APPENDIX 2

CHECKPOINTS

ANSWERS TO QUICK QUIZZES

CHECKPOINT 1

Section 1: Rock Deformation

1. (a) Deformation is the change of shape that results from applied stress on a rock.

   (b) Strain has a similar meaning to deformation. It is the result of stress in a rock which leads to the change of shape or volume or both.

   (c) Elastic strain is the type of strain where the original shape and volume of a rock is re-established when the stress is removed.

   (d) Plastic strain is the type of strain where the new shape or volume of a rock is retained when the stress is removed.

   (e) Ductile behaviour means that the rock does not break easily and will continue to change shape even at high levels of stress. Rupture/fracture does not occur until extremely high levels of stress.

   Brittle behaviour means that the rock is easily broken. Rupture/fracture occurs at low levels of stress before little elastic or plastic strain has occurred.

   (f) The strict definition of stress is the amount of force applied to a unit area of rock. Geologists often use the word in a looser context referring to the forces being exerted on a particular piece of rock.

   (g) Compressive forces are squeezing or pushing forces.

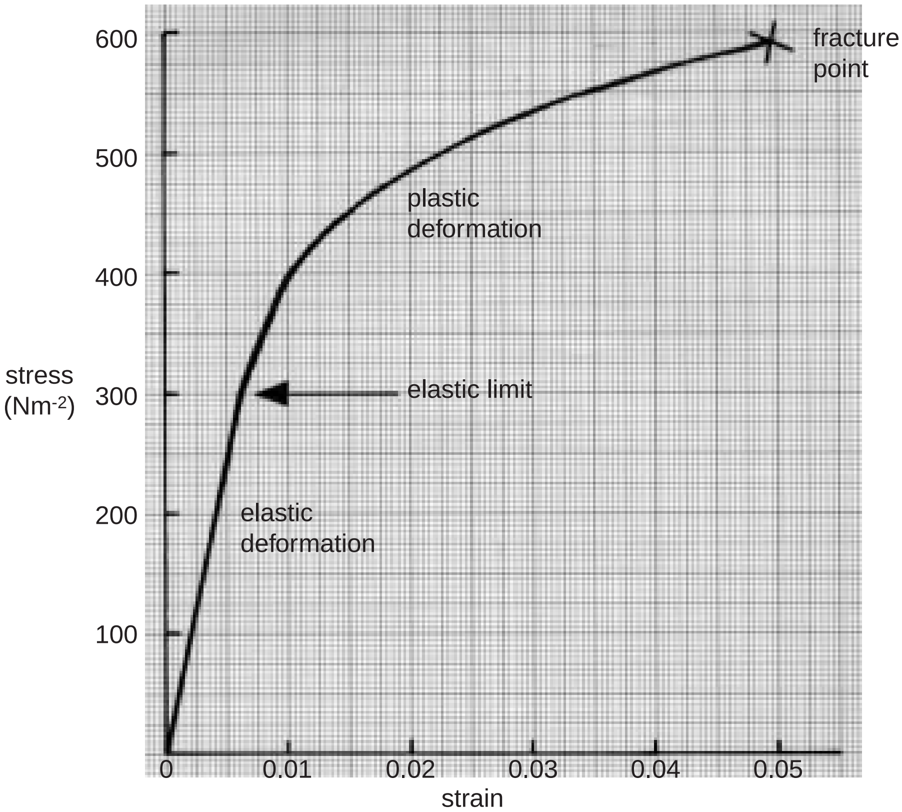
   Tensile forces are pulling or stretching forces.

   Shear forces cause one part of an object to slide past another.

   (h) Creep introduces the extra dimension of time into deformation. Long periods of low stress can cause plastic strain at levels below the elastic limit. This is creep taking place.

2. (a) Cold toffee: a short period of elastic strain followed by fracture. This is brittle behaviour.
   (b) A rubber: a long period of elastic strain.
   (c) Plasticine: a long period of plastic strain, it is very ductile.
   (d) Hot toffee: a long period of plastic strain, ductile behaviour.
   (e) Blackboard chalk: short period of elastic strain followed by fracture, brittle behaviour.
   (f) Chewing gum: long period of plastic strain, fracture only in extreme extension, plastic behaviour.

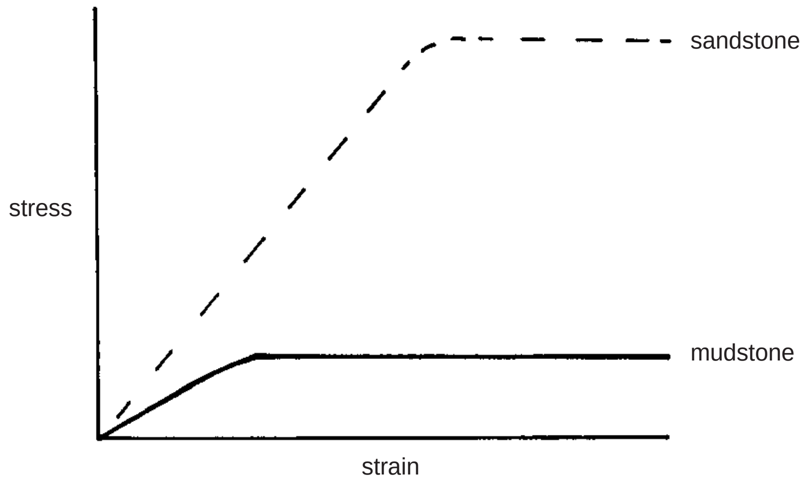
3. (a)



(c) marked on graph
(d) marked on graph.

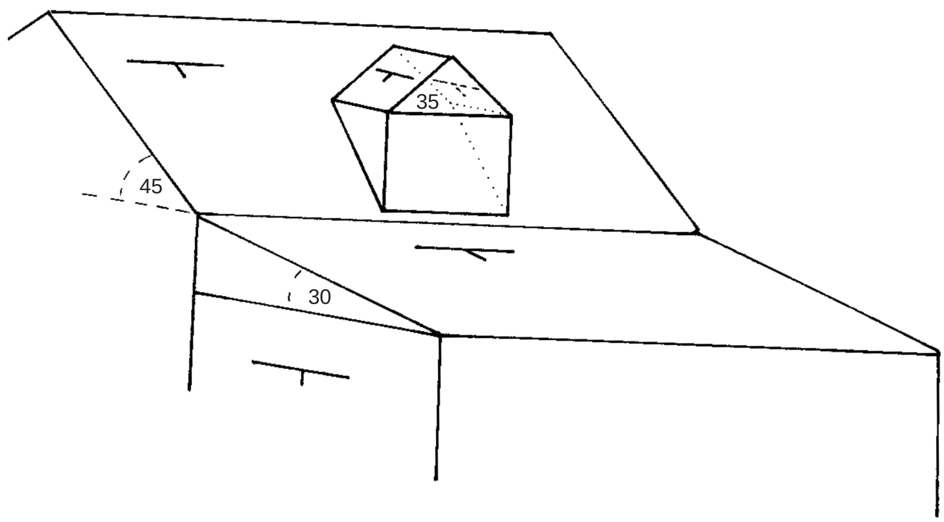
4. (i) Elastic behaviour is taking place between point A and point B.
(ii) The rock is near the surface of the Earth at point A.
(iii) Plastic behaviour is taking place between point B and point C.
(iv) The rock is broken at point C.
(v) The rock will recover its original shape if the stress is removed between point A and point B.

