Blasts from the past: 9 The length of geological time - Charles Lyell and Mount Etna

Background

PDFs of Teaching Earth Sciences 26.3 onwards may be downloaded from the ESTA website and there is an archive section on the website that includes copies of the earlier publications of ESTA and the Association of Teachers of Geology (the precursor to ESTA). There are some useful teaching ideas in these earlier publications. Some of these ideas are being updated and re-published in the magazine under the heading: "Blasts from the Past".

A perspective on the length of geological time: Charles Lyell and Mount Etna

This activity, originally produced by Peter Whitehead (Whitehead, 1982), was based on the work of Wadge *et al* (1975). It is very difficult for students to grasp the extent of geological time and this is an exercise that encourages students to look at the ways in which geologists began to understand time. The exercise simulates how Charles Lyell tried to work out the time involved in the formation of Mount Etna in order to solve the problem of how long it had taken for all of the rock layers in Earth's history to be formed. The exercise allows pupils to use simple mathematics whilst solving a geological problem. It was designed to be used with students in Y9, Y10 and Y11 classes. The original activity has been updated and re-titled. Illustrations and web links have also been added to provide background information about volcanic activity on Mount Etna.

***Please note**: The figures used for the calculation are very rough, and the answer is not necessarily compatible with any real estimate of the age of Etna. (The principle of how to set about estimating the age of something is the key idea here)*

Introduction: Charles Lyell, Mount Etna and the length of geological time

By the 1820s William Smith (an English canal engineer) and Georges Cuvier (a French biologist) had worked out the order of formation and ages of many rock layers based on the fossils found in these rock layers. This discovery allowed scientists like Smith and Cuvier to match up rocks of the same age in sequences of rocks in different places and so work out a general order of the events in Earth's history. Unfortunately, a problem remained - there was still no way of accurately working out how long it had taken for all of the rock layers in Earth's history to have formed.

Figure 1: Charles Lyell at the British Association meeting in Glasgow 1840. Painting by Alexander Craig. [Public domain], via Wikimedia Commons.

In 1828 Charles Lyell (a Scottish lawyer and geologist) set himself the challenge of answering this problem. Lyell believed that the Earth's geological features could best be explained by the slow action of geological forces that have occurred throughout Earth's history and are still occurring today. He travelled to the south of Italy to study Mount Etna because this was one place on Earth where he knew eruptions had been happening over a long time.

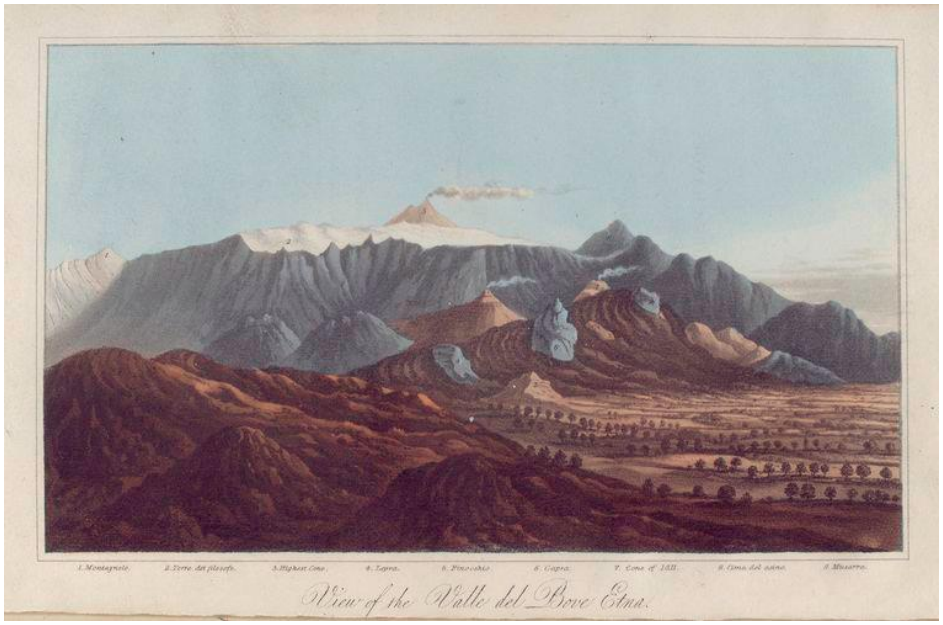

Figure 2: The frontispiece from Charles Lyell's *Principles of geology, being an attempt to explain the former changes of the Earth's surface, by reference to causes now in operation* (volume 2, 1832), showing the view of the Valle del Bove, Etna.
Drawing by Charles Lyell [Public domain], via New York Public Library Digital Collections.

Lyell found that Etna was a volcano 3km (3000m) high and roughly circular in plan, having a radius of about 25km (see Figure 3 below).

