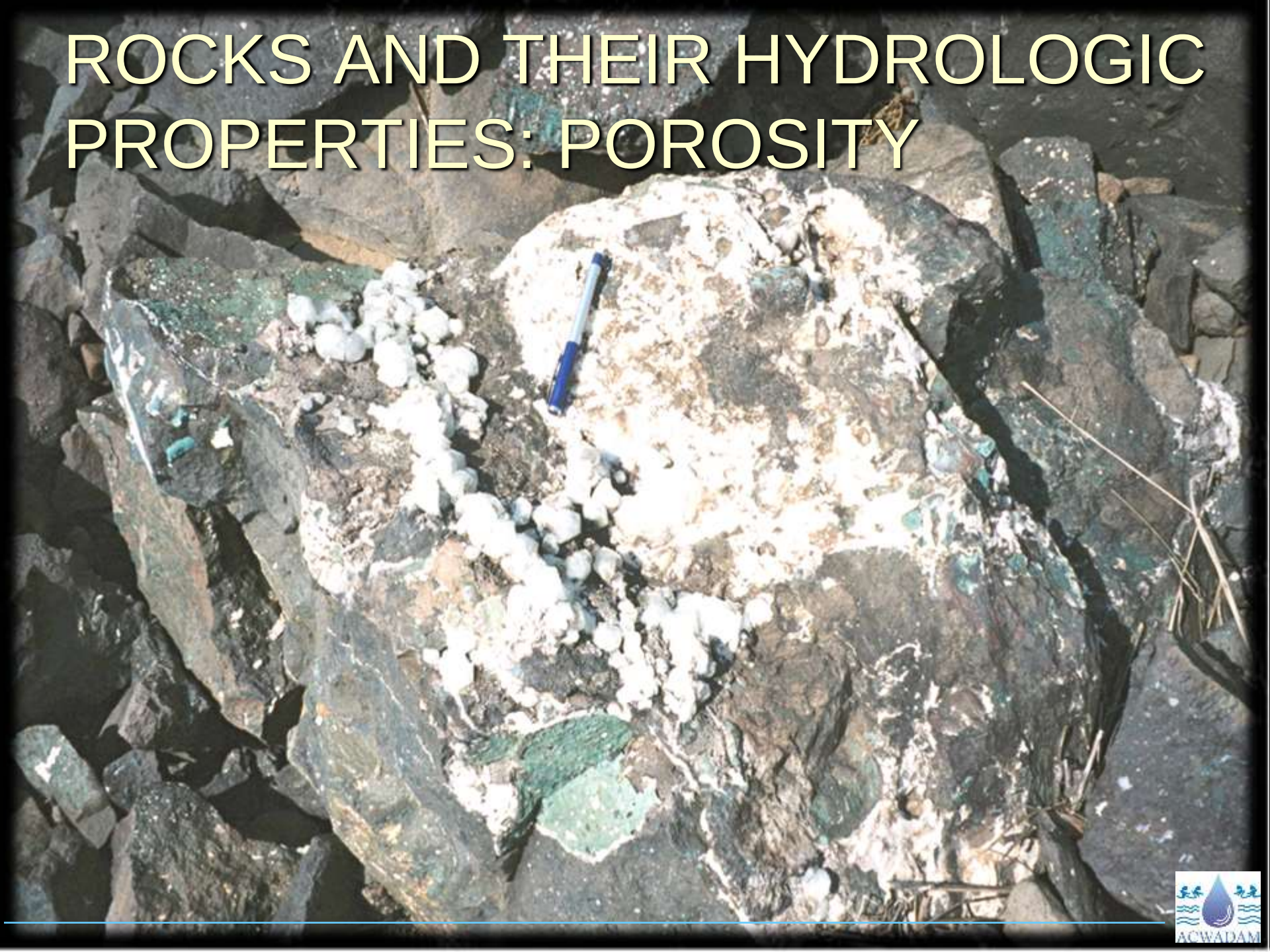
ROCKS AND THEIR HYDROLOGIC PROPERTIES: POROSITY



Can you imagine how water flows into a well or how it flows to a spring?

