Environmental Studies
FACT SHEET
www.curriculum-press.co.uk Number 117

Mineral exploration techniques

For the exam, the key point to understand is the difference between mineral resources and mineral reserves. Take copper as an example:

Copper resource = all the copper, anywhere in the world that can theoretically be exploited now or in the future. This includes the copper that is easy to extract now and the copper that cannot be exploited now because e.g.
- it is too deep
- the grade (%) is too low
- it's present in economically insufficient quantities
- it is in the ground under a protected area e.g. National Park

All of these form part of the copper resource.

The copper reserve, on the other hand, is that portion of the total resource that it is economic to exploit **now** with current technology.

The resource is finite – but the reserve changes as technology changes and the price of copper changes. If the price of copper goes up then ores that weren't economically worth exploiting might become so – the reserve will increase in size. Similarly, if we invent a new machine or technique that enables us to extract copper that we couldn't before, then this too will increase the size of the reserve.

The rest of this Factsheet summarises the most important new techniques for finding and exploiting minerals.

1. Remote sensing

Remote sensing includes any technique used to locate mineral deposits without actually coming into physical contact with them. Usually this involves analysing aerial photographs, satellite images or thermal images.

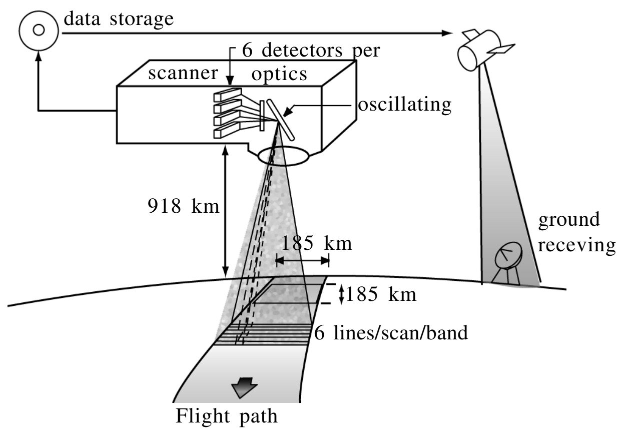
How can photographs of the land surface tell us anything about the rocks underground?

Mineral deposits often occur at geological faults and these can be detected and mapped using aerial and satellite images. The instruments might use visible light, infrared or radar – often in combination – to provide useful clues about the underground rocks.

Geologists study the way that materials exposed at the Earth's surface reflect or emit parts of the electromagnetic spectrum e.g. infrared radiation. As well as reflecting radiation, the surface materials also absorb it and consequently heat up.

When they cool, they emit different wavelengths of radiation according to their chemical composition. In other words, different types of rocks and soils have unique spectral signatures. By combining several types of spectral information, geologists can identify the mineral composition of a rock from data collected by an aircraft at 20,000 ft! (Fig.1).

Fig 1. Remote sensing



Even the vegetation can yield useful data. In the densely vegetated terrain of the Eastern United States, rock and soil composition can be determined indirectly by analysing the distribution and health of naturally occurring plants. For example, coniferous trees often grow preferentially on well-drained sandy soil, whereas deciduous trees dominate where the bedrock is made up of shales. These two forest types reflect solar radiation quite differently and can easily be identified using aerial photographs. In simple terms, the tree species we see give us clues as to what the hidden rocks below might be.

2. Gravimetric surveys

These measure variations in the strength of the Earth's gravitational field and, hence, the **density** of rocks. Different rocks and minerals have different densities so they can easily be identified (Table 1).

