Building silicates

Simulating crystal size during the cooling of magma and during recrystallization in solid rock

Silicates are the most common rock-forming minerals in the Earth's crust. The basic unit of all silicate minerals is the silicon/oxygen tetrahedron (SiO_4) in which one silicon atom is bonded to four oxygen atoms forming the shape of a regular tetrahedron.
This can be simulated by attaching four balls, representing the oxygen atoms into a tetrahedral shape (a smaller silicon ball within the centre) or, alternatively, as a ball-and-stick model (silicon excluded) using a magnetic construction kit such as **Geomag™**. (For a cheaper alternative, use large marshmallows (oxygens) and cocktail sticks linked by Blu Tack™, to increase the crystal size).

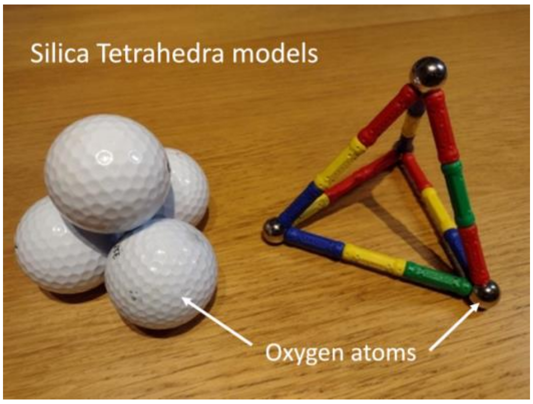

Fig 1. Silicon/oxygen tetrahedron models (*Pete Loader*)

Simulation of crystal size in a cooling magma

- Split the **Geomag™** kit into three containers, each with four balls but different numbers of magnetic rods to make up the sides of the tetrahedra. (It is suggested that the three tetrahedra are made up with sides of one, two and four magnetic rods per side).
- Demonstrate the building of one tetrahedron to the whole group and revise silicate structure (See Fig 1).
- Identify three 'volunteers' and explain they are each going to make a tetrahedron from the components in their container but **must use all the pieces**. Explain they are in competition with each other to see who can be first to complete their tetrahedron.
- Students complete the tetrahedra and they are displayed according to the order in which they were completed ('crystallised') (Fig 2).
- Ask students the following questions: -
  (i) which tetrahedra 'crystallised' first – grew the fastest? (*the smallest*)
  (ii) which took longest to 'crystallise'? (*the one with the larger sides*)
- Students are asked to consider the size of the crystals in a selection of chemically similar igneous rocks (e.g. gabbro, dolerite and basalt). What hypothesis related to cooling might be used to explain the size of crystals in igneous rocks? (*the larger the crystals the slower the cooling rate and vice versa*).
- Tell the volunteers to dismantle their tetrahedron and repeat the exercise (as a fair test). Seconds after commencing, stop the simulation and ask volunteers to hold up the tetrahedra they have been able to form in the time given. (*no crystals will have formed*).
- Ask students how this might fit into the hypothesis and what sort of rock texture might form? (when *cooling is too rapid to form crystals = glassy texture)*

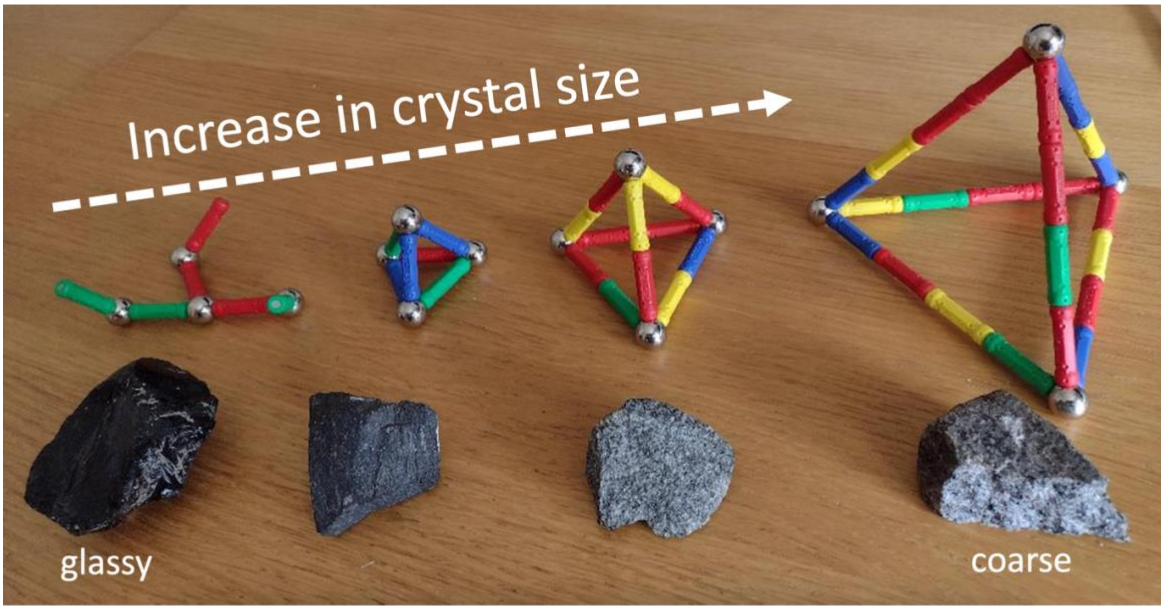

Fig 2. Tetrahedra arranged showing rates of cooling linked to rock texture (rapid/glassy to slow/coarse from left to right) *(Pete Loader)*

