The space within – the porosity of rocks
Investigating the amount of pore space between the 'grains' of a model 'rock'

Make a model sedimentary 'rock' by packing any roughly sphere-shaped things of the same size into a suitable container (e.g. a small bucket). The objects could be fruit, spherical beads, ball bearings, etc. They are like the grains which make up a sedimentary rock, e.g. sand grains in a sandstone.
Mark the level of the top of the objects around the inner rim of the bucket.
Add water to fill the spaces between the 'grains'. (If the objects tend to float, they may need to be held down by hand, as in the photograph, or by using a wire mesh).
Pour out the water into a container of known volume, e.g. a measuring cylinder or a 2 litre soft-drinks bottle, and record the volume of water which was needed (W_1). Remove the spheres and measure the total volume of the container up to the mark made previously, by filling it up with water (W_2).
Porosity is measured as the space between the grains, compared with the total volume. It is shown as a percentage, i.e. W_1 / W_2 x 100%.
In the example using oranges in a bucket, in the photograph, the values were W_1 = 700 ml; W_2 = 1900 ml = 36.8% porosity.

Repeat the activity, using a measured volume of loose dry sand in a clear plastic container. Add a known volume of water up to the top of the sand, allowing plenty of time for it to trickle through all the sand. Measure the volume of water needed to saturate the sand. In the example in the photograph, the volumes were W_1 = 160 ml; W_2 = 500 ml = 32.0% porosity.

Measuring the porosity of a container of oranges

Measuring the 'porosity' of a container of glass marbles

Measuring the porosity of a container of loose sand
(*Photos: P. Kennett*)

You can get the pupils more involved in this demonstration as follows: when a container is full of spheres, ask 'Is it full'? It is after they answer 'Yes' that you add the water to show that there was still lots of space.

Similarly, before pouring in the water, ask them to predict how much water could be added. Most will be surprised at how much water can be poured in – and that apparently solid materials can be more than a third space.

Natural sandstones have porosities that range up to around 50%, so they may have plenty of space for water or oil/gas. Natural clays can have porosities up to more than 80% - but they are often impermeable, since the pore spaces are so small that water cannot flow through.

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The back up

Title: The space within - the porosity of rocks

Subtitle: Investigating the amount of pore space between the 'grains' of a model 'rock'

Topic: Investigating the porosity of large scale 'models' of sedimentary rocks by filling up the gaps between the 'grains' with a known volume of water.

Age range of pupils: 11-18 years

Time needed to complete activity: 20 mins

Pupil learning outcomes: Pupils can:
- test the porosity of a model in the classroom;
- work out the percentage pore space;
- explain why some rocks are porous;
- apply their knowledge of rock porosity to real world situations, such as oil and gas reservoir rocks and rocks containing water (aquifers);
- (in the context of other activities from the earthlearningidea series) explain the difference between porosity and permeability.

Context:
Underground water supplies and reserves of oil and gas depend on the presence of porous rocks, which are capable of holding such fluids in their pore spaces.
The lesson could form part of an investigation in science or in geography, or could be used when pupils are trying to understand why their country has, or lacks, good underground water, oil and gas resources.

Following up the activity:
Pupils can gain some idea of the porosity of real rocks by slowly dripping water onto the top surface of various samples and seeing how long it takes for the water to soak in. This will enable them to put the rocks in rank order of their porosity.
If equipment is available, the porosity of a rock sample may be measured more accurately as follows: The sample is thoroughly dried out, e.g. in an oven, and then weighed (in grams) before and after being immersed in water for several days. Since the density of water is 1 gram per ml, the numerical value for the volume taken up by the rock sample is the same as the difference in mass before and after soaking it.
The volume of the rock sample may be obtained by wrapping it in thin plastic and immersing it in a measuring cylinder half-full of water and noting the rise in water level (in ml).

Underlying principles:
- Porosity is the percentage of pore space in a material, (rocks which are good for holding oil/gas and water often have around 15% porosity).
- The maximum theoretical porosity for spheres packed one above the other (simple cubic packing) is 48%.
- The most porous rocks are well sorted sandstones (with grains of similar sizes).
- Oil, gas and water are held in the pore spaces of rocks and are not generally found as underground lakes.
- To be useful as a reservoir rock, the pore spaces must be interconnected, to allow fluids to flow within the rock. This is called ‘effective porosity’.
- Porosity is the percentage of the rock which is composed of pore spaces: permeability is a measure of the rate at which fluids can pass through a rock.

Thinking skill development:
- Several different materials can be tried, to establish a pattern of porosity.
- Cognitive conflict arises when a porosity measurement turns out differently from the pupils’ predictions.
- Metacognition skills come into play when pupils try to work out the reasons.
- Applying the results to economic situations such as oil or water supplies involves bridging.

Resource list:
- a small bucket and a quantity of roughly spherical objects, such as oranges, beads, ball bearings
- the base of a plastic soft-drinks bottle and dry sand (e.g. about 500g)
- a measuring cylinder or a plastic soft-drinks bottle of known volume
- water
- optional – a balance and a measuring cylinder
- optional – samples of different rocks

Useful links: Try the Earthlearningidea activities ‘Modelling for rocks: what’s hidden inside and why?’ (published December 1st 2007) and ‘Permeability of soils - the great soil race’ (published 28th April 2008).

Source: This activity is based upon a more rigorous approach, described under the title ‘Experiments on porosity and permeability: Part 1’, by D.B. Thompson in *Geology Teaching* (Now *Teaching Earth Sciences*) Vol 4.1 March 1979 pp 26 – 31.