5.



Section 2: Thinking in Three Dimensions

1.

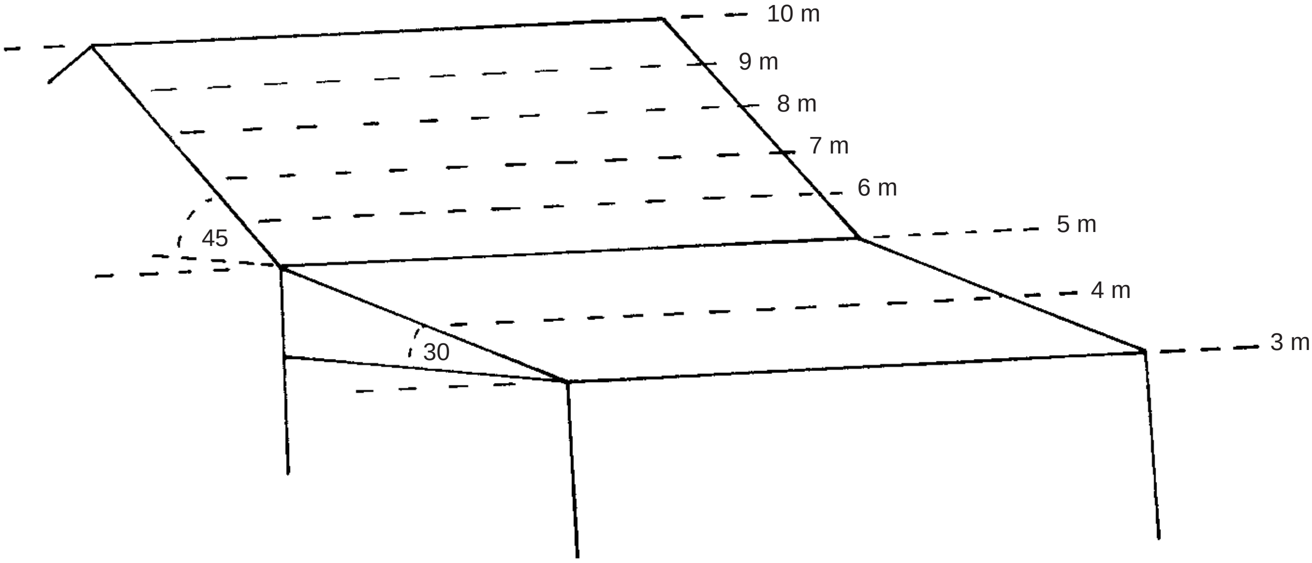


(i) strike 135° dip 30° NE
(ii) strike 135° dip 45° NE
(iii) strike 45° dip 35° SE
(iv) strike 45° dip 35° NW
(v) strike 45° dip 90°

CHECKPOINT 2

Section 3: Structure Contours

1. (a)



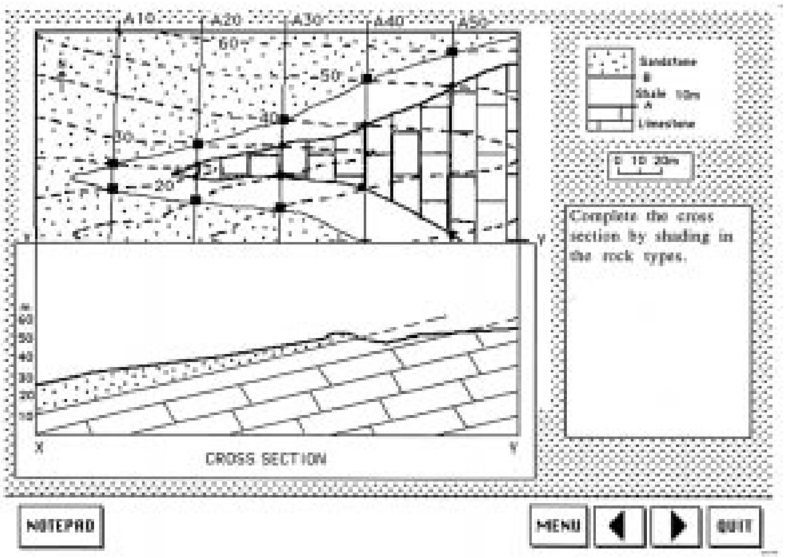
(b) The structure contours are closest together on the upper part of the roof as this is the steepest.

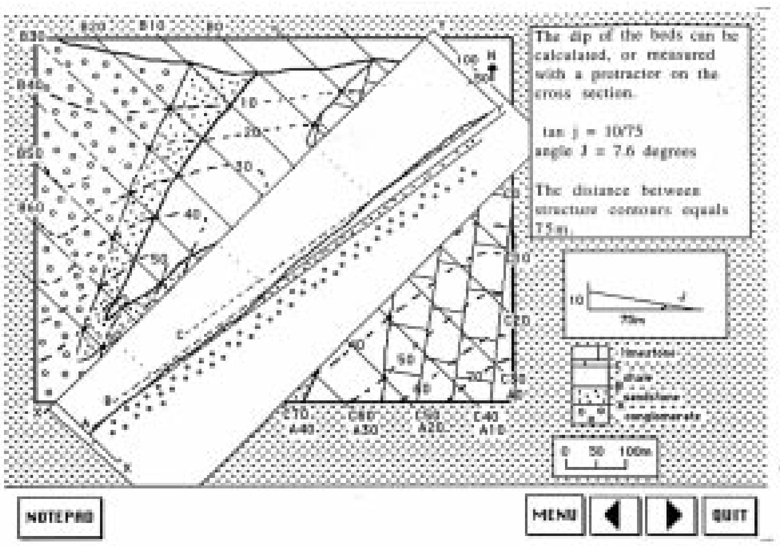
(c) $\tan 30^o = \frac{2}{x}$ so $x = \frac{2}{\tan 30^o}$ = 3.5 metres

$\tan 45^o = \frac{5}{y}$ so $y = \frac{5}{\tan 45^o}$ = 5 metres

2. Refer to the hypercard print out if you require to see each of the steps in the construction of the section in Worksheet 3.3. The final section is shown below.

Worksheet 3.3





Worksheet 3.4

3. Refer to the hypercard print out if you require to see each of the steps in the construction of the section in Worksheet 3.4. The final section is shown above.

CHECKPOINT 3

Section 4: Faults and Folds

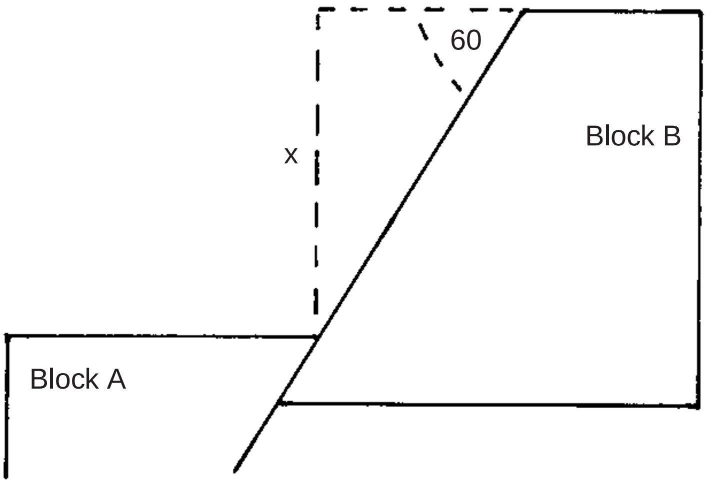
1. Check Intermediate 1 unit *Geology: The Study of the Earth* answers as appropriate.

