

455/02

GEOLOGY GL5

THEMATIC UNIT 2

GEOLOGY OF NATURAL RESOURCES

P.M. TUESDAY, 20 June 2006

For Examiner's Use only.

Section A	1	
	2	
Section B	3	
	4	
	5	
Total	50	

Answer **both** questions in Section A (25 marks) and **one** question in Section B (25 marks).

SECTION A Answer both questions 1 and 2 on the lines provided in the question.

1 (a) Figure 1 is a simplified geological section through the aquifer around Bath, from which hot springs emerge at temperatures of 40°C – 50° C.

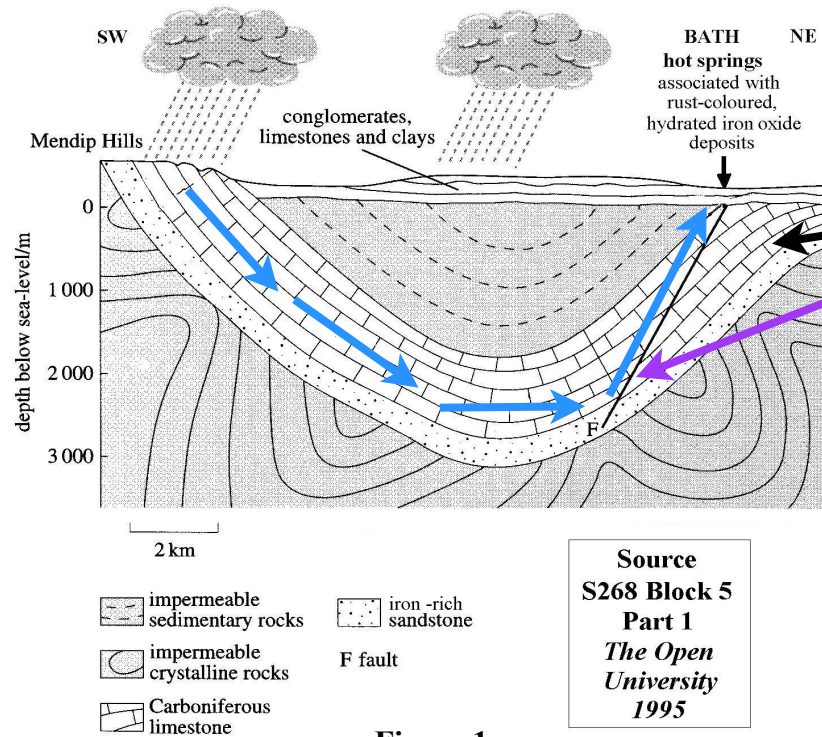


Figure 1

Labelling of figure has to be clear.

For (a)(ii) - arrow pointing to the limestone was the most common correct response. An arrow within the limestone but pointing very closely to the fault plane was not accepted as this is not clear.

For (c)(i) one continuous arrow would have sufficed. It just had to be clear that the water would have flowed down through the aquifer and up the fault.

Refer to Figure 1

(a) (i) State what is meant by the term **aquifer**. [1]

a rock that contains water that can be extracted for economic purposes

Many ways to answer this question but must include the words **ROCK** and **WATER**. One other point was needed for the mark. Any reference to porosity, permeability or, best of all, its economical value.

(ii) Clearly label **Figure 1** to show the position of a major aquifer. [1]

Easiest way is to draw an arrow pointing to either the Carboniferous limestone or the sandstone. Either, or both, could have been coloured in.

(b) The average geothermal gradient is 25°C km⁻¹. Calculate the average temperature of rock at a depth of 3000 m below sea level. Show your working. [2]

depth x geothermal gradient = 3 x 25 = 75
Temperature 75 °C

2 marks here. One for the answer = 75°C and the other for showing how the figure was obtained. Therefore, either “depth x geothermal gradient” or “3 x 25”.

(c) (i) Using arrows ($\rightarrow \rightarrow$), show the probable pathway for groundwater flow which results in hot springs at Bath. [2]

(ii) Explain how the following geological factors have contributed to the hot springs at Bath.

1. rock type
2. geological structures.

