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Identifying Rocks

Rocks are made of minerals, and the Earth is made of rocks. (Indeed, so is the Moon, and the other so-called terrestrial planets: Mercury, Venus, and Mars.) Rocks form mountains, of course, but sand is rock that has been ground down by time and weather, and soil is rock that has been ground finer still, and mixed with organic materials and other substances.

Technically, a rock is simply a solid composed of one or more minerals. (Note, however, that sand and soil are not rocks—they are derived from rocks but lack coherence.) Rocks are described variously by composition, grain size, texture, structure, color, and method of formation.

Of course, method of formation is the most general and therefore the most convenient way to classify rocks. Igneous rocks are formed by the cooling and solidification of molten material: lava or magma. Sedimentary rocks are formed by the slow accumulation and layering of granular material. Metamorphic rocks are produced through the alteration by several means of igneous, sedimentary, or even of previously altered metamorphic rock.

Rocks are constantly (though very slowly) undergoing the process of change. All three kinds of rock are ground down by wind, weather, and water, becoming sediment of some sort—sand, silt, or clay. This sediment will eventually compress into sedimentary rock. Sedimentary or igneous rock may be altered by heat or pressure, eventually becoming a metamorphic rock. Deep within the Earth, or in the presence of rising magma or lava, igneous or metamorphic rock can be melted into magna, from which it will eventually re-solidify into igneous rock again. This never-ending process of formation, alteration, and reformation is known as the *rock cycle*.

Igneous Rocks

Beneath the Earth's crust is a thick layer called the mantle, where heat and pressure liquefy the rock there. This liquid rock—called *magma*—migrates upward into the crust, where it cools and forms solid rock. If magma rises all the way through the crust and flows out onto the Earth's surface before solidifying, it is called lava. Any rock formed from cooling magma or lava is an igneous rock (from the Latin *ignis*, meaning fire).

Igneous rock is differentiated into subcategories based on where it formed: *plutonic* (or intrusive) igneous rock is that which forms underground, from magma; *volcanic* (or extrusive) igneous rock is that which forms on the surface, from lava. But no matter where it forms, all igneous rock shares many characteristic properties. Igneous rock is typically very hard (5½ or greater hardness) and dense, and generally lacks any distinctive structures such as layering.

The classification and identification of igneous rocks is based primarily on their particular mineral content, but the boundaries between rock names are arbitrary, and no sharp distinction between species exists, as it does for minerals. Fortunately, while magma is a complex stew of melted silicates, you need only to be able to identify a few minerals to identify a rock—as long as the grains are large enough to see without a microscope, it is easy to determine the presence and relative amounts of these minerals, and from that you can identify the rock. A *classification diagram* provides a general key to identifying the minerals by color and grain size.

In technical terms, these minerals are referred to as felsic and mafic. *Felsic* is short for feldspar/silicon; felsic rocks contain a great degree of silica, sodium, and calcium, and therefore form quartz and feldspar minerals. Felsic rocks are generally very light in color. Mafic rocks have a great degree of magnesium and iron—*mafic* is short for magnesium/ferrous—and are much darker than felsic rock.

Igneous rocks are further described by their texture, which ranges from glassy (amorphous, lacking any crystalline mineral grains) to aphanitic (fine-grained) to phaneritic (coarse-grained). In general, the more slowly igneous rock cools, the larger its constituent grains will be.

While color and texture can provide clues to identifying an igneous rock, only its specific mineral content determines its actual species.

For instance, granite is a generally light-colored phaneritic felsic rock, containing (according to one definition) between 20 percent and 60 percent quartz and both alkali and plagioclase feldspars, with not more than 65 percent of the feldspar content being plagioclase feldspar. But again, there is no absolute definition—a rock that is 50 percent quartz, 25 percent alkali feldspar, and 25 percent plagioclase feldspar is definitely granite, while a rock of 50 percent quartz, 17 percent alkali feldspar, and 33 percent plagioclase feldspar might be classified as granite by one person and as granodiorite by another!