Rocks have openings of different shapes and sizes…

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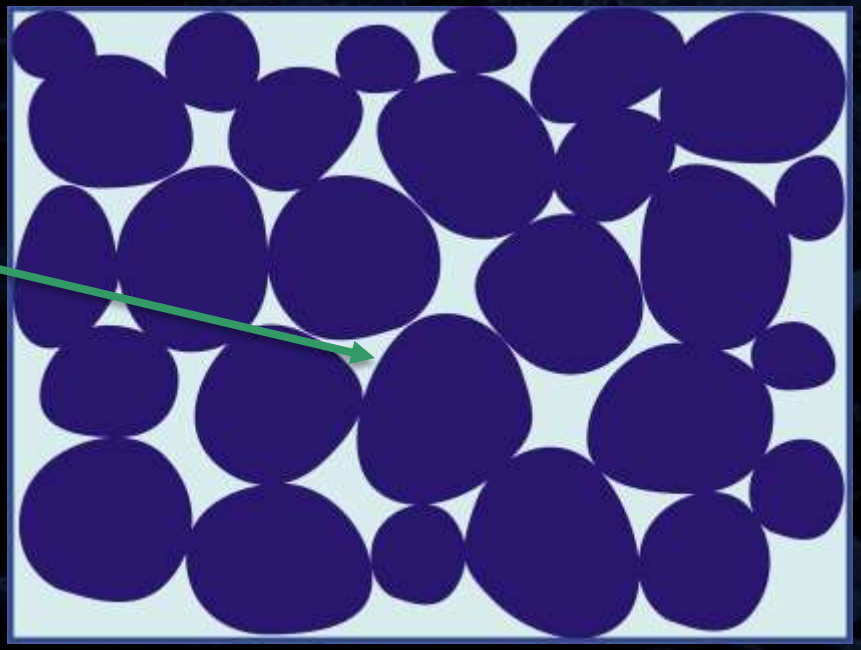
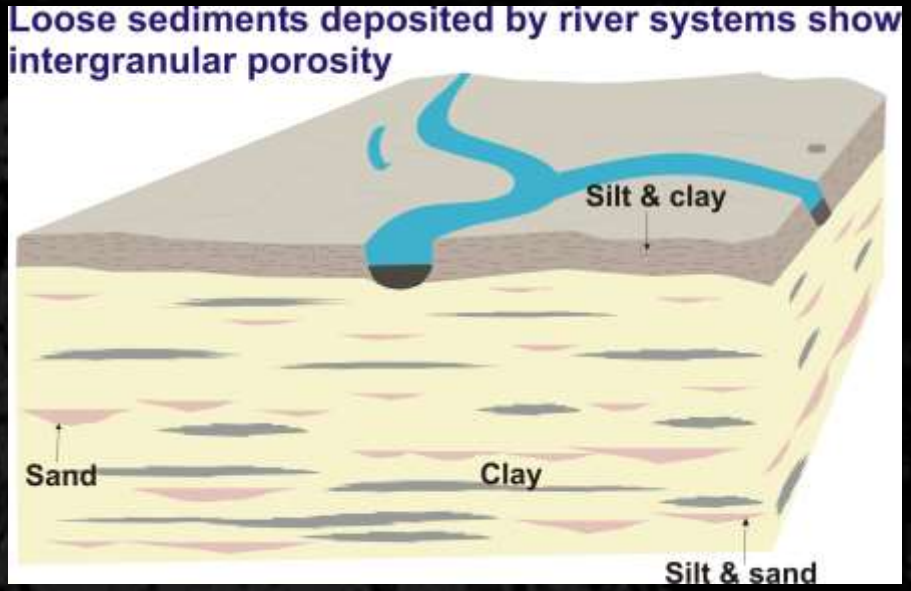
Porosity

