Student: …… Date received: ……

Handout 8 of 14

(*Topics 3.1 & 3.2*)

Uniformitarianism and Rock Relationships

Image: http://www.jpl.nasa.gov/images/mer/2006-04-11/pia08064-browse.jpg

Coarse-grained layers on within the Erebus crater, Mars. The Principals of Uniformitarianism and Superposition can be used to interpret images like the one above.

The History of the Earth

Uniformitarianism and Rock Relationships

Key Ideas	Intended Student Learning
Uniformitarianism	
The processes occurring in the present can be used to explain processes that occurred in the past.	Explain, giving examples, the principle of uniformitarianism. Understand the limitations of this principle. Explain how the texture, colour, and other characteristics of a rock provide information about its history. *Apply the principle of uniformitarianism to interpret geological features seen in the field.*
Fossils may provide information about past environments.	Define the term 'fossil'. Relate the present environment of living organisms to the past environment of fossils of similar organisms.
Rock Relationships	
The principle of superposition states that in an undisturbed sedimentary sequence the oldest rocks are at the bottom.	Explain, with the aid of diagrams, how the principle of superposition can be used to determine the relative ages of rock strata. *Determine the relative ages of rocks found in the field.*
Depositional structures and features that occur on the surfaces of sediments enable the facing of strata to be determined.	Explain, with the aid of diagrams, how features such as ripple marks, mud cracks, cross-bedding, and graded bedding provide information about whether or not a rock stratum or a sequence of strata has been overturned.
An igneous intrusion must be younger than the rocks into which it has intruded.	Explain the concept of crosscutting relationships. Determine the relative ages of igneous intrusions and/or sedimentary strata.
Index fossils are useful in determining the relative ages of rocks in a sequence, and in correlating rock strata.	Explain why some fossils are useful as index fossils. Explain how index fossils may be used to correlate rock strata from different locations.
An unconformity represents a break in the geological history of an area.	Define the term 'unconformity'. Explain, with the aid of diagrams, how an unconformity may be formed. Identify an unconformity on a map, photograph, diagram, or in the field.
Geological histories of regions can be determined by using the concepts of uniformitarianism, superposition, cross-cutting relationships, facing, and index fossils.	Use these key ideas to interpret geological histories of regions shown on maps, cross-sections, and diagrams. *Use these key ideas to interpret the geological history of an area studied in the field.*

3.1 – Uniformitarianism

Note: when describing geological age, there are three internationally recognised symbols that you must become familiar with:

- ka = thousand years before present/ago
- Ma = million years before present/ago
- Ga = billion years before present/ago

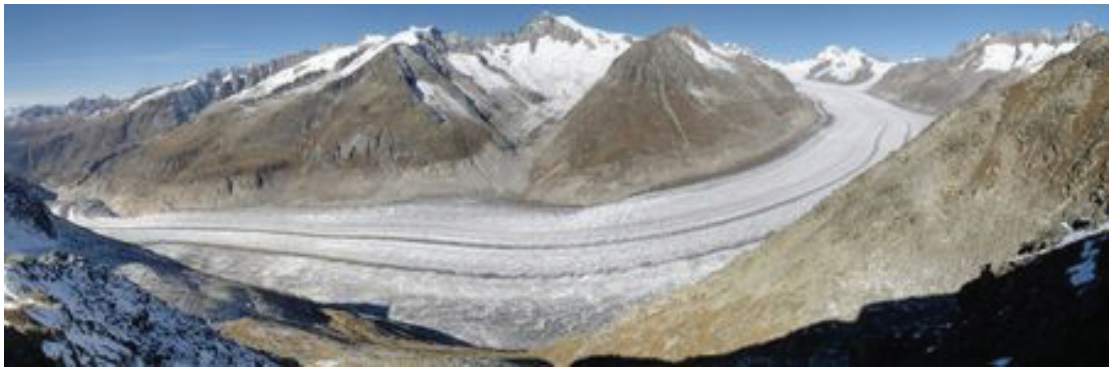
Many aspects of the science of geology are based on the

PRINCIPLE OF UNIFORMITARIANISM

Uniformitarianism, is the assumption that the natural processes operating in the past are the same as those that can be observed operating in the present

In geological terms:

Processes we see happening on Earth today have occurred for millions of years, and have formed the rocks and landforms around us.



This principle can be stated more simply as:

The present is the key to the past.

Uniformitarianism was first postulated by the English geologist James Hutton (1785). Using this principle, observations of present day geological processes are used to interpret the geological history of ancient rocks and other features of Earth's crust.

All around us there are many geological features that are interpreted by applying the Principle of Uniformitarianism. Some examples are given below.

- It is possible to see lava from volcanoes in Hawaii cooling to form a black rock known as **basalt.** This black rock is also found at Mt. Gambier,

although no volcanoes are present. We therefore conclude that volcanic activity once occurred in the Mt. Gambier area.

- Opalised fossils of **marine molluscs** are found at Coober Pedy, which is a very long way from the sea. We conclude from these fossils that this area was once under the sea.

- We observe that large crystals form when a molten substance cools slowly, so we assume that coarse-grained rocks, such as granite, must have been formed from magma cooling slowly.

Although the **Principle of Uniformitarianism** is used to interpret geological features, it cannot be applied indiscriminately. It is not entirely valid to assume that conditions on Earth millions of years ago were exactly the same as they are today. For example, up to about 600 Ma, which is not long in geological terms, there was less oxygen in the atmosphere than there is today. Oxidation of iron minerals in rocks would have occurred much more slowly than it does today.

Even earlier, during the Archaean and Proterozoic eons, Earth would have generated much more geothermal heat than it does today, so the crust would have been hotter than it is at present. Regional metamorphic processes would therefore have occurred comparatively quickly.

Left: Above is a U-shaped valley, Mt Hood Wilderness, North America. Since we know that U-shaped valleys are carved by glaciers in the present day, we can use the principal of uniformitarianism to interpret that a glacier carved out this valley. Indeed, in the foreground there is a moraine of till, confirming our hypothesis.

Right: Striations on polished rock surface (carved by Permian glaciers), Hallett Cove.

Fossils

Organisms may leave traces of their existence in the sediments formed during, or shortly after their lifetimes.

FOSSILS are preserved remains of living organisms.

Using the **principle of uniformitarianism**, we say that if an organism lives in a particular environment today; then its ancestors — which we find as fossils — must have lived in a similar **palaeo-environment.** We therefore infer a palaeo-environment from the type of fossils we find. Some examples of this are:

- In the Kimberley Region of Western Australia, there is a Devonian limestone formation with a structure similar to today's Barrier Reef. It is composed largely of corals. Since modern corals live in warm, shallow seas, we conclude that such a sea must have existed, during the Devonian era, where the Kimberleys are today.
- The plant fossils found in the Golden Grove and Maslin Beach Quarries are of trees similar to those found today in tropical rainforests, such as the Daintree. We therefore conclude that the climate of South Australia was much hotter and wetter at 40 Ma than it is today.
- Fossils found in the cliffs of Maslin and Port Willunga Bays are similar to those of organisms presently living in Gulf St Vincent. Conditions in the seas that existed in the region around 60 Ma must have been similar to those in today's gulf waters.

Above is a field photograph of one of the most famous fossils ever found, “Ötzi” the Iceman. Discovered in 1991, at 5300 years old, he is the oldest freeze-dried human ever discovered.