Table 1. Typical densities of rocks and minerals

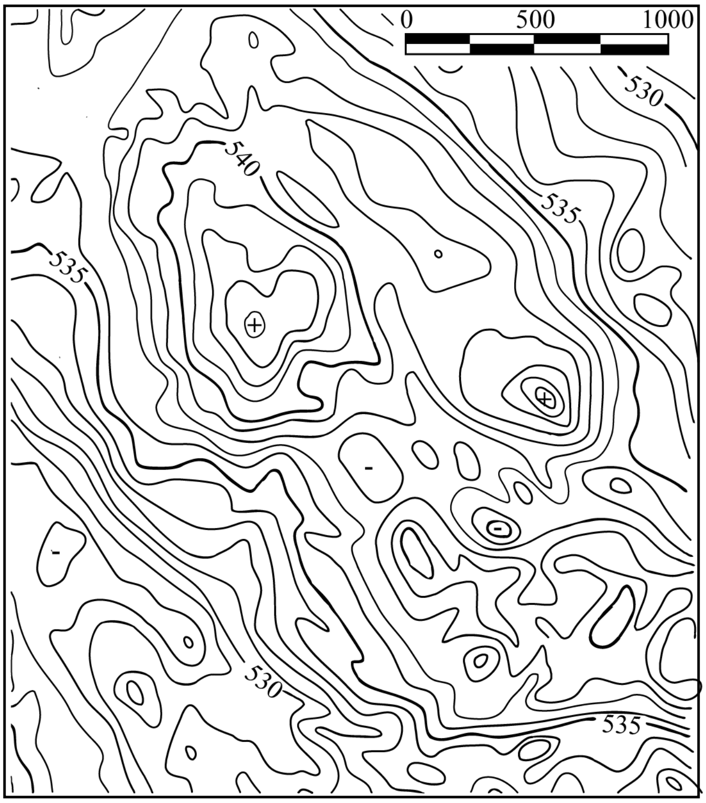
Rock	Typical density g/cm^3
Granite	2.64
Basalt	2.99
Gabbro	3.33
Sandstone	2.35
Limestone	2.55
Sand and gravel	2.00
Quartzite	2.60
Schist	2.64
Marble	2.75
Metallic Mineral	**Typical density g/cm^3**
Bauxite	2.45
Chromite	4.36
Haematite	5.18
Galena	7.50

Q. Which rock type – igneous, sedimentary or metamorphic tend to have the highest density?

Hence, gravimetric surveys can help identify rocks types or the likely locations of specific minerals, especially when the densities of the target minerals are significantly different from their host rocks.

The results can be shown as a gravity contour map showing deviations from expected gravity (Fig 2.).

Fig.2 Typical gravity anomaly contour map



This allows geologists to construct a density map and to identify rocks of abnormal density that are near the surface (Fig 3 and 4)

Fig 3. Gravity profile

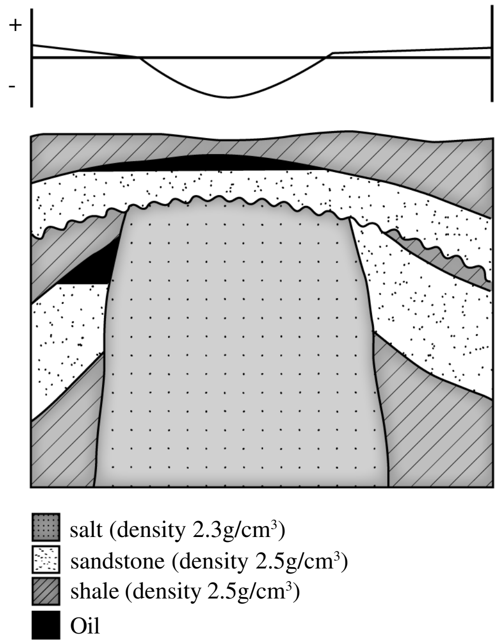
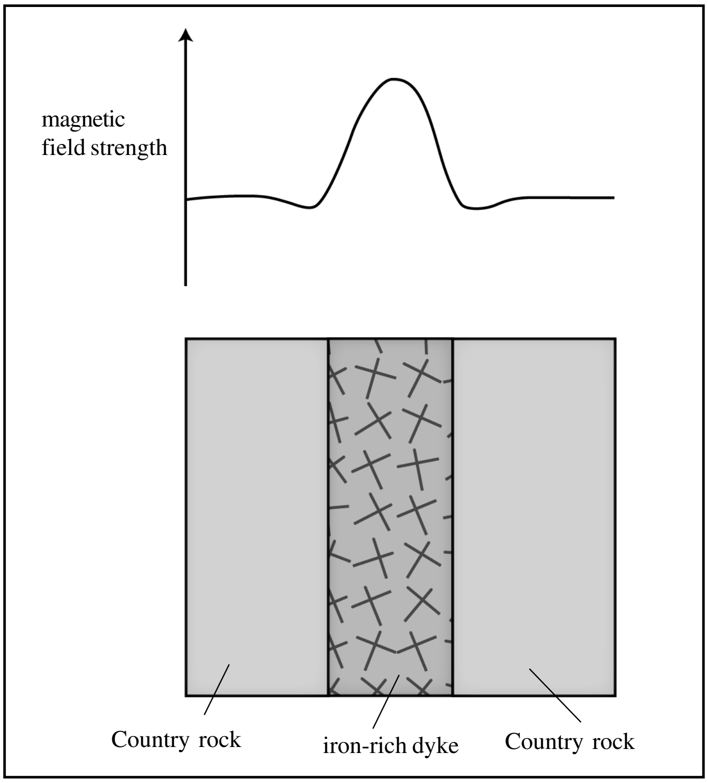