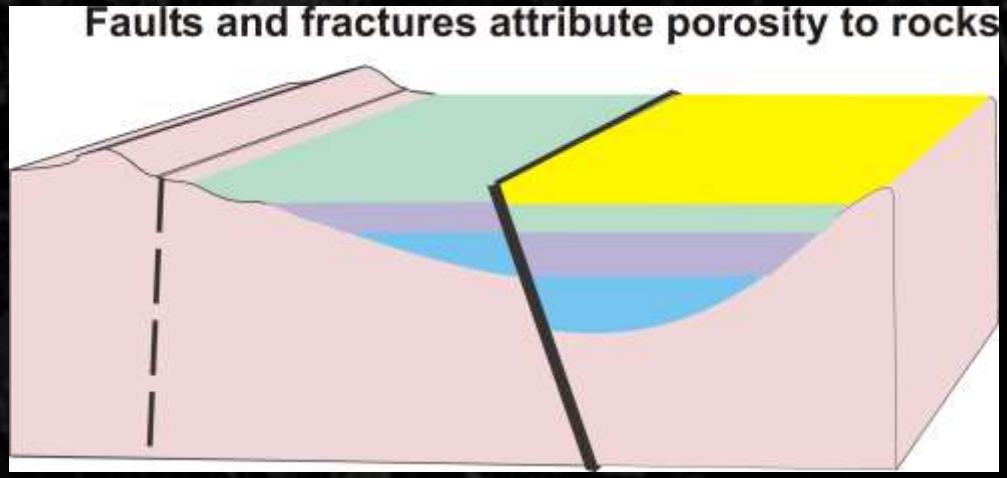
- Material that contains voids or openings is said to be *porous*.
- The property is called POROSITY.



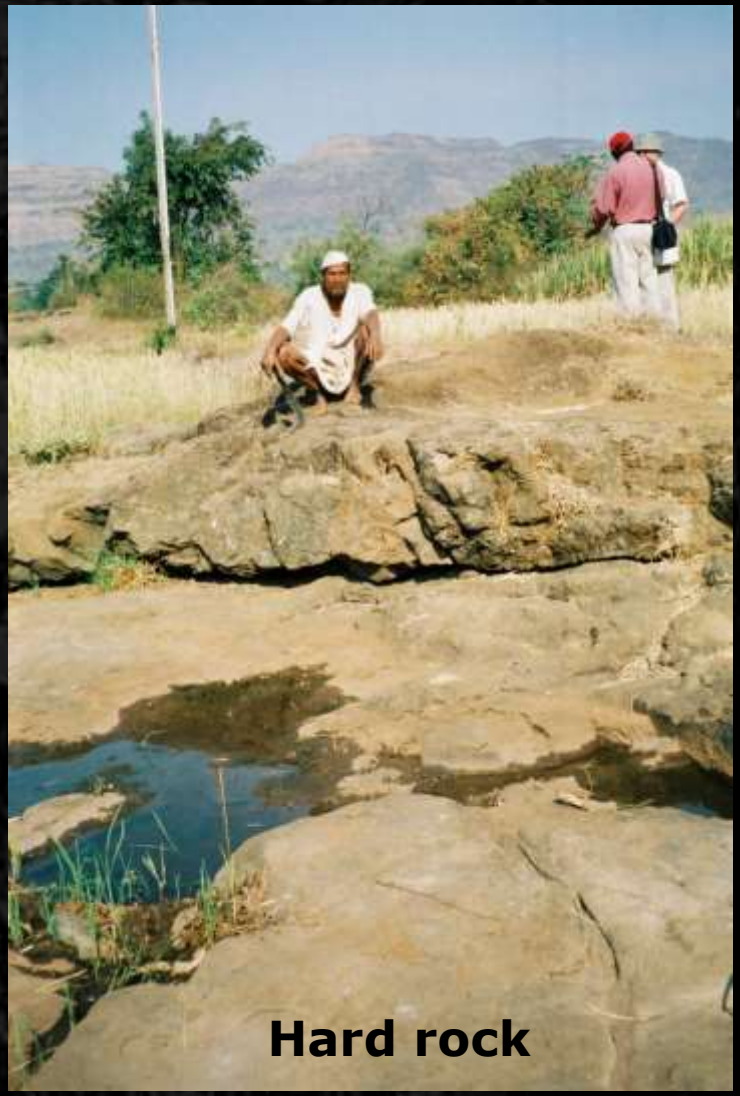
Types of rock openings that attribute porosity to rocks

- Between grains – *intergranular*
- Within grains – *intragranular*
- Vesicles in basalts
- Joints and fractures – divisional planes that have some opening
- Solution channels from where rock material has been removed in solution, in limestones, for instance
- Lava tubes or tunnels





Porosity in alluvium (gravel, sand & clay) is different from porosity due to fractures in hard rock



Practical manifestation of porosity – the floor mop case 1

- Water spilled on the floor can be wiped with a mop or sponge.
- The mop absorbs the water because it is porous in nature - POROSITY.
- Squeezing the mop drives out some water.
- Does the mop go dry…completely???