3.2 – Rock Relationships

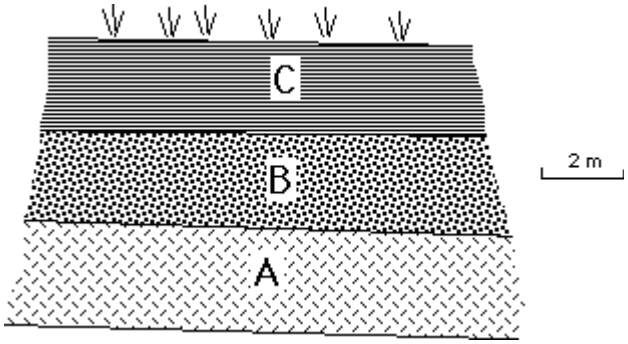
ROCK RELATIONSHIPS

Superposition

A basic principle used to interpret the geological history of a rock sequence is the **Principle of Superposition**, which states that:

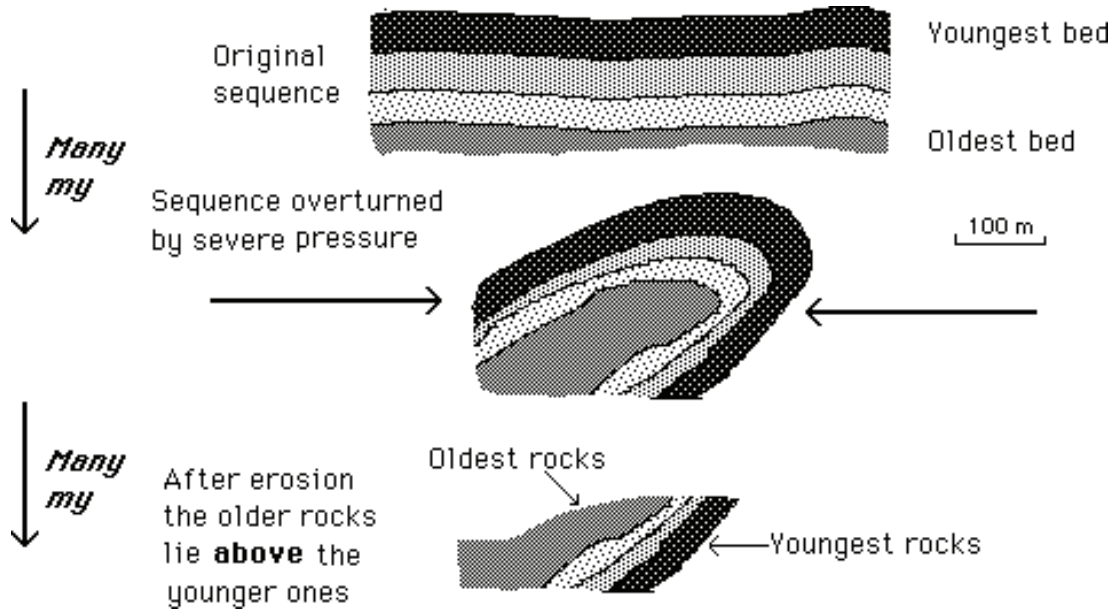
> **In an undisturbed sedimentary sequence, the uppermost strata are younger than those on which they rest.**

Thus in the adjacent diagram showing three layers of sedimentary strata (perhaps in a cliff face), the oldest stratum is A, and the youngest is C.

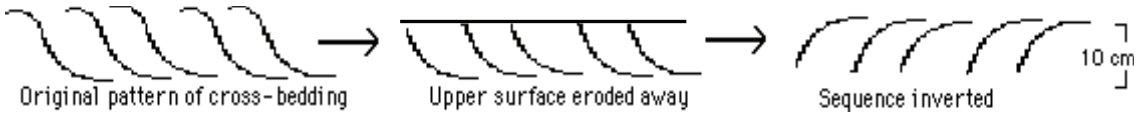


A very good, almost undisturbed, sedimentary sequence can be seen in the cliffs at Maslin Bay and Port Willunga.

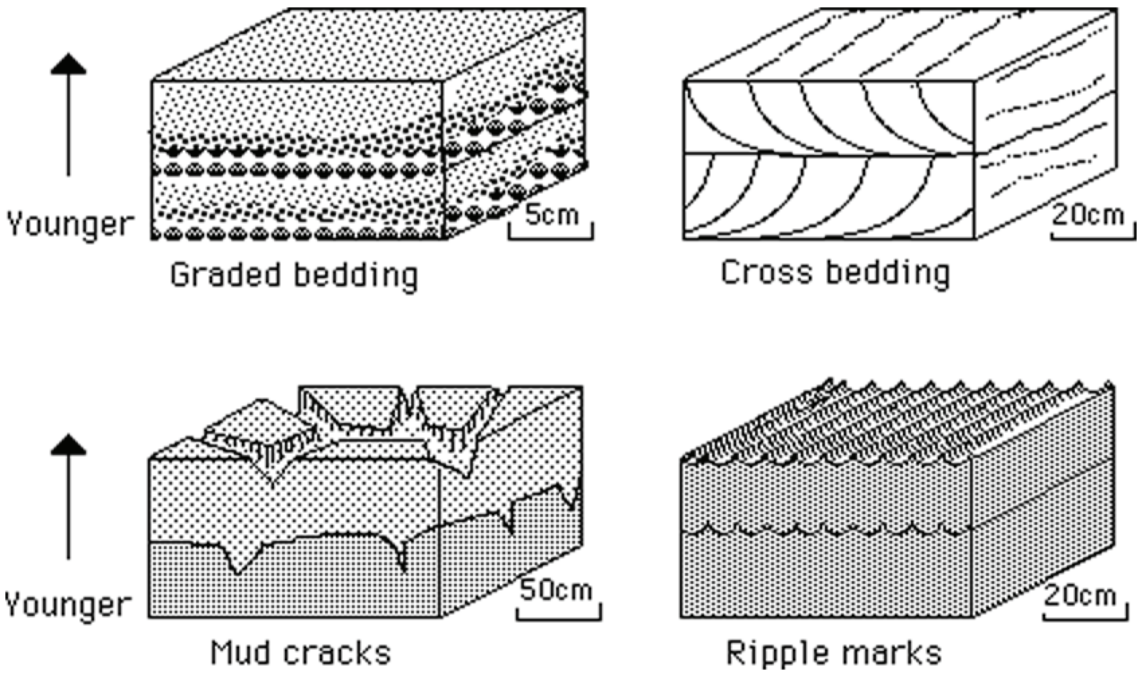
However, a rock sequence can be overturned by severe pressure, and then the younger rocks are no longer above the older ones, as shown in the following sequence of diagrams.



Thus, in order to construct a geological history, it is important to determine if a sequence is right-way-up, or has been inverted. Sedimentary structures provide information on the way-up, or younging, of a sequence of sedimentary strata: For example, cross-bedding which has been eroded on its upper surface.



The four diagrams below show examples of sedimentary structures that can indicate whether a sequence of strata has been overturned.

