

Monday 11 June 2012 – Afternoon

A2 GCE APPLIED SCIENCE

G628 Sampling, Testing and Processing

INSERT

Duration: 1 hour 30 minutes



INFORMATION FOR CANDIDATES

- Questions 1 and 2 are based on the articles which follow on pages 2–6 of this Insert.
- This document consists of **8** pages. Any blank pages are indicated.

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Silica – friend or foe?

The element silicon makes up about 26% by mass of the lithosphere. It is not found free but occurs chiefly as its oxide, silica (silicon dioxide, SiO_2), which may also be combined with other elements to produce silicate minerals. Silica is found in sedimentary rocks such as sandstone and in metamorphic rocks such as quartzite. Some forms of silica are used in jewellery; these include amethyst, agate and opal.

Flint is another form of silica and is shown in Fig. 1a. It occurs as nodules in the sedimentary rock, chalk, which may contain a number of fossils.



Fig. 1a

The origin of these flint nodules is thought to be partly organic, perhaps from siliceous sponges. Flint has been known to humans since 3000 BC, when it was first mined by Neolithic man. Flint mining is thought to have been carried on through the Bronze Age and into the Iron Age because of its ready usefulness and availability. This material could simply be dug out from the ground, whereas metals such as copper and iron had to be obtained by the extraction and then smelting of their ores. In Britain, the remains of a large Neolithic flint-mining complex are found at Grime's Graves in Norfolk. It has been estimated that the Neolithic miners needed to remove more than 2000 tonnes of chalk when digging pits before reaching the flint bands. These pits were up to 10 m deep and 5 m wide, Fig. 1b.

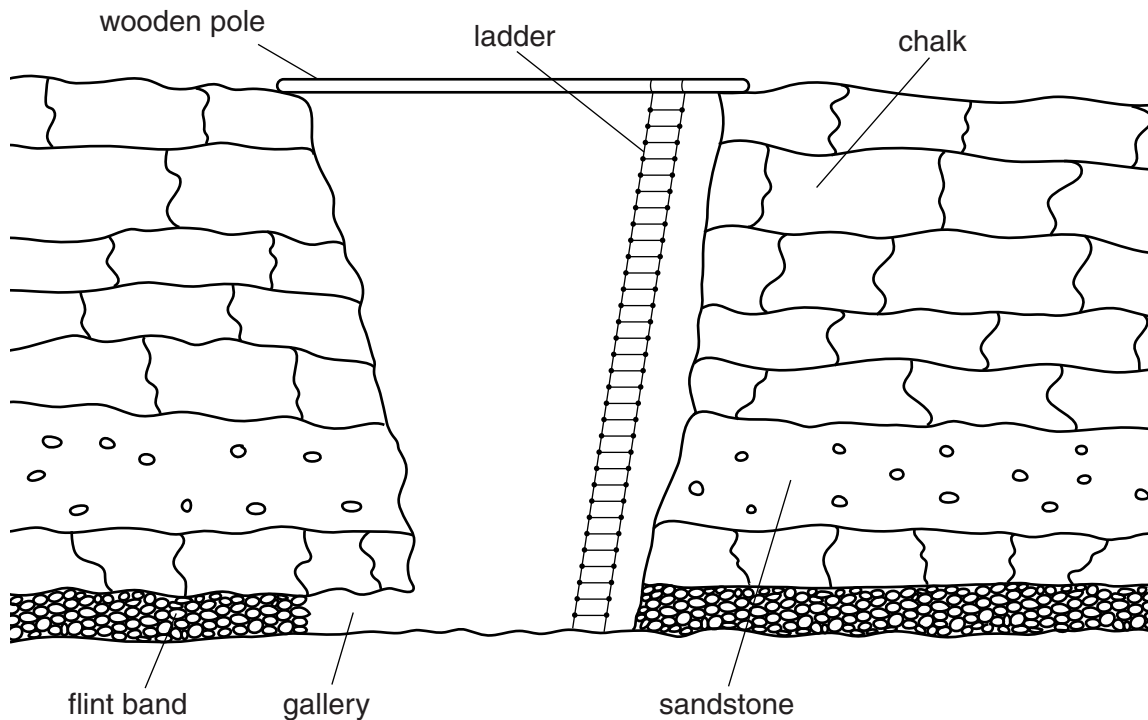


Fig. 1b

It is difficult to imagine how these miners, using only primitive hand implements such as picks made from deer antlers, Fig. 1c, were able to remove the covering chalk layer and then dig out and transport to the surface considerable quantities of flint. It was dark in the galleries at the bottom of the pit and the miners had to design suitable lamps to help them see when they were digging out the flint. Many of the flint nodules were then shaped to provide axe heads, Fig. 1d.