Can you relate this concept to water in rocks?

Floor mop, rocks and porosity

- How much water was mopped up?
- Is it equal or less than the volume of the mop?
- Does squeezing out the mop release all the water mopped up?

Can you write this in some volumetric form of an equation?

Porosity, as a number

- Represented as percentage or fraction related to the finite volume of the rock.
- Porosity in percentage is a ratio given by

ή or φ=

(Vol of openings/Total vol of rock sample)x100

- e.g. if the total volume of rock is 100 m^3 and the volume of openings within the rock is 40 m^3 then the porosity in %

= (40/100)x100

= 0.4x100

= 40%

- 100% porosity is considered as 1.00 units in fraction. Hence, 40% porosity in fraction means a value of 0.4.

10% porosity means 0.1
50% porosity means 0.5
75% porosity means 0.75 and so on…

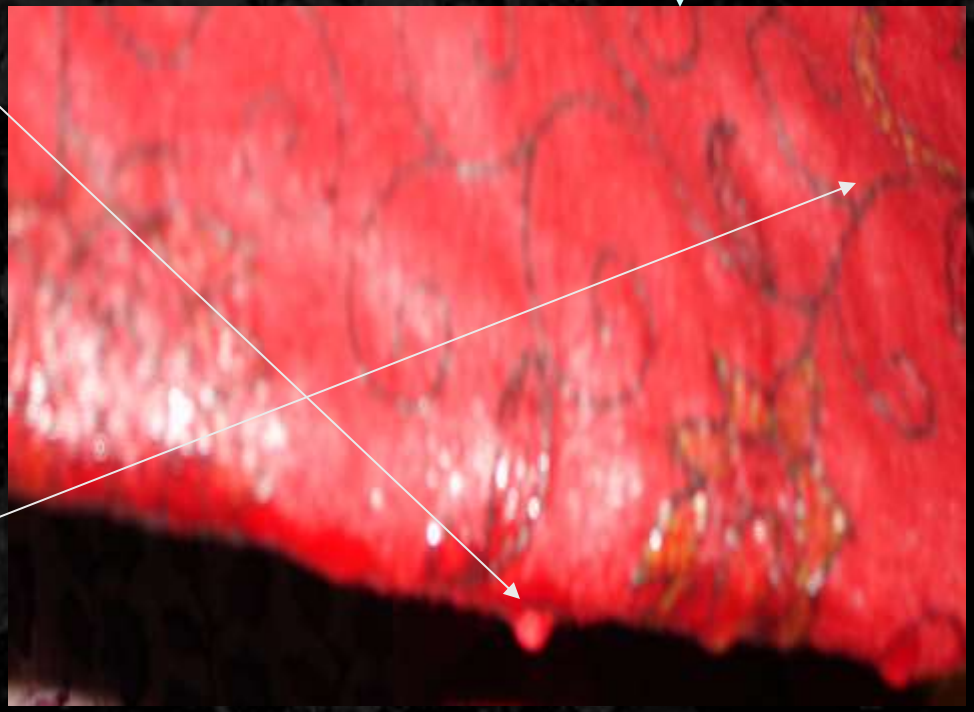
Types of porosity in different rocks

- Primary porosity – rocks acquire porosity during their formation through an arrangement of grains
  - intergranular porosity in sedimentary rocks or
  - vesicles in volcanic rocks
- Secondary porosity – rocks acquire porosity due to processes like weathering and fracturing acting on the rock after its formation
  - weathering
  - joints
  - fractures & faults
  - solution channels.

Porosity is that part of the volume of rock (open phase) not occupied by rock material (solid rock phase)

Practical manifestation of porosity – the clothesline case 2

- A wet kurta hung out to dry…
- The kurta "yields" part of the water stored within its pores…
- However, even after water is drained out the kurta remains wet; some water is "retained".



