# WATER STORAGE AND MOVEMENT IN ROCKS

## POROSITY AND PERMEABILITY

- **Groundwater** is the water retained in the pore spaces of rocks below the water table.
- **Porosity** is the volume of pore space in a rock or sediment.

Porosity is usually expressed as a percentage of the total rock's volume.

Porosity (%) = (total vol. of pore space X 100) / total volume of rock

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*A simple practical to calculate % porosity of some sediments:*

1. *Measure out three equal volumes of different sediments using a measuring cylinder. Weigh the initial mass of each sample using a top pan balance.*
2. *Place the samples into separate beakers. For example, angular, rounded and mixed.*
3. *Add water to each beaker so each sediment becomes saturated in water but ensure the water level does not exceed the level of the sediment.*
4. *Reweigh each sample. The mass of water in each sample is equal to the difference in mass (final – initial) for that beaker.*
5. *Apply the following calculation to get the volume of water in each sample:*
   *Mass of Water (g) / Density of water (1g/cm3) = Volume of water (cm3)*
6. *Volume of pore space = volume of water*

   *So use: Porosity (%) = (total vol. of pore space X 100) / total volume of rock*

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- **Permeability** is the rate at which a fluid flows through a rock.

This is determined by the ability for the fluid to pass through the rock.

Permeability = (distance the water has travelled X 100 )/ time taken

This can be measured in cm/s or m/s etc.

## FACTORS AFFECTING POROSITY

The most obvious factor affecting porosity is rock type. Crystalline igneous and metamorphic rocks have virtually no porosity. Porosity only comes about within these rocks if there are fractures (joints or faults). Sedimentary rocks however, are affected by the following….

- The degree of sorting. Well sorted rocks have a higher porosity than a poorly sorted rock. This is because finer grains have the ability to fill in the spaces that occur between coarser grains. On the contrary, this would not happen if only one grain size were present.
- The amount of diagenesis. A loose unconsolidated rock has a higher porosity than a rock which has undergone compaction and cementation, which both work to reduce porosity.
- The grain shape. Rocks containing rounder grains have a higher porosity than those with angular grains, which fit together.
- The packing/tessellation of the grains is the way the grains fit together

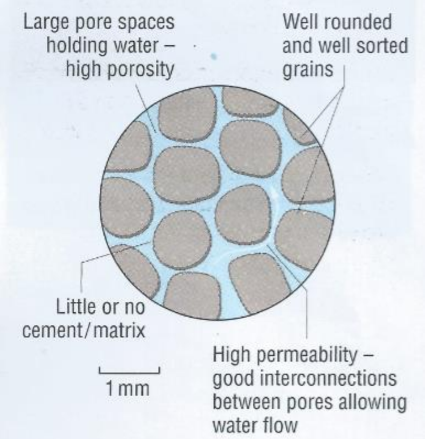


**Figure 1** Thin section diagram of desert sandstone with high porosity and permeability

Grain size is not a factor affecting porosity since the coarser the grains are, the larger the pore spaces but the fewer there are. Fine grained rocks have more pore spaces but they are much smaller.

Rocks can develop secondary porosity through features like joints and faults. This is particularly so in limestones. **Porosity is only creates effective permeability if the pore spaces are interconnected.**

**Sandstones:** Most pore spaces are interconnected, porosity of ~ 15%

**Clay**: pore spaces are not interconnected as much, it has a porosity of 50% but its effective porosity is zero.

| Rock type | Porosity / % |
|---|---|
| Sand | 35 |
| Limestone | 10 |
| Sandstone | 15 |
| Clay | 50 |
| Shale | 18 |
| Granite | 1 |
| Basalt | 1 |

