AUSTRALIAN SCIENCE INNOVATIONS

School ID

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Australian Science Olympiads

# 2015 AUSTRALIAN SCIENCE OLYMPIAD EXAM

## EARTH & ENVIRONMENTAL SCIENCE – SECTIONS A & B

SOLUTIONS

All Multiple Choice answers are highlighted in yellow.

All Written Answers are given in blue text highlighted in yellow. Not all diagrams required for the answer are drawn but are described. With written answers there may be other answers which are valid. All valid answers are awarded marks.

AUSTRALIAN SCIENCE INNOVATIONS

Australian Science Olympiads

# 2015 AUSTRALIAN SCIENCE OLYMPIAD EXAM
# EARTH & ENVIRONMENTAL SCIENCE

Time Allowed
Reading Time: 15 minutes
Exam Time: 120 minutes

## INSTRUCTIONS

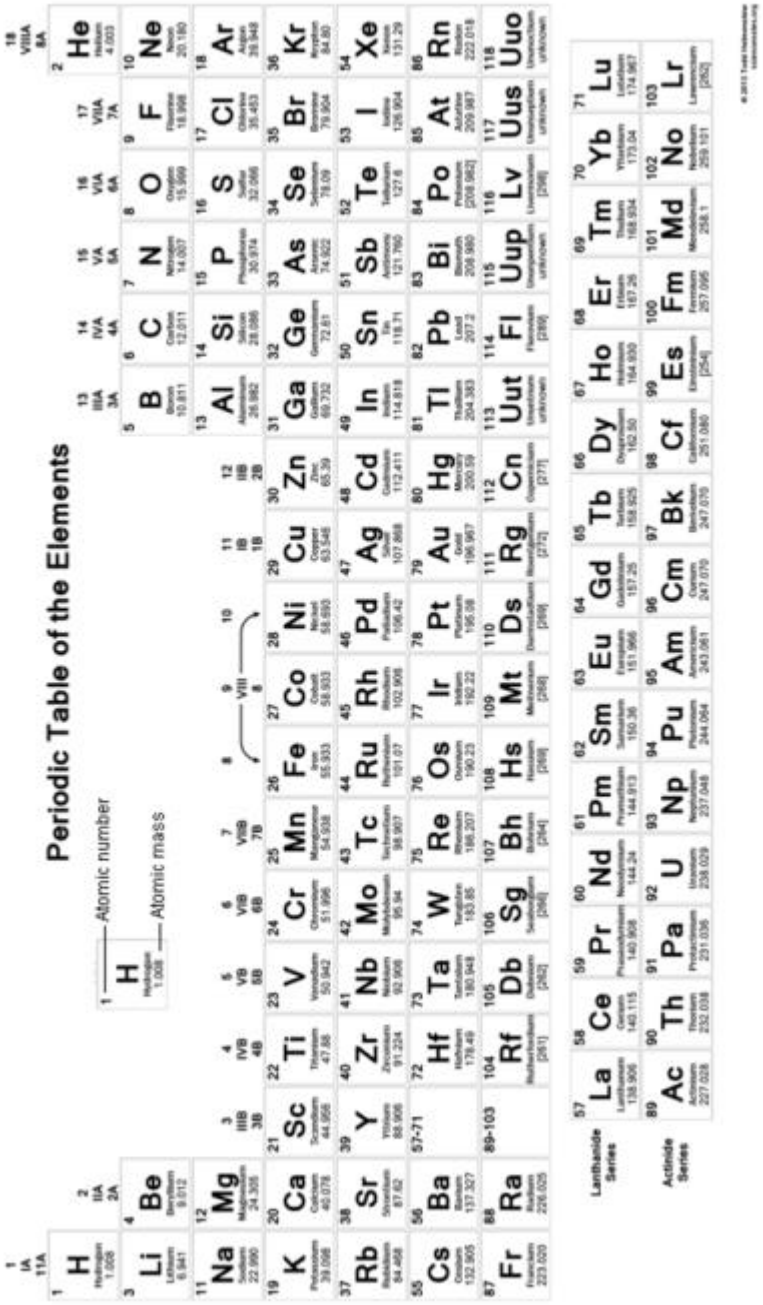
- *Attempt ALL questions in ALL sections of this paper.*
- Permitted materials: Non-programmable, non-graphical calculator, pens, pencils, erasers and a ruler.
- Answer SECTION A on the Multiple Choice Answer Sheet provided**. Use a pencil.**
- Answer SECTION B in the spaces provided in this paper. Write in pen and use pencils only for annotating or making diagrams.
- Ensure that your diagrams are clear and labelled.
- All numerical answers must have correct units.
- Marks will not be deducted for incorrect answers.
- Rough working must be done only on pages 44 and 45 of this booklet.
- Data that may be required for a question will be found on pages 3 to 5.
- Do NOT staple the multiple choice answer sheet to this booklet.

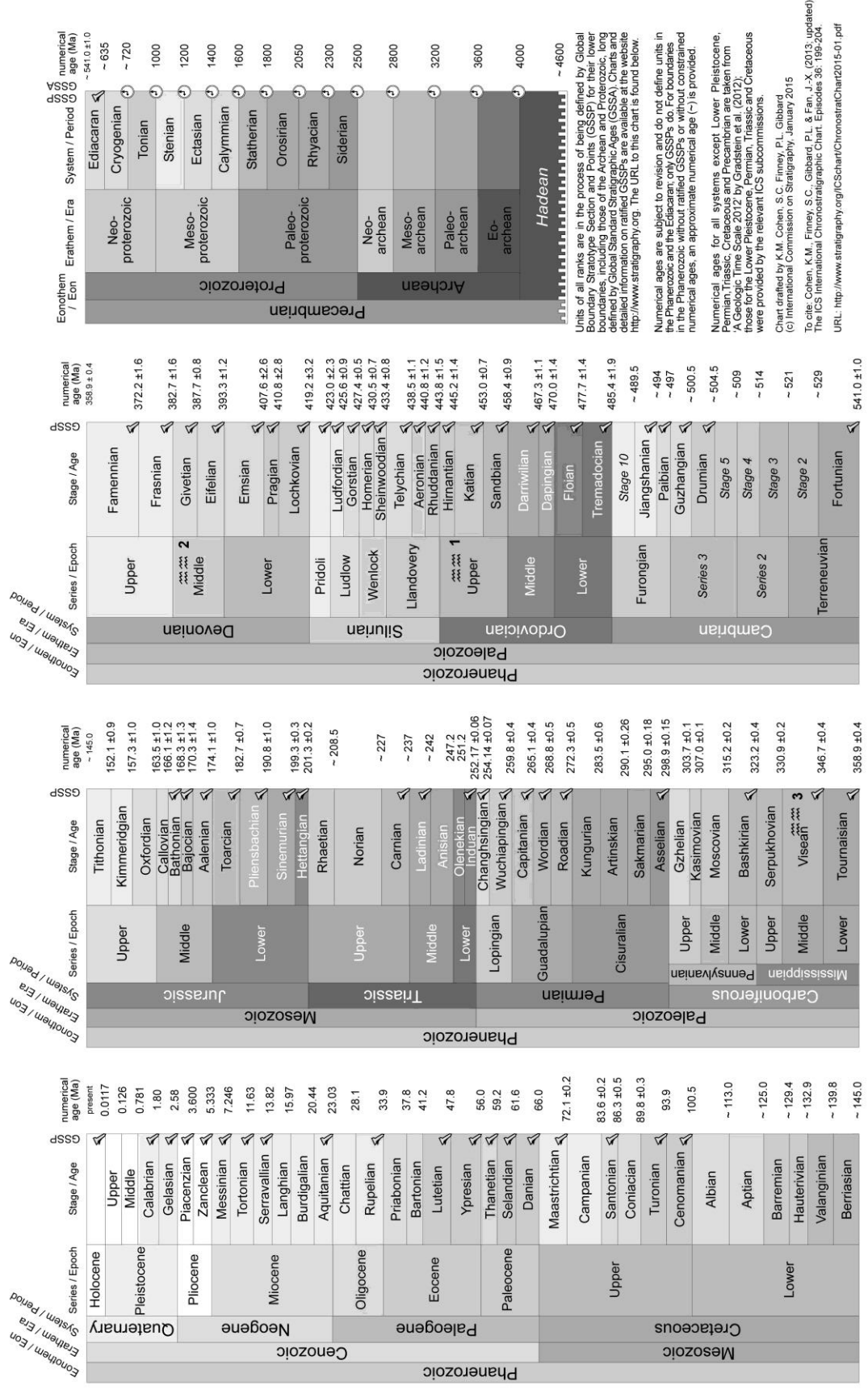
## MARKS

| | | |
|---|---|---|
| SECTION A | 30 multiple choice questions<br>Each question worth one mark | 30 marks |
| SECTION B | 17 written answer questions<br>Marks for each question are specified | 80 marks |
| Total marks for the paper | 110 marks | |

Material supplied:

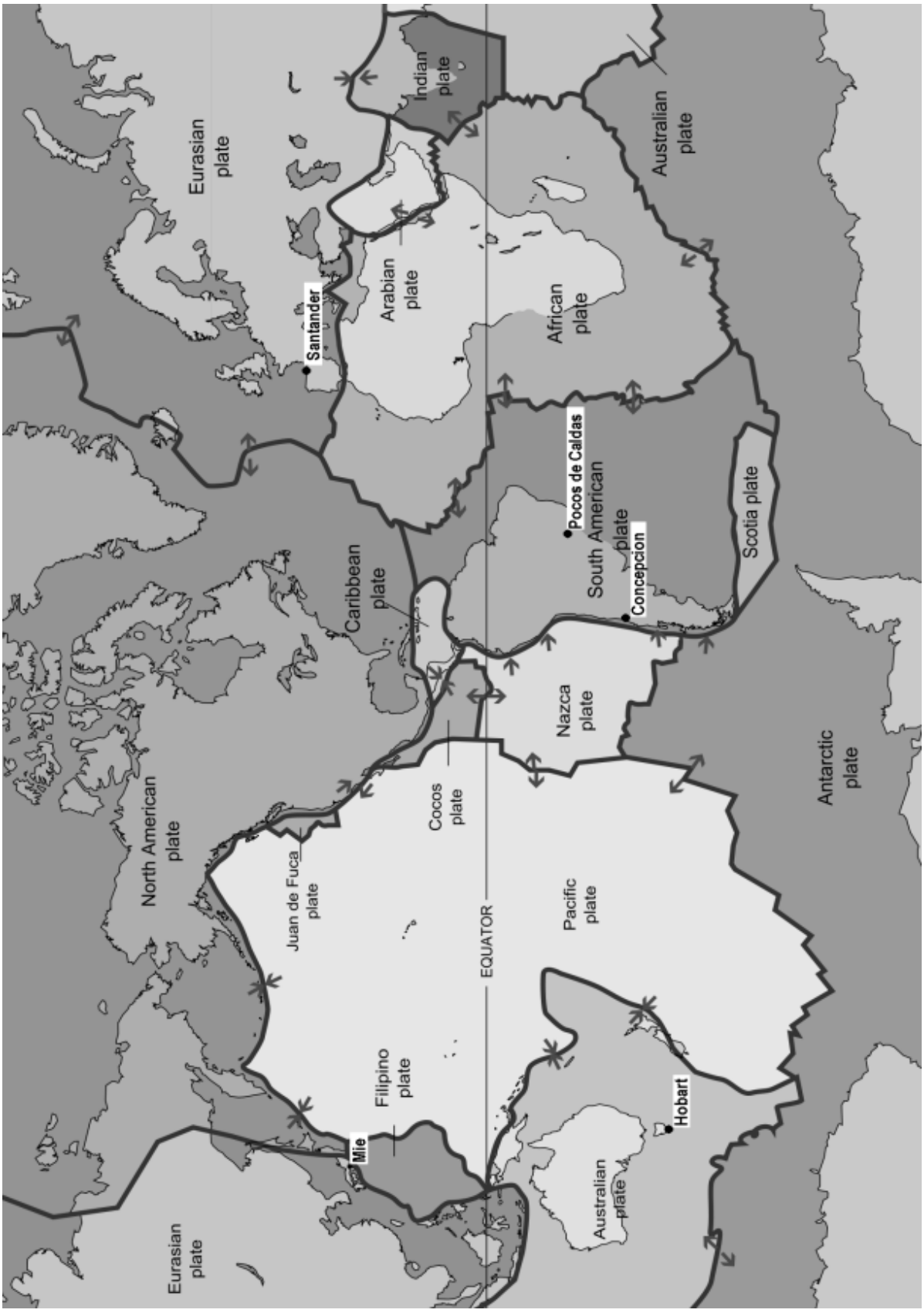
- Periodic Table of the Elements: Page 3
- A Geological Timescale: Page 4
- Map of Earth's Major Plate Boundaries and sense of plate motions: Page 5






A Geological Timescale.

