POROSITY AND PERMEABILITY

Ever spray water onto a grave marker, see the moisture soak into the surface and declare it to be "porous?" If so, you're making one of the most common mistakes when it comes to describing rocks. There are two separate, but interrelated measures that are used when describing how liquid (or gas) moves through a rock. This article will help you understand the difference between the two and what's really going on when a liquid is (or isn't) absorbed into the surface of a stone.

Porosity and Permeability
By Don Hilton Geologist

Porosity:

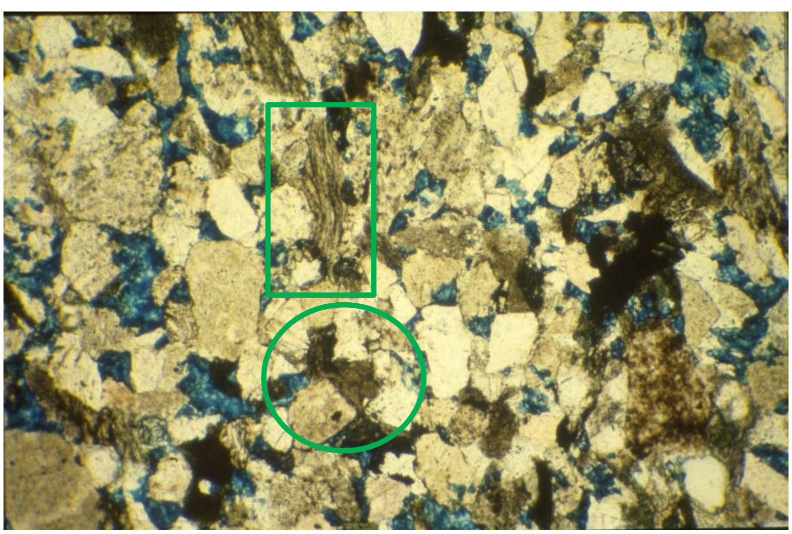
ALL rock has porosity. For ease of understanding, what follows discusses sandstone.

Porosity is the void space within a solid material. Simply put, porosity is the amount of space inside a rock that isn't rock. A freshly-poured pile of undisturbed dry sand is about 40% empty space, that is, it's porosity is about 40%. Funny thing is, a freshly-poured pile of fist-sized-and-shaped rocks is about 40% empty space, too, because porosity doesn't depend as much on the size of the material as it does the shape of the material and what happens to the rock as, and after, it forms.

Grain shape: Imagine a pile of baseballs. Such a pile has about 40% porosity. Meaning about 40% of the pile isn't baseballs at all, but the space in between them. No matter what you do, as long as you simply toss the baseballs into a pile, there will be plenty of space around them. Now, imagine a pile of bricks. Not so much space, is there? It's the shape of the bricks that allows them to naturally fill the space. They can interlock in a way that baseballs cannot.

Sorting: Your pile of baseballs is going to have a lot of space in it no matter how you try to stack them. That is the nature of spheres. Bricks, however, can be stacked in such a way as to leave very little space in between; think of a brick wall. Natural processes, like the action of wind and water, are as capable as we are when it comes to modifying and sorting shapes. Ever been to a wave-washed stone beach or a cobble-rich flowing stream and been amazed by the apparent uniformity of the rocks you find there? That's some of nature's finest sorting in action.

Compacting: Any potential rock material is subjected to compaction. If the grains within it are hard (like quartz) they won't squeeze together as much as minerals with give (like mica). The grains of harder material may melt, recrystallize, interlock and reduce the porosity, but they won't deform all that much. Minerals that do deform can drastically reduce the space within a rock.



Microscopic examination of a sandstone shows the following. This sample is cut and polished thinly enough to allow light to shine through it. Magnification is 200x:

The porosity is the blue, filled with an epoxy to keep the rock from coming apart as it is prepared. The "clear" grains are quartz. The dirtier one are feldspars. The muddy brown ones are limestones. Here we see about 18% porosity, which is high, but not unusual. Grain shape is generally angular with some rounded corners. The grains are poorly sorted for composition and direction but fairly well sorted for size. Look to the green box. See the mineral with the vertical, but wavy lines? This is muscovite, a type of mica, that has been distorted by compaction. Just below it, in the green circle, is a dark, soft clay of some sort that has been squeezed at right angles around harder minerals. If you look around the thin section you can find other examples of compaction.