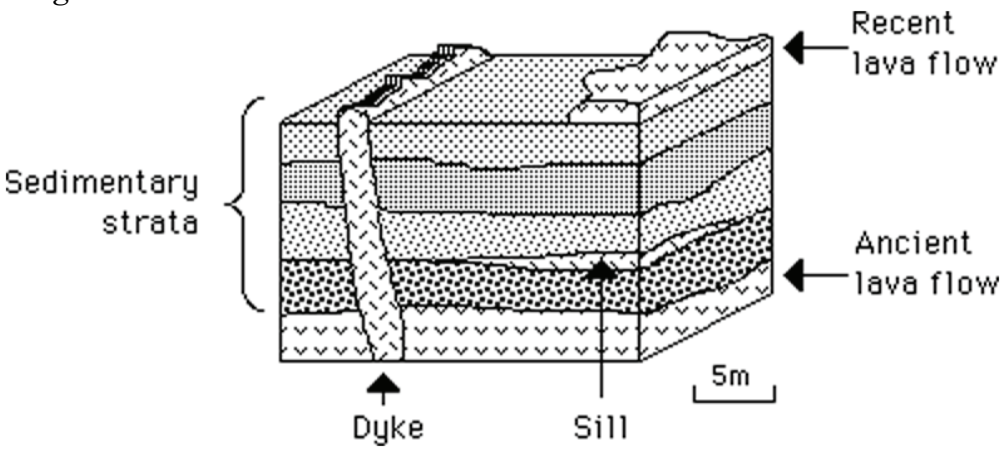


In the above examples, the sediments are undisturbed, or the 'right way up'. The youngest sediments are on the top, and the direction of 'younging' is upwards.

Cross-Cutting Relationships

Any body of igneous or sedimentary rock that **cuts across** the boundaries of another body of rock must be **younger** than that across which it cuts.

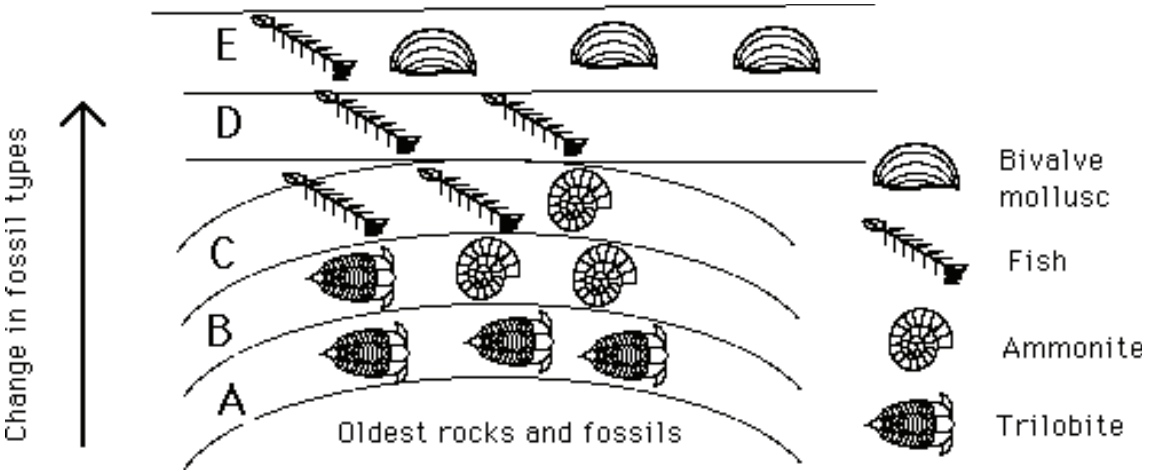
The diagram below shows a sedimentary sequence that has been intruded by magma on several different occasions.

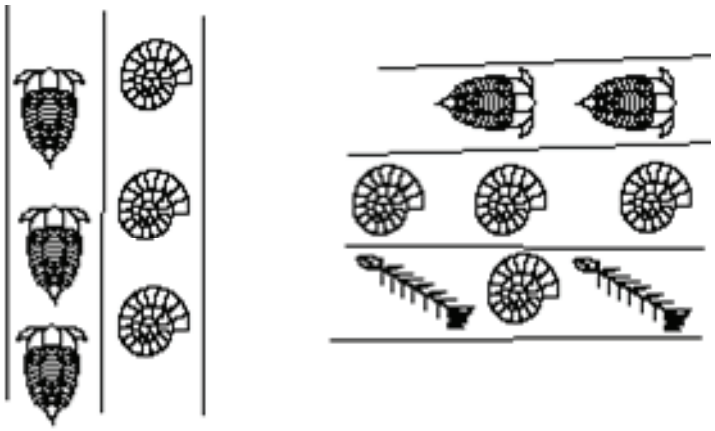


Because the dyke cuts across the ancient lava flow and the sedimentary layers, it must be younger than they are. There is not enough evidence in the diagram to enable the relative ages of the sill, dyke and recent lava flow to be determined.

Index Fossils

As a general rule, in a sequence of sedimentary rocks, we can apply the **principle of superposition** and say that 'the rocks underneath are older than the rocks on top'. In the diagram below, layer A is considered to be the oldest, and layer E is the youngest.





A vertical sequence An overturned sequence

However, severe pressure can cause rock layers to be vertical or even overturned. Then additional evidence is needed to determine the relative ages of the layers. Sedimentary structures (eg flute casts) can be used to provide this evidence but a fossil assemblage is likely to provide more convincing evidence.

Since trilobites became extinct long before ammonites evolved, a rock containing a trilobite fossil **must** be older than one containing an ammonite fossil.

Fossils that provide useful information about the relative ages of rocks are known as **index** fossils. They must possess the following characteristics:

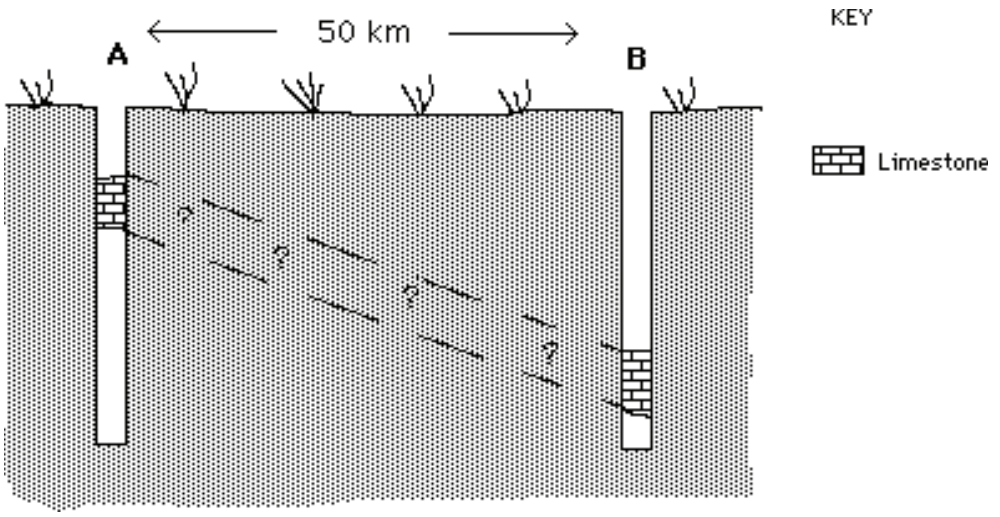
- **existed only in a short geological time range**
- **be easily preserved**
- **be abundant**
- **be easily recognised**
- **have a wide geographical distribution.**

Species of **trilobites** are good index fossils, but **cockroaches** have remained unchanged for many millions of years. They do not make good index fossils. It is difficult to determine the age of a fossilised cockroach.

