Exercise 2 Effects of volcanism (Chapter 7 of *The Cretaceous World*)

You should allow about 1 hour to complete this Exercise. You will need a calculator, a pencil and The Cretaceous World*.*

As discussed in Section 7.3.1 of *The Cretaceous World*, the global effects of effusive volcanism are difficult to quantify because they are dependent upon the height of the tropopause (the lower boundary of the stratosphere) above the eruption. We have no real way of knowing how high the tropopause was during the Cretaceous but there is one type of eruption that might have been prevalent during the mid-Cretaceous, typified by a small recent eruption which created the new island of Surtsey, south of Iceland. Surtsey began a series of episodic eruptions in early November 1963 starting with submarine eruptions in 130 m of ocean but later breaking surface to form an island about 1.5 km in diameter. Initial activity was not explosive and probably consisted of pillow lava style eruption, but as the edifice approached the surface and pressure reduced, the eruptions became phreatomagmatic (eruptions caused by the interaction of water and magma). A column of ash and steam was carried 10 km above the growing island. The eruptions lasted 3.5 years and finally resulted in lava flows being erupted at the surface, the total volume erupted being equivalent to around 1 km^3 of magma.

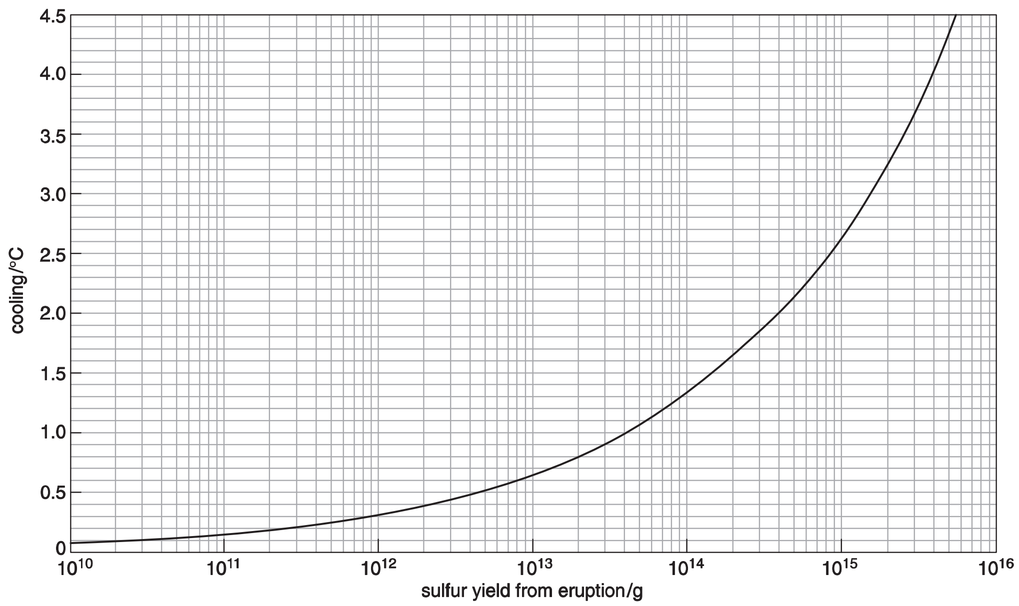
Surtsey was a small eruption yet it has some relevance to the ocean crust formed in the Pacific during the Cretaceous, since, like Iceland, many of the eruptions were associated with mid-ocean ridges and mantle plumes. You can perform a short series of simple calculations to estimate the effects of such eruptions and test whether eruptions like Surtsey occurring all over the Cretaceous Pacific might have been sufficient to affect the climate.

Question 2.1

(a) Assuming that the power of the plume was sufficient to lift sulfur aerosols from Surtsey into the stratosphere, and that sulfur was released at the same rate as the Laki eruption (0.0013 g sulfur for every gram of magma), how much cooling could a Surtsey-size eruption cause? Assume 1cm^3 of lava weighs 3g. To do this calculation you will need an approximate relationship between sulfur emitted by volcanic eruptions and the average global cooling. Haraldur Sigurdsson of the University of Rhode Island, USA, produced such a relationship by plotting the sulfur released by modern eruptions and the resulting global cooling and obtained the relationship:

$\Delta T = 5.9 \times 10^{-5}$ ºC $(S^{0.31})$

where ΔT is the temperature decrease in ºC and S is the amount of sulfur released by the eruption in grams. The line of this equation is plotted on the graph below. Use the curve to estimate the relative global cooling due to Surtsey.



Graph relating eruptive sulphur yield to mean climatic cooling effect.

(b) The actual global cooling resulting from Surtsey was too small to measure, probably less than 0.1 °C. Why do you think the cooling was less than your estimate? To help you think about this problem, plot the global average sulfur released by volcanoes every year, and the industrial sulfur output on the same graph, for comparison (you can obtain these figures from the data given in Section 7.1.4 of *The Cretaceous World*; remember the atomic weight of sulfur is about half the atomic weight of SO_2).

Question 2.2

The Ontong–Java Plateau (Figure 7.21 in *The Cretaceous World*) erupted during the early Cretaceous close to 122 Ma, and again at 90 and 60 Ma, and is the largest oceanic large igneous province (LIP) on Earth. Perhaps 2×10^6 km^3 of magma were erupted very rapidly at 122 Ma, producing a huge submarine plateau which occasionally broke surface, like Surtsey, though the ocean was much deeper than 130 m. The volcanic eruptions at that time were probably larger than Surtsey-size eruptions, and are perhaps better represented by the Laki eruption of 1783–4 or even the 14.7 Ma old Roza flow in the Columbia River Flood Basalts, which were discussed in Section 7.1.4 of *The Cretaceous World*. Given that the Ontong–Java Plateau erupted in the ocean, its interaction with water might have produced large-scale phreatomagmatic eruptions, lasting years. (a) Calculate the effects of large phreatomagmatic eruptions the size of Laki (14 km^3 magma) and the Roza flow (1200 km^3 magma) in the ocean and plot them on the graph. (b) Do you think eruptions on such scales could have had an important effect upon the climate around 122 Ma ago? Think also about the effect that the inclusion of large quantities of water in the plume might have had upon global climatic effects.