2. Check Intermediate 2 unit: *Earth Physics and Earth Movements* answers as appropriate.

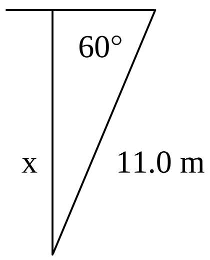
3. & 4. Notes to be taken.

5. (a) (iii) oblique slip
   (b) accept a or c
   (c) no steps in the grooves will be felt towards c. Steps will be felt towards a.
   (d) (i) normal
   (e) Block A

E1



$$\sin 60^o = \frac{x}{11.0}$$
$$x = 11.0 \times \sin 60^o$$
$$x = 9.5 \text{ metres}$$



CHECKPOINT 4

Section 5: Fold Types

1. Notes to be taken.

2. (i) Fold A is just about a parallel fold, if you were measuring the thickest layer. You will notice that if one layer is to maintain parallel geometry some of the other layers must flow to fill in the gaps and hence they do not have parallel geometry.
   (ii) Fold C is the one with a similar geometry. If you draw layers like this on a pack of cards and then slide them past each other you should be able to duplicate the overall shape.
   Folds B and D are not consistently parallel or series.
   (iii) No, not all beds can maintain parallel geometry over a large distance. Try bending a telephone directory into a number of tight folds, you will find some movement is taking place between the layers, this is the only way it can maintain parallel geometry.
   (iv) Yes

3. (a) syncline plunging southwest
   (b) anticline plunging northeast
   (c) anticline plunging southeast
   (d) syncline plunging northwest

Section 6: Igneous bodies and unconformity

E1 & E2 Your teacher or lecturer should check these for you.

CHECKPOINT 5

Section 7: Analysing Geological Maps

Worksheet 7.1

Normal type is used for the answer and italic is used for any additional teaching points

1a (i) Fault F1 has displaced the felsite dyke. *To be sure that you are dealing with a tear fault you must look for the displacement of a near vertical or vertical structure such as a dyke or the edge of a batholith or volcanic plug.*

1a (ii) Fault F1 does not displace the dolerite dyke and hence the dyke is younger than it.
Fault F2 however does displace the dolerite dyke (underneath the conglomerate) and hence is younger than the dyke. *The order of events must therefore be:*
(a) Fault F1
(b) Intrusion of dolerite dyke
(c) Fault F2

1a (iii) The microgranite is not displaced by fault F1 or fault F2 and hence is younger than both. The felsite is displaced by both faults F1 and F2 and hence is the oldest. The other dyke of dolerite is between the felsite and microgranite in age as it is displaced by F2 and not by F1.

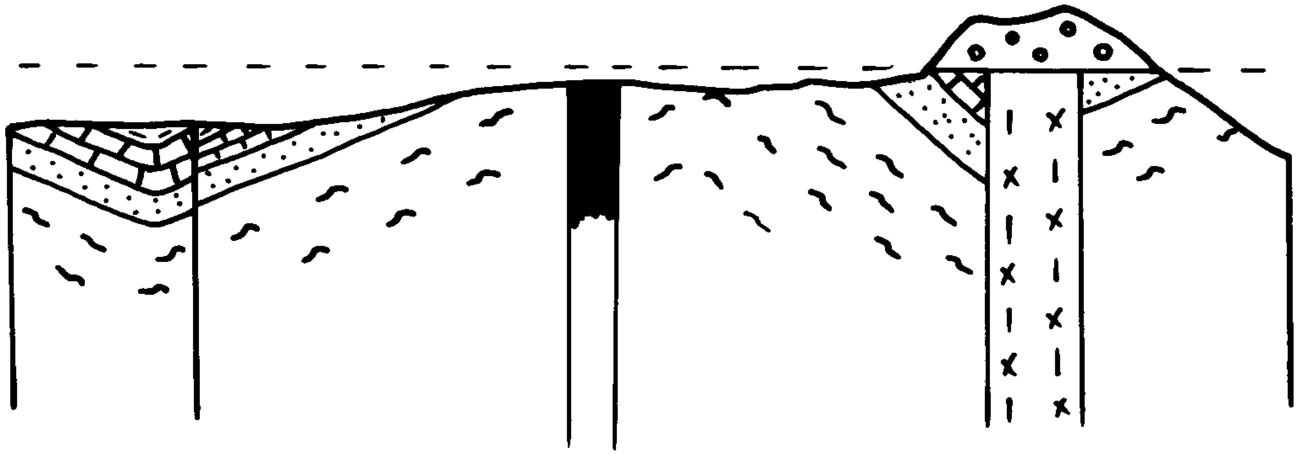
1a (iv) The amount of displacement on the felsite dyke is greater than on the dolerite dyke. This means that the felsite dyke must have been displaced a little before the dolerite was intruded and then they were both displaced.

1a (v) The granite intrudes into the conglomerate and hence is younger than it. The conglomerate is unconformable on the faults F1 and F2 which cut the diorite and therefore the conglomerate is younger than the diorite.

1b (i) 2

1b (ii) The oldest unconformity is between the schist and sandstone. The other unconformity is below the conglomerate.

1c The main features of the section are the unconformity, the two tear faults and the folding. The most difficult part to draw is the syncline cut by a tear fault under the unconformity. To draw it successfully you must use information just off the line of section and project it onto the line of section.



1d Starting with the oldest event :

(i) Depostion of original sedimentary rock [possibly mudstone or shale] followed by regional metamorphism to form a schist.

(ii) A period of uplift and erosion was followed by the depositon of a conformable sequence of sedimentary rocks. First sandstone, then limestone and finally mudstone were deposited.

(iii) Folding took place along an east-west axis producing both anticlines and synclines.

(iv) The felsite dyke and diorite were intruded. There is no evidence which came first.

(v) Tear faults F1 and F2 were produced displacing the folded rocks, the diorite and the felsite dyke.

(vi) The dolerite was intruded.

(vii) Further movement took place on fault F2.

(viii) The micrograniite was intruded.

(ix) A period of uplift and erosion was followed by the deposition of the conglomerate and rock Q.

(x) The granite was intruded.

(xi) A final period of uplift and erosion.