Infill and Cement: Typically, as a rock hardens (or lithifies), mineral-rich water circulates through it, depositing material as it goes. This cement decreases the porosity of the stone as it fills in the space around the grains. As it fills the pore spaces it also makes the rock heavier. A cubic foot of dry sand weighs about 100 pounds. The same amount of sandstone is usually calculated at 150 pounds. The difference is porosity being filled by compaction and cementation.

Secondary Porosity: This is empty space created within the rock after it forms. This can be chemical, like the dissolution of cement or certain minerals in the rock, or mechanical, like the fracturing of the rock material.

Notice that, so far, there's been no mention of liquids flowing through a rock. That's because such flow is measured by a different variable.

Permeability:

Permeability is the ease of flow of air or liquid through a material. Porosity is how much space there is in a rock, permeability is one measure of how interconnected that pore space is.

Go back to your pile of baseballs. If you pour a bucket of water in the top of the pile nearly all of it will come out the bottom. So, you have *high porosity and high permeability*.

Take your pile of bricks and stack them in a solid cube. If you pour a bucket of water on top of it nearly all of it will flow off the top and down the sides. So you have *low porosity and low permeability*.

Now... Take your pile of bricks and rearrange them so there is big room inside, but the walls and floor are solid. If you pour a bucket of water in it, the room holds the liquid but very little of it flows out. In this case, you have *high porosity and low permeability*.

One more: Take your bricks and arrange them so there is a single hole that goes from the top to the bottom of the pile. Pour your bucket of water into the hole and it flows straight out the bottom. *Now, it's low porosity and high permeability*.

What does all this imagining prove? That you have to have some porosity to have any permeability, but the two things, while related, are completely different to each other.

What makes fluids flow within rocks:

Water flows downhill, right? Nope. Not always. Within a restricted system (like a grave marker) Water flows for two major reasons:

Capillary action: The best example of this is a sponge which is very porous and has high permeability. Water is pulled up into the sponge's structure by the water's need to stick together. Anything that's absorbent takes advantage of water's surface tension to "pull" it in the direction you want it to go. This is what happens when you spray water and it vanishes into the surface of a grave stone that has both porosity and permeability.

Changes in pressure: When constricted, water always flows from areas of greater pressure to those with less. These pressure differences can be great, like a burst pipe, or subtle, like water evaporating from the surface of a stone. This, along with capillary action, is one big reason water rises from the earth into and out to the surface of a porous and permeable stone. The weathering along the bottom of some markers are indicative of this behavior.

Other controls of fluid flow:

Flow within any stone is often directional. In sandstone grave markers, water moves along the path of any obvious bedding lines which might appear as stripes or layers within the stone. Remember that the sandstone has those lines of preferred flow, even if you cannot see them.

In non-sedimentary stones, like granites, water has a tougher time finding its way along. Rule of thumb is that nearly any stone has at least a few percent of porosity. But many are considered to have little to no permeability. Ever hear of "fracking" wells? They're fracturing the rock to make the fluids within them flow more easily.

Porosity and permeability can vary widely, even within a very small distance. All grave makers, even those that are inside of buildings, are subject to weather that alters the characteristics of the surface. Smoothing and filling in porosity, in some instances, but more often, coarsening and increasing the porosity. Hand in hand, an increase of porosity *tends* to increase permeability, making it more likely that the stone, at least at its surface, will accept and incorporate liquids more easily. This process then feeds-back on itself. Slow changes lead to faster change. Minor degradation leads to major failure. *This is true of all natural stone marker.*

This is a big reason that markers must be carefully cleaned. Using the wrong cleaner (like vinegar) "opens the pores" on many different kinds of rocks. Others (like bleach) leave behind salts that will damage the stone's surface as they repeatedly dissolve and recrystallize. Some (like "fatty" soaps) clog what pores and permeability are already present and while keeping water out sounds like a good thing, it also alters any establish flow of liquids within the marker, setting it up for future failures.

Summary:

ALL rock has porosity (void space) and most have permeability (interconnected voids). The initial porosity and permeability of raw material are altered by the process of becoming a rock and can also be changed after the rock has formed. While necessary for fluid flow, permeability, like porosity, can be controlled by a marker's internal structure. They can also be changed by poor cleaning techniques.

Thin section: Squaw Lake Formation, Alaska North Slope, c640-caco3, 1985-07, METC, WV, courtesy of Don Hilton.

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