Fig 4. Transect magnetic survey

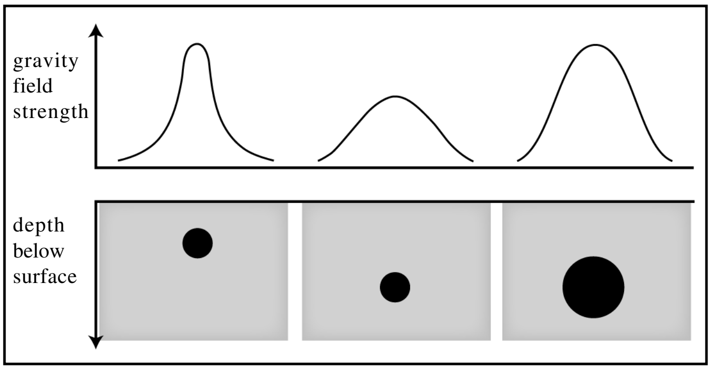


When using the gravimeters, corrections are necessary to account for the elevation at which the measurements are made and the shape of the ground surface.

The size of a gravity anomaly is influenced by:
- latitude
- the difference in density between an anomalous rock and the surrounding rocks
- the depth of the rock
- the size of the rock

Thus, a small, shallow deposit may produce a similar gravity response as a larger, deeper one (Fig 5)

Fig 5. Gravity field strength, depth and size deviations

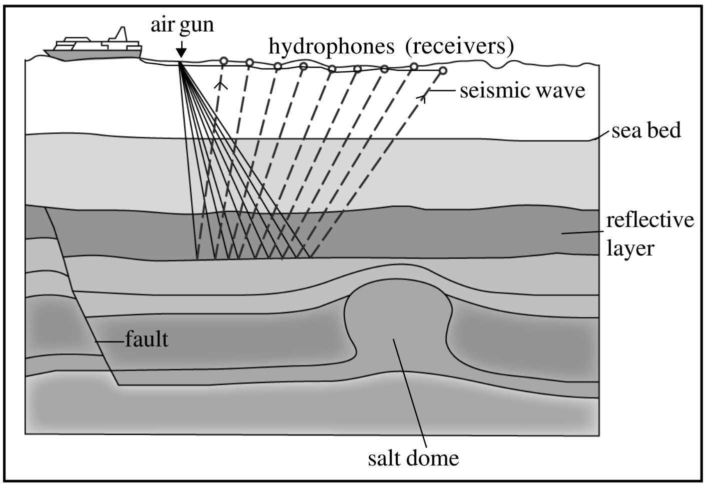


So, gravimetry is unlikely to be able to detect a narrow vein deposit that is surrounded by material of similar density. However, gravimetric surveys are extremely useful in, for example, the detection of massive high-density metal sulfide deposits e.g. iron sulfide (pyrites) and metal oxides.