Section 8: Foliation and Lineation

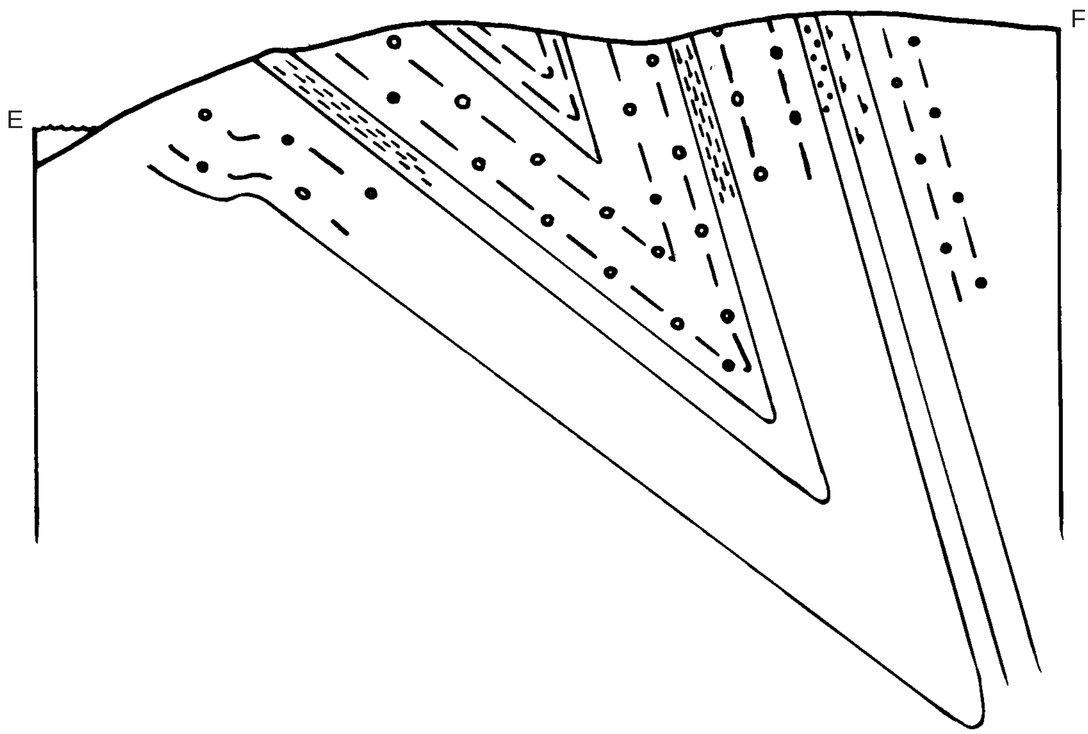
1. Notes to be taken

2. Worksheet 8.1

1a (i) At E the bedding is inverted as the coarser part of the graded beds is uppermost. (Oldest top right, youngest bottom left.)
At F the bedding is steeply dipping with the oldest on the left and the youngest on the right.

1a (ii) At E the cleavage is steeper than the bedding and at F the bedding is steeper than the cleavage.

1a (iii)



1a (iv) A tight overturned syncline.

1b Within the area shown the age of the rocks to the north of the sea loch cannot be definitely given. As gneiss exists it is likely they are the oldest and exist underneath the other rocks. It is however possible that a major tear fault passes down the sea loch and has moved them into this position.

Starting with the oldest event :

(i) Formation of original rocks and regional metamorphism to gneiss & schist
(ii) Intrusion of dolerite dykes with a NNE-SSW trend.
(iii) Uplift and erosion.
(iv) Deposition of shales, mudstones and grits, probably in a deep sea.
(v) Tight overturned folding to produce the major syncline and foliation.
(vi) Uplift and erosion.
(vii) Depostion of conglomerate, siltstone, sandstones and shales followed by Rock Type C (which is tuff), more sandstone and shales, limestone, coal, more limestone, marl, sandstone and breccia.
(viii) Regional tilting and faulting.
(ix) Intrusion of gabbro. The relative ages of faulting, tilting and gabbro intrusion are less certain as no direct relationship exists between the intrusion and the faults.
(x) Final uplift and erosion

Section 9: Joints

1. Notes to be taken

2. (i) A - There are three directions of strike for steeply dipping joints. The gently dipping joints all dip southwest.
B - The jointing is columnar jointing caused by contraction in basalt after it has crystallised. The three directions of strike suggest hexagonal columns. The gently dipping joints formed horizontally in the igneous body. It appears that the igneous body now dips gently southwest.

(ii) A - There are two directions of steeply dipping joints which would produce diamond shaped blocks of sandstone.
B - From the angle of intersection of the two sets of joints they could have been formed by stress applied during deformation (folding)

(iii) A - On gently sloping ground the joints dip gently to the north. On the sides of the valley the joints dip steeply toward the valley bottom.
B - These are sheet joints in granite that are formed by erosion of overlying rock removing downward pressure. The valley has probably been glaciated from its shape and the joints on the valley walls may have formed in response to the erosion by ice removing a large mass of rock from the valley.

CHECKPOINT 6

Section 10: More on Structure Contours

1. See the print out from the hypercard stack for Worksheet 10.1.

2. See the print out from the hypercard stack for Worksheet 10.2.

CHECKPOINT 7

Section 11: Continental Drift

1. The present day coastlines do not represent the lines along which the continents split. Since the continents split apart their coastlines have become modified by erosion and deposition. The 1000 m submarine contour is close to being the edge of the continental crust and is used to reconstruct major continents from the past.

2. Rocks carried in the base of the ice scratch grooves in the underlying bedrock. The direction of the grooves gives the direction of movement of the ice in two possible directions. If steps can be located in the grooves then the only possible direction of movement of the ice can be established.