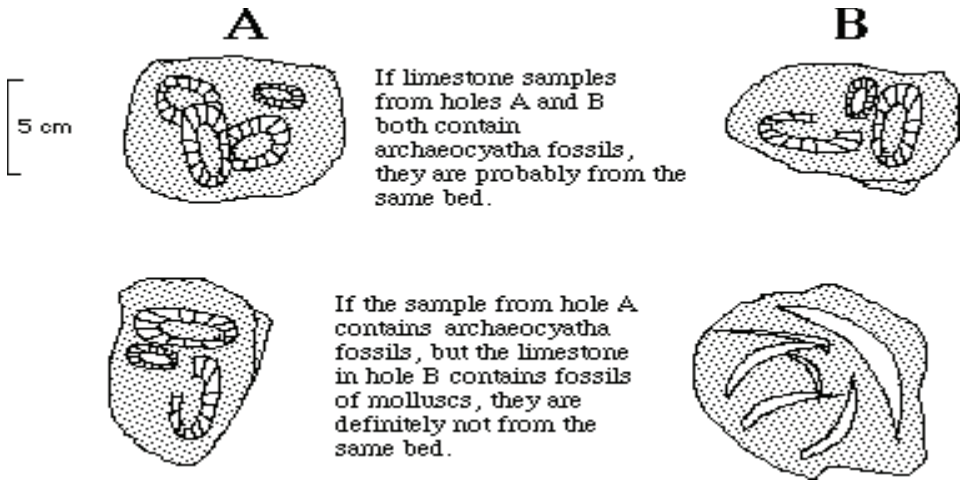
Correlation of Rock Strata

Index fossils are useful for **correlating** rock strata. This involves comparing sedimentary rocks in different locations to determine whether they are part of the same bed or sequence.

For example, if two holes drilled on the Adelaide Plains intersect layers of limestone, it is important to determine whether these layers are part of the same sedimentary bed.



If the layers contain index fossils, correlation is comparatively simple. If the fossil assemblage is the same in the two beds, they are probably part of the same layer. Different fossil assemblages would indicate that the two beds are different.

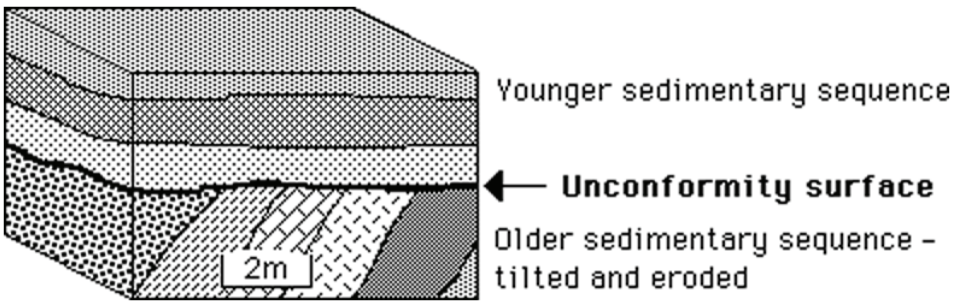


A very good example of a fossiliferous bed that extends over a wide area is the **Hallett Cove Sandstone**, which extends at least from Adelaide, (where it was used to build the Legislative Council Building) to Port Willunga. The same fossil assemblage is found throughout the whole layer.

Unconformities

An unconformity is a **boundary** between two groups of rocks that are separated by a period during which no rocks were formed. The area was above sea level and **erosion** occurred. This boundary represents a break in the geological history of an area.

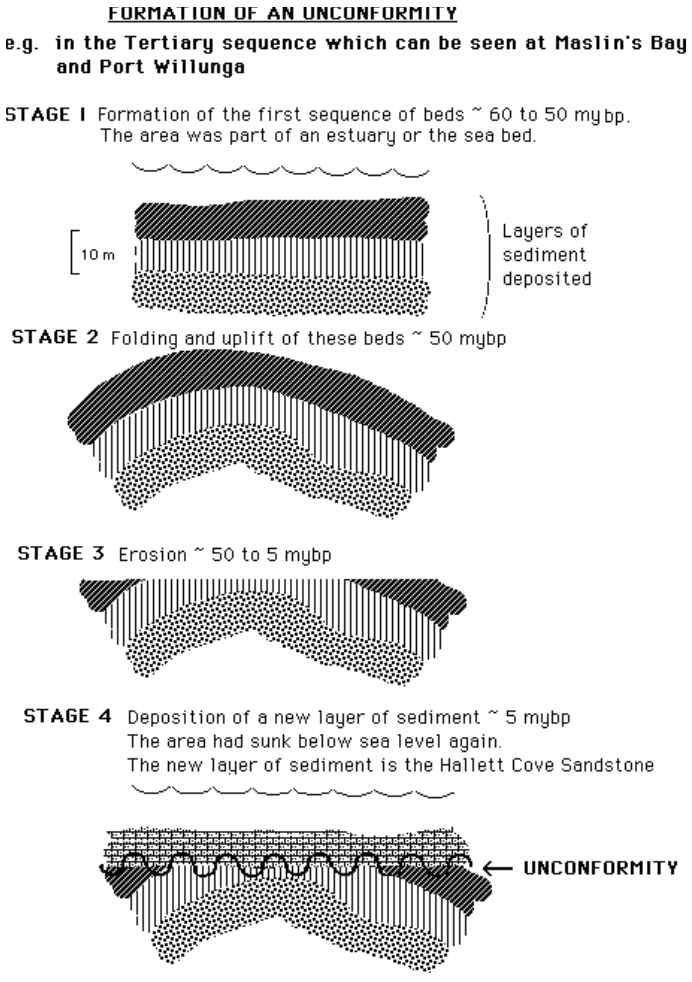
An unconformity is the erosional surface that cuts across structures in the older sequence of rocks and forms the lower surface of the younger sequence.



We will see many examples of unconformities on our excursions. The diagrams below illustrate the sequence of events that produced the unconformity seen in the cliffs of Maslin and Port Willunga Bays.

Geological Histories

The Principles of **Superposition** and **Cross-cutting Relationships**, as well as the idea of an unconformity, can be used to deduce the geological history of an area from a cross-sectional diagram (see below).



EXERCISES

UNIFORMITARIANISM

1. In 1877, Professor Ralph Tate was the first person to recognise the striations on Black Cliff at Hallett Cove and the boulders on the beach as signs of past glaciation. How did he know that these features were produced by glacial action?

2. Name the principle he was using when he made these deductions.

3. State this principle.

4. How do we know that volcanic activity once occurred in the Mt Gambier area?

5. A rich deposit containing a wide variety of mammalian fossils has been found at Riversleigh, in northwest Queensland, which is now a very dry area. What information does that deposit provide about the palaeo-environment of this area?

6. The diagrams below show two examples of marine mollusc shells.

A B

One of these organisms could have lived on a rocks intertidal platform and the other in deep water.

State, giving reasons, the likely environment of each organism.

7. Why should we be careful when using the Principle of Uniformitarianism to interpret features of rocks that may be 2500 Ma old?