Adapted from: http://www.stratigraphy.org/index.php/ics-chart-timescale




Major Tectonic Plates on Earth and sense of movement at plate boundaries.

Modified from http://commons.wikimedia.org/wiki/File:Plates_tect2_en.svg

# SECTION A : MULTIPLE CHOICE
# USE THE ANSWER SHEET PROVIDED

***Use the following information and figure 1 to assist in answering questions 1, 2, 3 and 4.***

NASA's Kepler Space Telescope has recently been used to identify the first Earth-sized planet. It has a radius 1.11 times that of Earth's radius and is designated Kepler-186f. It orbits the star Kepler-186 in the circumstellar habitable zone (figure 1). There are four other observable planets inside the orbit of Kepler-186f identified by the suffixes b, c, d and e. Kepler-186, the star that they orbit, is a red dwarf bordering on being an orange dwarf half the size and mass of the Sun. Kepler-186f orbits its star once every 130 Earth days and receives ~32% of the energy from its star that Earth gets from the Sun, placing it nearer the outer edge of the habitable zone. On the surface of Kepler-186f, the peak brightness of its star is only as bright as the Sun appears to us about an hour before sunset.

Curiously, a file on Kepler-186 and its planets has been found on the ground outside a police box in London. According to this London file, acceleration due to gravity on the surface of Kepler-186f is equivalent to 0.950 of Earth's. It also confirms Earth-based observations that Kelper-186 has a solar luminosity of ~0.04 and a solar radius of ~0.47.

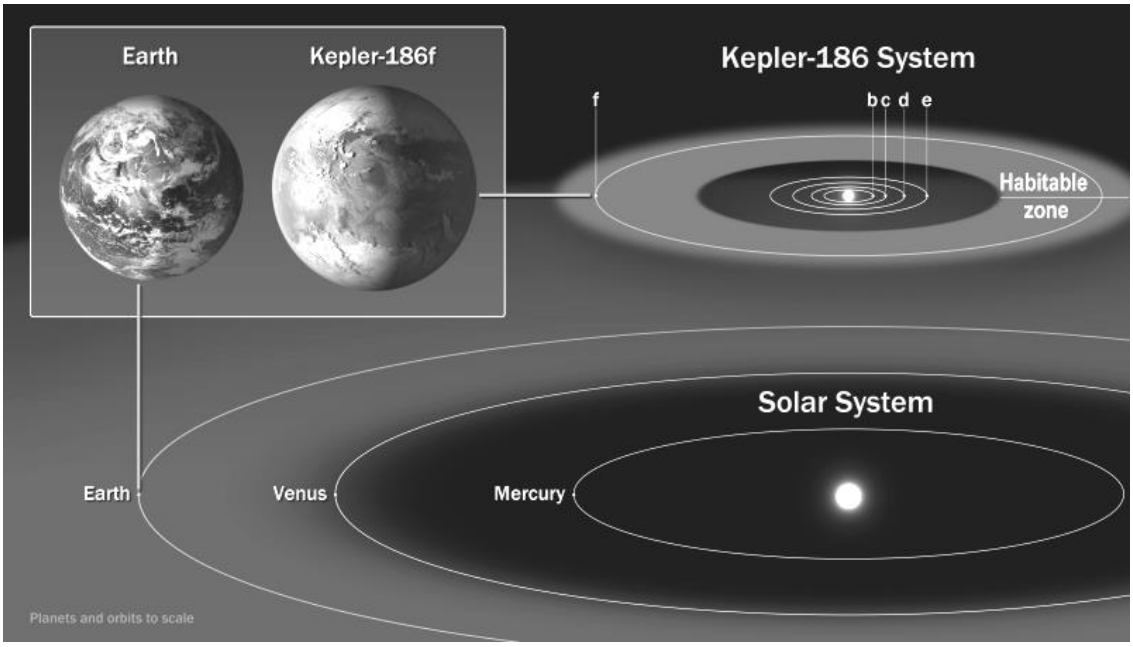



Figure **1**: Comparison between the Solar System and the Kepler-186 system.
Modified from an image provided by NASA/Ames/SETI Institute/JPL-Caltech (http://tinyurl.com/o8ehydy)

1. In order for Kepler-186f to be orbiting its star in the circumstellar habitable zone which criterion must be satisfied assuming it has sufficient atmospheric pressure?

    a. It must be orbiting at a distance from its star which is exactly the same distance as the Earth orbits the Sun.
    b. It must be orbiting at a distance from its star which allows it to receive enough incoming solar energy for liquid water to exist in the mantle.
    c. It must be orbiting at a distance from its star such that tidal heating warms the planet enough to enable water to be liquid beneath a frozen surface.
    d. It must be orbiting at a distance from its star which allows it to receive enough incoming solar energy for liquid water to exist at the surface.
    e. It must be orbiting at a distance from its star which allows it to receive enough incoming solar energy for liquid carbon dioxide to exist at the surface.

2. The London file reveals there are other planets in the Kepler-186 system not yet seen from Earth. One, known as *Kepler-186x*, is closer to the star Kepler-186 and has an orbital period of 120 Earth days. *Kepler-186x* is very like *Kepler-186f* in size, geology, abundance of surface water and major atmospheric gases yet its average planetary temperature is much lower. A feasible explanation for this could be:

    a. The colder planet, *Kepler-186x*, has very high concentrations of greenhouse gases. The warmer planet, *Kepler-186f*, has low concentrations of greenhouse gases and retains more heat in the atmosphere on average thanks to an absence of these gases.
    b. The colder planet, *Kepler-186x* has a very low albedo. The warmer planet, *Kepler-186f*, has a very high albedo and despite being farther from the star is warmed more effectively thanks to this feature.
    c. Both planets have the same mix of greenhouse gases. The warmer planet, *Kepler-186f*, retains more heat in the atmosphere on average than Kepler-*186x* because it is further from the star and needs the heat more to remain habitable.
    d. The warmer planet, *Kepler-186f*, has a longer orbital period than the colder planet, *Kepler-186x*, resulting in a greater accumulation of heat through friction as it interacts with the dust in the solar system.
    e. The colder planet, *Kepler-186x* has very low concentrations of greenhouse gases. The warmer planet, *Kepler-186f*, has relatively high concentrations of greenhouse gases and despite being farther from the star retains more heat in the atmosphere on average thanks to the presence of these gases.

3. The London fact file reveals the planet *Kepler-186f*, like Earth, is tilted on its axis at 23$^{o}$ which facilitates seasons through the same process as on Earth. However, *Kepler-186f* rotates on its axis somewhat slower and has a day length equivalent to 48 Earth hours. Assuming the orbital path of *Kepler-186f* is similar in shape to Earth's orbit, winter comes and the winter solstice occurs just as on Earth. How many *Kepler-186f* days are there between each winter solstice?

   a. 65
   b. 130
   c. 260
   d. 195
   e. Not possible to know

4. *Kepler-186f* receives ~32 % of the intensity of stellar radiation as that received by Earth from the Sun. Despite receiving less energy *Kepler-186f* orbits within the habitable zone. Where is the centre of the habitable zone around Kepler-186 likely to be compared with the centre of the habitable zone around the Sun?

   a. The centre of the habitable zone around Kepler-186 will be the same distance from that star as the centre of the habitable zone is from the Sun
   b. The centre of the habitable zone around Kepler-186 will be closer to the star than the centre of the habitable zone is from the Sun
   c. The centre of the habitable zone around Kepler-186 will be further from the star than the centre of the habitable zone is from the Sun
   d. The centre of the habitable zone around Kepler-186 will depend upon how many planets there are in that solar system and cannot be compared with the habitable zone around the Sun
   e. Since *Kepler-186f* has a larger radius than Earth the centre of the habitable zone must be further from the star than Earth is from the Sun.

***Use the following information and figure 2 to assist in answering question 5.***

Figure 2 is a Hertzsprung–Russell diagram, a scatter graph of stars showing the relationship between the stars' luminosities versus their spectral class (O, B, A, F, G, K & M) and effective surface temperatures. By definition the Sun has a luminosity of 1 and a solar radius of 1. Kelper-186 has a solar luminosity of ~0.04 and a solar radius of ~0.47.

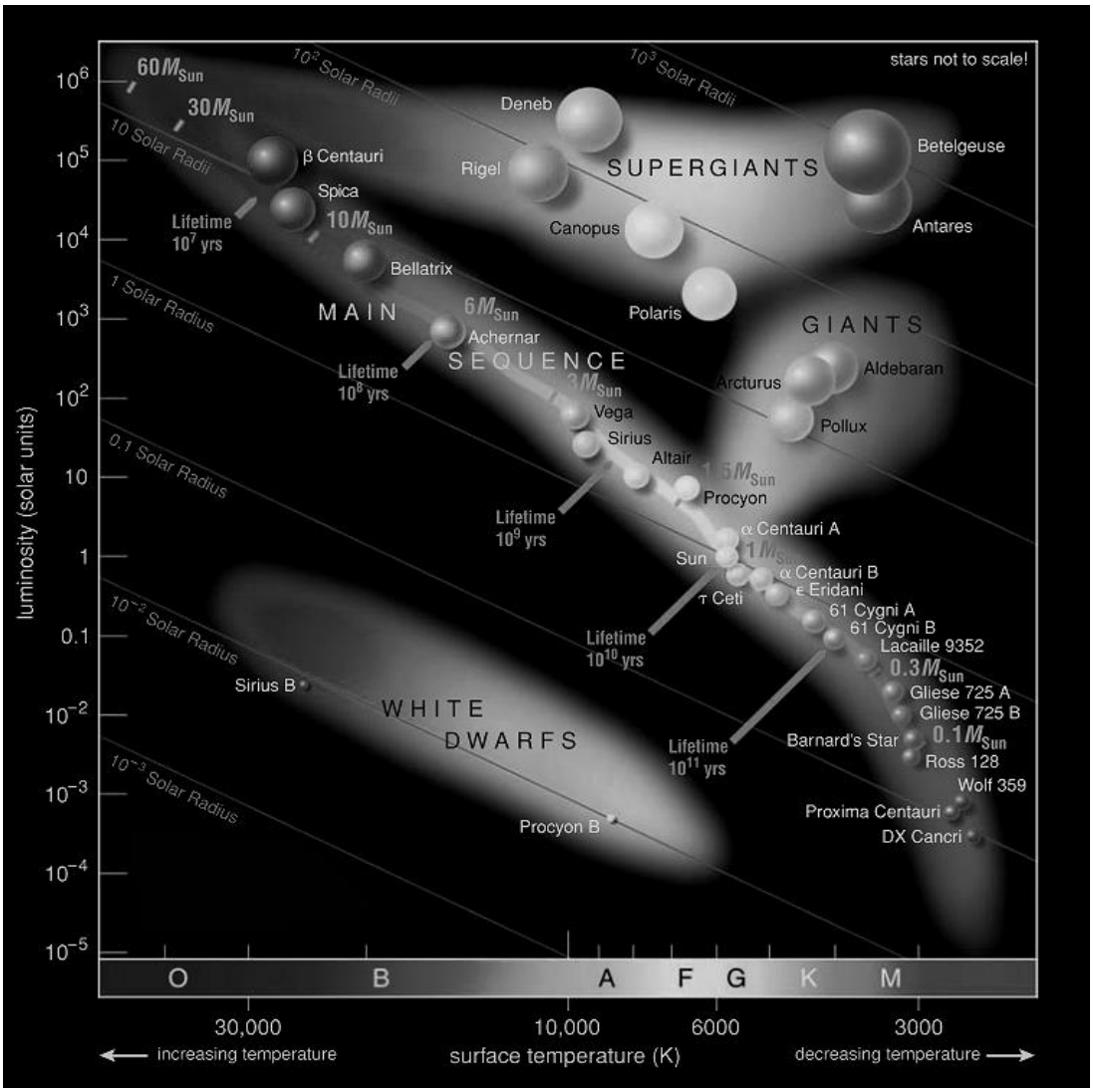



Figure 2: Hertzsprung-Russell diagram.