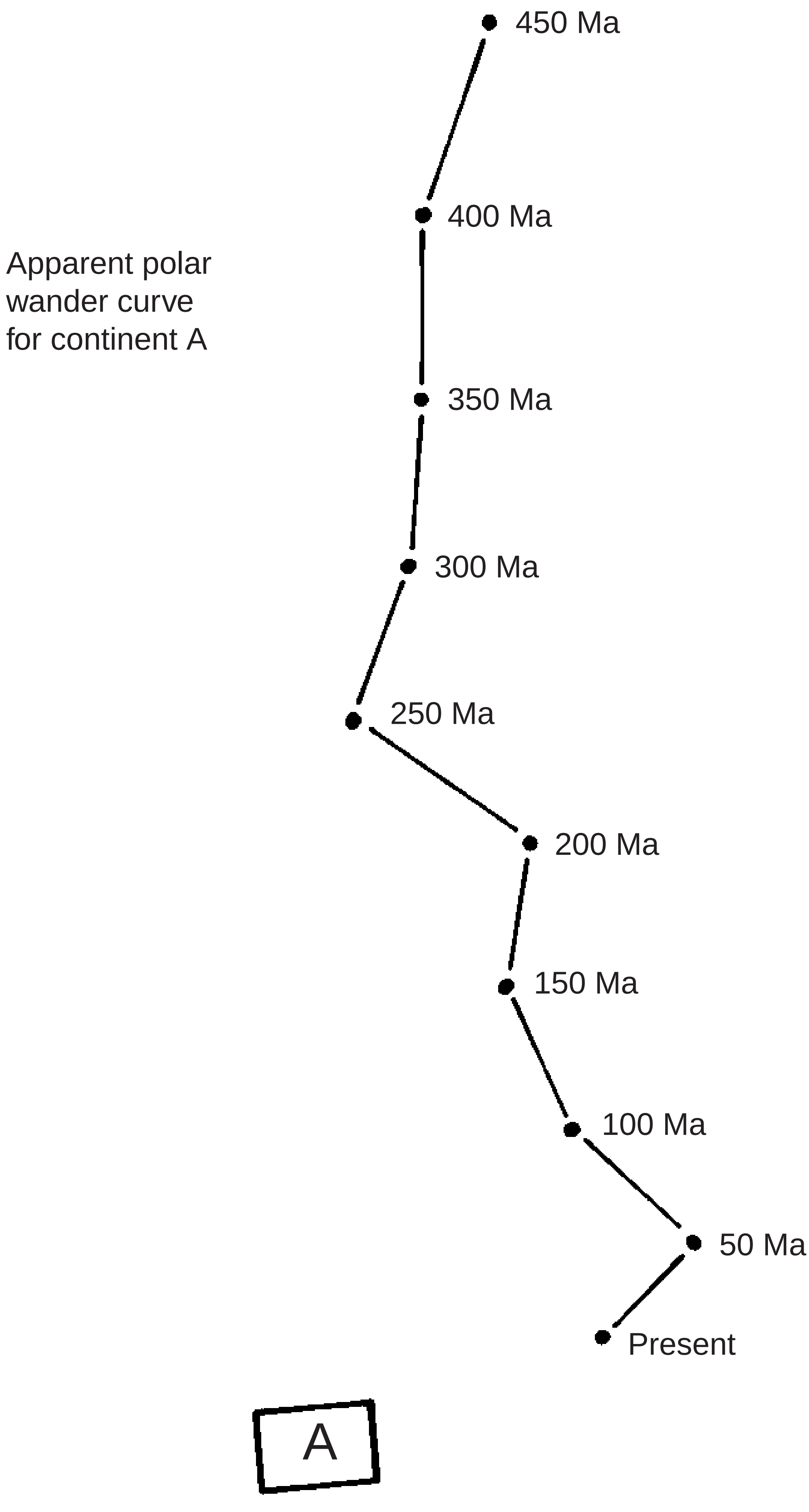
Section 12: The Earth's Magnetic Field

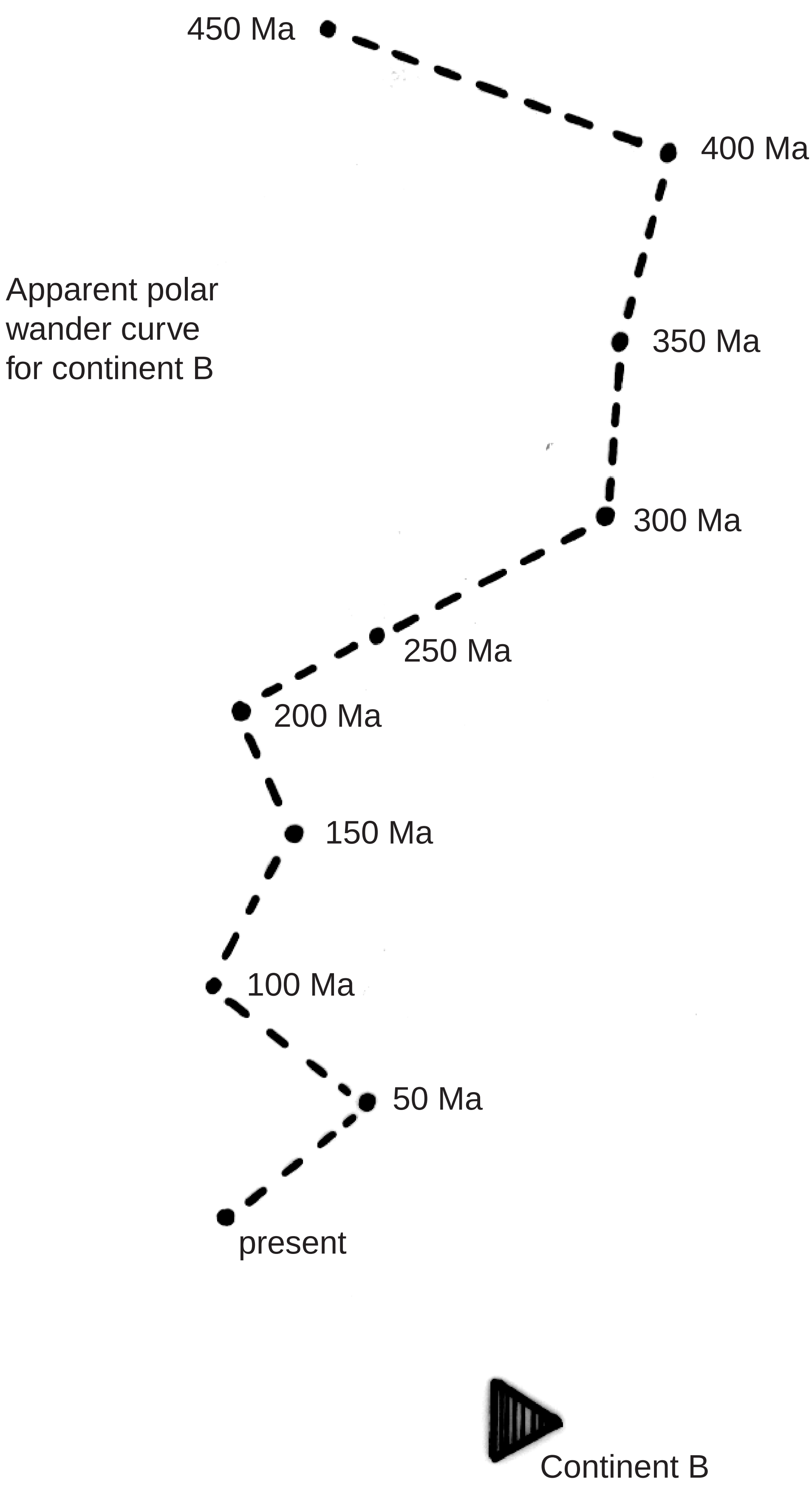
1. A permanent magnetic field cannot exist at temperatures as high as those which exist in the core of the Earth.

2. Similarities – Both are mainly dipole fields.
   The shapes are similar.
   Differences – The Earth's magnetic field continually changes its shape, position and strength whereas a bar magnet has a static field.

