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Explosive Volcanic Eruptions – Processes and Hazards

The aim of this exercise is to investigate explosive eruption processes for two different types of magma, and to consider how and why this leads to different hazards and impacts.
Additional introductory information will be provided. Discuss the questions in small groups as you go through the worksheet.

A. Explosive eruption processes

Magma is a silicate liquid, containing variable amounts of other elements and dissolved volatiles, such as H_2O, CO_2 and SO_2, and potentially mixed with crystals and a gas phase. A key influence on magma behaviour is its viscosity, which is affected by several factors. A high silica content results in extensive silicate polymerisation, increasing viscosity. Water and cations (e.g. ions of Na, Ca) break up these polymer chains.

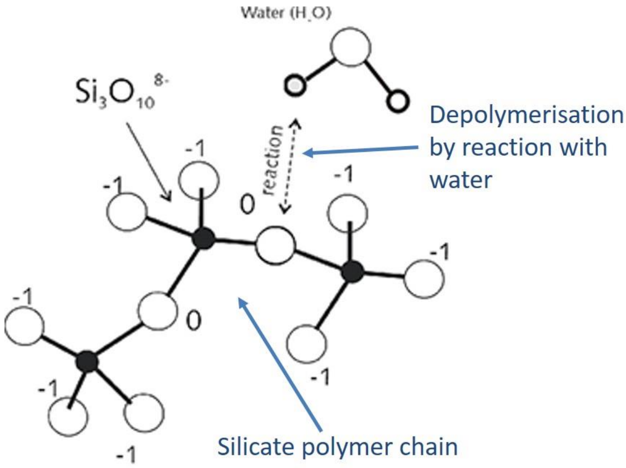

Fig. 1: Silicate polymerisation in magma *(https://www.alexstrekeisen.it/english/vulc/index.php)*

i. Discuss how different factors might affect magma viscosity, completing the table below:

	Effect on viscosity *(mark with arrows to show high/low viscosity)*	
Low silica content - mafic (e.g. basalt, ~50 wt% SiO_2)		*High silica content - silicic (e.g. rhyolite, ~75 wt% SiO_2)*
Low water content		*High water content*
Low temperature		*High temperature*
Crystal-free magma		*Crystal-rich magma*

As well as viscosity, a key influence on the eruptive behaviour of magma is its volatile content. The solubility of volatiles depends on pressure. As magma ascends towards the surface, volatiles begin to come out of solution as pressure decreases. This exsolution results in a gas phase (bubbles) forming in the magma. It is this gas phase that is responsible for driving explosive eruptions.

For magma to erupt *explosively*, there needs to be sufficient gas exsolution to fragment the magma.

ii. Why might magma erupt *effusively* (e.g., forming lava flows), rather than explosively?
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If magma erupts explosively, the fragmented mixture of gas and pyroclastic material can ascend into the atmosphere. The clasts are then transported by wind as they fall back to the surface. The resultant *tephra fall deposits* are well-sorted and become thinner and finer-grained with distance from the volcano. They blanket the topography, and are easily recognised from these characteristics.