Modified from *The Cosmic Perspective.* O. Bennett, J, Donahue, M. Schneider & N. Voit. 7th Edition.

5. What is the surface temperature of Kepler-186 likely to be?

   a. ~22,400 K - close to that of Spica
   b. ~3,600 K - close to that of Lacaille 9352
   c. ~6,000 K - close to that of the Sun
   d. ~3,100 K - close to that of Barnard's Star
   e. Not possible to determine

***Use the following information and figure 3 to assist in answering questions 6, 7 and 8.***

Students Roxanne Stone, Philip Light, Gabi Roe, Daytona Light, Vincent Knight, Ariel Windlass, Sandra Shore and Gayle Snowdon have enrolled in an Earth and Environmental Science class along with many others. All eight students have been assigned to the same group for team work in class and on field trips.

The class has recently returned from a mapping field trip to Cape Enterprise. As part of their field trip report the students must document and identify geological structures they find in their field area. Figure 3 features five geological structures they found at Kirk Point in interbedded sandstones and mudstones. The students plan to submit this labelled image, with the helpful unlabelled inset image, as part of their written report describing all five features.

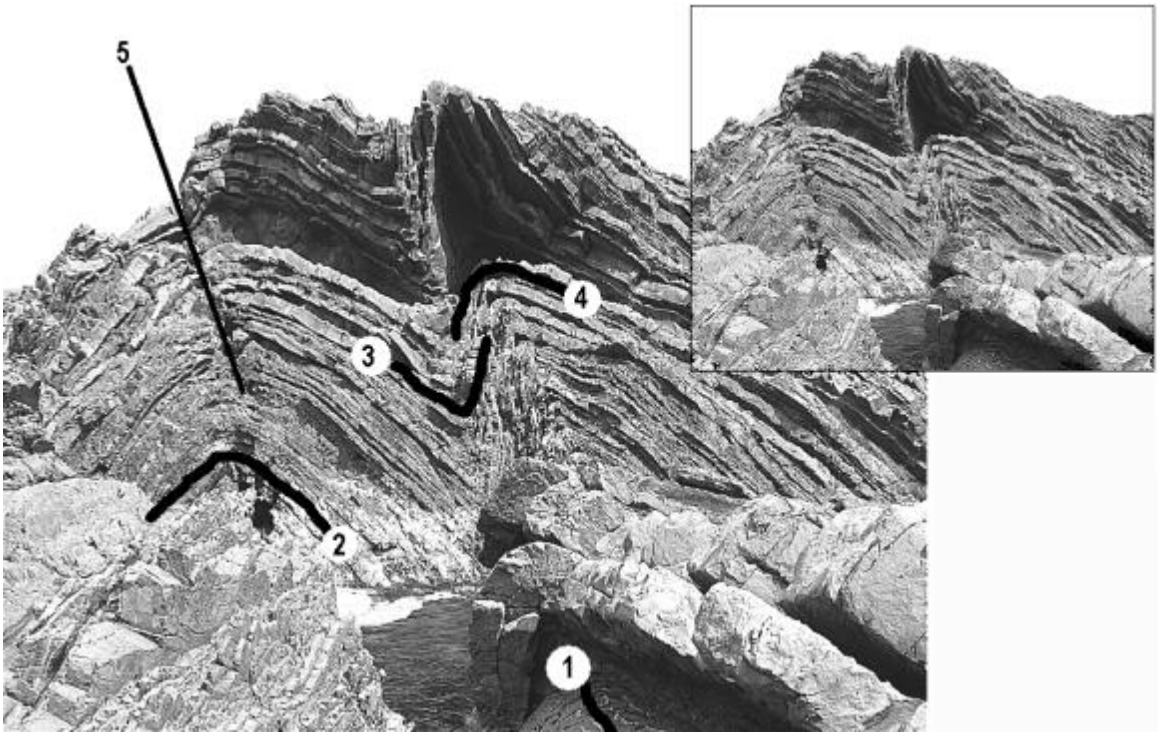



Figure 3: Five geological structures in one outcrop of interbedded sandstones and mudstones at Kirk Point, Cape Enterprise. The sandstone unit marked by the line labelled 4 is 20cm thick. The rock face displaying most of the structures is close to vertical. Image courtesy of Roxanne Stone.

6. The students agree that the correct labels for all five structures are:

a. 1: Syncline fold hinge, 2: Anticline; 3: Syncline, 4: Anticline, 5: Fault
b. 1: Anticline fold hinge, 2: Syncline, 3: Anticline, 4: Syncline, 5: Fault
c. 1: Anticline fold hinge, 2: Anticline; 3: Syncline, 4: Anticline, 5: Fault
d. 1: Syncline fold hinge, 2: Syncline, 3: Anticline, 4: Syncline, 5: Fault
e. 1: Strike slip fault, 2: Syncline, 3: Anticline, 4: Syncline, 5: Fault

7. Philip and Gabi have examined the sandstone beds and determined they have ~15% mud in the matrix and the sand grains are dominantly quartz with minor feldspar and lithic fragments. This type of sandstone is sometimes called a Greywacke. In outcrop, as seen in Figure 3, the sandstones protrude from the outcrop whereas the mudstones are recessed. As part of their field trip report their teacher, Mr Smith, has asked them to explain why the mudstones are recessed into the outcrop while sandstones protrude from the outcrop. They decide the best answer to write in the report is:

    a. The quartz rich sandstone is less resistant to weathering and erosion than the mudstone so over time the mudstone is removed faster than the sandstone creating an outcrop where the sandstones protrude and the mudstones are recessed.
    b. The quartz rich sandstone is more resistant to weathering and erosion than the mudstone so over time the mudstone is eroded more slowly than the sandstone creating an outcrop where the sandstones protrude and the mudstones are recessed.
    c. The quartz rich sandstone is less resistant to weathering and erosion than the mudstone but over time the mudstone is removed faster than the sandstone by burrowing worms thus creating an outcrop where the sandstones protrude and the mudstones are recessed.
    d. The quartz rich sandstone and mudstone erode at the same rate but the mudstone is weathered faster than the sandstone by ultraviolet light acting on the matrix mud, creating an outcrop where the sandstones protrude and the mudstones are recessed.
    e. The quartz rich sandstone is more resistant to weathering and erosion than the mudstone so over time the mudstone is removed faster than the sandstone creating an outcrop where the sandstones protrude and the mudstones are recessed.

8. At Cape Enterprise students Vincent and Ariel located a roughly horizontal shore platform adjacent to Kirk Point. Their photograph (figure 4) shows tightly folded interbedded turbidite sandstones and mudstones. Some students in the team are puzzled by the fact that this horizontal outcrop looks similar to the vertical outcrop at Kirk Point (figure 3). Both photographs are looking south towards the ocean although the ocean is not visible in figure 3. In their report the students correctly explain this outcrop's appearance as being due to the fact that:

   a. The folds are plunging eastwards
   b. The folds are plunging westwards
   c. The folds are plunging northwards
   d. The folds are plunging southwards
   e. The folds are not plunging

Figure 4: Shore platform adjacent to Kirk Point, Cape Enterprise, looking south towards the ocean. Photograph courtesy of Vincent Knight.

9. In some of the rocks at Cape Enterprise small fractures and tension gashes are filled with an opaque white mineral. Daytona and Gabi found an outcrop where large crystals of this mineral had fallen out naturally, enabling them to examine it in detail without damaging Schumann National Park where the Cape is located. They observed it has 3 good cleavages and a hardness of 3. They correctly concluded this mineral is:

   a. Quartz
   b. Plagioclase feldspar
   c. Calcite
   d. Gypsum
   e. Opal

***Use the following information and figure 5 to answer questions 10, 11 and 12.***

There are eight particularly important minerals that can illustrate the fundamental processes which determine the mineralogy of igneous rocks. Figure 5 shows the minerals ranked according to their crystallisation temperatures, an arrangement called Bowen's Reaction Series. The crystallisation temperatures of these minerals approximately correspond to their position relative to the temperature scale in figure 5. The crystallisation temperatures of olivine, pyroxene, amphibole and biotite overlap with the range of plagioclase feldspar. However, the crystallisation temperatures of plagioclase varies continuously from calcium-rich at high temperature to sodium-rich at lower temperature. Iron-magnesium rich silicate minerals such as olivine, pyroxene, amphibole and biotite tend to be dark in colour and are referred to as mafic minerals. Rocks rich in these minerals are referred to as mafic rocks. Likewise, low iron-magnesium silicate minerals such as quartz, feldspar and muscovite tend to be light in colour and are referred to as felsic minerals. Rocks rich in these minerals are referred to as felsic rocks.

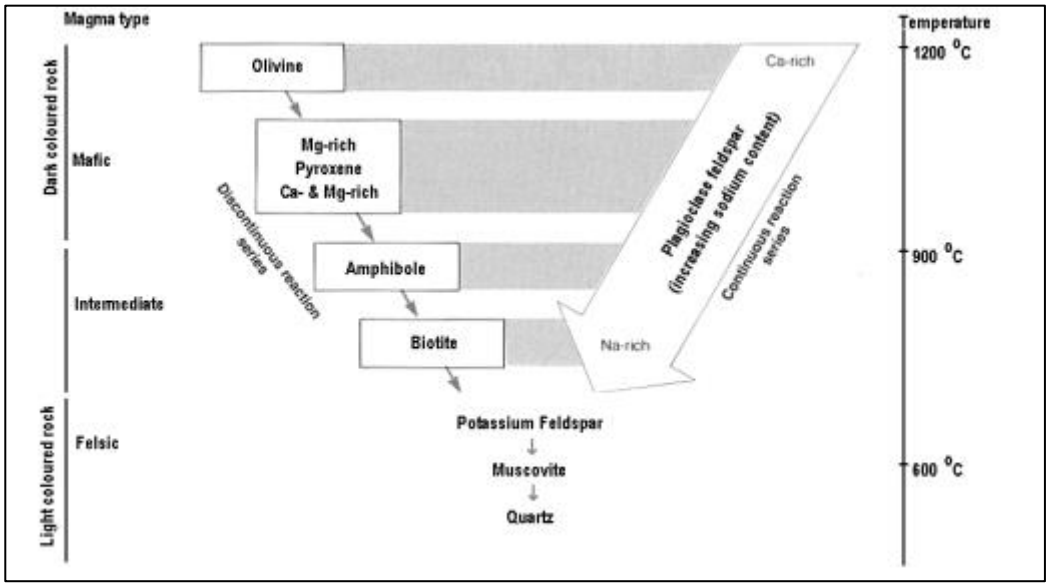



Figure 5: Bowen's Reaction Series.
Modified from Skinner & Porter - The Dynamic Earth (2nd Ed.) 1992.

10. As part of their field trip the Earth and Environmental Science students also visited Balon Beach, Yara Point and Cape Greyjoy at the far western end of the beach. Flood basalts forming the shore platform create an excellent squid fishery just off-shore. Basalt usually contains the mineral olivine. Close inspection of the Cape Greyjoy rock by the students also revealed an abundance of pyroxene and which other mineral?

    a. Quartz
    b. Sodium-rich plagioclase feldspar
    c. Potassium-rich plagioclase feldspar
    d. Calcium-rich plagioclase feldspar
    e. Magnesium-rich plagioclase feldspar

11. In their mapping of Cape Greyjoy Phil Light has identified an igneous intrusion as the foundation of Stark Reef, an off-shore outcrop of rocks notorious for shipwrecks due to its effect on compasses. The rock is dark in colour and very fine grained, except for large easily visible white opaque crystals several millimetres long that account for about 5% of the rock. The crystals are slightly rectangular and display 2 good cleavages at ~90 degrees to each other. In his notebook Phil has written the correct description of this rock which reads:

    a. The white crystals are plagioclase feldspar. The rock is probably mafic given its dark colour and is therefore a mafic feldspar porphyry.
    b. The white crystals are plagioclase feldspar. The rock is probably felsic given its dark colour and is therefore a felsic feldspar porphyry.
    c. The white crystals are potassium feldspar (k-spar). The rock is probably mafic given its dark colour and is therefore a mafic k-spar porphyry.
    d. The white crystals are potassium feldspar (k-spar). The rock is probably felsic given its dark colour and is therefore a felsic k-spar porphyry.
    e. The white crystals are quartz. The rock is probably mafic given its dark colour and is therefore a mafic quartz porphyry.