Rock type

the limestone is porous and permeable

there are impermeable rocks (above and) below

the aquifer is confined

Geological structure

the aquifer is in the form of a syncline (synform)

fault provides a pathway for to the surface

geothermal gradient means temperature will be high at depth

(d) Explain the formation of the hydrated iron oxide deposits associated with the hot springs. [2]

the iron comes from the sandstone

it is dissolved by the hot water and

precipitated at the surface

Arrows must flow from the surface (Mendips the best) to show the source of the water. Then to depth so it will be heated and then along the fault plane to show how it got back to the surface.

5 marks nearly always means 5 points. Two things to comment on means 2 + 3. It does not matter if the 2 is for the rock type or the structures.

The rock properties may relate to the limestone or sandstone or both.

Joints are an awkward property here. Is jointing a property of the rock type or a geological structure found within rocks? Both are reasonable arguments and so would be accepted under either heading.

Because the question specifically refers to HOT springs, it is important that this is addressed. Therefore, 1 of the 5 marks is reserved for an explanation of how the water comes to be hot. There must be some reference to temperature increasing with depth.

Some amongst you will be only too aware that there are better ways of explaining this from a chemical point of view. This is not necessary to obtain the marks here, although it should not be discouraged. From a geological point of view, the main points are as given here.

Total 13 marks

2. **Figure 2a** shows the relationship between three of the chemical elements of the coal rank series.

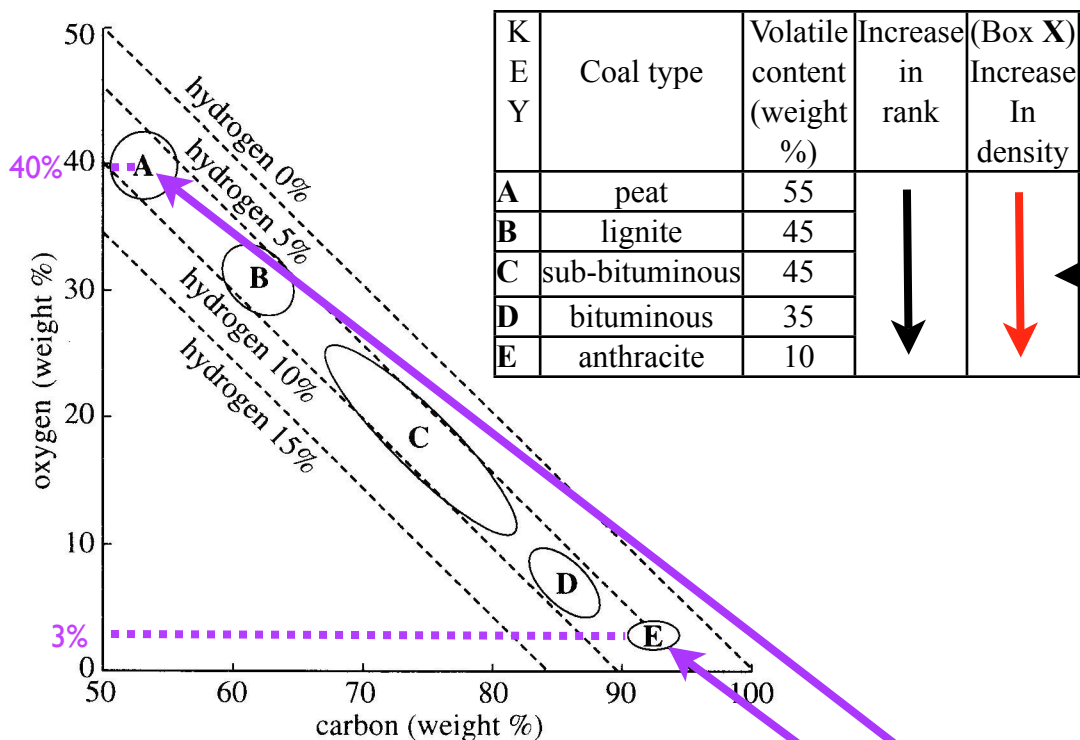


Figure 2a

(a) Refer to **Figure 2a**

(i) With an increase in the rank, state which chemical element shows:

1. a reduction in percentage
2. least change in percentage

[2]

1. Reduction in percentageoxygen.....

2. Least changehydrogen.....

(ii) Draw an arrow in the box labelled **X** to show how the density of coal is related to its rank. Explain your answer.