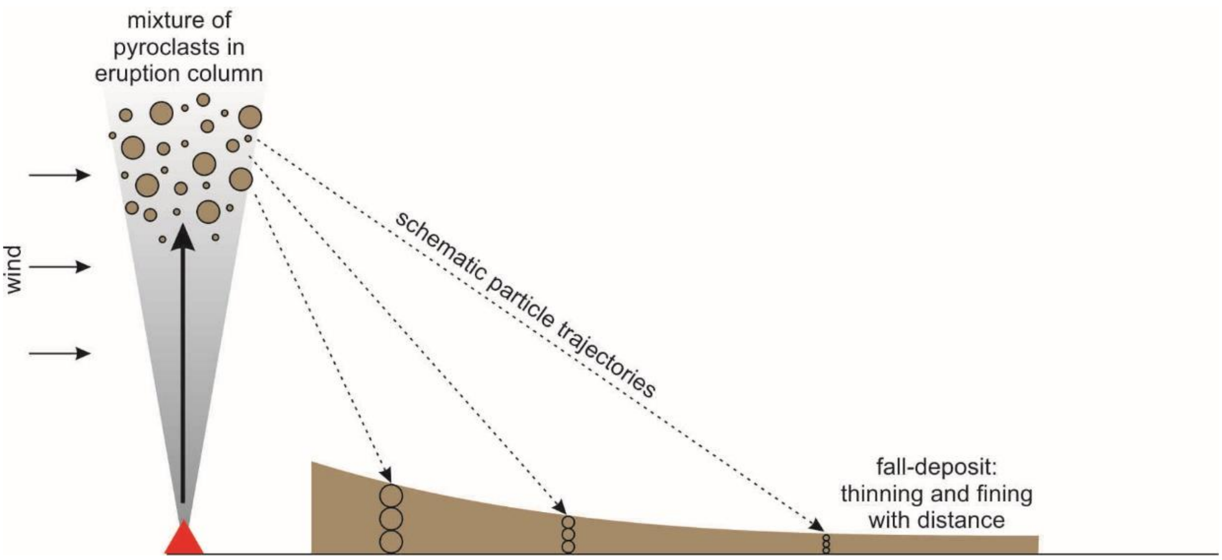

Fig. 2: Characteristics of fall deposits produced by explosive eruptions

iii. What factors do you think influence how far the tephra particles in fall deposits travel from the volcano?

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B. Comparing two different magmas

You are geologists assigned with advising on the potential impacts of an *explosive* eruption at Volcano X. There are no historically recorded eruptions of Volcano X and there is very little geological information about the volcano. Seismic monitoring beneath the volcano has detected increasing numbers of volcano-tectonic earthquakes (small earthquakes resulting from rock fracturing driven by magma movement) at increasingly shallow levels, suggesting that an eruption is imminent. It is probable that the initial stages of the eruption will be explosive.

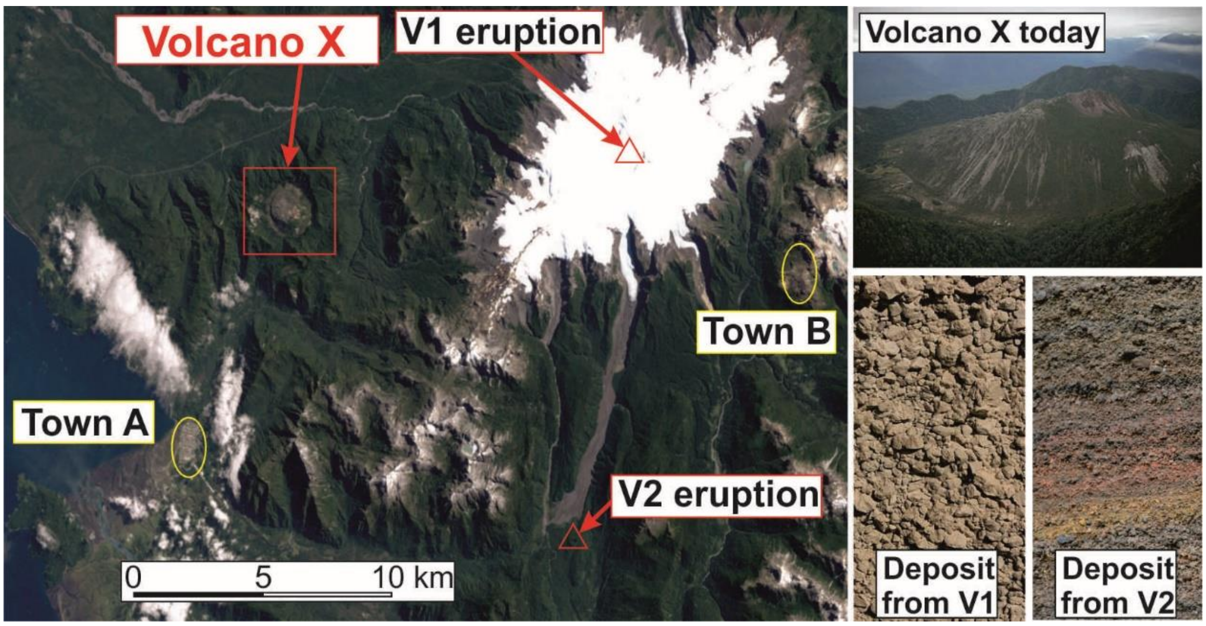

Fig. 3: Map of Volcano X and the nearby sites of eruptions V1 and V2.

Because so little is known about volcano X, you decide to compare deposits from the most recent explosive eruptions of two nearby volcanoes – eruptions V1 and V2.

i. You are provided with samples from eruptions V1 and V2. Describe these in terms of their texture, colour, density and any other physical characteristics.