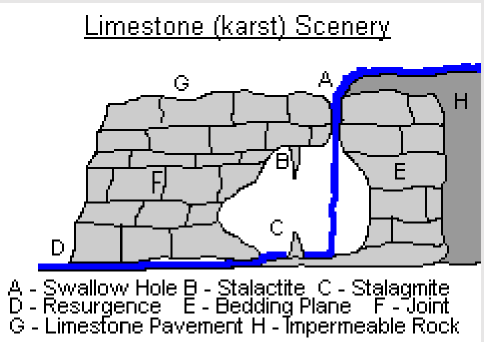
## FACTORS AFFECTING PERMEABILITY

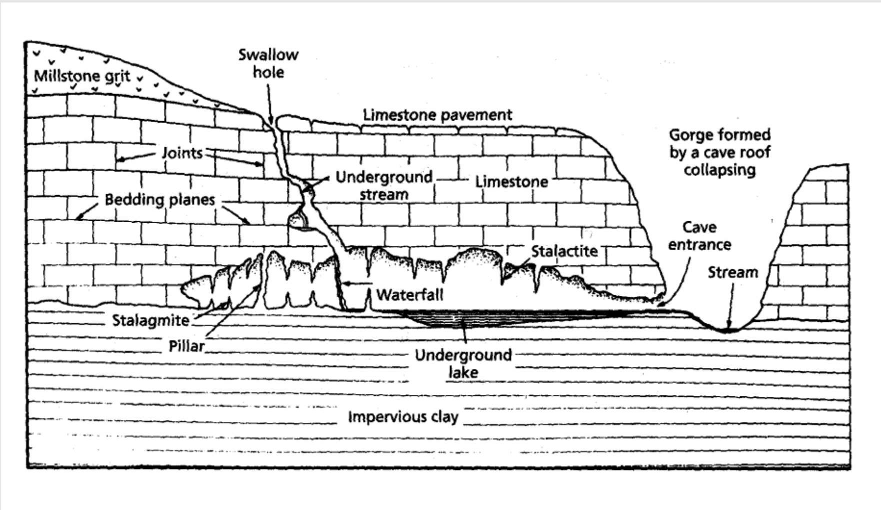
A rock with a high porosity and good interconnections between pore spaces will also have a high permeability. Although grain size is not a factor in porosity, it is important in determining permeability.

Coarse grained rocks have a higher permeability than fine grained rocks because there is a lower surface area around coarser grains than fine grains, reducing resistance to flow around the grains.

Secondary permeability results from the presence of fractures, such as joints and faults, **and voids, such as caves** produced by solution.

**Limestone tends to have a high permeability** by virtue of the secondary structures which increase pore spaces and their interconnect ability.




## GROUNDWATER AND THE WATER TABLE

- **<u>Water table =</u>** The surface separating unsaturated rock above from saturated rock below.
- **<u>Hydrostatic pressure</u>** = the pressure at a point in a body of water due to the weight of the overlying column of water.

- **Hydraulic gradient** = the difference in hydrostatic pressure ( or hydrostatic head) between two points divided by the distance between them.
  Most groundwater originates from rainwater that has infiltrated into soil and then percolated downwards through the pore space of rocks to reach the water table.

  The water table is the level at which the water sits within the ground. Rocks above the water table are unsaturated and have air in their pore space. Rocks below are saturated in water. The shape of the water table will generally follow the overlying topography, but with less relief, and intersects the ground surface at most lakes and rivers. The position of the water table can change depending on the season and amount of rainfall.

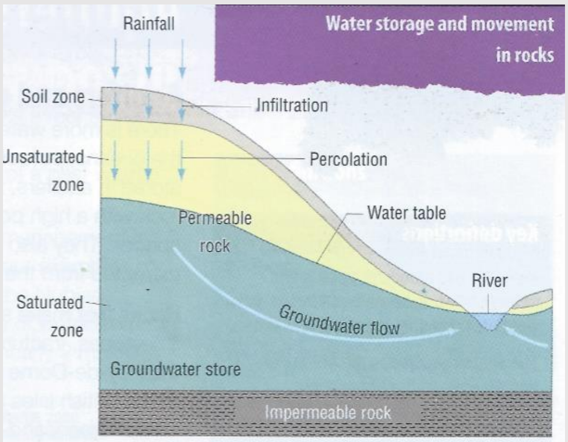



**Figure 2** Cross-section of groundwater zones and the water table

## GROUNDWATER AND THE WATER TABLE

Hydrostatic pressure results from the weight of the overlying column of water and increases with depth (Pressure = density X gravity X depth).
**The height of the overlying column of water is called the hydrostatic head.**

Ground water flows due to pressure differences. Water will always flow down the hydraulic gradient from areas of higher pressure to areas of low pressure. The rate at which the water flows is proportional to the drop in hydrostatic head.
These principals are used to model the flow of water.
Hydraulic gradient (ratio) = difference in hydrostatic pressure (or hydrostatic head) / distance between two points

Hydrostatic head can be used rather than the difference in pressure since Pressure *PROPORTIONAL TO* Depth (when gravity and density are constants).

### Worked example: calculating the hydraulic gradient

Figure 3 is a cross-section through part of the South Downs in Sussex. Calculate the hydraulic gradient of the water table between points A and B.

$$\text{Hydraulic gradient} = \frac{\text{difference in hydrostatic pressure or hydrostatic head}}{\text{distance between two points}}$$

$$= \frac{130 - 100}{300} = \frac{30}{300} = 0.1 \text{ or } 1{:}10$$

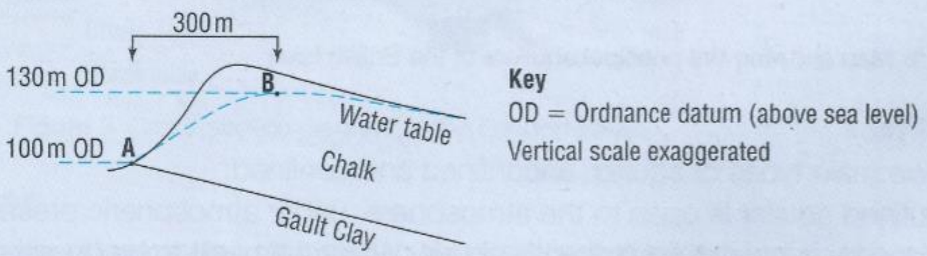



**Figure 3** Cross-section through part of the South Downs in Sussex