Igneous Rock Texture

Glassy. Amorphous and lacking any crystalline mineral grains. Formed of volcanic flow or ejecta that cooled too rapidly for crystals to form.

Aphanitic. With mineral crystals too fine-grained to be seen with the naked eye. Generally formed from lava that cooled before large crystals could form (but not as quickly as glassy rock).

Porphyritic. Aphanitic rock with some larger crystals (phenocrysts) embedded in its matrix. Porphyritic rock can be formed when different minerals within cooling magma crystallize faster than others, or when cooling magma begins to form large crystals but is then erupted by a volcano, and the rest of the rock cools quickly.

Phaneritic. Even-grained rock with all crystals large enough to be visible to the naked eye. Phaneritic rock forms when magma cools slowly, giving the minerals inside time to grow and form large, sometimes complex arrangements.

Pegmatitic. Very coarse-grained rock, with uneven texture. Occurs when some minerals in cooling magma grow massively large.

Pyroclastic. Also called *fragmental*. Lava violently ejected from a volcano may include fragments of solid rock broken in the eruption. Pyroclastic rock is formed by lava that solidifies around these fragments.

Sedimentary Rocks

Sedimentary rock is formed from the accumulation and compression of mineral sediment in a process called *lithification*. As wind, water, and glaciation erode rock surfaces, the particles worn off are carried away to other locations, where they settle in layers. As these sentiments build up, the weight of the upper layers compresses the lower layers, and this compaction transforms the sediments into solid rock. Materials dissolved in water may also act to cement the sediments together into solid rock. Often, both compaction and cementing act together to form sedimentary rock. Sedimentary rock covers more than 75 percent of the Earth's surface, but only in a thin layer—it accounts for just five percent of all solid rock on Earth.

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Sedimentary rocks contain important information about the history of Earth. The sediments themselves provide clues about the original rock that created them. The layers, or *strata*, provide a timeline of their formation, and hence of the age of the materials found within them. Differences between successive layers provide evidence of environmental changes. And most spectacularly, sedimentary rocks contain fossils—the calcified remains of ancient plants and animals. (The processes that form igneous and metamorphic rocks destroy such remains, but sedimentation actually acts to preserve them.)

Sedimentary rock is differentiated into three types by the source of the sediments from which it forms.

Clastic sedimentary rock forms from sediments produced by mechanical weathering and erosion of other rock. Also called detrital rock because it forms from the detritus of other rock, clastic rock is very loosely graded according to particle size—from shale (individual particles less than 0.004mm in diameter) to conglomerate and breccia, which can include rock fragments as large as boulders.

Chemical sedimentary rock is nonclastic rock whose constituent particles precipitated out of salt water or fresh water. Just as you can only dissolve so much sugar in a glass of water before the excess begins to settle to the bottom, beyond a certain concentration, minerals will no longer dissolve in water but will instead settle, or precipitate, eventually cementing together into solid rock. If the water environment becomes "super-saturated" with minerals as a result of evaporation, the resulting chemical rock is referred to as an *evaporite*. Travertine and flint are chemical sedimentary rocks; gypsum rock and rock salt are evaporites.

Biochemical sedimentary rock forms from the remains of living organisms. Corals, seashells, and skeletons will form limestone: coal is a biochemical rock derived from the remains of plant material. It should be noted that carbonate rocks—those composed primarily of calcium carbonate (CaCO3), such as limestone, chalk, and dolostone—tend to form by both chemical and biochemical processes, even within the same individual specimen, and plant-based biochemical rocks always form in the presence of clastic rocks. In fact, biochemical rock is differentiated from clastic and chemical rock only because it forms from organic remains—its content is biological in origin, but it still forms through mechanical and chemical processes.