Rocks yield some water and retain the rest…

Porosity….from a more practical angle

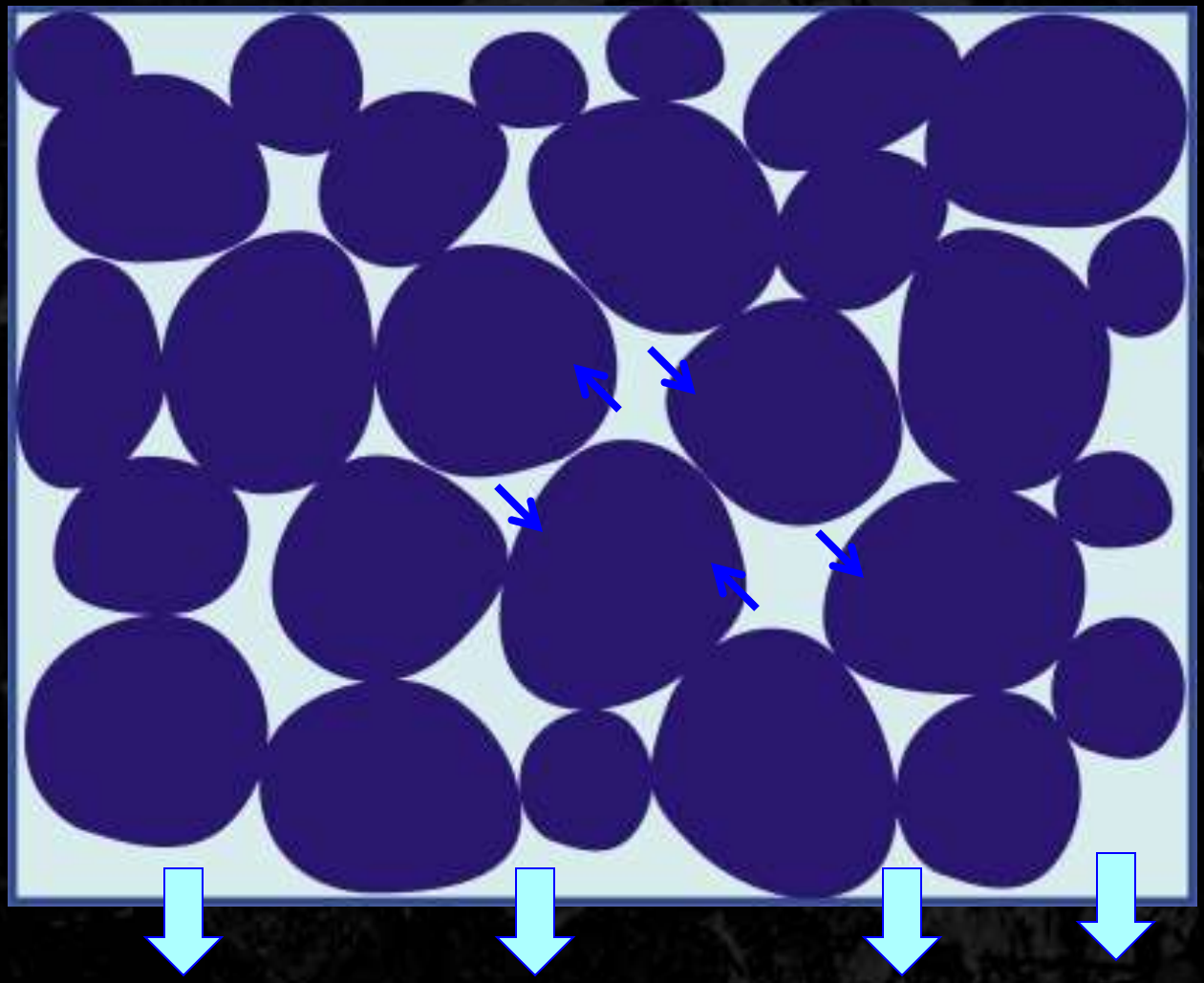
- Porosity is an indicator of how much groundwater the rock will store.

- In reality, however, we are interested in the **quantity** of water a saturated volume of rock will release or yield from this storage.