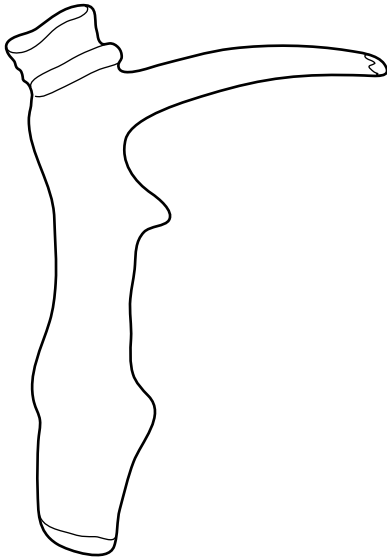


Fig. 1c

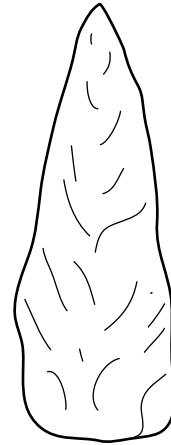


Fig. 1d

It took around 60 tonnes of flint to produce 10 000 flint axes. In the later Neolithic period, some flint was used for making arrowheads for use in hunting. During Roman times and up to the Middle Ages, flint was used for building. With the development of firearms in the early 17th century, flint gained another use as part of the firing mechanism in flintlock weapons.

During April 2010, a volcano erupted underneath a glacier in Iceland. One problem with this eruption was that the magma, containing silica, came into contact with water and ice. This resulted in a large amount of volcanic ash being ejected high into the atmosphere. It is estimated that the rate of ash ejection was up to 500 tonnes per second. Volcanic ash contains irregularly-shaped particles that can be glassy or crystalline, often with sharp edges, Fig. 1e. The particles in the ash vary in size from 1 to 100 microns (a micron is 1×10^{-6} m).

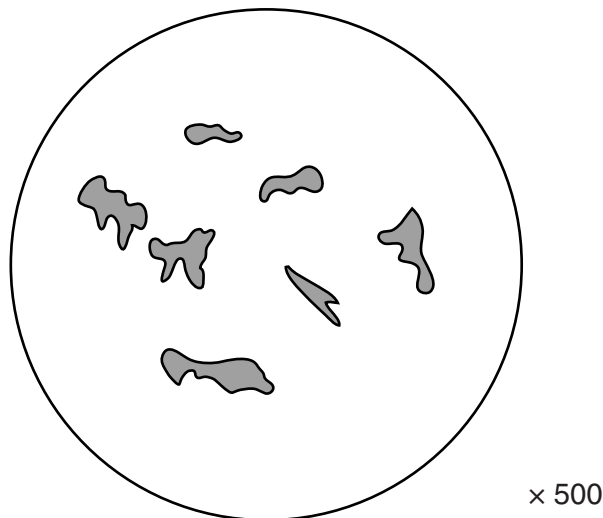


Fig. 1e

The ash cloud drifted over the United Kingdom and Northern Europe, causing major disruption to air travel. This cloud of fine material was difficult to detect with any certainty although sensors on satellites were used to give an idea of its flow pattern and depth. A specially equipped aircraft flew close to the ash cloud to give a better idea of its size and position. The aircraft was equipped with particle counters and sensitive gas analysers. Sulfur dioxide is one of the gases that is closely associated with volcanic ash clouds and infrared absorption spectroscopy could be used to determine the concentration of this gas. Fortunately, although air travel was disrupted for a period, the volcanic eruption died down and the dust cloud slowly dispersed.

It is ironic that Neolithic people were able to use silica in the form of flint as part of their primitive technology but some 5000 years later, silica and its minerals present in volcanic ash are able to disrupt everyday life in these times of sophisticated modern technology.

Salt – an essential commodity

Salt is essential for life. A human adult contains about 250g of salt (sodium chloride, NaCl) but it is constantly being excreted and needs to be replaced. The daily amount required is 3 to 4 grams but many people consume much more and this can lead to health problems.

In the early 1920s, a book was published by the Diamond Crystal Salt Company entitled 'one hundred and one uses for salt'. The modern salt industry would dispute this figure and would say that the figure is nearer 14000. It is not surprising therefore, that such an essential material was one of the most desirable commodities in times past and this need led to an enormous trade in salt. What the salt traders of the past did not perhaps realise was that salt is everywhere both on the land and in the sea. It was just that a number of the extraction methods were waiting for discovery.

A geologist would classify a salt deposit as an evaporite. This name arises because it is formed by the evaporation of water from an aqueous solution. Two thirds of the Earth's surface is covered by water. Much of this water is saline but the quantity of minerals (principally sodium chloride) dissolved in the water (the salinity) varies. Table 2a shows the salinity of several different 'types' of water.

Table 2a

'type' of water	salinity / g kg ⁻¹ water	density / g cm ⁻³
Dead Sea	192	1.253
Pacific Ocean	35	1.026
river water	0.2 or less	1.000

When water is evaporated from these saline solutions, deposits of salt are left. Over long periods of time, sediments cover these deposits, giving the banding that is characteristic of many sedimentary rocks. An example is shown in Fig. 2a.