12. Most inorganic components of sediments and soils are derived from the weathering of rocks. During weathering most common minerals found in igneous rocks break down into clays but in some places of rapid erosion minerals that normally weather to clays can be released from the rock and become sediment grains. Quartz normally survives the weathering that reduces other minerals to clays. Which of these statements is correct?

    a. Sediment containing quartz grains is unlikely to have had a felsic rock as part of its source.
    b. Sediment containing pyroxene grains must have both a mafic and felsic rock as part of its source
    c. Sediment containing both muscovite grains and quartz grains must have both a mafic and felsic rock as part of its source
    d. Sediment containing quartz grains and olivine grains must have both a mafic and a felsic rock as part of its source
    e. Sediment containing quartz is likely to have had a mafic rock as part of its source

13. Phil Light lost some marks in his notebook assessment as he did not use the correct terminology for the large easily visible white opaque crystals he observed in the rock. He just called them “big crystals”. His mapping partner, Roxanne Stone, did not lose marks because in her notebook she identified these crystals as:

    a. Crystallites
    b. Phenocrysts
    c. Xenoliths
    d. Porphyryites
    e. Australites

***Use the following information and figure 6 to answer questions 14, 15 and 16.***

Beaches are dynamic. As waves approach the coastline their energy lifts sand on the near-shore sea-bed into suspension and the associated currents transport the sand. The sand on the seabed is mobilised by every wave passing over it and some of it is washed up onto the beach. Sand grains are washed up the beach face in the direction of the wave's movement. In the backwash from the wave the sand grains are moved back down the beach face. If the wave is at an angle to the shoreline the sand grain will travel up the beach face at an angle but come back down to the shoreline further along the beach from where it started (figure 6), resulting in the grain travelling along the beach in one direction for as long as the waves run onto the beach in the same direction.

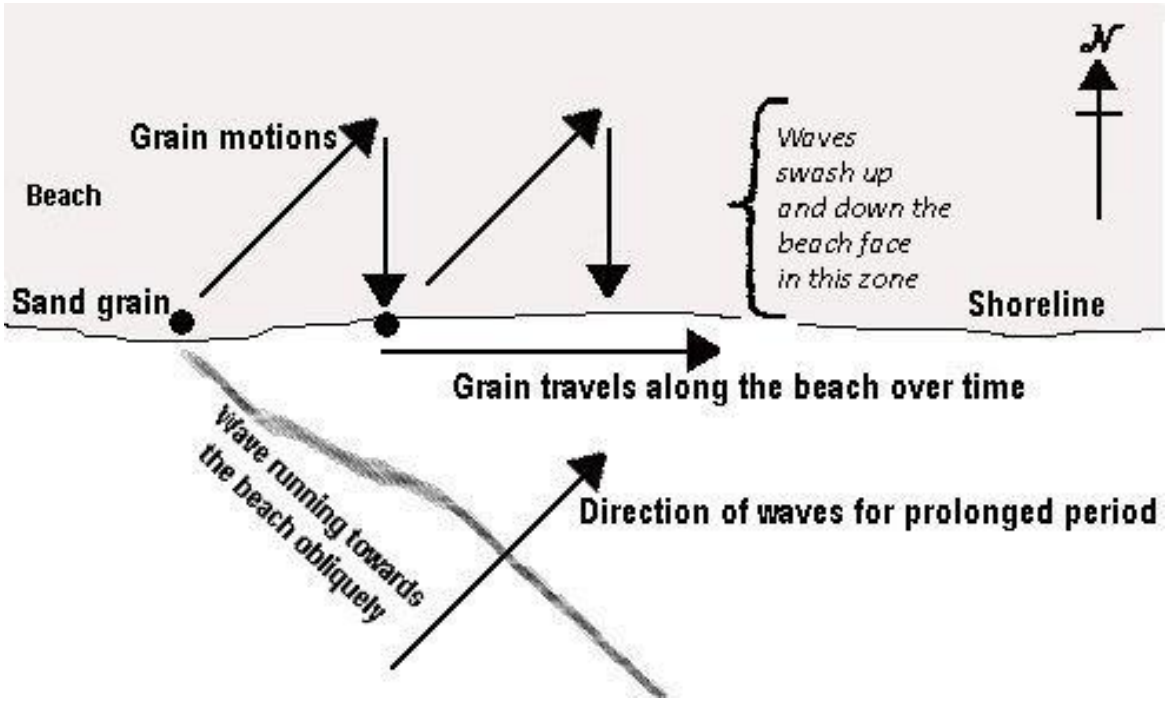



Figure 6: Motion of a sand grain along a south facing beach under the influence of waves oblique to the beach

14. What direction will the sand grain move on this beach over time if the wind and waves are consistently from the south?

    a. It will move North along the beach
    b. It will move South along the beach
    c. It will move East along the beach
    d. It will move West along the beach
    e. It will not move very far along the beach in any direction

***Use the following information and figures 7 and 8 to answer questions 15 to 19.***

During periods of drought, the river flow is reduced and the entrance to Blackwater Estuary is blocked by sand. The students have been asked to assist local fishermen as they decide where to build a wall across the beach into the sea – usually known as a groyne – to prevent sand from closing the entrance to Blackwater Estuary. Figure 7 is an orthophotomap of the region. Figure 8 is a rose diagram displaying the dominant wind directions which, in this region, control the dominant directions from which waves roll in.

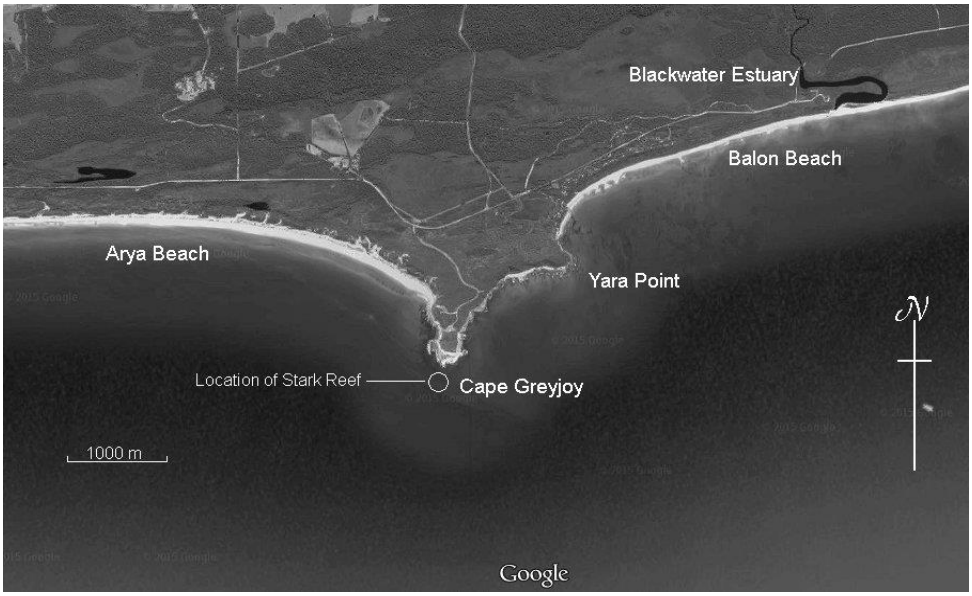



Figure 7: Geography of the Cape Greyjoy area. Modified image courtesy of Google Maps.

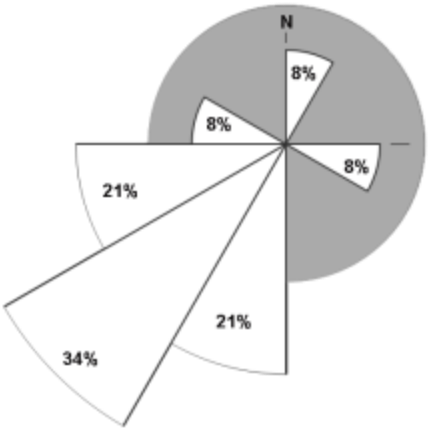



Figure 8: Annual wind rose data from Yara Point. Each slice collates wind directions from a 30° range (0 to 30, 30 to 60 etc.). The point of each slices points in the direction of wind movement. The size of each slice and given percentages indicates how frequently the wind came from this direction during the year.

15. The students decide that the most cost effective way to prevent the estuary entrance from closing during a drought using a groyne is to build a groyne 100 metres into the sea:

a. on Yara Point
b. on Cape Greyjoy
c. west of the entrance
d. east of the entrance
e. on both sides of the entrance

***Use the following information and table 1 to answer questions 16, 17 and 18.***

Sand samples collected on Balon Beach by Sandra Shore and Gabi Roe have been examined by the whole student group and the range of minerals, rocks and other flotsam and jetsam found on the beach documented and tabulated below (table 1). The students are puzzled by the range of grain types and what they might mean for the geology and environment of the region.

| **On the beach close to Yara Point** | **On the beach west of Blackwater estuary** | **On the beach east of Blackwater estuary** |
|---|---|---|
| Quartz (abundant) | Quartz (abundant) | Quartz (abundant) |
| Calcite (shell fragments) | Calcite (?shell fragments) | Calcite (shell fragments) |
| Muscovite (common) | Pumice (common) | Coloured plastic of all kinds |
| Feldspar (common) | Coloured plastic of all kinds | Pumice (common) |
| Coloured glass of all kinds | | Biotite |
| Olivine (rare) | | Garnet (rare) |
| Pumice (golf ball sized bits) | | |

Table 1: Inorganic materials collected on Balon Beach.

16. The students know flood basalt forms the elevated shore platform at Yara Point but before mapping the point in detail the students debate what the Yara Point sediment results suggest the overall geology of the point might be. Which student or pair of students is most likely to be correct in their assessment of the rocks underlying the flood basalt?

    a. Daytona and Ariel think the Yara Point sub-basalt rocks are dolerite
    b. Vincent and Gabi think the Yara Point sub-basalt rocks are granite
    c. Gayle and Sandra think the Yara Point sub-basalt rocks are gabbro
    d. Roxanne thinks the Yara Point sub-basalt rocks are more basalt
    e. Phil thinks the Yara Point sub-basalt rocks are marble

17. The pumice at all three sites also caused some debate. Which student or pair of students is most likely to be correct about the origin of the pumice?

    a. Roxanne and Phil think the pumice has come from a modern submarine volcano
    b. Gayle and Vincent think the pumice has weathered out of local basalt
    c. Gabi and Ariel think the pumice has weathered out of local granite
    d. Sandra thinks the pumice has formed from lightning strikes on the beach sand
    e. Daytona thinks the pumice has weathered out of a local mafic intrusive

18. The results for the beach east of Blackwater Estuary were so different to that west of the estuary that an explanation was discussed at length. After thoroughly resampling all three beaches and arriving at the same result much debate amongst the team resulted in five alternative proposals. Which proposal would the team need to choose to get the best marks for their report?

    a. The minerals found in the sand east of the Blackwater Estuary indicate the flood basalt at Cape Greyjoy is underlain by a garnet-biotite schist
    b. The minerals found in the sand east of the Blackwater Estuary indicate there is a garnet-biotite schist at the far eastern end of Balon Beach
    c. The minerals found in the sand east of the Blackwater Estuary indicate there is an amphibolite somewhere in the catchment of the Blackwater Estuary
    d. The minerals found in the sand east of the Blackwater Estuary are not useful in coming to a conclusion as to why they are present
    e. The minerals found in the sand east of the Blackwater Estuary indicate there are garnet and biotite bearing rocks somewhere in the catchment of the Blackwater Estuary

19. The surface rocks at Cape Greyjoy and Yara Point are flood basalts. All the students think these rocks overlie a crystalline rock. Irrespective of whether the rocks beneath the flood basalts are granite, gabbro, basalt, dolerite or marble the one thing all the students agree upon is that the contact between the flood basalt and the underlying rocks is not an angular unconformity. What would the students need to find beneath the flood basalt in order for the contact to be labelled an angular unconformity?

    a. More flood basalt
    b. Flow banded rhyolite
    c. A thrust fault
    d. Horizontal sedimentary rocks
    e. Dipping or folded sedimentary rocks

***Use figure 9 to answer question 20.***

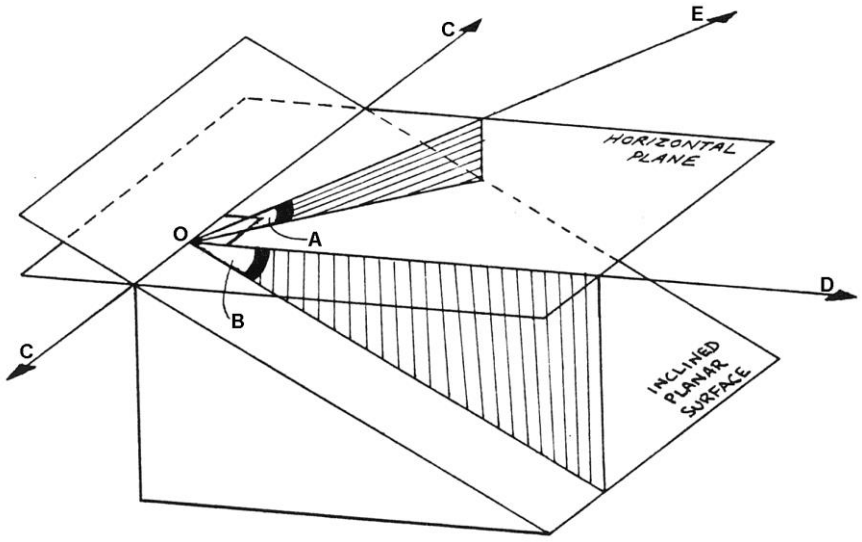



Figure 9: Schematic diagram of the intersection of a horizontal plane and an inclined plane. Lines C-O-C, O-E and O-D are all in the horizontal plane. Angles A and B are measured in a vertical plane between the horizontal and inclined planes. Lines C-O-C and O-D are at right angles to each other.