8. a. Name one important change in Earth's atmosphere which has occurred over the past 2000 Ma.

   b. How would this change affect the rate of weathering of rocks?

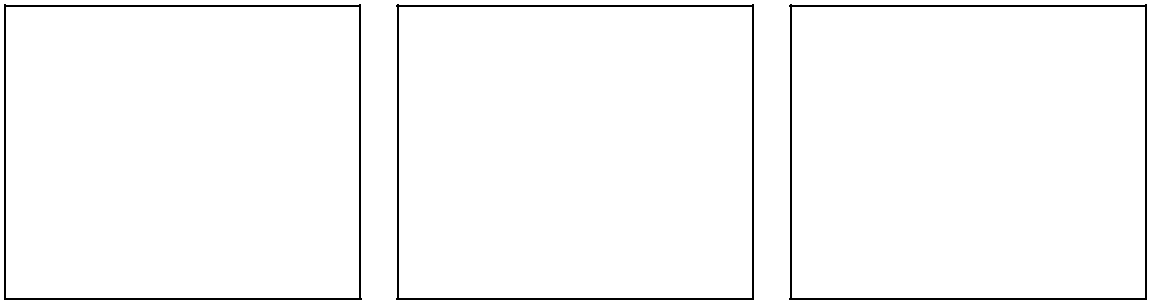
9. a. What has happened to the temperature of the Earth's crust since the Archaean and Proterozoic eons?

   b. What processes would have been affected by this change?

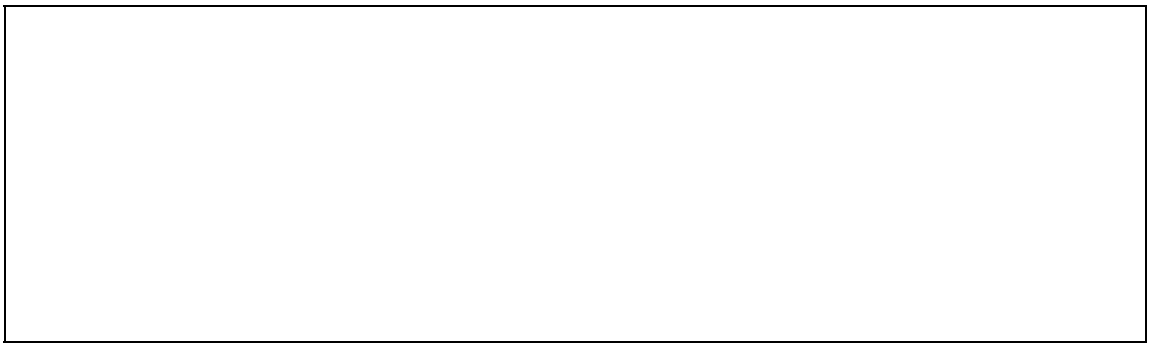
ROCK RELATIONSHIPS

1. State the **Principle of Superposition**

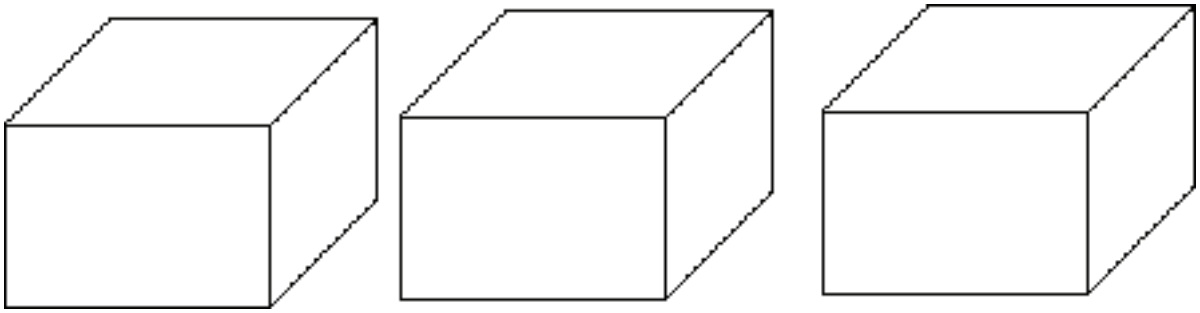
2. Explain, with the aid of a series of diagrams, why it is very important for a geologist trying to determine the geological history of an area to decide whether or not a sequence of rocks has been overturned.



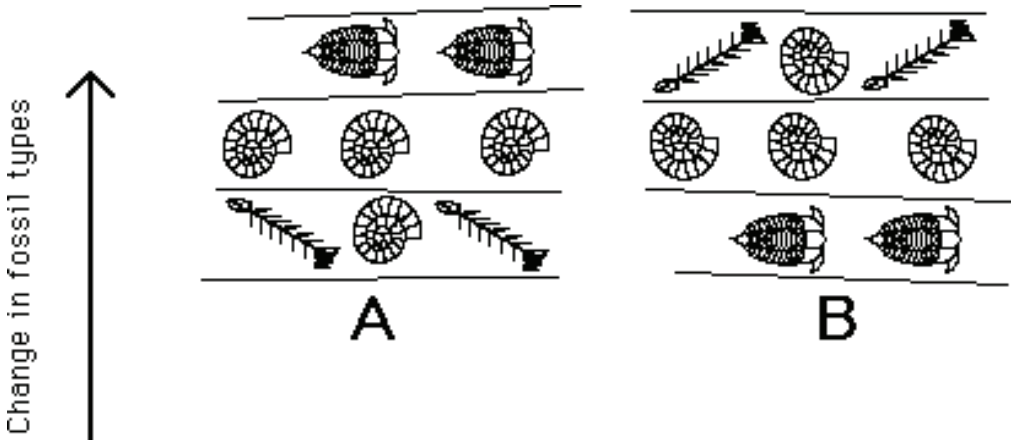
3. Use a series of diagrams to explain how some types of cross-bedding can show whether a sequence has been overturned.



4. Use the blocks below to draw **block diagrams** of sedimentary sequences in which ripple marks, mud cracks and graded bedding show that the sequences **have been overturned**.



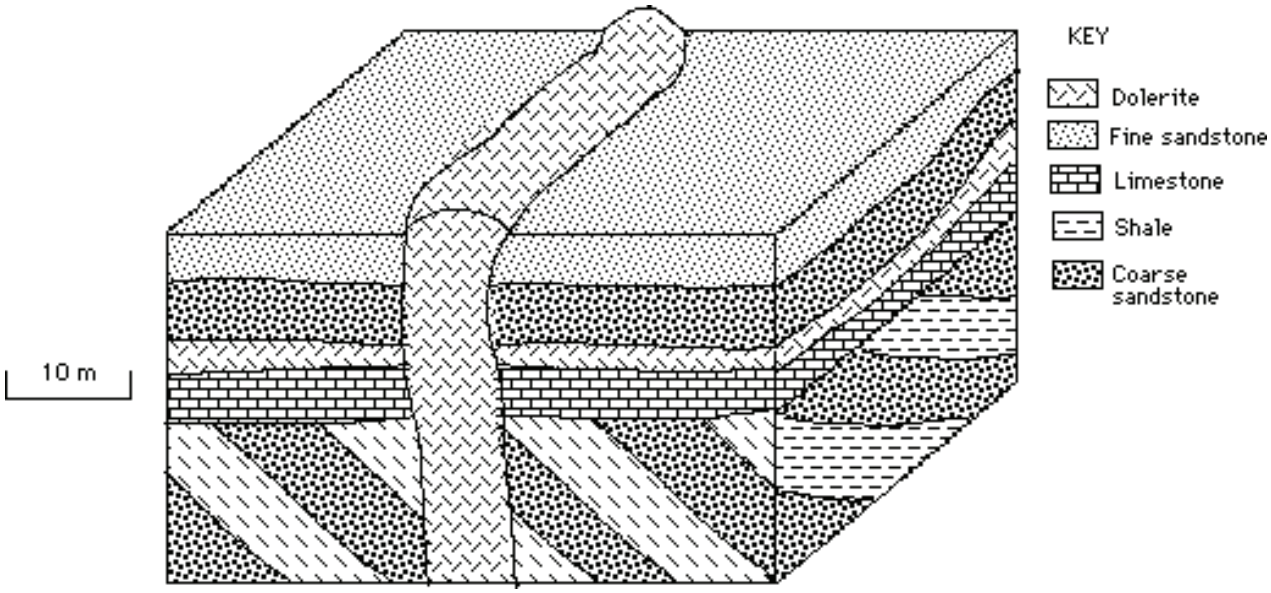
5. State, giving a reason, which of the rock sequences shown below has been **overturned**.