3. Seismic surveys

This involves passing sound waves into the rock strata and then detecting, recording and measuring the reflected signals via receivers Fig 6.

Fig 6. Seismic reflection survey



The time taken for the reflected wave to be picked up by the receivers is used to calculate the depth of the reflective layer. The resulting seismic map gives a detailed picture of subsurface layering.

Seismic surveys are invaluable in the petroleum industry but, as technology has improved, they are now increasingly being used to explore sedimentary rocks. Seismic surveys yield data on the depth, thickness, density and angle of the strata. The acoustic waves can be generated using sound guns, air guns or even dynamite. One of the most successful applications has been in the location of gold deposits that are strongly combined within iron or iron sulfide deposits. Both of these produce strong seismic reflections.

The big advantage of seismic methods is that they can yield valuable information about rocks up to 3km below the surface – much deeper than techniques such as gravimetry. The disadvantages include:

- They are very expensive
- They are technically challenging – trying to interpret data on reflected sound wave velocities 2000m underground is difficult
- Valuable ores are often found in igneous or metamorphic rocks that don't have layers

4. Magnetometry

Magnetometers measure the strength of the Earth's magnetic field. They can therefore be used to detect abnormalities in this field caused by magnetic mineral e.g. magnetite, a form of iron ore.

The results of aerial surveys are plotted on a map with lines joining points of equal magnetic field strength. A magnetic metal such as iron will then give a positive magnetic anomaly, allowing the shape of the ore body to be delineated.

5. Core sampling

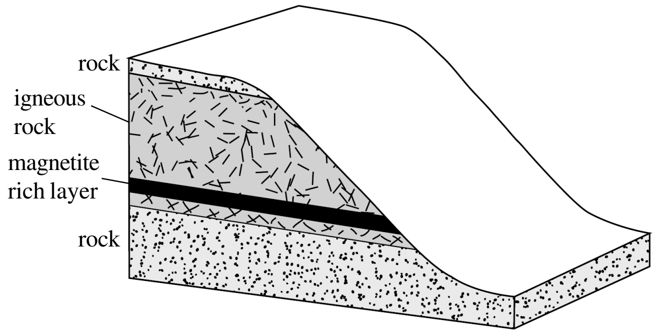
Remote sensing, gravimetry, seismic surveys and magnetometry can be used to locate deposits but the only way of proving that they exist is to drill into the ground. Grids of cores are taken in order to identify the precise positions of the deposits. Samples can then be analysed to determine their purity and chemical form.

Summary

Technique	Key points
Remote sensing	Any technique used to locate mineral deposits without actually coming into contact with them e.g. analysis of aerial photographs, satellite images or thermal images
Gravimetry	Measure variations in the strength of the Earth's gravitational field and, hence, the density of rocks. Igneous rocks tend to have the greatest density
Seismic surveys	Passes sound waves into the rock strata and then detects, records and measures the reflected signals
Magnetometry	Measures the strength of the Earth's magnetic field to detect abnormalities in this field caused by magnetic mineral e.g. iron ore
Core sampling	Extracting rock cores to prove the existence of the rock/mineral

Practice Questions

1. The diagram shows the position of an iron ore deposit of magnetite.



(a) What is an ore? (2)
(b) Iron ore is magnetic. Describe a simple technique by which the location of the deposit could be identified. (3)

Markscheme

1. (a) rock containing metal/mineral;
whose concentration is high enough to make it economically worthwhile extracting;
(b) Magnetometry;
Reference to sampling/use of a grid;
Measures magnetic anomalies;
Region of high magnetism indicates magnetic rocks/minerals/magnetite;

Acknowledgments: This Factsheet was researched and written by Kevin Byrne.
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ISSN 1351-5136