20. When measuring dipping lithological units each of the lines C-O-C, O-E and O-D have specific names as do angles A and B. The correct names for all 5 features are:

a.
| | |
|---|---|
| Angle A: | True dip |
| Angle B: | Angle of strike |
| Line C-O-C: | Dip direction |
| Line O-D: | Apparent dip direction |
| Line O-E: | Strike |

b.
| | |
|---|---|
| Angle A: | True dip |
| Angle B: | Apparent dip |
| Line C-O-C: | Strike |
| Line O-D: | Apparent dip direction |
| Line O-E: | True dip direction |

c.
| | |
|---|---|
| Angle A: | Apparent dip |
| Angle B: | True dip |
| Line C-O-C: | Strike |
| Line O-D: | True dip direction |
| Line O-E: | Apparent dip direction |

d.
| | |
|---|---|
| Angle A: | Apparent dip |
| Angle B: | Angle of strike |
| Line C-O-C: | Strike |
| Line O-D: | True dip direction |
| Line O-E: | Apparent dip direction |

e.
| | |
|---|---|
| Angle A: | Apparent dip |
| Angle B: | True dip |
| Line C-O-C: | Strike |
| Line O-D: | Apparent dip direction |
| Line O-E: | True dip direction |

21. In attempting to understand the way the Earth works early geoscientists formulated the idea that understanding modern processes is the key to understanding the past. This concept is otherwise known as:

    a. The Law of Superposition
    b. Catastrophism
    c. Uniformitarianism
    d. Neptunism
    e. Naturalism

22. Albedo is the name given to the reflectance of shortwave/solar radiation off a surface. The higher the albedo the more light is reflected. Which of these statements is correct:

    a. Snow and ice have a low albedo
    b. Bare soil has a high albedo
    c. Snow and ice have a high albedo
    d. Forests have a lower albedo than bare soil
    e. Bare soil has the same albedo as snow and ice

23. Warm air, rising in the heat that develops over equatorial regions of the globe, moves north or south of the equator before cooling and descending to the surface where it moves back towards the equator, thus establishing a circulation cell. This equatorial cell, either side of the equator, is known as:

    a. The Hadley Cell
    b. The Non-polar Cell
    c. The Intemperate Cell
    d. The Humid Cell
    e. The Ferrel Cell

***Use the following information and figure 10 to answer questions 24, 25 and 26.***

The students stopped at a nice new road-cutting on the road trip to Cape Enterprise because it revealed an excellent cross-section through some interesting rock formations. Roxanne Stone has drawn a schematic diagram, shown below in figure 10, of the cross-section based on photographs taken on site and rock identifications confirmed by their teacher.

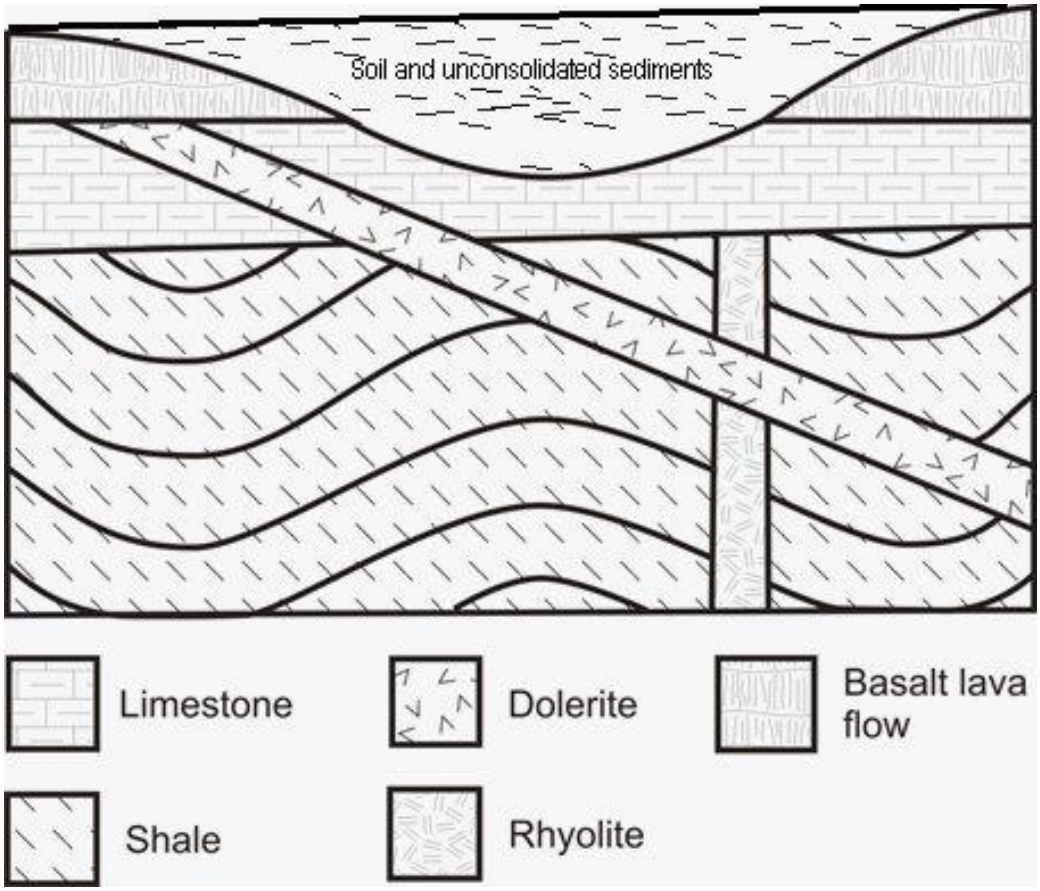



Figure 10: Schematic cross-section, drawn by Roxanne Stone, based on photographs of a road cutting near Cape Enterprise and on-site rock identifications

24. The students all agree that Roxanne's diagram is correct but cannot agree about the following statements that they plan to put into their field trip report. Only one statement is correct. Which one is it?

    a. The rhyolite is the oldest rock in the outcrop
    b. The limestone is conformable with the shale
    c. The shale was folded after the dolerite intrusion
    d. The dolerite was intruded before the rhyolite
    e. The folding happened prior to the rhyolite intrusion

25. In their field trip report all the students correctly noted that the soil and unconsolidated sediments at the top of the sequence, as shown in figure 10, were infilling an ancient stream channel that eroded though the basalt lava flow and into the limestone. The limestone, of Devonian age, contains numerous marine fossils. The basalt has a Potassium/Argon age date of 4.01 ± 0.05 million years. The partial skull and femur of a megafaunal marsupial, *Protemnodon anak* (a kind of giant wallaby that was extinct by ~30,000 years ago), was found in the sediments near the bottom of the channel fill by Ariel Windlass. He was so excited but not as excited as the museum staff he took it to after the field trip. They noticed the femur, the long leg bone that joins to the hip, had cut marks in it consistent with the animal having been butchered by human hunters. What age are the marsupial bones?

    a. Pliocene
    b. Miocene
    c. Devonian
    d. Pleistocene
    e. Holocene

26. The rhyolite intrusion shown in figure 10 is thought to be a feeder dyke from a large magma source several thousand metres below this outcrop. It is presumed the dyke fed a volcano which has long since been eroded away. However, the very slowly cooling magma has now formed a solid batholith which, despite being solid, is still very hot - nearly 400$^{o}$C – making it a target of interest for geothermal energy exploration companies. If an exploration company were to drill down to this hot rock what type of rock would they find has crystallised from the magma given there was no magmatic fractionation between the time of the intrusion and the eruption of the magma?

    a. Gabbro
    b. Granite
    c. Rhyolite
    d. Hornfels
    e. Dolerite

***Use the following information and figure 11 to answer questions 27 and 28.***

The student's field camp was set up next to the Palpatine River. In figure 11, a schematic cross-section of the location shows that there are four units beneath the soil in this area. Unit A is poorly consolidated sand that is thought to be the remnants of some Pleistocene wind-blown sand dunes. Unit B is a dense mud. It has been quarried locally and used as water proofing in bark canoes and slab hut walls. Unit C is a coarse, poorly consolidated sandy gravel. Unit C is thought to be the remains of a river bed. Unit D is a slightly weathered granite. It is fracture-free and impermeable. The hills behind the river land are a recharge zone for the local aquifers.

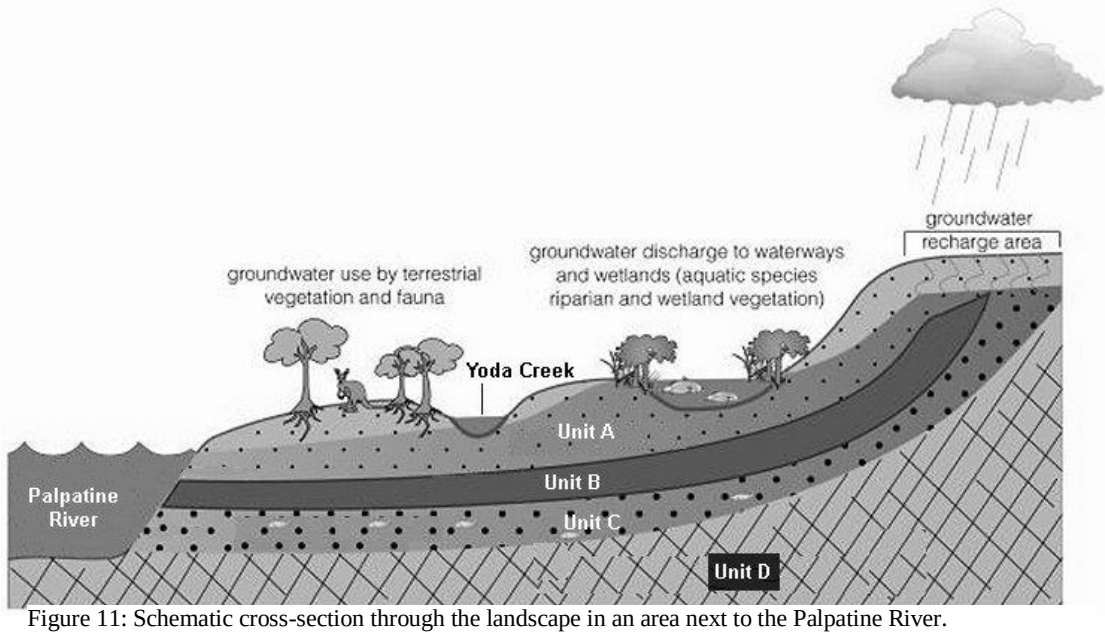



Figure 11: Schematic cross-section through the landscape in an area next to the Palpatine River.
Modified from an image sourced via: http://www.wetrocks.com.au/

27. For their field trip report the students must correctly identify the nature of Units A, B and C with respect to the groundwater environment. Which student or pair of students will get the best mark for this part of their report?