[2]

.....as rank increases so does compaction.....
which removes volatiles and increases density.....

Arrow pointing down

Oxygen falls from around 40% in A (peat) to approximately 3% in E (anthracite)

Large variety of acceptable answers given for this question. Ranged from the physical : increased compaction leading to loss of porosity / water / volatiles to the chemical : loss of oxygen (and hydrogen to a lesser extent) which have lower atomic weights than carbon (which increases in percentage).

(b) Using your knowledge, explain how you would distinguish between the following coals in hand specimen.

A small proportion of candidates misread this question. It does NOT ask for a comparison between “peat and lignite” on the one hand and “anthracite and bituminous” on the other.

(i) Peat and Lignite. [2]

What is required is evidence that you have seen both of these in hand specimen. So anything that indicates that peat is made up of plant fibres while lignite is a soft brown coal.

.....distinct plant fibres can be seen in peat.....

That peat is of lower density and less compact than lignite would be OK.

.....lignite is brown / black.....

Beware of the word ‘lighter’. Does this mean lighter weight or lighter in colour ? It is not the examiners job to guess what you mean. Also “peat is lighter weight than lignite” is not clear. Are the specimens the same size ?

(ii) Anthracite and Bituminous coal [2]

Essential to mention that bituminous is banded while anthracite is not. Second point is open. Lustre was the most common. Density was also common but the wording was important as it would not be obvious in the hand specimen. If the latter was stated, that would be OK. A few said that there might still be evidence of fossils in bituminous but not anthracite. This too was credited.

...bituminous coal is banded while anthracite is not.....

...bituminous coal is dull black with some brighter bands while

.....anthracite has a bright vitreous lustre throughout...

(c) Discuss the relationship between coal formation and the formation of natural gas. [4]

Two ways to approach this. Either gas forming at the same time as coal - hence methane in mines; OR, how conditions lead to the formation of coal and (contrastingly) how they lead to the formation of gas. Either is acceptable.

.....both coal and gas are hydrocarbons.....

This answer takes a combined approach.

.....they both form due to the thermal alteration of.....

.....organic matter.....

4 valid points. Breadth or depth both accepted.

.....coal forms from the plant material while gas forms

.....from plant or animal material.....

(Another example of the last part of a question being more demanding / open. Examiners looking for quality of response rather than a set answer.)

.....gas is mobile and migrates while coal does not.....

SECTION B

Answer **one** question from this Section on the following pages.

You are advised to make use of examples where possible in your answer.

- 3 With reference to the **quarrying** or **mining** of one or more geological raw materials, explain how careful planning and development legislation are used to protect the environment and limit the effects of pollution.

[25]

The important thing to note about this essay is that it is asking how the environment might be protected. Many students went into great detail about how materials are quarried or mined. This was NOT asked for, so would be given no credit.

4. (a) Describe the formation of a named bulk mineral deposit and assess its economic importance in the construction industry.
- (b) Explain the **processing** steps by which **one** element or compound of industrial value is derived from a geological raw material.

[25]

- (a) Biggest problem here was that a significant number of students did not really know what is meant by a “bulk” mineral. Copper ore was a popular (incorrect) choice.
- (b) This was quite well done. Mostly it was compounds that were chosen, such as calcium oxide or carbonate (from limestone), china clay (from granites). The use of crushers, froth floatation etc was generally well known and understood.

5. Evaluate the use of **two** of the following techniques in the exploration of mineral resources:

- (i) geological mapping;
- (ii) geochemical prospecting;
- (iii) satellite remote sensing;
- (iv) seismic reflection.

[25]

This was probably the worst done of the three essays so let's try this one !

