. Based on the picture above, and the reference material on page 8, what kind of unconformity do you think is represented? (your demonstrator can help to explain this concept of 'lost' rocks).

TASK B: MAKING A CROSS SECTION.

This vantage point is a great place to put all this geology together into a cross section, which is a view of the earth as if cut open and seen from the side. Your task is to create a vertical east-west cross-section across the entire Hallett Cove area in the vicinity of Waterfall Creek, noting and labelling all the geological features seen. This is necessarily interpretive, but in front you there is a hillside that you can imagine is a bit like a slice into the earth. Your cross section will look pretty much like this. The skyline of the view of the hillside south of Waterfall Creek is provided below as a template to draw the cross section.



Station 3: Below Black Cliff

The purple rocks are interrupted by occasional green layers. These are rocks deposited in the Ediacaran Period (Neoproterozoic Era) and are called the Brachina Formation. They are deformed into a series of folds.

The rocks are sedimentary rocks. Can you find two sedimentary structures that help tell us how they were deposited? Sketch them below and say what you can infer about how they were deposited from them.

1.

………
………
………
………
………

2.

………
………
………
………
………

From the top of the lookout, make a field sketch of the folds (your demonstrator will help you here).

Collect dip and dip direction data from three separate fold limbs, record them below and plot them on your field sketch.

1. …………… / ……….
2. …………… / ……….
3. …………… / ……….

Measure an Axial Plane to one of the folds

1. ………… / …………

What direction was the area:
a) compressed to form these folds? ……………………
b) which direction did it extend? ………………………..

Station 4: unusual erratics

Your task is to find the very unusual erratic on the beach near the concrete roadway, and describe that rock below.

Sample location:					**Rock Name:**	
Circle only one rock type below. Next, answer and/or circle as many as apply beneath the subheadings (only for the correct rock type!)						
Igneous		**Sedimentary**			**Metamorphic**	
texture	**crystal size**	**if clastic:**			**texture**	**crystal size**
		grain size(s)	**grain sorting**	**grain shape**		
phaneritic aphanitic porphyritic-phaneritic porphyritic-aphanitic pyroclastic vesicular glassy pegmatitic	coarse-grained medium-grained fine-grained	gravel sand silt mud	poorly sorted moderately sorted well sorted	angular in-between rounded unknown	slaty phyllitic schistose gneissic non-foliated lineated granoblastic porphyroblastic	coarse-grained medium-grained fine-grained
	if 2 or more grain sizes, give size info on coarsest:	**describe any bedding/layering present:**				**if 2 or more grain sizes, give size info on coarsest:**
		if chemical:				
		biochemical	chemical			

Composition & Abundance (in %). (Make sure it adds up to 100%)

Reflection and questions on the day's events:
Hand-write your answers in the blank space below

1) What is/are the biggest question(s) you have from today's activities? What did you struggle to understand?