    a. Ariels thinks Unit A is a confined aquifer, Unit B is an unconfined aquifer and Unit C is an impermeable layer called an aquitard
    b. Roxanne and Phil think Unit A is an unconfined aquifer, Unit B is a confined aquifer and Unit C is an impermeable layer called an aquitard
    c. Daytona and Vincent think both unit A and C are confined aquifers and Unit B is an impermeable layer called an aquitard
    d. Gabi thinks Unit A is an unconfined aquifer, Unit C is an confined aquifer and Unit B is an impermeable layer called an aquitard
    e. Sandra and Gayle think Units A and C are both unconfined aquifers and Unit B is an impermeable layer called an aquitard

28. All students agree Unit A is an aquifer. The local land manager has a bore and pump on the hillside, adjacent to the wetland (located directly above the Unit A label in figure 11). The bore hole ends about 2 metres above the base of Unit A, well above the level of the river and about level with the bottom of Yoda creek. In their report the students note the bore is a cause for concern because excessive rapid pumping could harm the environment. Which of the five possible harms they nominate is the one most likely to actually happen?

    a. Rapid pumping will suck Unit B muds up and pollute the irrigated environment with bad smelling iron sulphide rich mud
    b. Pumping that exceeds the recharge rate will cause salinity issues in the Palpatine River by pulling fresh water from the river into the aquifer
    c. Pumping that exceeds the recharge rate will lower the top of the aquifer to be level with the bottom of Yoda Creek, causing the swamp to dry out
    d. Pumping will change the recharge point on the hill top, causing the aquifer to fail completely
    e. Rapid pumping of water for irrigation will create a microclimate that changes the local rainfall pattern, causing rain to fall further inland from the recharge point

29. Cyanobacteria evolved approximately 3.5 billion years ago and are credited with radically altering the Earth's atmosphere. What process did they evolve to do this and what chemical did they produce in this process?

    a. Chemosynthesis to produce methane
    b. Photosynthesis to produce ozone
    c. Chemosynthesis to produce ozone
    d. Cytokinesis to produce oxygen
    e. Photosynthesis to produce oxygen

30. 2015 has been declared the International Year of Soils by the 68th UN General Assembly. Soils are important for agriculture and the students have taken a day off field mapping to visit the caves in the upstream reaches of the Palpatine River valley and to sample the products on offer at the local farmers market. One stall holder credits his success to the local "Terra rossa" soil. This is a red soil that forms on limestone, a rock made up mostly of calcium carbonate. Ever mindful of the geological connections, the students are curious to know why the limestone, which erodes through dissolution of the calcium carbonate in naturally acidic rainwater, would form any soil at all. The limestone at this location is 98.5% calcium carbonate with the remainder clays and insoluble mineral material. What is the best explanation for most of the red soils that form on limestone?

a. Limestone totally dissolves but windblown red dust from central Australia that has fallen on the area in modern times is concentrated into a soil
b. Limestone totally dissolves but the small amounts of iron-bearing clay and other insoluble iron-rich minerals in the limestone accumulate as a soil which turns red as the iron released from the clays is oxidised to "rust"
c. Limestone creates chemical conditions that favour plants with red sap. As the plants decompose the soil they form is also red
d. Limestone totally dissolves but the solute has a red colour that stains everything
e. The soils on limestone form from the rocks that were above the limestone, not from the limestone at all

# SECTION B: WRITTEN ANSWER QUESTIONS
# ANSWER IN THE SPACES PROVIDED

***Use the following information and figure 12 to assist in answering questions 31, 32 and 33.***

As you know from Questions 6, 7 and 8 the Kirk Point outcrop at Cape Enterprise consists entirely of interbedded sandstones and mudstones. Earth and Environmental Science teacher, Mr Smith, has told the class that the sandstones are called Greywackes because the matrix has a lot of mud in it and one of the reasons for this is because they are turbidites. Turbidites are sand bodies deposited by submarine mass-flow events that rush down the continental slope as a turbulent packet of sand and mud. The packets are deposited as layers of muddy sand on the deep sea floor in a geological instant. Each layer of sandstone is referred to as a bed. Careful observations by students Gabi and Daytona reveal each sandstone bed has a sharp, well defined base, generally fines upwards from coarse or medium grained into very fine grained sandstone and then grades into the overlying mudstone over a very short vertical distance. They have logged 21 distinct sandstone beds in the 3 metres of outcrop in section A-B shown in Figure 12. This section was chosen for measurement because it is relatively undeformed and, accounting for the orientation of the folds, represents a true vertical thickness in the sequence. The students have also calculated sandstones represent 90% of the vertical accumulation in this section.

Ariel and Gayle have undertaken a literature search and discovered that there are rare coral fossils found in these turbidites that indicate the sediments are Middle Devonian in age. They have also discovered a major tectonic event, the Tabberabberan Orogeny, was responsible for the folding and faulting in this region. One paper also notes that regionally the turbidite sequence is unconformably overlain by shallow marine Pliocene sediments with windblown Pleistocene sands conformably overlying the Pliocene sediments and Holocene windblown sands conformably overlying the Pleistocene sands.

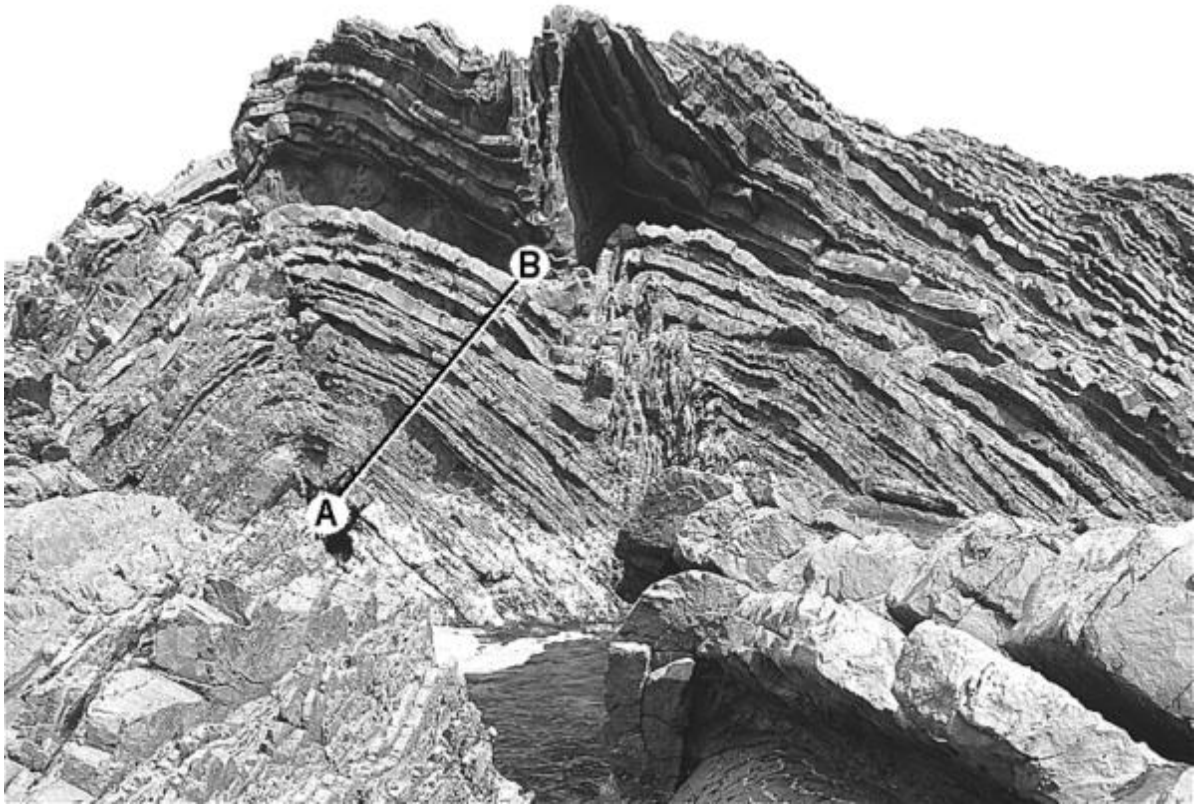



Figure 12: Logged section A-B in the outcrop of interbedded sandstones and mudstones at Kirk Point, Cape Enterprise. Note: The sandstone unit at the top of the logged section is 20cm thick and section A-B is 3 metres. Image courtesy of Roxanne Stone.

31. In their field trip report the students must discuss the time interval represented in the outcrop as exemplified by the section A-B in figure 12. Given what you know about this outcrop and the rock types present, what can you say about the time interval represented in section A-B? **(5 Marks)**

- Each sandstone interval can be regarded as instantaneous because of the way turbidites are deposited.
- 90% of the section is thus more or less instantaneous, given they are turbidites.
- However, each mudstone interval slowly accumulates from mud settling out of the water column on to the deep ocean floor at an unknown rate.
- For 10% - all the mudstones - we don't know the settling rate so it is impossible to estimate the time interval represented by them.
- Therefore impossible to say anything about the time represented by A-B even though effectively only ~300mm of mudstone is involved.

32. The students must also discuss the geological history represented in the Kirk Point outcrop as part of their report. Using the blank geological column (figure 13) schematically draw in the rock units from oldest to youngest and write a note about each geological event next to the column given what you know about this outcrop, the rock types present and the information revealed in literature searches. **(10 Marks)**

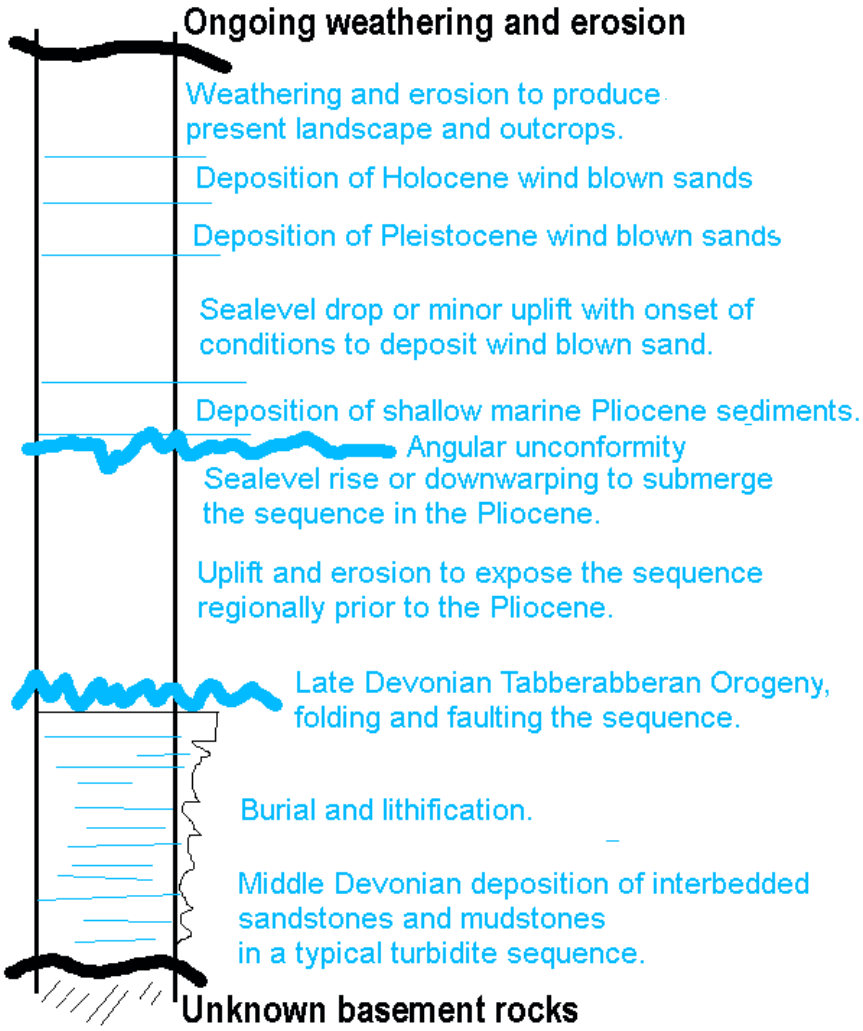



Figure 13: Blank geological column to be completed in answer to Question 32.

