GRAVITY SETTLING

Purpose

To plot the speed of fall of olivine, augite and plagioclase in glycerol and to calculate the speed of fall of crystals in basic and acid magma.

Background and data

Glycerol has a density of 1261 kg m^{-3} and a viscosity of 1.4kg $s^{-1}m^{-1}$ at 20°C

Use the following densities for the minerals and magma

For basic rocks

Olivine, 3500 kg m^{-3} augite 3400kg m^{-3}

plagioclase (an) 2700kg m^{-3}.

Basic magma at 1200°C 2600 kg m^{-3}

For acid rocks

Plagioclase (ab) 2600kg $m^{-3.}$ orthoclase 2600kg m^{-3}

quartz 2700kg m^{-3}

Basic magma at 1200°C has a viscosity of 30kg $s^{-1}m^{-1}$

Acid magma at 1000°C has a viscosity of 10^{12}kg $s^{-1}m^{-1}$ and a density of 2200kg m^{-3}

Activity 1

1 Set up three tables like this each with 10 clear lines.

Mineral name			Distance of fall				
Mineral density			Glycerol				
			Temperature	density	viscosity		
Diameter mm of an individual grain			Average diameter (d) mm	Type of fall	Time s	speed (v) m s^{-1}
maximum	medium	minimum				

2 Record the temperature of the glycerol

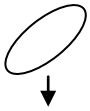
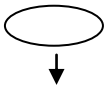
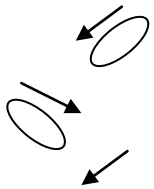
3 Choose a sample and if more than 5mm use the callipers to measure it. If it is less than 5mm put it on the graph paper and estimate its size.

4 Hold it in the centre of the measuring cylinder, just above the glycerol and let it fall. If it is a small crystal you may need to use the wire to prod it through the capillary film to start its fall.

5 Start the timer as soon as the crystal reaches the top of the top rubber band and stop it when it reaches the top of the lower band. Make sure you have your eyes at the same level as the rubber band to avoid parallax effects.

6 Repeat for several different sizes and for each of the minerals.

7 Record on the table above the type of fall.

				
sphere	End first	oblique	side first	zigzag

8 Calculate the speed of fall in metres per second.

9 Plot a graph of speed of fall (v) against the square of the average diameter (d^2).

Activity II Photomicrographs

Examine the photomicrographs and measure the diameter of the olivine augite and plagioclase grains.

Activity III Calculations

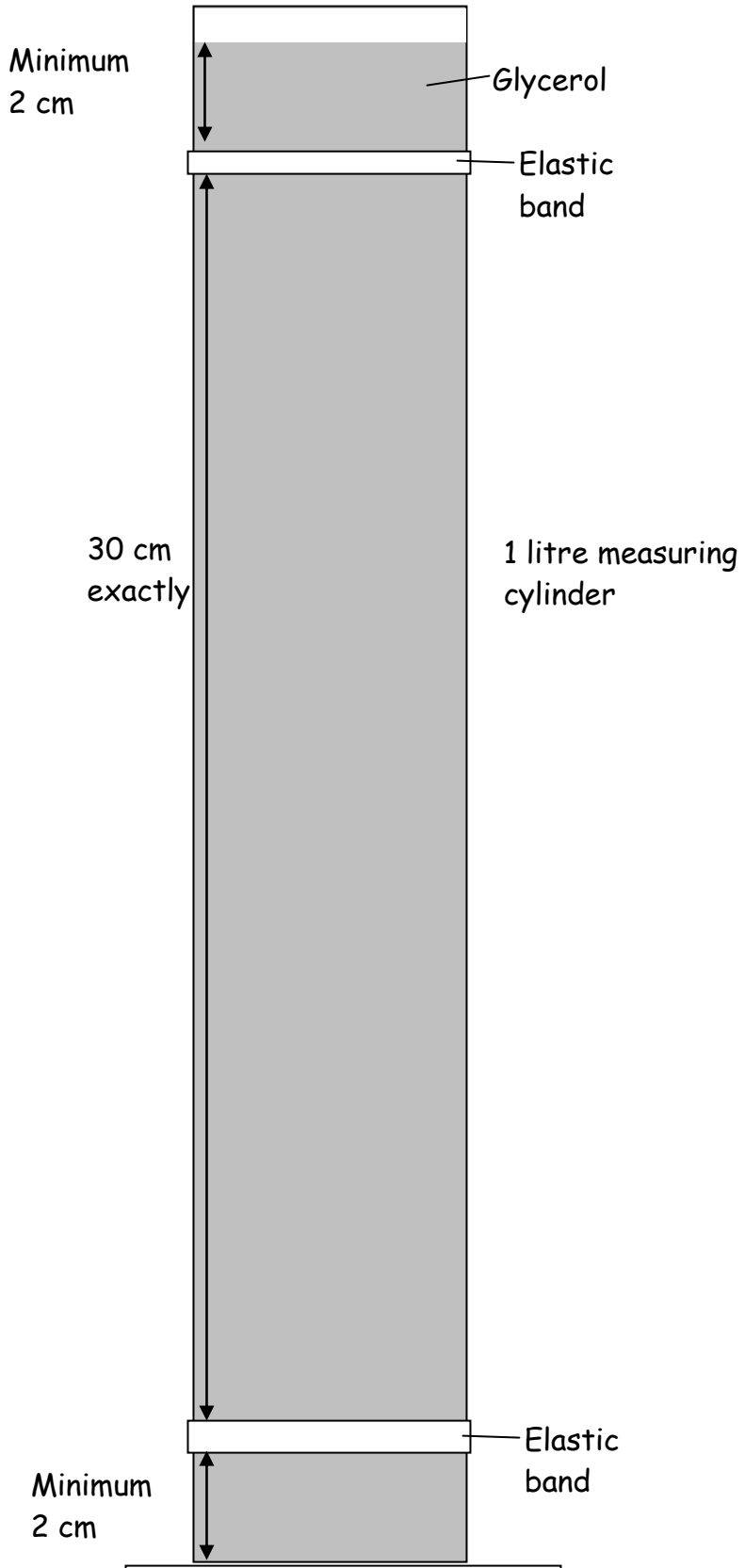
The speed of fall is given by Stokes' equation.

