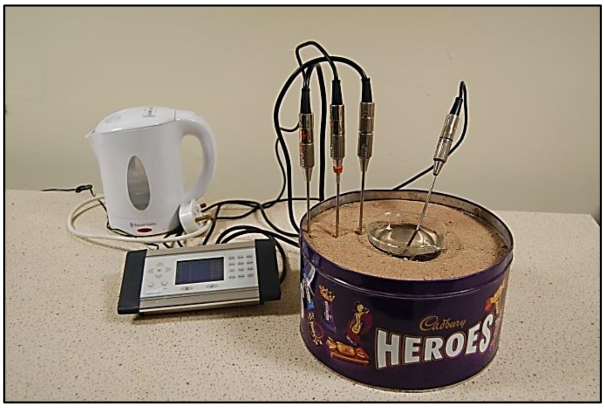
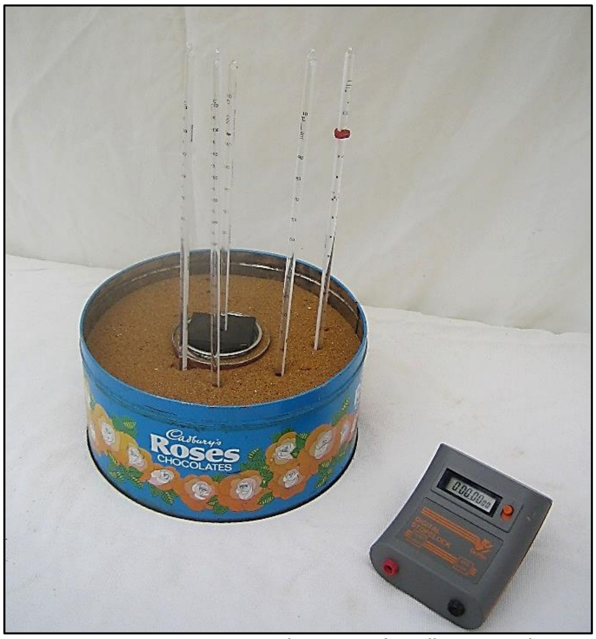
Metamorphic aureole in a tin
Investigate what controls the changes in temperature around an igneous intrusion

When a mass of molten rock (magma) intrudes into existing rocks (country rock), the heat of the magma affects the rocks near the intrusion. The country rock is metamorphosed, and its texture may be altered as new minerals are formed. This activity models the rate at which heat travels through the country rock and how this relates to the distance from the intrusion.
Set up the apparatus as shown in the diagram on page 2 and in one of the photographs.

The apparatus consists of a circular cake tin or container (which may be plastic). In the centre place a metal tin, or a glass beaker, with a lid, but don't fill it with hot water until everything else is ready; i.e. fill the space around it with dry sand, well shaken down, and insert 3 or 4 thermometers, or data logger probes, at increasing distances from the central container, with the bulbs/probes about 5cm deep.



Apparatus set up to measure the rates of cooling around an 'intrusion' of hot water into sand using a central glass beaker and a datalogger with 4 probes. (*Chris King*).



Apparatus set up to measure the rates of cooling around an 'intrusion' of hot water into sand using a central metal tin with a lid and five thermometers . (*Mike Tuke*).

If students are using thermometers, ask them to prepare a table as shown, but with about 30 lines. When data loggers are available, the screen provides a graph of the variations in temperature over time.

Time	Temperature of water ^oC	Temperature of sand ^oC			
		1	2	3	etc.

etc.

Record the temperature at each thermometer, or start the data logger, and pour boiling water into the central container. Put the lid on the hot water container and insert a further thermometer through a hole in the lid, to a depth of 5cm in the water. Start the timer and record the temperature at each thermometer every 2 minutes. The temperature will rise and will then begin to fall. Readings may be stopped when the last thermometer shows a fall in temperature.
If there is sufficient equipment, groups of students may simultaneously be set variations on the basic activity, e.g. by using damp sand instead of wet sand, or by varying the size of the hot water container. Alternatively, if time allows, the investigation may be repeated several times, varying the factors as above.
Plot all the temperatures on a single sheet of graph paper, or record the results from the data logger.
How does the temperature change with increasing distance from the 'intrusion'? (*The maximum temperature reached decreases with distance from the hot water-filled central container. The furthest probe or thermometer shows the longest time to reach maximum temperature*).