33. The team of students are confident the sedimentary section at Cape Enterprise has not be turned upside down by the folding event because each sandstone bed has a sharp, well defined base, generally fines upwards from coarse or medium grained into very fine grained sandstone and then grades into the overlying mudstone over a very short vertical distance. This asymmetry in the sedimentary structures clearly defines the bottom and the top of the turbidite beds allowing "wayupness" – also correctly known as younging - to be determined. Give two examples of other sedimentary structures that could be used to determine younging in sedimentary rocks other than turbidites. Be sure you sketch and label each structure and explain why each structure would be useful in this way.
**(8 Marks)**

- Valid structures have a clear asymmetry
- Structure's labels need to be clear and correct
- Text must explain each structures asymmetry
  ➔ drawing shows structure in cross-section inside a bed

- Possible examples: Scour & fill, load casts, crossbedding, desiccation crack infills, etc

***Use the following information and figure 14 to assist in answering questions 34 to 38.***

In 1946 a technique known as astronomical interferometry was developed which typically consists of an array of dishes or antennas which are widely separated and connected by some form of transmission line, typically coaxial cable, waveguide or optical fibre. The advantage of interferometry is that not only does it increase the total signal collected from an astronomical radio source, such as a quasar, but more importantly it vastly increases the resolution of the signal.

Since 1970, advances in the stability of electronic oscillators also now permit interferometry to be carried out by independent recording of the signals at the various antennas, without the need for connection by a transmission line. Instead, the signals from the arrays are later correlated at a central facility. This is known as Very Long Baseline Interferometry (VLBI). In VLBI a signal from an astronomical radio source, such as a quasar, is collected at multiple radio telescopes on Earth. The distance between the radio telescopes is then calculated using the time difference between the arrivals of the radio signal at different telescopes. This distance, which is very accurately calculated using this technique, is referred to as the baseline.

One such baseline has been established between a radio telescope in Hobart, Australia, and the TIGO radio telescope in Concepción, Chile. Figure 14 documents the variance on the 9, 208,110 metre baseline between 2002 and 2013.

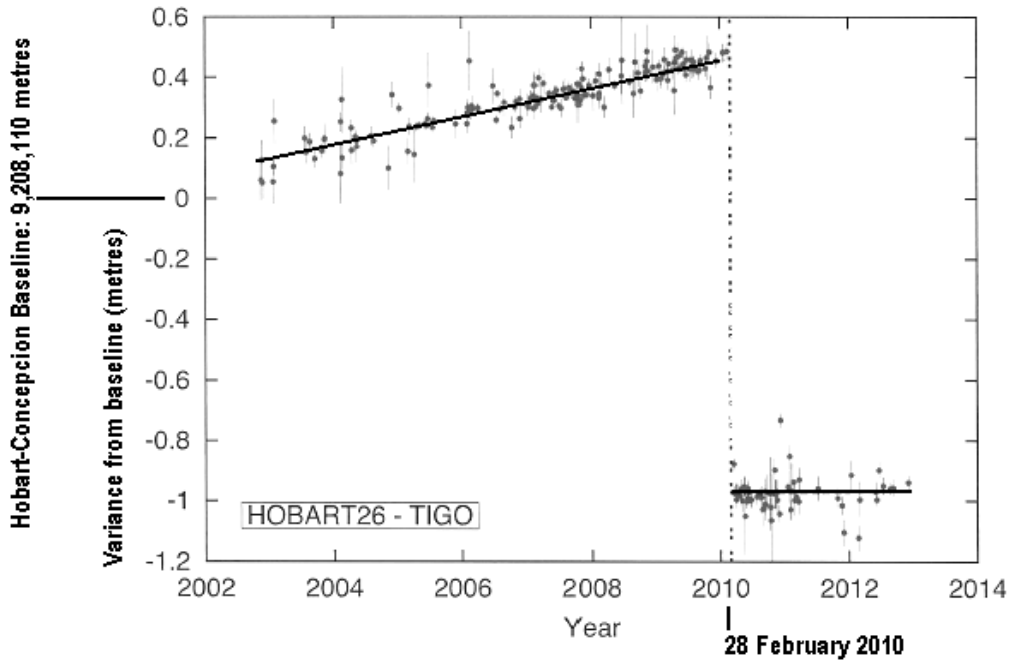



Figure 14: Variance in the Hobart-Concepción baseline.
Data and graph courtesy of Dr Shabala, University of Tasmania

***Questions 34 to 38 below relate to the lines of best fit on the figure 14 graph.***

34. Assuming the baseline was exactly 9,208,110.1 metres at the beginning of 2003 what was the baseline length on the 27 February 2010?

    9,208,110.43 metres_but_accept .42-.45 given measurement uncertainty in graph of this size **(1 Mark)**

What is the average annual rate of baseline change between 2003 and 27 February 2010? Explain your reasoning and show your calculations. Express your answer using appropriate units. **(3 Marks)**

- From start 2003 to start 2009 the baseline lengthens by ~300mm.
- Slope of best-fit graph is constant so the rate of change is constant across this time.
- ~300mm/6 years equates to an average rate of change of ~50mm/year.

35. What is the average annual rate of baseline change between 28 February 2010 and 28 February 2013? Explain your reasoning and comment on the accuracy of the result for this calculation. Show any calculations used in producing your answer. Express your answer using appropriate units. **(4 Marks)**

- From 28/2/ 2010 to 28/2/2013 the baseline lengthens by no more than 20mm
- Slope of best-fit graph is constant so the rate of change is constant across this time and the line of best fit suggests ~20mm/3 years which equates to an average rate of change of ~3.3 mm/year but given the size of the graph many will see the line as horizontal
- HOWEVER, the data has a big spread so while the line of best fit apparently gives ~20mm/3 years, which equates to an average rate of change of ~3.3 mm/year, given the nature of the data spread the accuracy of the result is not likely to be very good and an answer of ZERO is likely to be a better solution until better data emerges

36. What is the best terrestrial (non-astronomical) explanation for the variance in the baseline from 2003 to 27 February 2010? Use labelled diagrams and schematic cross-sections that feature all relevant geological structures to illustrate your answer, ensuring your answer not only suggests the reason for the change but explains the geological processes behind it. **(7 Marks)**

Should know from previous questions ➔Baseline is getting longer at a rate of ~50mm/year.

- Best explanation would be Plate Tectonic movements that slowly but consistently puts more distance between Hobart and Concepción.

- The best source of this movement would be the sea-floor spreading between the Pacific Plate and the Nazca/Antarctica Plates. Note: On map it shows no other spreading centres that could do the job.

Cross-section diagram should show

a) Pacific-Nazca spreading centre and spreading directions
b) Mantle convection and other notations to explain plate motion
c) Nazca-Sth Am subduction arrangement and movement directions
d) Australian-Pacific subduction near NZ and movement directions

37. What is the best terrestrial (non-astronomical) explanation for the variance in the baseline from 27 February 2010 to 28 February 2010? Use labelled diagrams that feature all relevant geological structures to illustrate your answer, ensuring your answer not only suggests the reason for the change but explains the geological processes behind it. **(8 Marks)**.

- Best explanation would be sudden Plate Tectonic movements reduced the distance between Hobart and Concepción.

- The best explanation for this movement would be the sudden subduction [thrust fault] of the Nazca Plate under the South American Plate during a major earthquake.
- The sudden movement would be because the "stuck" subduction zone movement became unstuck and allowed for the rapid subduction to occur during the concomitant earthquake resulting in an effecting shortening of the baseline. However, in the absence of other data this could also be explained by a similar event on the Australian-Pacific subduction zone near NZ so both scenarios should be acceptable as both structures are crossed by the baseline.

Cross-section diagram should show

a) Nazca – South American subduction zone and plate movement directions
b) Mantle convection and other notations to explain plate motion
c) Nazca-Sth Am subduction arrangement before and after the earthquake showing an effective shortening of the baseline
d) Australian-Pacific subduction near NZ and movement directions

38. The planet Kepler-186f has a radius 1.11 times the radius of the Earth and acceleration due to gravity at its surface of 0.950g (where g is the acceleration due to gravity at the Earth's surface). Given this information and assuming a spherical planet, what is the mass of *Kepler-186f*, $M_P$, in terms of the mass of the Earth, $M_E$? Show all your calculations. (**3 Marks**)

See below for a worked solution but note in this question: $R_E$ is 1.11 (not 1.10) and $g_K$ is 0.950 so in the worked example 1.1 should be replaced by 1.11 and the answer will come out to 1.170495 which to 3 sig figs is 1.17 $M_E$

We are given:

$R_{K\text{-}186f} = 1.1R_E$

$g_{K\text{-}186f} = 0.95g$

We want to find

$M_{K\text{-}186f} = ?M_E$

Solution:

$$F = \frac{GMm}{R^2} = ma = mg \Rightarrow g = \frac{GM}{R^2} \text{ or } M = \frac{gR^2}{G} \text{ so making a ratio,}$$

$$\frac{M_{K-186f}}{M_E} = \left(\frac{g_{K-186f}}{g}\right)\left(\frac{R_{K-186f}}{R_E}\right)^2 \Rightarrow M_{K-186f} = \left(\frac{g_{K-186f}}{g}\right)\left(\frac{R_{K-186f}}{R_E}\right)^2 M_E$$

and on substitution gives $M_{K-186f} = \left(\frac{0.95g}{g}\right)\left(\frac{1.1R_E}{R_E}\right)^2 M_E$ and so

$$M_{K-186f} = (0.95)(1.1)^2 M_E = 1.15\,M_E$$

***Use the information below and figure 15a to answer question 40.***

Hamill Point marks the eastern end of Harrison Beach. This beach also hosts the mouth of the Palpatine River behind which is found an extensive estuary and wetlands complex, including Ford's Swamp and Federation Lake. Students Ariel Windlass and Gayle Snowdon have been studying the satellite imagery of the area and have identified an ancient meander of the Palpatine River in the area bordered by the Palpatine River, the Tarkin River and Federation Lake. Field mapping reveals the ancient meander is now a slightly swampy depression in the relatively flat landscape. The entire flood plain is less than 2 metres above sea level and the rivers and lakes are tidal across the map area.


Figure 15a: Coastal wetlands of the Palpatine and Tarkin Rivers.
Modified image; original courtesy of Google

39. Using a brightly coloured pen or pencil highlight the ancient meander identified by Ariel and Gayle on figure 15b below to indicate the previous path of the Palpatine River. (**1 Mark**)

40. Ariel and Gayle also think the modern path of the Tarkin River, including where it comes out of Federation Lake and where it enters the Palpatine River, post-dates the ancient meander. They think there is visible evidence in the satellite image for a "palaeo-Tarkin River" that was a much shorter waterway between different points on Federation Lake and the Palpatine River. Using a brightly coloured pen or pencil highlight the "palaeo-Tarkin River" identified by Ariel and Gayle on figure 15b below. (**1 Mark**)


Figure 15b: Use this figure to answer questions 40 and 41

PINK ➔ ancient meander

GREEN ➔ probable palaeo-Tarkin

41. Starting at a point in time when the Palpatine River followed a course that flowed along a channel prior to the development of the ancient meander, describe the processes that lead to the present course of the modern Palpatine River. Your explanations should include labelled diagrams and cross-sections that show how the ancient meander formed, how it came to be as it is today and what might happen to it in the future. (**8 Marks**)

Meanders develop on low angle flood plains by slowly moving rivers.

Diagrams should show:

- Ancient river prior to meander developing
- Ancient river meander loop growing laterally – bank erosion on outside edge
- Ancient river meander loop growing laterally – deposition on inside edge
- Ancient river meander gets to a pinch-off point
- Ancient river meander gets cut off in flood or similar event
- Meander bypassed, starts to fill water and with flood sediments (billabong)
- Meander fills with organics and mud to the point where it is a swamp
- Ancient meander disappears into dry landscape once swamp is filled / or new meander develops and obliterates the structure of the old meander fill

42. Sometimes, mainly over summer, the Palpatine River mouth is closed to the sea by sand migrating along Harrison Beach and the water level slowly rises in the estuary and associated upstream parts of the Palpatine and Tarkin rivers. When this happens, the river water that would normally flow out to sea backs up and Federation Lake and Ford's Swamp deepen. Farmland and forests surrounding Federation Lake and Ford's Swamp are located just above normal water level and begin to flood as soon as the water level rises. In Federation Lake and Ford's Swamp the very still waters eventually become anoxic as the crops and animal manure of the drowned farm land begin to decompose. Fish move out of the lake and swim down the Tarkin River to the estuary where wave action keeps the water oxygenated. Farmers, whose land is drowned by the rising lake, and people who like to fish in Federation Lake are often tempted to forcibly open the river mouth by digging a trench through the sand barrier to let the water rapidly drain out to sea and lower the lake to its normal level.