5. Evaluate the use of **two** of the following techniques in the exploration of mineral resources:
- (i) geological mapping;
 - (ii) geochemical prospecting;
 - (iii) satellite remote sensing;
 - (iv) seismic reflection.
- [25]

First thing to note is that TWO are asked for. Being gluttons for punishment we will try all four and see how we get on. But, in and examination, we would just be wasting time and effort.

The key word in the stem is EVALUATE. To obtain the highest marks we will have to make a case for the method to be foolproof, or useless, or (more likely) somewhere in between.

Mineral resources are mentioned. So although it is not essential to name them it will be the easiest way of making sure that we fully answer the question. Also, as in all questions, credit is always given for mention of field observations or case studies that have been undertaken.

(i) geological mapping

Geologists use maps and draw cross sections to find out what the geology is like under the surface. This tells them where the minerals are likely to be found.

This is, more or less, the sum total of what the weakest candidates did in the examination. It looks as though they thought that geological mapping is what we might call a geology classroom practical. This shows that the student has very little idea about what is involved.

Lets look at a better attempt.

Field geologists collect data from the field. That is, they have to travel to the area to be studied by car, helicopter, plane or any other means of transport (camels ?).

Shows awareness of practical problems.

They need a map on which to record many of their findings. At the same time they keep a copy of this and any other data in a field note book, or the equivalent. Often it is done digitally these days. They may be lucky to be going to an area that has map coverage. As often as not though, there is **no map coverage**. There will probably be (plane or satellite) photo coverage which may be used directly or a drawing obtained from it before they travel to the area. If there are prominent features, like mountain peaks, in the area it is possible to locate themselves accurately using a compass. These days though it is much more convenient to use **GPS**.

Knowledge of basic procedures = need a base map and note book (or equivalent) on which to record data.

Once in the field, the geologist has to make detail recordings of position and collect relevant data. The latter will include rock types, minerals, fossils and structures (mostly **dip and strike**). This enables the field geologist to make, and record, very detailed observations.

Knowledge of what the field geologist actually does.

The geologist will probably be looking for something in particular such as an ore deposit, coal or oil. In such cases they will be looking for certain critical things. In the case of oil four things are required : **source rock, reservoir rock, cap rock and trap**. Thus the geologist will be looking for each of these. Recordings will be made and specimens collected, all the time keeping a precise record of where the data was recorded.

More, in depth account, to show the sorts of approach or problems a field geologist might have. Also, the question mentioned mineral resources, so some reference should be made. Here, both of these have been covered by selecting a particular case study. However, it could just as well have been any other mineral resource.

Once back from their travels the geologist will produce a report which includes a geological map, sections and details of the rocks encountered.

Recognition of what is done with the data once it has been collected.

The above is a well-rounded account of what a field geologist might do. It has touched on the major parts i.e. getting there; collecting data; returning and processing data. Although an evaluation has not been done formally (siting advantages and disadvantages) one is implicit within the account.

This is however, not the only way the essay can be approached. Some students chose to describe how they have undertaken a field mapping exercise. They may have included comments on the weather and equipment (including clothing). This is quite acceptable.

You might also argue that not all of the possible considerations have been covered. What sorts of things would you look for in the rocks (permeability ?). What about the availability of outcrops ? Are there any old mines in the area ? What id they mine ? What about the spoil heaps ? If you landed from a helicopter, how would you decide in which direction to go ? Examiners are not looking for the perfect answer (whatever that is) and here all the major aspects have been mentioned. Also there are some nice touches shown in **purple** which show this student is fully aware of what field mapping entails and so the above account is the sort that would get full marks.

(ii) geochemical prospecting

Geologists collect samples from streams and analyse them to find out what metals they contain. They trace the metals upstream until they do not appear anymore. They then know that they have gone beyond where the ore deposit is.

This is about the minimum amount that received credit. It was quite a common response and, although this is basically the correct answer, there is far too little detail for it to score a significantly high mark.

Prospecting geologists collect samples for analysis. These may include water samples or sediment from streams; core (auger) or soil samples, or samples of the vegetation. These are analysed for their metal content. Soil samples may consist of only a few grammes and yet early reconnaissance analyses may look for up to 30 different elements. If the sediment in a stream contains a higher than normal proportion of a certain element, this would suggest that the drainage area includes a mineral deposit.