How does the temperature at any one place change with time? (*Temperature rises quite quickly and then gradually reduces with time. The* *innermost probe/thermometer shows a particularly rapid rate of increase*).

If it has been possible to change the size of the container of hot water, or to use damp sand instead of dry sand, students should compare their results by contributing to a table such as that below, (with one line per group), or should compare data logger outputs:

Time to maximum temperature								
Name of student group	Diameter	Dry or damp sand?	Thermometer					
			1		2		3	
			Time	Temp °C	Time	Temp °C	Time	Temp °C

etc

They could then be asked:
How does the size of the intrusion affect the size of the metamorphic aureole? (*The larger the central container, the slower its cooling rate, and the further away will the heat reach.*

Does damp sand transmit heat energy more or less quickly than dry sand? (*Damp sand cools more quickly than dry sand because circulating water aids heat removal*).

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The back up

Title: Metamorphic aureole in a tin

Subtitle: Investigate what controls the changes in temperature around an igneous intrusion

Topic: An investigation modelling the factors affecting changes in temperature around an igneous intrusion, using a container of hot water embedded in sand.

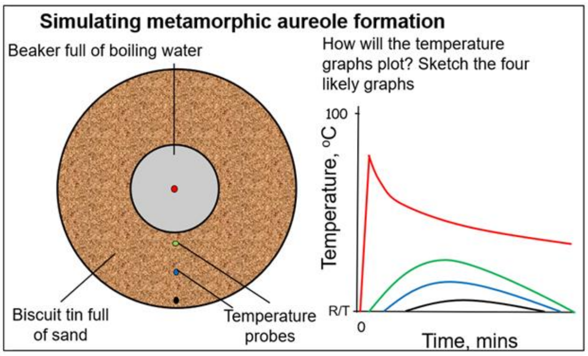
Age range of pupils: 14 – 19 years

Time needed to complete activity: About an hour if variations are conducted consecutively. If data loggers are available, the investigation can be set up and left to run whilst other work is undertaken.

Pupil learning outcomes: Pupils can:
- describe how changes of temperature are related to distance from a hot body;
- describe how changes of temperature are related to the time during which the hot body has been in place;
- describe how the size of the hot body affects the width of the heated zone around it;
- describe how the size of the hot body affects its rate of cooling.

Context: The activity can be used to aid the understanding of the processes acting around an igneous intrusion, in the context of teaching about metamorphism.

By asking the pupils to draw sketch cooling curves before the activity is carried out, you will encourage them to think through the cooling process and deepen their understanding of the activity.



Likely sketch cooling curves (*Chris King*).

Following up the activity:
Study a metamorphic aureole around a major igneous intrusion, looking for evidence of the effects of heat upon the country rocks, and variations in mineral content and rock texture with distance from the intrusion.

Underlying principles:
- Rising magma forms an <u>intrusion</u> when it solidifies, cools and crystallises below ground. This may be exposed later by erosion of the overlying country rock. Magma which erupts at the surface as lava (i.e. as an <u>extrusion)</u> may affect the rocks beneath it to a limited extent, but this is not sufficient to create a metamorphic aureole.
- The rise of temperature in rocks adjacent to an igneous intrusion is dependent on the distance from the intrusion, the size of the intrusion and the properties of the country rocks themselves.
- Larger igneous bodies cool down more slowly than smaller ones.
- A slower cooling rate allows more time for new minerals to form in the country rocks.

Thinking skill development:
A pattern is constructed as students plot their temperatures and compare them with distance from the 'intrusion'. Cognitive conflict may arise

when the results of using dry sand compared to damp sand are considered. Relating the investigation to a real metamorphic aureole involves bridging skills.

Resource list:

- large round tins, e.g. cake tins or chocolate tins (plastic is acceptable)
- several smaller metal tins or glass beakers of varying diameters. e.g. from 55mm to 100mm.
- dry sand
- 4 or 5 thermometers, or data loggers for each set up (1 in water, 3 or 4 in sand)
- timers if necessary
- kettles to boil water

Useful links: The British Geological Survey website shows the outcrops of many roughly circular igneous intrusions, such as that of the Shap Granite, although the widths of their metamorphic aureoles are not shown. See: http://mapapps.bgs.ac.uk/geologyofbritain/home.html?location=wickersgill

Source: First published by Mike Tuke in *Earth Science Experiments for A Level*, Earth Science Teachers' Association and Petroleum Exploration Society of Great Britain 2007.