	V1	**V2**
Physical characteristics of pyroclasts:		

ii. Which of V1 or V2 has smaller bubbles? Why is this (think about magma viscosity, and how this might affect the ability of gas bubbles to expand and coalesce)?

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It is bubble formation and expansion that breaks the magma apart in the explosive eruption process.

iii. Which magma do you think would produce more *volcanic ash* (particles <2 mm diameter; consider how bubble size might control the efficiency of fragmentation)?

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Can you give names to V1 and V2 (basalt, rhyolite – refer to the table on page 1)?

C. Fall deposits and explosive eruption hazards

The thicknesses of tephra fall deposits from the V1 and V2 eruptions have been measured at several field sites around the volcanoes. These measurements of fall deposit thickness (in cm) are shown on the maps on the final page. Note the different scales of the two maps.

i. Sketch *isopachs* (contours of thickness values) on each map for values of 1 m, 10 cm, and 1 cm (don't worry about being too precise, just base your contours on the available field data).

Mark an arrow to show the prevailing wind direction that influenced each eruption.

ii. What is the maximum distance of the 10 cm isopach from the volcano? 10 cm marks the approximate thickness when roof-collapse of buildings starts to occur.

Maximum extent of 10 cm isopach for: V1: …….. km V2: …….. km

iii. What is the approximate area affected by >10 cm of tephra deposition in each eruption?

Area of 10 cm isopach: V1: …….. km^2 V2: …….. km^2

The graph below shows average wind measurements from a nearby weather station.

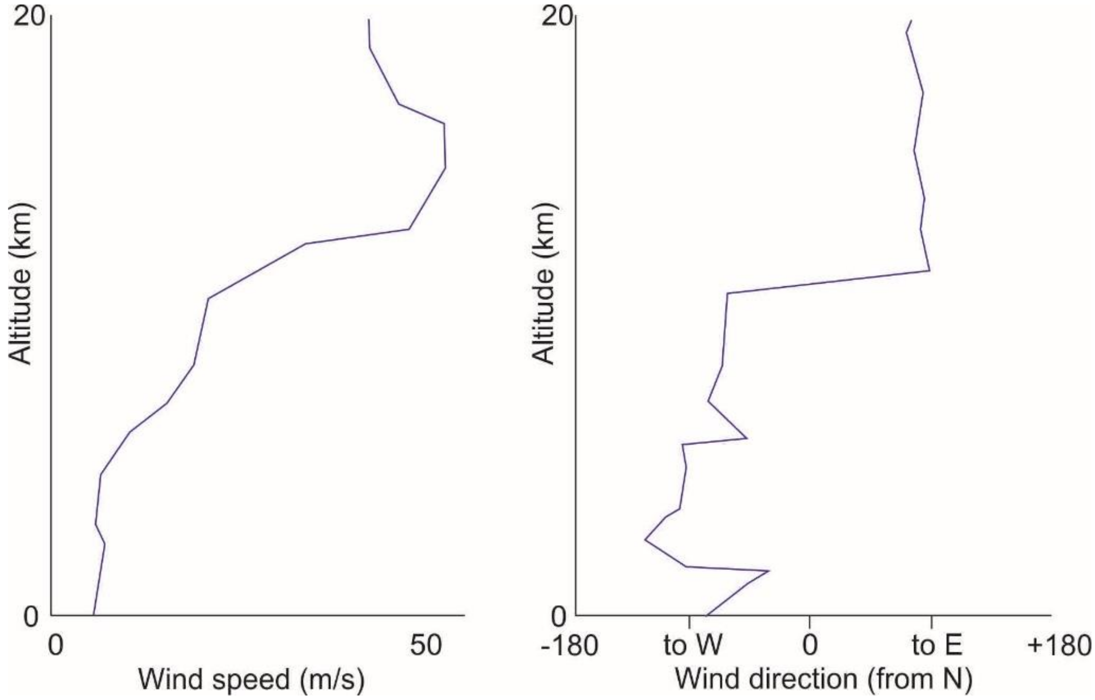

Fig. 4: Average wind conditions near Volcano X, showing speed and direction against altitude

iv. Based on your isopach maps and wind directions, do you think the V1 or V2 eruption reached higher into the atmosphere? Why (consider magma properties and explosivity)?

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v. Finally, you have analysed a rock from Volcano X and find that it is rhyolite.

Discuss the following:

- Is V1 or V2 the best analogy for a potential eruption at Volcano X?
- Is roof collapse a potential hazard in Town A and Town B (Fig. 3)?
- What other impacts might we expect from the eruption?