    In the past, use of this management technique in summer has led to massive estuarine fish kills in the hours and days immediately after the draining started. Why would this happen? (**4 Marks**)

- The low oxygen water develops in the flooded swamp, pasture and forest area due to rapid decomposition of the dryland vegetation and animal manure under floodwater
- Rapid drop in the estuary water level at opening time allows the low oxygen water upstream to rapidly move into the estuary
- Oxygenated estuary surface waters drain out to sea after opening time
- "Flooding" of the estuary with low oxygen water from upstream rapidly reduces the oxygen content of the estuary and "drowns" / suffocates the estuary fish, leading to a mass fish kill

***Use the information below and figure 16 to answer question 44.***

Roxanne Stone, Phil Light and Gabi Roe all applied for a special Martian Curiosity space academy event. In the application form they were asked to classify the Martian rock photographed by Curiosity and shown below in figure 16. They were also asked to explain how this type of rock could form on the surface of Mars. In figure 16 the solid rock in the right hand side of the image has been sheading material on to the Martian ground as it weathers. The left hand side of the image shows the debris shed by the rock as it has fallen apart.

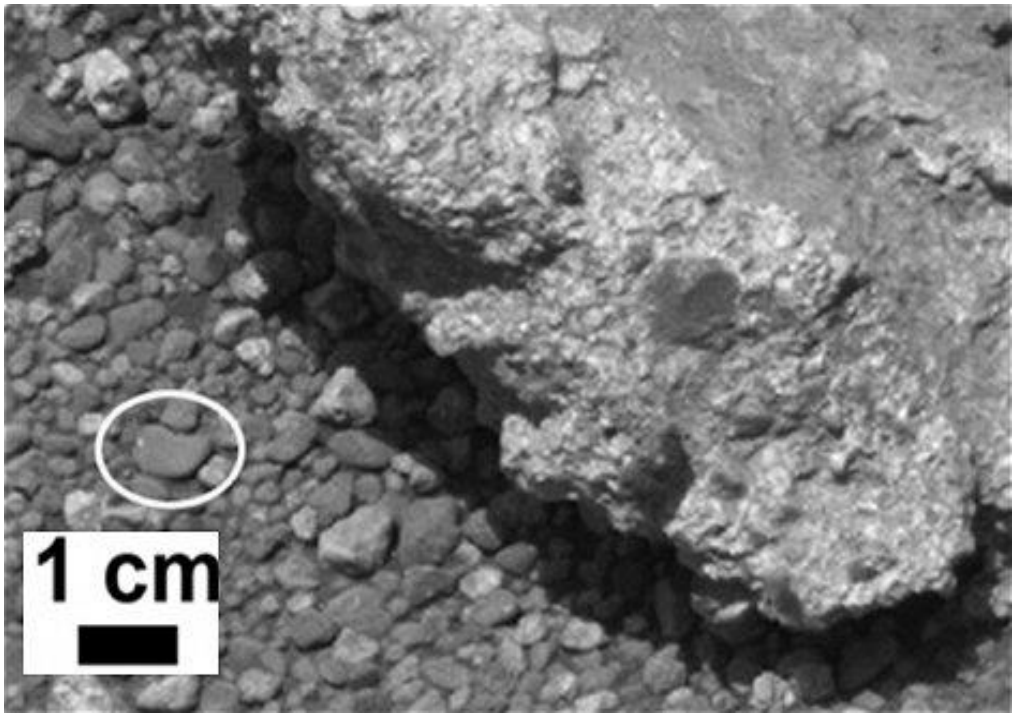



Figure 16: Rock and weathering products photographed by Curiosity on Mars
Image courtesy of NASA/JPL

Roxanne thought the rock was granite with the debris being quartz and feldspar crystals falling to the ground. Roxanne's application was not successful. However, both Phil and Gabi did receive and invitation to the event. Both their applications correctly classified the rock using the grains forming the debris as a guide (a typical grain is circled). They also correctly suggested how such a rock might have formed on the surface of Mars.

43. On the following page, write an explanation for Roxanne, noting:

    a. the correct classification of the rock,
    b. why you chose that classification and not granite
    c. how such a rock might form on the surface of Mars

(**10 Marks**)

***Write your answer to question 44 here:***

a)

- The rock would be classified as a sedimentary rock, a conglomerate
- The debris from the rock is almost entirely rounded clasts greater than 5mm in diameter
- Conglomerate is a rock made of rounded clasts greater than 2mm in diameter

b)

- Granite is a crystalline rock, the resultant grains/fragments would not be rounded

c)

- Rounded clasts imply lengthy transport distance/time
- Mars must have had flowing water in the form of rivers etc
- Erosion of rock into the flowing water produced clasts
- Clasts were transported and rounded in flowing water
- When water flow velocity dropped, larger clasts were deposited, forming a gravel bed
- Gravel sediments lithified to conglomerate over time [burial/compaction/cementation]

***Use the information below and figure 17a to answer questions 45 and 46.***

The surface waters of the major ocean basins circulate in gyres. A gyre is a circular ocean surface current formed by long term global wind patterns. Storm winds can disturb the ocean surface and cause the actual flow of ocean currents locally to deviate temporarily from long-term average patterns but the net result is the formation of distinct gyres that circulate in the each ocean basin. In figures 17a and 17b below, the five labelled ocean basin gyres are marked by white lines. The Indian Ocean South gyre, as marked on figures 17a and 17b, is west of and independent of the more coastal Leeuwin current that travels close to and along the Western Australian coast. The Antarctic Circumpolar current is also marked by white lines. The flow lines around Iceland have arrow heads indicating the direction of current flow in this region.

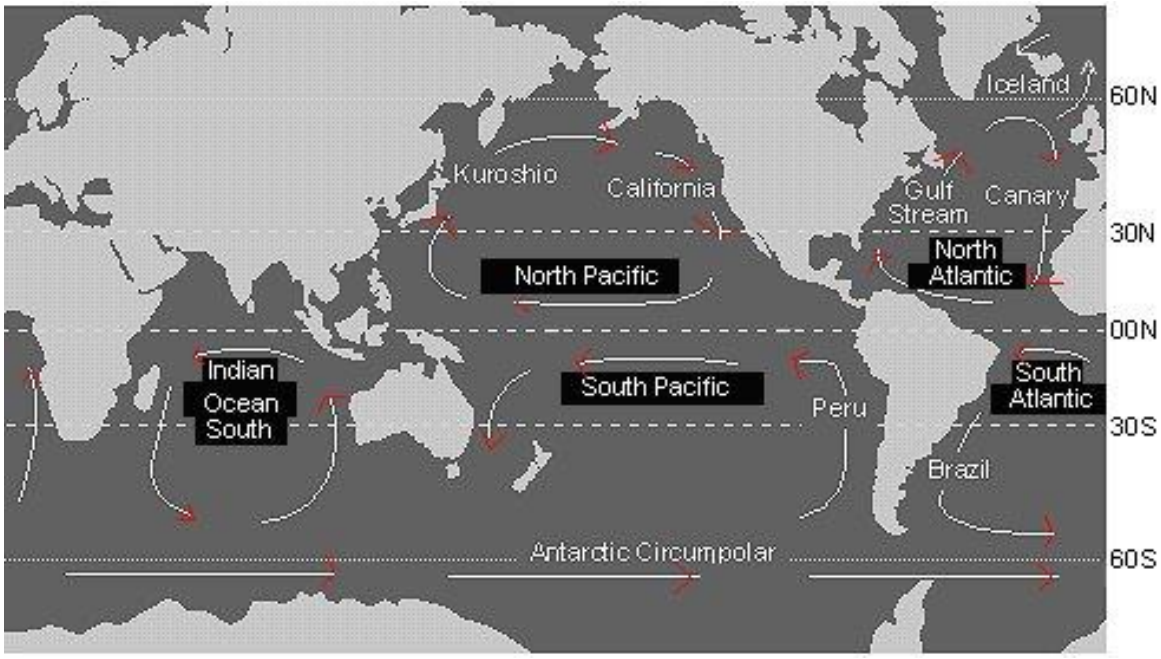



Figure 17a: The major ocean basins with ocean gyres marked.
Modified from an image sourced via Melbourne University - http://tinyurl.com/n6pavla

44. Using a coloured pen or pencil on figure 17a above, mark arrow heads on the white lines of the Antarctic Circumpolar current to indicate the direction of current flow. (½ **Mark**)
Red arrows on diagram lines below the 60S line.

45. Using a coloured pen or pencil on figure 17b below to mark arrow heads on the white lines for each of the 5 named ocean gyres so that it is clear whether the gyre in each basin rotates clockwise or counter-clockwise. (**2½ Marks**) Red arrows on diagram's 5 gyres

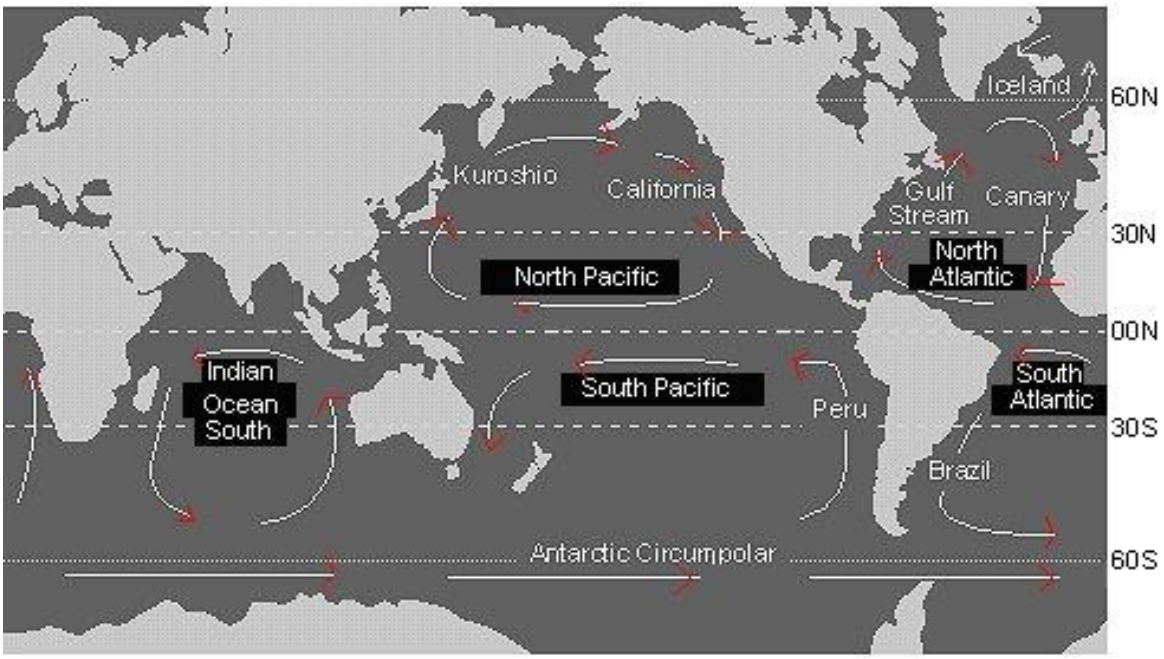



Figure 17b: The major ocean basins with ocean gyres marked.

Modified from an image sourced via Melbourne University - http://tinyurl.com/n6pavla

46. Using the North Pacific Basin as an example, explain what global factors produce the situation where wind movements create a circular gyre in the surface currents of the ocean basin. (**4 Marks**)

Gyres are caused by:

- Wind drags on the ocean surface, causing water to move in the direction the wind is blowing.
- The Earth's rotation deflects the direction of these wind-driven currents. This deflection is a part of the Coriolis effect.
- In the Northern Hemisphere – for the North Pacific Basin for example - ocean currents are deflected to the right, in a clockwise motion.
- The borders of the basins {landmasses} and {equator/ACC} confine the currents to the basin

***References to places and characters of popular fiction found in this document:***

The Tardis (a blue box that frequents London), Dr Who's transport through time and space.
Starship Enterprise, the main vessel in the Star Trek TV series.
Captain Kirk, captain of the Starship Enterprise.
Mr Smith, a character in the Matrix films.
House of Stark, (winter is coming) Games of Thrones TV series (Arya)
Rick Schumann, a character in the *Draco Tavern* series by Larry Niven
House of Greyjoy, Game of Thrones TV series (Balon & Yara)
Geography of Westeros, Game of Thrones TV series
Tony Stark, Ironman in the Marvel superhero comics
Star Wars characters and actors

***No marks for spotting them but hopefully you found a few reasons to smile!***

***Integrity of Competition***

*If there is evidence of collusion or other academic dishonesty, students will be disqualified. Markers' decisions are final.*