6. List the characteristics that must be possessed by **index** fossils.

7. Explain the meaning of the term **unconformity**.

For questions 8 and 9, refer to the block diagram below, which shows a region containing both igneous and sedimentary rocks.



8. On the diagram, draw a wavy line to indicate the position of an unconformity.

9. State, giving a reason, whether the sill is older or younger than the dyke.

_____

_____

_____

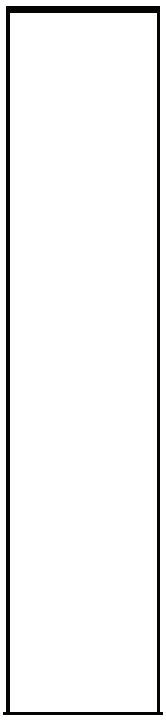
_____

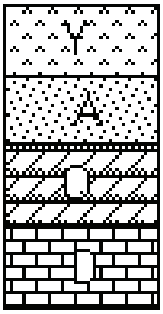
_____

10. The diagrams below show sequences of sedimentary rocks obtained at four different locations. All the sequences are portions of one large sequence. In the space provided, arrange the strata in the four sequences to form the complete **stratigraphic column** for the whole sequence.

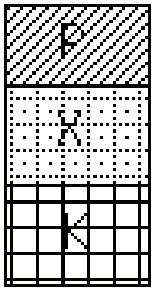
ST.

Stratigraphic Column

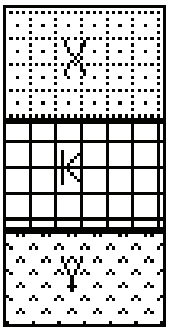




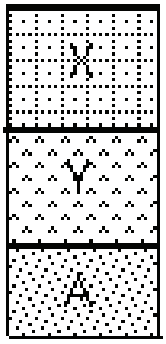
REGION 1



REGION 2

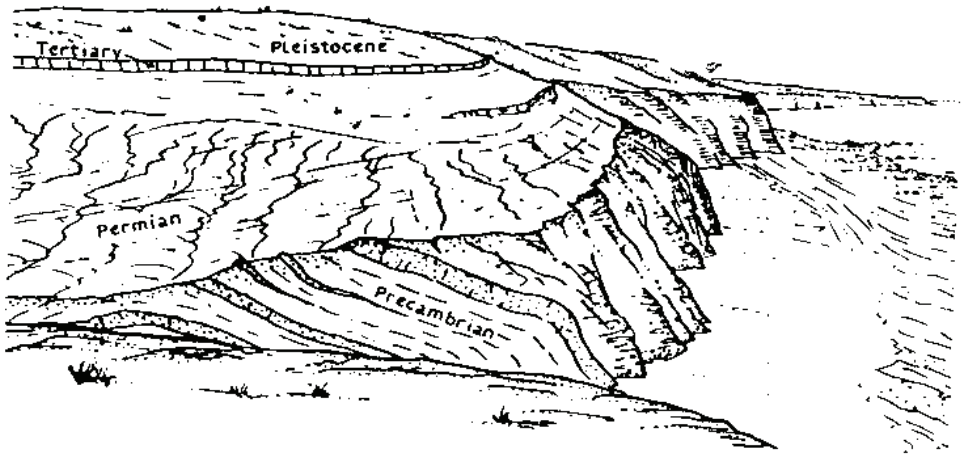


REGION 3



REGION 4

For questions 11 and 12, refer to the diagram below that shows the view across Waterfall Creek at Hallett Cove.



Section on the south side of Waterfall Creek, Hallett Cove.

11. Draw wavy lines to indicate the positions of **two** unconformities that are shown on the diagram.

12. Describe, with the aid of diagrams, the various stages in the formation of these unconformities, setting out your answer in a similar manner to the example on page 9.