This explains fully what is collected, which the previous example does not do. Again, it would not be expected that all of these would be covered and there is the usual trade off between breadth and depth. You could discuss soil sampling in depth and not bother with the others. Although this could gain you very high marks it would have to be exceptional to get you full marks. This account would score highly although it does not explain fully what is done with the samples once they have been collected.

Sediment and soil samples are put into labelled packets and sent to laboratory. The locations at which they are collected are recorded as accurately as possible. It may be that the best method is to use a grid marked out on a map. The element content is obtained using a spectrometer. The results are then plotted on the grid / map, producing a separate map for each element. Soil sampling is usually the most effective in locating an ore body as an anomaly is often found directly above the body.

This has added much more to the account, making it clear that the student really knows what they are talking about. We've covered what's collected and what's done with it. You could argue this bit of the account is not "geochemical prospecting" and certainly the examiner would not demand a detailed account. However, this is relevant and the examiner will always reward any relevant discussion. Case studies are a particularly good means of obtaining high marks.

The major problem with these types of sampling is (cross) contamination. This might occur in several different ways. The geologist must be careful with the equipment and packaging. The area might have been previously mined. There may be some redistribution of materials due to wind and / or water.

It was claimed above that the ore deposit is often found directly below the anomaly. However, it is also common for the anomaly to move downslope from the ore body. This may be due to soil creep or metal (ion) containing groundwater permeating the soils.

There is one thing that really is missing so far because, of course, I'm expecting to get full marks ! This thing is an EVALUATION. This is an attempt to cover this aspect of the question. Again, not all aspects would be expected to be covered BUT there must be some attempt at evaluation to give us a chance of obtaining full marks.

Some nice points showing real insight.

Conclusion : briefly cover all of the things above, or fewer in detail and we have full marks.

(iii) satellite remote sensing

Photos are taken from satellites which are orbiting the Earth. They are able to detect different ore bodies which reflect different radiations.

The typical sort of correct response that is much too brief to secure high marks. It has all the ingredients : photos; satellites; orbiting; ore bodies and reflections, but there is no details as to how each of these relate.

An American system of remote sensing is done via Landsat. NASA launched the first Landsat satellite in 1972, and the most recent one, Landsat 7, in 1999. Instruments onboard the satellites have acquired millions of images of the Earth.

An initial aerial photo survey may indicate that mining has already taken place in the area. Similar locations can be looked for and old spoil heaps identified. These might be reworked.

Images are built up using many different wavelengths including some from the visible spectrum. Different materials reflect different wavelengths. Infrared is particularly useful in deciding what rocks are present. It may be by way of the vegetation. If we know what the vegetation is it can indicate the type of soil and so the rock underneath from which the soil formed. In particular, any underlying metalliferous deposit can have very drastic effects on the vegetation. The temperature of the rocks can also be gauged, as can the presence of faults. The latter is often critical in establishing the position of ore deposits.

There are far too many ways to tackle this question for the attempt to the left to be anything other than a guide.

You could discuss the satellites (orbit etc) in more detail. Consideration of the types of radiation recorded could be expanded. How is the data processed ? All the time there is the trade off between DEPTH and BREADTH. The words shown in purple are obvious terms that could be looked at in more detail. The choice is yours !

The account has completely ignored geophysical surveys. Any / only consideration of these would be fully credited. The

The use of satellites has made an enormous contributions to regional and global surveys. This is because it is very difficult and costly to conduct ground and aerial surveys over large areas and then to coordinate the individual surveys by joining them together. Operating from the global perspective afforded by orbiting satellites is the only reasonable alternate way to provide widespread coverage.

Although a very sound attempt, the above has not really EVALUATED the use of remote sensing. This is essential if you want to obtain the highest marks. Again, there are many varied views here but something along the lines of this is required.

(iii) seismic reflection

This is one of the most commonly used geophysical methods of exploration. Seismic waves are produced and these reflect off rocks underground. They are picked up at the surface and a computer is used to show where ore bodies are underground.