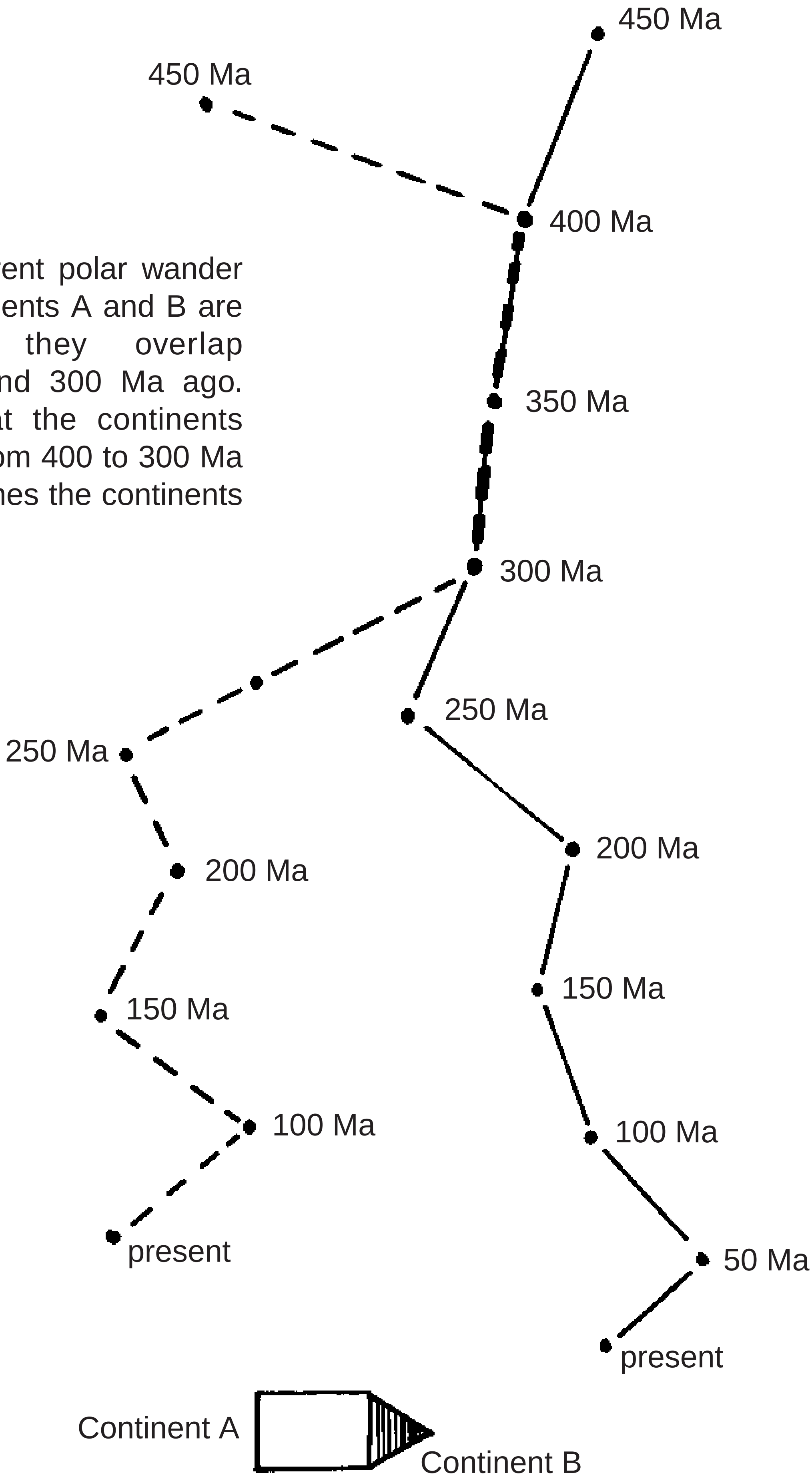
3. Notes to be taken.

4. The polar wandering curves should match up between 400 Ma and 300 Ma when they are overlaid. The polar wandering curve for continent A, the polar wandering curve B and the two together are shown on the next three pages.


450 Ma
400 Ma
Apparent polar
wander curve
for continent A
350 Ma
300 Ma
250 Ma
200 Ma
150 Ma
100 Ma
50 Ma
Present
A


450 Ma
400 Ma
Apparent polar
wander curve
for continent B
350 Ma
300 Ma
250 Ma
200 Ma
150 Ma
100 Ma
50 Ma
present
Continent B

When the apparent polar wander curves for continents A and B are superimposed they overlap between 400 and 300 Ma ago. This shows that the continents were together from 400 to 300 Ma ago. At other times the continents were apart.



E1 As it was part of continent A up until 300 Ma and then part of continent B it will have continent A’s polar wandering curve up until 300 Ma and then continent B’s afterwards.

E2 If drawn accurately it should match with the prediction in E1.

5. Continents A and B joined at 100 Ma and remain joined today.
   Continents B and C joined 150 Ma and then split again at 10 Ma.

6. Notes to be taken

E3 Notes to be taken

E4 (a) Vertically downward
   (b) Horizontally toward the North Pole.
   (c) Vertically upward
   (d) Toward the North Pole but downward into the Earth at an angle of 70° from the horizontal.

E5 (i) The position of the dipole field has drifted west.
   (ii) The non-dipole has also drifted west but faster than the dipole.
   (iii) The strength changes, currently decreasing at 5% per century.
   (iv) Magnetic reversal.

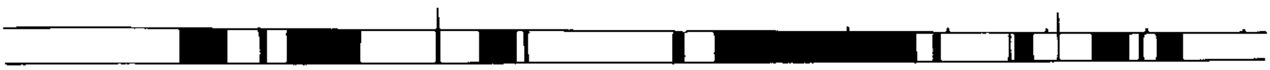
Section 13: Sea Floor Spreading

2. (a) Spreading rate = $\frac{\text{Distance}}{\text{Time}}$ = 2.8 cm/year (approx)

(b) Within the accuracy of measurement, it appears that the spreading rate is the same either side of the ridge.

(c) During the 4 million years recorded the spreading rate has remained unchanged.

E1 The left side should have the same reversal pattern but stretched over twice the distance.



E2 0-2 Ma should be compressed to half the distance and 2-4 Ma stretched to twice the distance.

CHECKPOINT 8

Section 14: Seismology

1. (a) $30 \times 30 \times 30 = 27000$ times more energy.

   (b) P-wave velocity = $\frac{\text{distance}}{\text{time}} = \frac{400}{66} = 6.1$ km/s

   S-wave velocity = $\frac{400}{130} = 3.1$ km/s

   (c) As both P and S- waves go deeper into the Earth they speed up and hence the lines are curves.

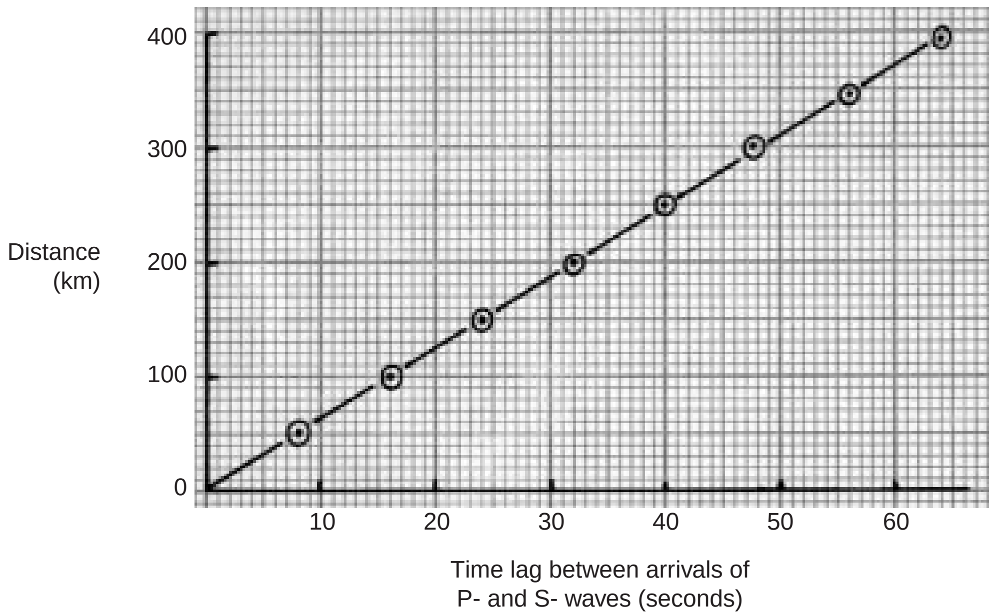
   (d) The L-waves remain near the surface and travel at the same speed.