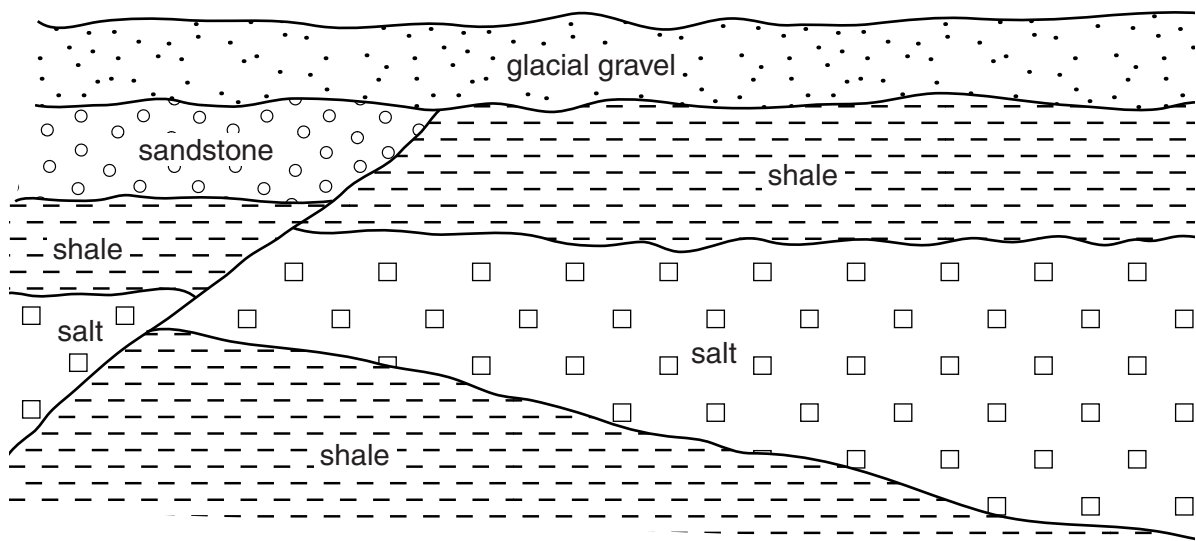


Fig. 2a

These evaporite deposits can be very extensive, with a thickness of up to 4500m in New Mexico, where they cover an area of 250 000km². Evaporite deposits are less dense than many sedimentary rocks and can rise, creating a salt dome. This type of feature sometimes allows oil to collect beneath it. This can be confirmed by drilling through the salt dome.

The United Kingdom is a large producer of salt with an annual output approaching 6 million tonnes. About 85% of all British salt production comes from Cheshire. There are two main ways of extracting salt.

Mining Rock salt is dug out, leaving galleries 8 m high and 20 m wide. Large pillars of unmined salt are left to prevent problems with surface subsidence. The mined salt is crushed underground to a suitable size. The material obtained is about 90 to 95% salt, together with a little mudstone. This gives 'road salt' its characteristic brown appearance. Up to 2 million tonnes of rock salt are extracted every year. Most of this rock salt is used for de-icing roads and the demand for the material varies according to the severity of the winter. An interesting practical exercise would be to obtain pure salt from rock salt and assess the purity of the rock salt by weighing.

Brine-pumping Water is pumped down one of three boreholes to dissolve the salt. Compressed air is then blown down another tube, forcing salt water (brine) up a third tube. Eventually, the caverns produced by removal of this salt reach 200 m high and 50 m wide. The material is not simply sodium chloride solution and it needs further purification before use. Although the production of salt from brine-pumping amounts to about 4 million tonnes a year, about 60 000 tonnes of impurities have to be removed from this pumped brine. The purified salt solution is then divided into two parts. Some is evaporated to produce the familiar pure white salt and the other part is pumped to factories where they use it to make sodium carbonate by the ammonia-soda process, and sodium hydroxide and chlorine by electrolysis.

There are three methods that can be used to produce sodium hydroxide and chlorine by electrolysis of the purified salt solution. These are summarised in Table 2b.

Table 2b

	mercury cell	diaphragm cell	membrane cell
construction costs	expensive	less expensive	less expensive
operating details	toxic mercury needs to be removed	frequent diaphragm replacement is necessary	membranes do not need frequent replacement needs purer brine to operate than the other two cells
sodium hydroxide product	high purity aqueous solution 50% concentration	less pure aqueous solution 10% concentration	purity similar to mercury cells 35% concentration

Analytical chemists can use a variety of methods to find the percentage of salt present in the brine. These include measurements of its density, by weighing after evaporation of the water, and by titration of the chloride present using silver nitrate solution.

This case study has made no attempt to discuss and comment on the many uses of sodium chloride and questions will not be asked on this aspect. What is clear is that salt continues to be an important commodity as the number of uses continues to rise from '101' to more than 14 000.

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