The scenario discussed here is hypothetical, but is based on the eruption of Chaitén volcano, Chile, in May 2008 (shown in Fig. 1). It wasn't thought to have erupted in the past 10,000 years, and was a relatively small, rhyolite lava dome. The explosive eruption led to a wide variety of impacts across an area around the size of the UK.

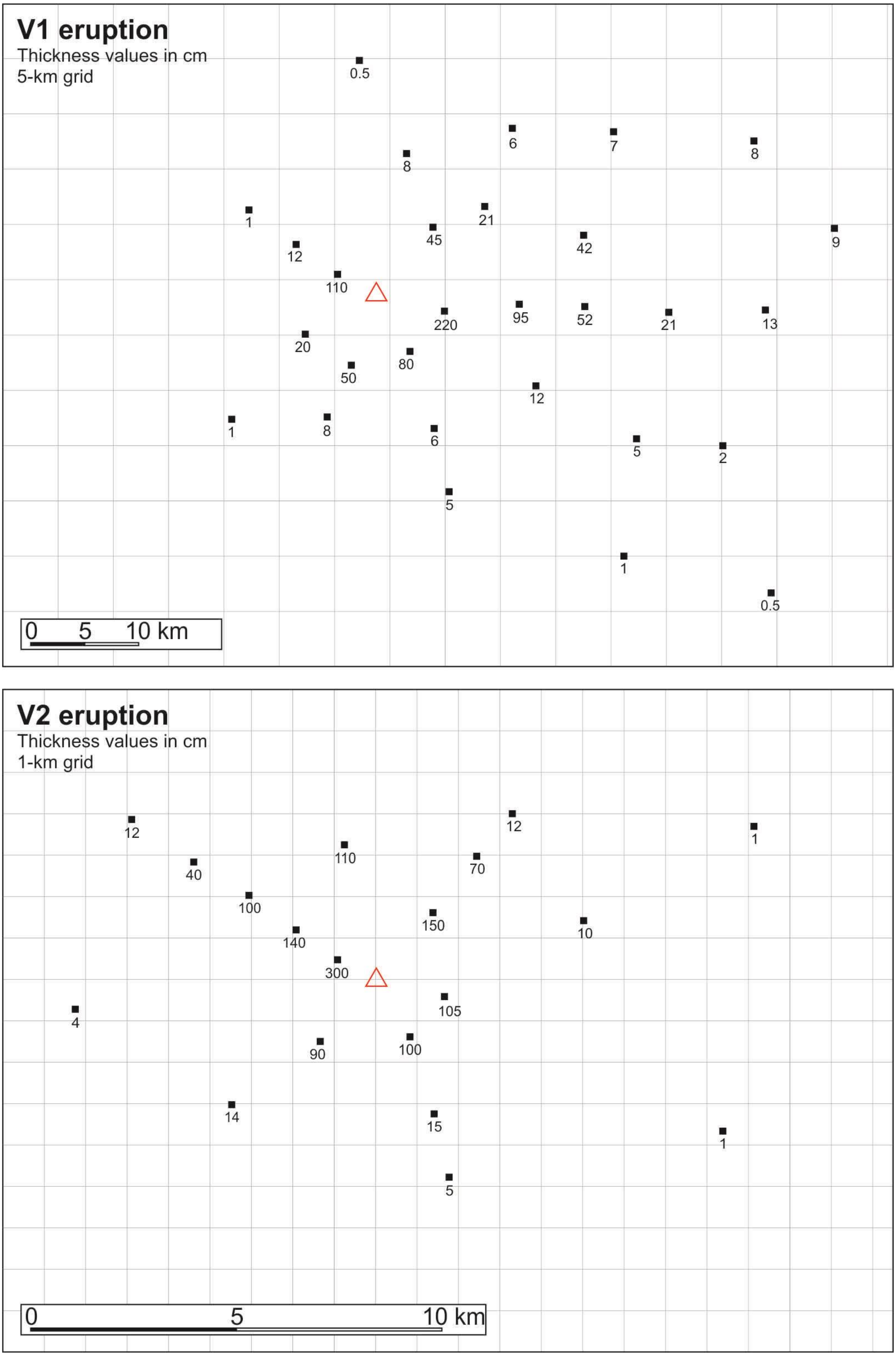

Fig. 5: Thickness measurements of fall deposits from eruptions V1 and V2.