Simulation of recrystallisation close to a large igneous intrusion.

Arrange the tetrahedra in size order as before and tell students they represent the mean crystal sizes of the country rock (i.e. the surrounding rock) affected by the heat from a large igneous intrusion. The heat has caused the country rock to recrystallise (metamorphose).

Using a rock specimen of granite to represent a large igneous intrusion ask students to:

- place the specimen where they think the contact might be between the intrusion and the country rock,
- discuss their reasoning (Fig 3).

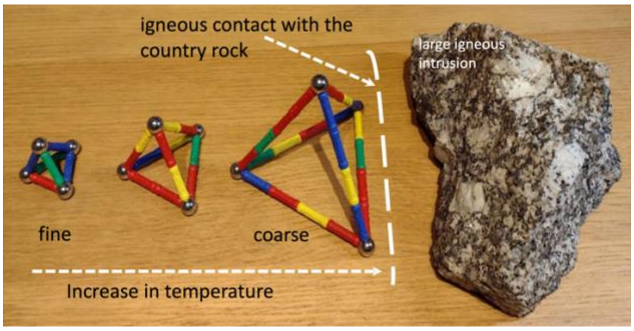

Fig 3. Tetrahedra arranged to simulate the change in crystal size with distance from a large igneous intrusion *(Pete Loader)*

The back up

Title: Building silicates

Subtitle: Simulating crystal size during the cooling of magma and during recrystallization in solid rock

Topic: A consolidation exercise to show how cooling/recrystallisation rates might explain crystal size in igneous and metamorphic rocks.

Age range of pupils: 16 – 18 years

Time needed to complete activity: 15 minutes

Pupil learning outcomes: Pupils can:

- explain the relationship between crystal size in igneous rocks and rates of cooling,
- suggest reasons for the variation in grain-size in some igneous rocks, linked to variations in cooling rates,
- identify the link between grain-size and the degree of metamorphism of the country rock close to a large igneous intrusion.

Context:
The simulation provides a model relating crystal size to the rates of cooling. Usually, the larger the crystal size of an igneous rock, the slower the cooling rate and vice versa. Coarse crystalline igneous rocks (granite or gabbro) form slowly at depth, whereas finer crystalline volcanic rocks, such as basalt, represent lava that cooled quickly at the surface. Igneous rocks, with both large and smaller crystals (e.g. the granite in Fig. 3) are considered to have had two stages of cooling.

Crystal size of the country rock close to a large igneous intrusion depends upon how long the minerals in the parent rock were subjected to high enough temperatures to recrystallise them. Generally, the longer that recrystallisation has had to take place, the larger the crystals. Larger crystals are therefore found nearer the contact with a large igneous intrusion.

Note:

- Igneous rocks typically contain several minerals which crystallise at different times and rates and so have different sizes.
- This represents a simplified model of cooling related to grain-size.

Following up the activity:

- Show students a granite with both large and smaller crystals and ask them to discuss why the crystals might be of different sizes in the same rock.

Underlying principles:

- In igneous rocks, usually the larger the crystal size the slower the rate of cooling.
- The slower the cooling rate the longer the rock has to crystallise/recrystallise.
- An igneous rock with both large and smaller crystals may show 2 stages of cooling. (deeper/slower cooling then faster as the magma intrudes higher).
- Close to a large igneous intrusion, the country rock will have been heated for longer, resulting in a larger mean crystal size which gets smaller with distance from the intrusion.

Thinking skill development:
Slow cooling resulting in large crystals and fast cooling in small crystals develops a pattern. Rocks containing both large and smaller crystals may cause cognitive conflict. Explaining and discussing the results obtained involves metacognition. Applying the results of the activity to the crystals in igneous rocks involves bridging.

Resource list:

- a magnetic construction kit such as **Geomag™** – or equivalent
- a model of a silicon/oxygen tetrahedron (4 golf balls, or equivalent, stuck together)

Useful links:
https://www.earthlearningidea.com/PDF/94_Salol.pdf
https://www.earthlearningidea.com/PDF/100_Crystallisation_in_pudding_dish.pdf

Source: Activity devised and written by Pete Loader of the ELI Team. Photos by Pete Loader