Porosity= specific yield + specific retention

Gravity

↖Surface tension, cohesion, adhesion



Specific yield and specific retention

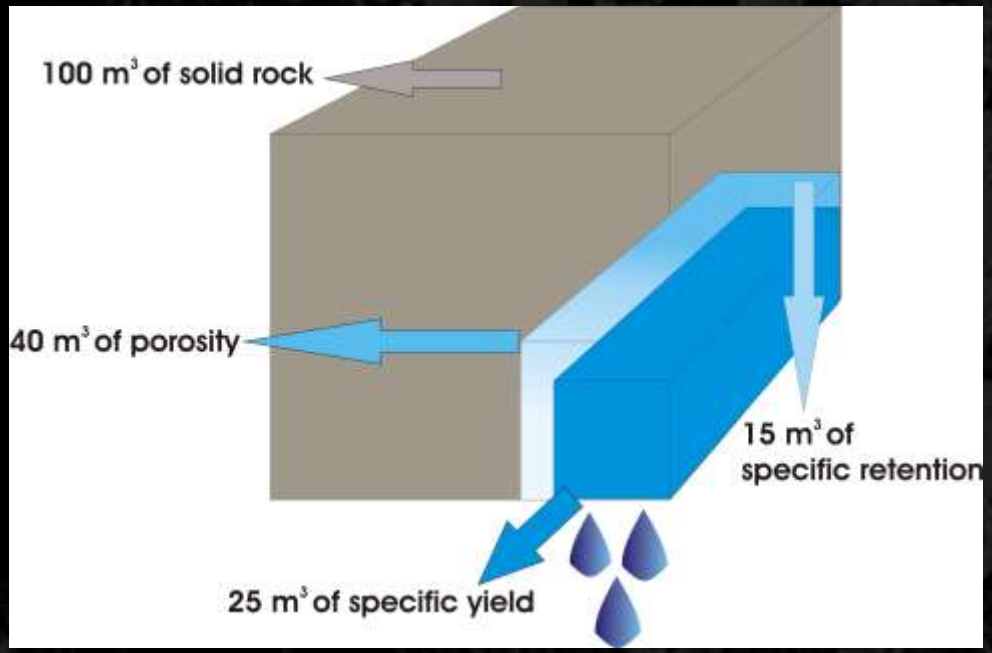
- **Specific yield (S_y)** is a part of the total porosity of the rock…
- In other words, it indicates the specific quantity of water released by the saturated rock under the influence of gravity (that is under gravity drainage).
- Gravity is a major force that drives the water out of the pore space in a rock.
- Not all water in the pore space is removed by gravity…some is retained as specific retention.

- **Specific retention (S_r)** is that part of the total porosity indicating the quantity of water retained by the rock after gravity drainage is complete.
- Molecular forces of cohesion, adhesion and capillarity are responsible for holding the water back against the force of gravity.

Both specific yield and specific retention are represented in percentage or fraction.

An example

- Total vol. of saturated rock= 100 m^3
- Porosity is 40%, i.e. 40 m^3 of water can be stored in the rock
  - The rock released 25 m^3 of water under gravity (SPECIFIC YIELD), *i.e. 25% of the total volume of 100 m^3*
  - The rock retained 15 m^3 of water (SPECIFIC RETENTION), *i.e. 15% of the total volume of 100 m^3*



…example (continued)