Lower Unconformity

Stage 1

_____

_____

Stage 2

_____

_____

Stage 3

_____

_____

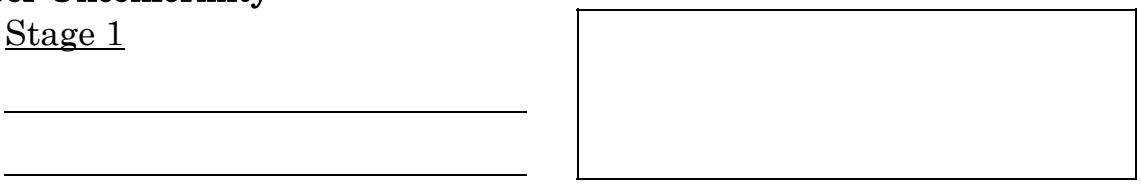
Stage 4

_____

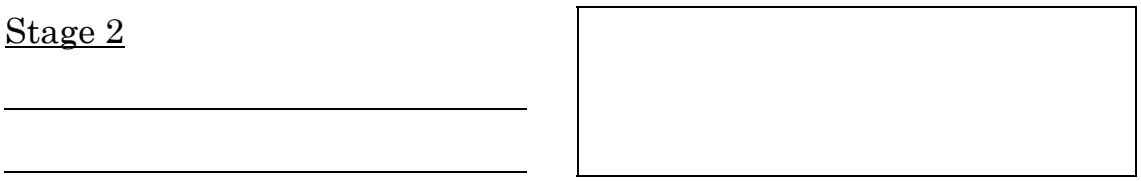
_____

Upper Unconformity

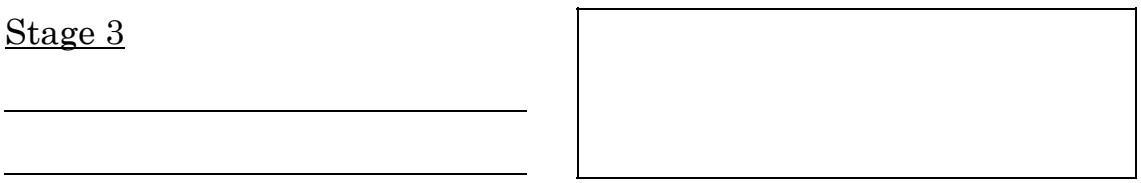
Stage 1



Stage 2



Stage 3

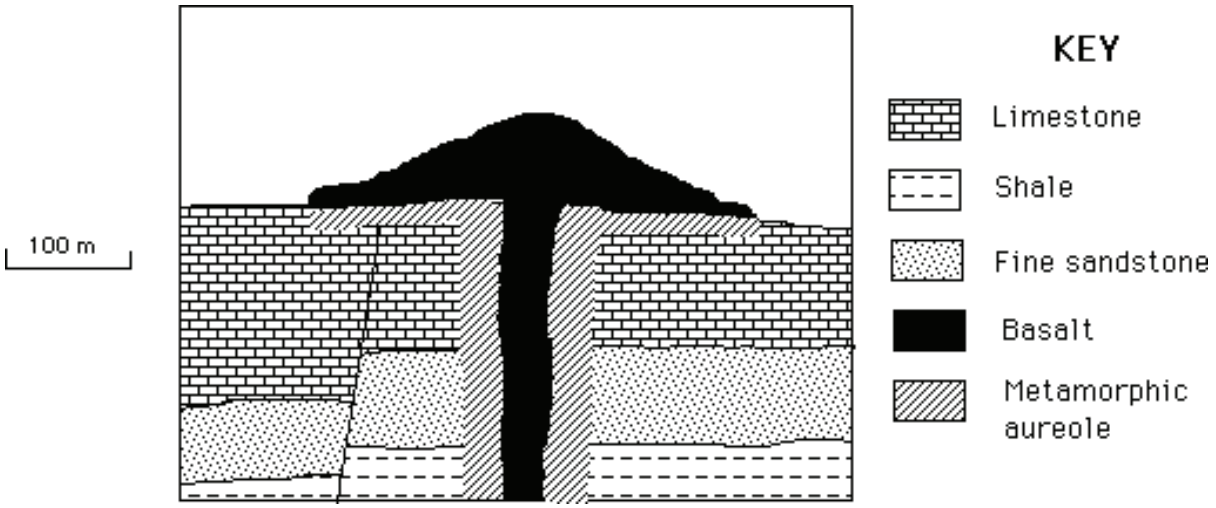


GEOLOGICAL HISTORY FROM A CROSS-SECTION

A common exam question involves describing the geological history of an area from a cross-section or a block diagram. Your answer should be presented in the form of a column, or table. The oldest rocks must be on the bottom. The following examples show one way of setting out your answers to geological history problems.

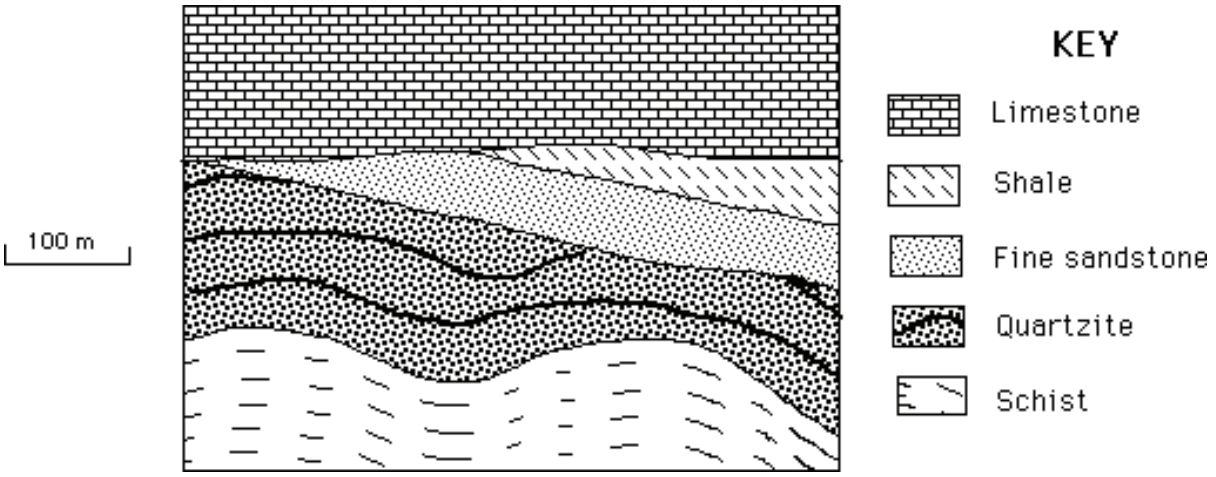
NB Always place the oldest rock types and events at the bottom!

1. Give the geological history of the region shown in the cross-sectional diagram below



	ROCK TYPES	EVENTS
YOUNGEST		
OLDEST		

2. Give the geological history of the region shown in the cross-sectional diagram below

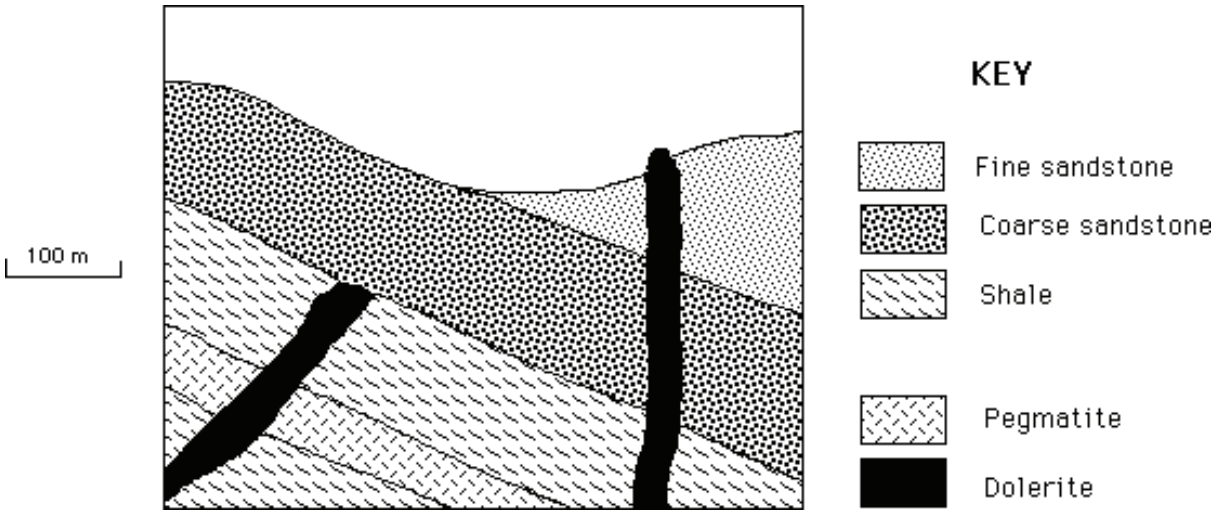


YOUNGEST

ROCK TYPES	EVENTS

OLDEST

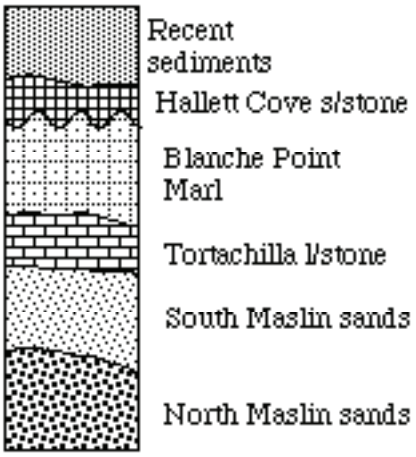
3. Give the geological history of the region shown in the cross-sectional diagram below