   (e) velocity = $\frac{\text{distance}}{\text{time}} = \frac{4000}{17 \times 60} = 3.9$ km/s

   (f) (i) Faster in rock 1 as it bends towards the normal in rock 2.
   (ii) Faster in rock 2 as it bends away from the normal in rock 2.
   (iii) There is no change of direction but there may be a change in speed. There could therefore be a change in velocity as velocity is speed in a certain direction. No definite answer can be given.
   (iv) The wave does not pass into rock 2.

   (g)

Distance travelled in km	50	100	150	200	250	300	350	400
Lag in time between P-wave and S-wave arrival in seconds.	8	16	24	32	40	48	56	64

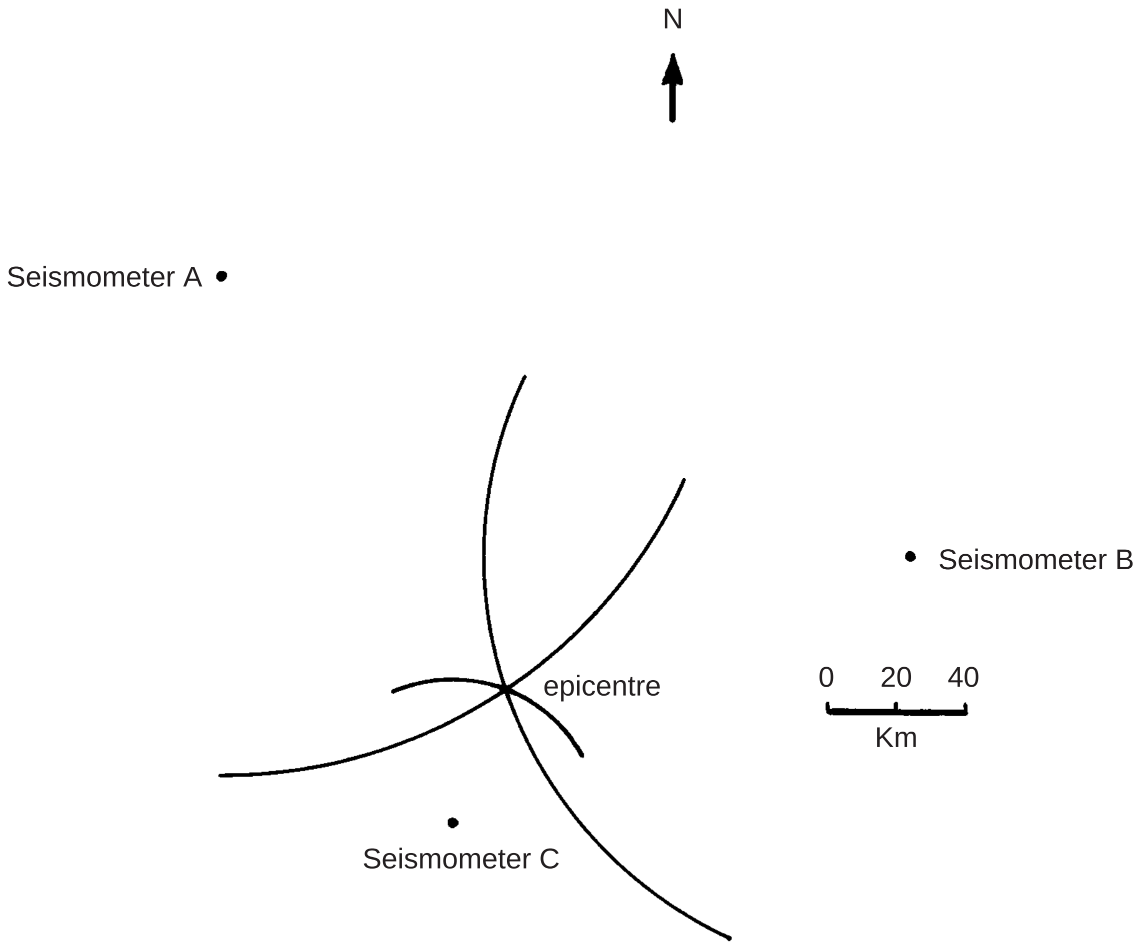


2. (a) The epicentre must be closest to seismometer C and slightly closer to B than A. That puts it perhaps close to C but between B and C.

(b)

Seismometer A	lag time 24 sec	distance = 150 km
Seismometer B	lag time 20 sec	distance = 125 km.
Seismometer C	lag time 6 sec	distance = 40 km.

(c) and (d)



3. The P-waves slow up due to a major change in rock type. This is a discontinuity. The S-waves stop as the layer being entered (the core) is a liquid.

4. Both P and S-waves slow up as they pass through this layer as it is partly molten.

Section 15: The Earth's Composition

1.

EARTH			SIMILAR METEORITES		
Layer	**% Mass**	**Material**	**Type**	**% Falls**	**Material**
Core	31.3	iron, nickel, sulphur	iron	6	iron, nickel, sulphur
Mantle / Crust	68.0	peridotite	stony	90	pyroxene, olivine

2. If the meteorites had always been small fragments they would have cooled very rapidly in space and hence they must have been part of larger bodies. The cooling rate is however quicker than the Earth and therefore these bodies were probably smaller than the Earth.

3. The bodies that broke up to form meteorites must have had a smaller core as only about 6% of meteorites are iron.

4. As the stony iron meteorites are hybrid between the stony and the iron they could have originated from a transition zone between the core and the mantle of the bodies that broke up.

5. Only about 7% of the stony meteorites have crystallised from a liquid, the rest have condensed from a gas when the bodies first formed.

6. If the average depth was 200 km then the radius of the body would have been 400 km, this compares with 6370 km for the Earth.

7. (a) 25-90 km, average 35km
   (b) 6-11 km.

8. Probably an iron and sulphur mixture in a liquid form.

9. Inner core P-wave speed 11.3 km/s
   Continental crust P-wave speed 6.0 km/s.

10. The low speed layer starts at a depth of 50 km below the surface and finishes at a depth of 250 km.

11. Inner core has a density of 13.5 kgm^{-3}
    Continental crust has a density of 2.7 kgm^{-3}

12. There are phase changes to higher density minerals with increasing depth.

CHECKPOINT 9

Section 15: The Earth's Composition - Extension Exercise

E1 P-wave speed = $\sqrt{\dfrac{\text{axial modulus}}{\text{density of the rock}}}$

S-wave speed = $\sqrt{\dfrac{\text{rigidity modulus}}{\text{density of the rock}}}$

The P-wave will travel faster as the axial modulus is greater than the rigidity modulus and the density is the same for both.

E2 P-wave speed = $\sqrt{\dfrac{3 \times 10^{11}}{10.5 \times 10^{3}}}$ = 5345 ms^{-1}

= 5.3 kms^{-1}

S-wave speed = $\sqrt{\dfrac{8 \times 10^{10}}{10.5 \times 10^{3}}}$ = 2760 ms^{-1}

= 2.7 kms^{-1}

E3 New P-wave speed = $\sqrt{\dfrac{17 \times 10^{11}}{13.5 \times 10^{3}}}$ = 11222 ms^{-1}

= 11.2 kms^{-1}

New S-wave speed = $\sqrt{\dfrac{0}{13.5 \times 10^{3}}}$ = 0 kms^{-1}

The P-wave will increase its speed as it enters the new material and the S-wave will stop.