Porosity	=	Sp. Yield	+	Sp. Retention
40%	=	25%	+	15%

In fraction, we can write this as

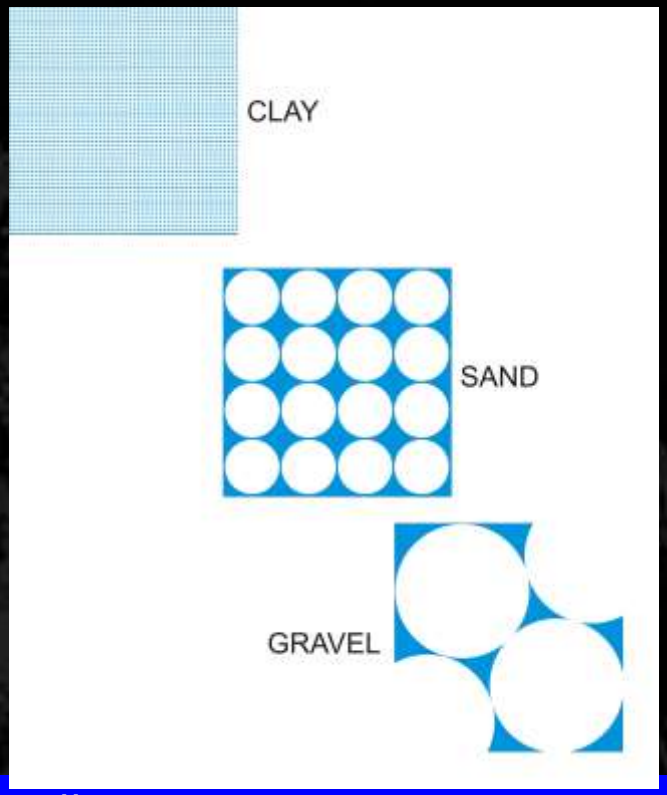
0.4	=	*0.25*	+	*0.15*

1. In hydrogeology, the specific yield is more significant than the porosity.

2. The specific yield of a rock depends upon the size, shape and the arrangement of grains.

Comparative table of values for typical rocks

Rock type	Size of grains in mm	Porosity as %	Specific yield as %
Clay	<0.004 to 0.1	45 to 50	≤ 3%
Sand	0.1 to 2	35 to 45	≤ 25%
Gravel	2 to 20	30 to 35	≥ 25%



Fine grained material has a higher porosity with smaller pore size, increasing the dominance of molecular forces and therefore resulting in higher specific retention of stored water.

Increase in grain size means the solid rock phase increases and porosity decreases.

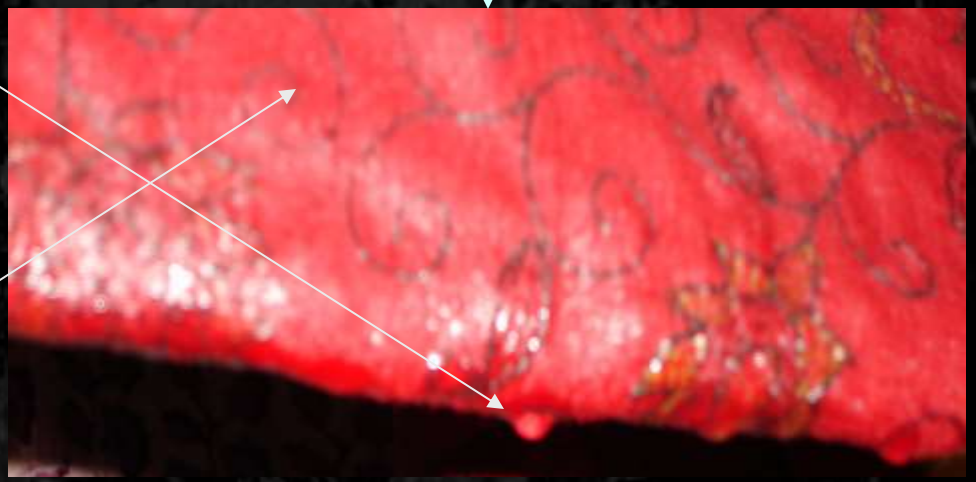
But as the grain size increases, the pore size (openings) becomes bigger, with an increase in the specific yield.

Practical manifestation of porosity – the floor mop case 1

- Water spilled on the floor can be wiped with a mop or sponge.
- The mop absorbs the water because it is porous in nature - POROSITY.
- Squeezing the mop drives out some water – SPECIFIC YIELD.
- However, some water is retained by the mop – it remains wet – SPECIFIC RETENTION.

Practical manifestation of porosity – the clothesline case 2

- A wet kurta hung out to dry – POROSITY.
- After a while, water starts draining out of the kurta in the form of droplets under the influence of gravity– SPECIFIC YIELD.
- However, the kurta still remains wet because water is held back in its pores against the force of gravity – SPECIFIC RETENTION.



Different rock types show different openings…
the specific yield depends upon these openings

Unconsolidated sediments	CLAY, SAND AND GRAVEL	Intergranular openings
Consolidated sediments	SANDSTONE, SILTSTONE	Intergranular openings and joints-fractures
Limestone	Intergranular openings and solution channels	
Basalt	Vesicles, fractures-joints and weathered portions, contacts between basalt units	
Crystalline rocks (granite, gneisses, quartzite, schists etc)	Weathering, joint-fractures	

Porosity deals with the accumulation of groundwater…permeability / hydraulic conductivity deals with its movement or flow…*next presentation*

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