	ROCK TYPES	EVENTS
YOUNGEST		
OLDEST		

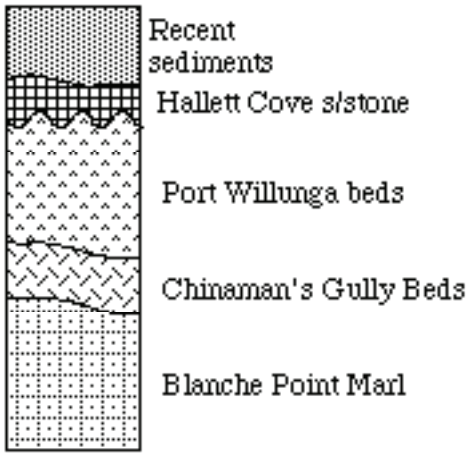
CORRELATION PROBLEMS

1. The diagrams below show the sequences of sedimentary rocks found in Maslin Bay and Port Willunga Bay.



Maslin's Bay Sequence

Note that some of the beds have been eroded away.



Port Willunga Sequence

a. Use the adjacent rectangle to complete the stratigraphic column for the Maslin Bay/Port Willunga Bay area.

b. Name the beds that do not appear at Maslin Bay because they have been eroded away.

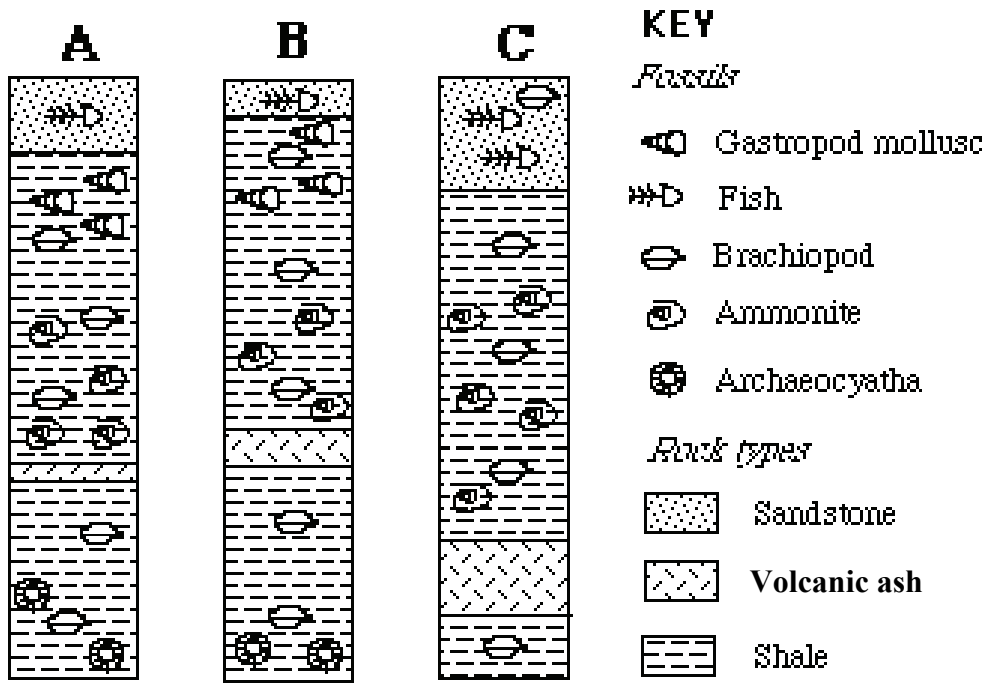
_____

_____

_____

_____

2. The diagrams below show stratigraphic columns obtained at three localities about 10 km apart.



a. Which fossil type is missing from locality C?

_____

b. What does this tell you about the probable age of the oldest rocks at locality C, compared with the oldest rocks at the other two localities?

_____

_____

c. Which location was closest to the volcano that deposited the ash?

_____

d. Why is the volcanic ash layer of particular significance in correlating the three sequences?

_____

_____

e. State, giving reasons, which of the three localities was closest to the land.

_____

_____

f. Explain how the sea level in the region varied over the period during which the sediments were being deposited. Provide **evidence** to support your explanation.

_____

_____

_____

g. At which locality is there an unconformity? _____

h. Explain how you know this.

_____

_____

i. Which of the fossil types is useless as an index fossil?

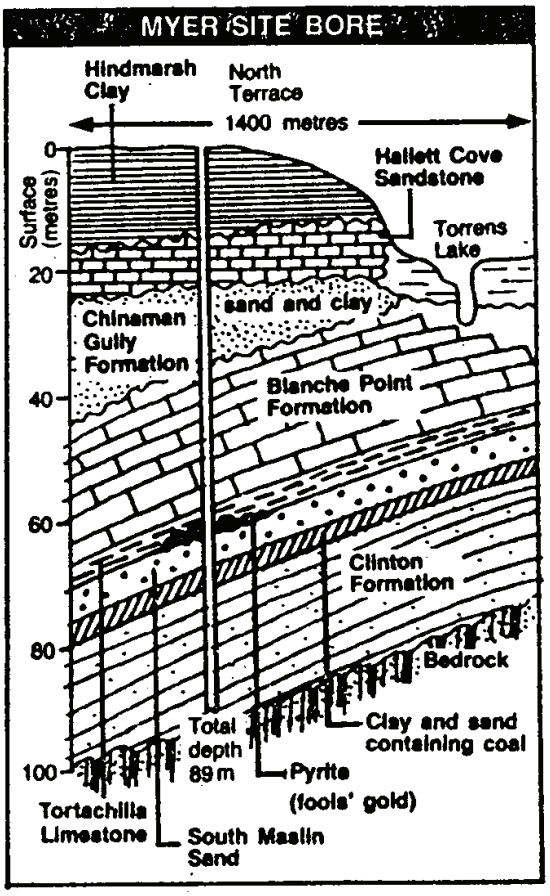
_____

j. Give a **reason** for your answer.

_____

_____

3. The diagram below was taken from the front page of the 'Advertiser' during 1989. It shows the sequence of sedimentary rocks that was revealed when a borehole was drilled below the Myer Development site. Use this diagram, together with the stratigraphic column for the Maslin Bay, Port Willunga area, which you drew on page 25 of these notes, to answer all parts of this question.



a. Why do you think the borehole was drilled below the Myer Redevelopment site?

_____

_____

b. Why is the rock sequence under the city of Adelaide similar to the sequence at Maslin Bay and Port Willunga?

_____

_____

c. Name the beds that are common to the two localities.

_____

_____

d. Name the two different beds that underlie the South Maslin Sands at the two localities.

_____

_____

e. What is the significance of the wavy lines between successive strata?

_____

f. In what way does the boundary shown in *The Advertiser* diagram between the Blanche Point formation and the Chinaman Gully Formation differ from the corresponding boundary shown on page 20?

_____

_____

g. Suggest a reason for this difference.

_____

_____

h. Name one use to which the Hallett Cove Sandstone has been put.

_____

_____

i. From where was the sandstone for this purpose obtained?

_____