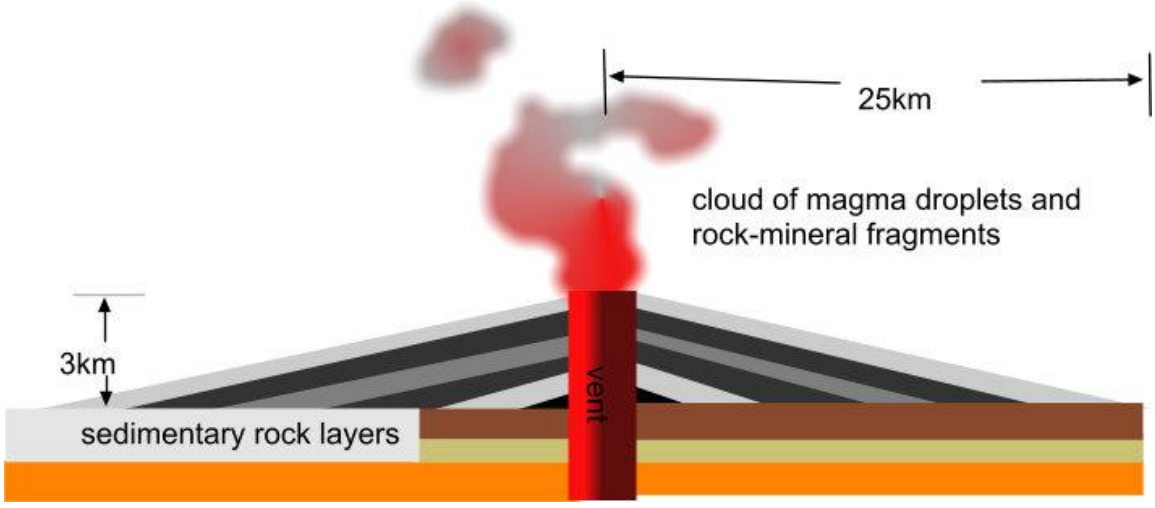

Figure 3: Sketch cross section of Mount Etna.

Lyell knew that volcanic eruptions are well-recorded events, because of the effect they have on everyday life, so he put together records of all the eruptions of Etna since Roman times. He found that on average there have been 5 eruptions every century in that time. He also found that on average

each eruption produced a lava flow 10km long, 1km wide and 2m deep. (Remember that 1km = 1000m).

The questions

Using the data given in the Introduction, try to answer the following questions, which will help you to understand how Lyell tried to work out how many years it had taken for all of the rock layers in Earth's history to have formed.

Question 1. What volume of lava is produced in an average eruption of Etna?
(Show your method of working this out and give your answer in km^3)

Question 2. What volume of lava has been produced by Etna in an average century?
(Show how you got your answer; give your answer in km^3)

Question 3. What volume of lava has been produced by Etna in the 2000 years since Roman times?
(Show your method and give your answer in km^3)

Lyell saw that the whole mountain was made of the products of volcanic eruptions, and assumed that it must have been built up at more or less the same rate since eruptions first began. (Here Lyell was using the principle that the present is the key to the past)
Lyell also saw that the total volume of material erupted since Roman times is very small compared with the total volume of the whole volcano. Therefore, the first eruption must have happened long ago.

Question 4. Using the information in the Introduction, calculate the volume of Etna. Assume the mountain is a simple cone, and use the formula:

$$V = {}^1/_3\pi r^2 h$$

where V is the volume of the cone, r the radius and h the height. Take π as 3.2.
(Show your working)

Question 5. Using your answers to Q. 3 and Q.4, calculate how long it has taken for Mount Etna to build up to its present size.
(Show your working)

Lyell now needed to fit this result into a geological column, which is a diagram that shows the rock formations arranged in the order in which they formed and showing their relations to the subdivisions of geologic time. A geological column shows the youngest divisions at the top of the diagram. An example of a geological column is shown in the table below.

Table showing the main divisions of the geological column

Era	Period	
Cenozoic (Age of Recent life)	Quaternary	Holocene epoch Pleistocene epoch
	Neogene	
	Paleogene	
Mesozoic (Age of Middle life)	Cretaceous	
	Jurassic	
	Triassic	
Palaeozoic (Age of Ancient Life)	Permian	
	Carboniferous	
	Devonian	
	Silurian	
	Ordovician	
	Cambrian	
Precambrian		

To do this Lyell needed to know during which geological period the eruptions started. He surveyed the whole of the area trying to find the lowest lava flow. Lyell based his search on the principle of superposition and looked for beds of sedimentary rocks below this lowest flow. This is because he needed to find fossils in these beds, which must be slightly older than the oldest lava of Etna. Eventually he found limestones just below the lowest lava. The fossil shells in the limestones were all almost identical with the shells of animals still living in the Mediterranean and so Lyell matched the fossils as belonging to rocks formed in the Quaternary period.

Question 6.

Look at your answer to Q. 5 and the position of the Quaternary period in the geological column. What conclusion can you draw about the age of the Earth?

Figure 4: Mt Etna, with Catania in the foreground
By BenAveling (Own work) [CC BY-SA 4.0-3.0-2.5-2.0-1.0 (http://creativecommons.org/licenses/by-sa/4.0-3.0-2.5-2.0-1.0)], via Wikimedia Commons.

Figure 5: Image from movie footage of Etna's eruptive episode (paroxysm) during the night of 16-17 November 2013.
By Boris Behncke (own work) [This file is licensed under the Creative Commons Attribution 3.0 Unported]

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