E4 Carbonaceous chondrite meteorites are the least altered type of meteorite with a few per cent of carbon. They may be typical of the original Solar System before planet formation.

Section 16: Plate Tectonics

2. Use the answers from Intermediate 2 unit: *Earth Physics and Earth Movements*.

E1 Notes are to be taken
Conservative margin – no volcanic activity
Constructive margin – basalt eruptions from fissures
Destructive margin – andesite eruptions from central vents.

E2 A large continent called Pangaea was formed about 300 Ma by all the main continental masses coming together astride the equator. Gondwanaland lay to the north made up of what is now Africa, India, Antartica and South America. The southern part of the continent was Laurasia and consisted of what is now Asia, Europe and North America.

About 160 Ma Pangaea started to break up into Gondwanaland first and later into Eurasia. The Atlantic was opening by 100 Ma.

E3 Ophiolites are the remains of a piece of ocean floor which has been added to the continental crust at a destructive plate margin.

Section 17: The Earth's Gravity

1. Notes to be taken

2. As the force is given by $F = \frac{GMm}{r^2}$

   The force becomes smaller the further away from the centre of the Earth. As the radius is greater at the equator than at the pole then the force of gravity must be less.

3. (a) A gu is a gravity unit and is an acceleration of 10^{-6} ms^{-2}.

   (b) The density of the rocks is greater below the positive anomaly.

   (c) It is roughly circular in plan.

   (d) The igneous body is certainly in excess of 15km across and with a roughly circular plan, it is a batholith. As basalt lavas exist the magma type was basic and as it is a higher density rock forming the batholith, the rock will be gabbro.

   (e) At the sides of the gabbro batholith will be the rocks into which the basic magma was intruded. These are likely to be sedimentary rocks. Also to the northwest and southeast recent sedimentary rocks have been deposited on top of the lava.

E1 (a) mass of Earth $= \dfrac{m \times a \times (\text{radius of earth})^2}{G \times m}$

$$= \frac{9.8 \times 6370000^2}{6.67 \times 10^{-11}}$$

$$= 6.0 \times 10^{24} \text{ kg}$$

(b) volume $= \dfrac{4\ \pi r^3}{3} = \dfrac{4 \times 3.142 \times 6370000^3}{3}$

$$= 1.1 \times 10^{21} \text{ m}^3$$

(c) average density $= \dfrac{6.0 \times 10^{24}}{1.1 \times 10^{21}}$

$= 5.5 \times 10^3 \text{ kgm}^{-3}$
$= 5.5 \text{ gcm}^{-3}$

(d) The density of the interior must be higher than 5.5×10^3 kgm^{-3} to give an average density of 5.5×10^3 kgm^{-3}

CHECKPOINT 10

Section 18: Isostasy

1. Use the answers from Intermediate 2 unit: *Earth Physics and Earth Movements.*

2. For isostatic adjustments to take place the mantle must flow. As the mantle is a solid this process of flow is very slow.

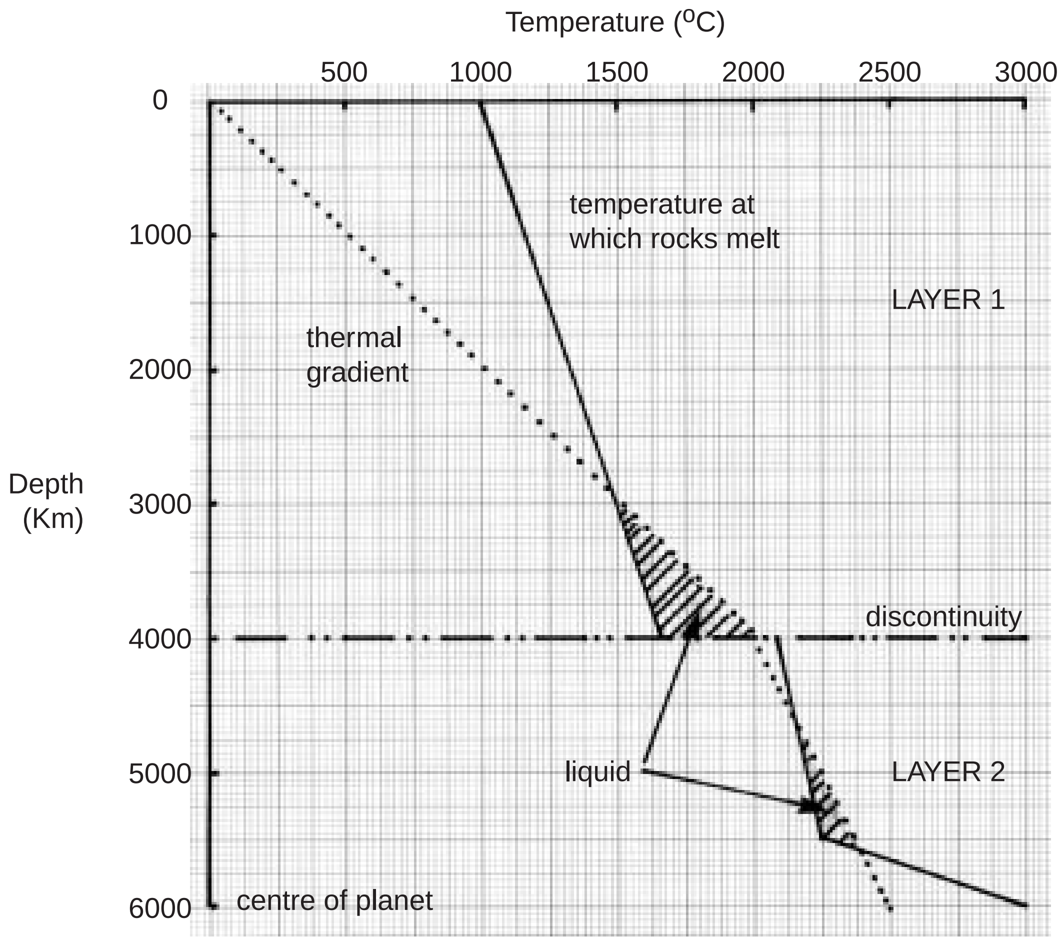
3. (a) A positive anomaly will exist.
   (b) The crust will gradually sink.
   (c) No anomaly will exist.
   (d) A negative anomaly will exist and the crust will gradually start to rise when the ice melts.

4 (a) Over 200 m of uplift since 6800 BC
   (b) 2.27 cm per year.
   (c) Faster than the present day.
   As isostatic equilibrium comes closer to being re-established the imbalance of force becomes less and hence the uplift is less rapid.
   (d) The land is still rising and hence there is a deficit of mass leading to a negative gravity anomaly.

Section 19: The Earth's Internal Heat

1. Notes to be taken

2. (a) & (b)



(c) Layer one will be liquid between depth 3000 km and 4000 km.
Layer two will be liquid between depth 4600 km and 5600 km.

3. (a) Increasing pressure increases the melting point of rock

   (b) The presence of water lowers the melting point of rock such as peridotite. It is likely that water is present in the upper mantle.

4 Heat is produced by the decay of certain radioisotopes within the Earth. This heat generates convection currents within the mantle that drive the plate movements.