This does not really tell us much more than is in the title. It says that seismic reflection is something that uses the reflection of seismic waves. It then uses a common “get out” of stating that a computer does the rest. Not much to credit here even though, again, it is basically the correct answer. There are just no details. What are seismic waves ? How are they produced ? Why do they reflect ? How are they detected at the surface ? What does the computer do ? Can they really tell us what is underground ? These are some of the questions that might be addressed.

Seismic waves are shock waves that are produced by a sudden input of energy into the ground. They are usually produced by an explosion or by striking the ground. A series of recorders known as geophones are positioned at regular known distances from the point of the wave production. These geophones are interconnected and also connect to a computer which records the arrival times of shock waves at each of the geophones. Depending on the size of the area to be covered the whole array is then moved to a different place and the procedure repeated. The waves travel into the ground until they meet a change of material. This might be where soil meets rockhead or where (for example) shale meets limestone. Whenever this happens some the waves energy is reflected towards the surface and is picked up by a geophone. The computer records the (two-way) time for the wave to travel down and then be reflected back. It is then possible for a correctly programmed computer to turn this into a representation of how the boundary (in this case between shale and limestone) is changing depth.

Could have added a little more detail on wave production by adding others (breadth) OR explaining (for example) how the ground is struck (depth). The description is getting quite complicated here. It would get full marks for what it has said so far but a diagram would have helped as a quick and efficient way to show how waves travel into the earth and are reflected towards the surface. Then labelling on the diagram could have replaced much of what has been written here.

A seismic profile is very effective at showing what the rock surfaces are doing below the ground. It has to be remembered that the profiles produced show the two-way arrival TIMES of the waves. Unless the rocks and the velocities of the waves in the rocks concerned is known, it is not possible to convert this into a true geological cross-section. Often a bore hole (which is expensive) has to be sunk as the cheapest way to produce a true profile. However, seismic profiles are excellent indicators of underground structures. They cannot identify mineral deposits, but they can strongly indicate where they are most likely to be found.

Good evaluation. This shows higher skills. Above is an explanation of what is involved and this evaluates its usefulness.

This plus the above is more than enough to secure full marks.

One thing that has not been included in any of the above but was, in fact, a very common consideration in the essays that students produced. That is COST.

For every student that claimed that geological mapping was cheap, there would be another that would state that it was expensive. This equally applied to each of the other three types of investigation.

Now, it is fair to say that they could have all been correct ! It all depends, and because it does, this provided students with an excellent opportunity to gain high marks as an EVALUATION is required to substantiate the claims. Thus to state “geological mapping is expensive” would have received no credit. The same would have applied to “geological mapping is inexpensive” If, however, it was claimed that “ it is expensive because it is labour intensive and time consuming” this would have been rewarded. If there was a little more detail such as “the collecting of field data can be very slow, particularly if the terrain is not very hospitable” the reward would have been greater. But what if a student claims that it is “cheap because no expensive equipment is needed only an experienced and capable geologist” ? This is a reasonable argument, particularly if there is a little more detail as regards “expensive equipment”. For example, a compass and clinometer hardly compares from a cost point of view with a satellite needed for the remote sensing. On the other hand, does the mining company interested in an area actually have to OWN a satellite ? How much does it cost to use someone else's satellite ? How would this compare with putting one or more geologists in the field ? Hopefully you will appreciate that these are not straightforward questions (or at least the answers aren't). To go back to the first line of this paragraph “it all depends”. This provides you with an excellent opportunity to bring in considerations that have been looked at in case studies.

THE VERY IMPORTANT POINT TO NOTE HERE (THAT APPLIES TO ALL DESCRIBE, DISCUSS AND EVALUATE QUESTIONS IN ALL UNITS) IS THAT EXAMINERS ARE GENERALLY MORE INTERESTED IN YOUR ARGUMENTS THAN YOUR CONCLUSIONS. MOST THINGS IN SCIENCE ARE NOT CLEAR CUT. THEY ARE OPEN TO DEBATE AND EXAMINERS ARE PREPARED TO GIVE CREDIT TO ANY VALID AND RELEVANT OBSERVATION OR ARGUMENT THAT CAN BE CONVINCINGLY BACKED UP.