$$\text{Velocity} = \frac{(\text{density of mineral} - \text{density of liquid}) \times g \times d^2}{18 \times \text{Viscosity}}$$

$g = 9.8 m\ s^{-2}$. d = diameter of grain in metres. The densities are in kg m^{-3} and the velocity in m s^{-1}

Viscosity kg $s^{-1}m^{-1}$

Work out the speed of fall of grains in the photomicrographs. Adjust the speed to take account of the different density and viscosity of the liquid, magma not glycerol.
Now calculate the speed of fall of the minerals in an acid magma.



Teacher's Section

Requirements

1 litre measuring cylinder
1.2 litres of glycerol
2 elastic bands to fit tightly around the measuring cylinder
Several (about 10) different sized crystals or pieces of the following minerals: olivine, augite and plagioclase. These should range in diameter from 10mm to 1mm.
Timer
Thermometer
Photomicrographs of olivine cumulate.
Small piece of Graph paper (normal with 1mm squares)
wire such as an unfolded paper clip
Tweezers
Callipers

Setting up

Pour the glycerol into the measuring cylinder. Pour it very slowly onto the side of the measuring cylinder to avoid getting bubbles in the glycerol. Place the top elastic band 2cm from the top of the glycerol and the lower one exactly 30cm below that. Make sure the bands are horizontal all around the cylinder. See diagram.

Notes

The experiment can be done by a student on his own or in pairs. Each pair can do one mineral and then collect data from other pairs.
At the end drain as much glycerol out of the measuring cylinder as possible. Then shake the minerals out onto tissue paper. The glycerol will drain off over night. Typing the data into a spreadsheet and allowing it to do all the calculating makes life easier.

Checks

Make sure the students lower themselves so that their eyes are level with the elastic band when timing the fall. With the slower grains there is a danger the students loose concentration and fail to notice when the grain reaches the lower band.

Results

Students should note that it is difficult to measure the size of small grains accurately. Stokes' equation is for spheres and the grains are not spheres. Useful class discussion can be had on the effect of this coupled with the type of fall, or the speed of fall. The line on their graphs should go through the origin.

Olivine crystals 1mm diameter should fall in glycerol at 20°C at about 1mm s^{-1}. Because of the high viscosity and small difference in density between minerals and magma the rate of fall is extremely small in acid magmas, 10^{-7} cm per year.

Time

30 minutes for each mineral

Cost

Minerals 10 pieces each of augite, olivine and plagioclase £13

Glycerol £28 for 2.5 litres

Data on viscosity of magma from Hall, A 1987 Igneous Petrology Longman London