Sedimentary rock texture is simply described as being fine-, medium-, or coarse-grained, or crystalline if it consists entirely of crystals or fragments of crystals. Sedimentary rocks are not easily differentiated by texture alone; the boundaries of grain size are set rather arbitrary, and even within categories particles are further divided by size. Clay and silt are both fine-grained particles, with clay being finer than silt, but the determination between siltstone and mudstone (which is made of clay) can really only be made under a microscope.

A much more important property for determining a sedimentary rock is its structure. *Structure* refers to large-scale features deriving from the environment and condition in which the sediments formed. Structures are particularly obvious in the field, and so are the best means by which to recognize and identify sedimentary rocks when collecting "in the wild."

Sedimentary Rock Structure

Strata. Strata (singular *stratum*) are simply the successive layers in which sedimentary rock forms as the sediments are deposited. Strata can be distinguished by variations in color, texture, hardness, and composition. Strata thicker than one centimeter are called beds; thinner strata are called laminations.

Cross-stratification. Caused by the action of wind or water on the sand, cross-stratification results in straight or scalloped rock strata forming at angles to successive layers.

Graded bedding. Graded bedding refers to rock strata where the size of the grains increases from top to bottom. It is caused by a current gradually slowing down, so that larger and therefore heavier particles settle out first.

Ripples. Ripples are parallel, undulating ridges caused by wind or water on sand. They can be seen on a beach or a sand dune.

Metamorphic Rocks

Metamorphic rock is exactly what the name suggests: rock that has been transformed. Any existing rock can be changed into metamorphic rock—igneous, sedimentary, even other metamorphic rock.

Metamorphic rock forms under intense heat and pressure. This can happen deep within the Earth, where such heat and pressure are the normal environment; tectonic forces such as continental drift can also create metamorphic rock. Such widespread metamorphism (which is responsible for creating massive structures over great areas such as mountain ranges) is called *regional metamorphism*. Or the heat of rising magma can alter the rock it moves through; this is known as *contact metamorphism*. However, if a rock is heated enough that it melts into magma, it will then form igneous rock when it cools and resolidifies, not metamorphic rock. Metamorphism only refers to changes that take place before actual melting occurs.

Because of the wide range of temperatures and pressures under which they may have formed and the variety of rocks from which they may have formed, metamorphic rocks can vary widely in their characteristics. Metamorphic rocks can contain unaltered fragments and even entire structures of their parent rocks. Particles may recrystalize, forming new structures without otherwise changing composition. As limestone metamorphoses into marble, for instance, the small calcite crystals become larger, giving marble the characteristic texture and appearance that make it so highly prized for sculpture and construction.

Above about 200°C, the individual crystals of many minerals begin to break down and will form new compounds and new crystals. Different minerals form at different temperatures, and certain minerals that form only at the high temperatures and pressures associated with metamorphosis are called *index minerals* because they can therefore be used to determine the degree of alteration a rock has undergone. Some of these index minerals are biotite, chlorite, garnet, kyanite, muscovite, sillimanite, and staurolite.

When stress (such as pressure) is applied to a recrystalizing rock in one direction, minerals such as micas and chlorite will grow with their long axes perpendicular to the direction of the force. These parallel mineral flakes produce a planar or banded texture called *foliated rock*. Foliated rock is described by its particular texture. *Slaty* rock is fine-grained with a prominent cleavage along which it splits into thin sheets. *Schistose* rock is coarse-grained, but still has a high mica content and distinct layers, and so splits easily. *Gneissose rock* is coarse-grained, composed mainly of quartz and feldspar; the layers are thicker and often less regular than in other foliated rock.

Among non-foliated rock, textures include *hornfelsic*, which is dense and even-textured, and fined-grained without any evident crystalline structure; and *granuloblastic*, which has larger mineral grains of the same general size.

Metamorphic rock may also be *porphyroblastic* or *poikiloblastic*. A porphyroblast is a large, well-shaped mineral crystal that has grown within the fine-grained matrix rock. A poikiloblast is a porphyroblast that contains inclusions of the original parent rock.