CHAPTER 1

GEOLOGY

1.0. ANALYSIS AND PROPERTIES OF COMMON ROCK. Within this manual a quarry is to be considered a facility to produce rock for construction operations. In general, the term rock refers to consolidated substances of the earth's crust that cannot be excavated without blasting or cutting. Rocks are conveniently classified into three groups, Igneous, Sedimentary and Metamorphic.

1.1. IGNEOUS ROCKS. Igneous rocks, which have been formed by the cooling and solidification of magma, comprise the first group. There are two different types, extrusive and intrusive.

- Extrusive. Extrusive igneous rocks are found when the magma is thrown out from the volcanoes or pushed slowly up through the cracks in the earth's crust. As the molten rock reaches the surface it usually spreads out and cools relatively rapidly resulting in small crystals or sometimes no crystals at all. Recently extruded lavas may contain long hollow tubes or tunnels.

- Intrusive. Intrusive igneous rocks are formed from deeply buried magmas that cool very slowly within the crust of the earth, thus forming larger crystals. There are three main types of intrusive masses. Smaller masses of a few square kilometers in surface area are called stocks. Tabular masses intruded between rock layers are called sills, and those that fill cracks or fractures, cutting across such layered structures are called dikes. All intrusive rock masses do not fit neatly into the three types and many times must be determined by detailed mapping or core drilling.


GRANITE.—An intrusive igneous rock with an even texture. Any light colored, coarse to medium grain rock may be called granite. Granite is gray, pink, or red, with crushing strength ranging from 15,000 to 30,000 pounds per square inch. Granite is found in all parts of the world and forms a large part of the continental masses. Unweathered granites are strong and durable rock suitable for bridge piers, sea walls, and foundations of buildings. Its chief defect lies in the fact that when heated and chilled, the quartz and feldspar grains expand or contract at different rates sometimes causing the rock surface to crumble or peel.

DIORITES.—A family of rocks that resemble dark granite, and are most often found in sills, dikes, and small stocks. Unweathered diorites are strong and durable, and have an average compressive strength of 28,000 pounds per square inch.

GABBRO.—A dark gray, green or black granular rock similar in appearance to diorites. Like granite, gabbro is found in batholiths, but it also forms small stocks, dikes, sills, and volcanic necks. Gabbro which is a durable construction material for all purposes, has a high degree of compressive strength (average is 26,000 psi), and low absorbability. Gabbro is chiefly used for road materials.

FELSITES.—A group of very dense, fine grained extrusive igneous rocks. They have dull, stony textures and are composed of quartz and feldspars. Colors range from light or medium gray to pink, brown, yellow, buff, purplish, and light green. Weathering causes felsite to become brown, rusty and crumble, eventually breaking down completely to become clay. Felsites are generally used as concrete aggregate.

BASALTS.—A group of very dense fine grained igneous rocks whose colors range from black to dark
gray to green to purplish. All basalts contain a great deal of lime, magnesium, and iron. They are a fine grained equivalent of gabbro and closely related to the andesites.

1.1.2. Engineering Properties of Igneous Rocks. All intrusive rocks, when fresh and unweathered have high crushing and shearing strengths and unless fractured too small, are satisfactory for all types of engineering construction operations. They often provide an excellent source of concrete aggregates and other types of construction materials. Extrusive igneous rocks require extensive examination before their engineering characteristics can be determined. Many lava’s are as satisfactory as intrusive rock, but the pyroclastic material may be unreliable.

1.2. SEDIMENTARY ROCK. Most sedimentary rocks result either directly or indirectly from weathering. They consist of hardened or cemented layers of sand, clay, and lime. The two major types of sedimentary rocks are chemical sediments, and clastic sediments. Chemical sediments are formed by material that has been transported in solution and later precipitated. Clastic sediments are formed by mechanical transportation (wind, water, glacial action, etc.) and deposition.

- Chemical Sediments. Limestone and dolomite are the most widespread of the chemically precipitated rocks, and the dense varieties of these carbonate rocks have high crushing and shearing strength. Their principal defects are solution cavities formed during past geologic time. Other chemically precipitated sediments (chert, flint, rock salt, anhydrite, coquina, caliche, and soft coral) are unsatisfactory for most engineering purposes due to their solubility, chemical reactivity, or low physical strength.

- Clastic Sediments. Are formed of fragments of other rock, transported from the original sources. These sediments may be cemented to form firm rock by a variety of materials, the most important being oxides, carbonates, and silica.


LIMESTONE.—Any rock that contains more than 50 percent calcium carbonate in the form of calcite are considered limestones. When pure, limestones are white or cream colored, but they are usually colored gray to black by carbon or stained buff, yellow, red, or brown by iron oxides. As a building stone it is used in both inner and outer walls and in floors and foundations, bridges, and a variety of other structures. Crushed limestone is used in the manufacture of Portland cement.

DOLOMITE.—Although similar in appearance and usage to limestone, dolomite is a calcium magnesium carbonate of varying proportions.

CHERT and FLINT.—Siliceous sediments are usually found in limestone and shale. They are very hard and difficult to drill. Chert can be used as a satisfactory road material.

ROCK SALT and ANHYDRITE.—Very abundant, soluble in water, and very soft. Rock salt deposits are of no value as a construction material.

CONGLOMERATES.—Composed of cemented gravel of varying sizes. Breccia (conglomerates composed of cemented angular fragments) may be used for road material if properly graded or crushed to size. It is usually susceptible to rapid weathering and consequent weakness.

TILL.—Consists of a heterogeneous group of materials that have been deposited by glaciers. Till is an excellent source of material for earth dams and embankments, but usually not suitable for concrete and bituminous aggregates.

SANDSTONE.—Consists of small grains (1/16mm to 2mm) that have been cemented together to form rock. The color of sandstone depends on the nature of the cement. Iron oxides give the red, yellow, and brown shades. Sandstone that splits easily into even slabs is known as flagstone commonly used as a decorative building material.

SILTSTONE.—Similar to sandstone, but composed mainly of cemented particles that are between 1/256 and 1/16mm in diameter.

CLAYS and SHALES.—Are made up of clay minerals, various oxides, Silica, fine particles of ordinary minerals, and a greater or lesser amount of colloidal and organic material
1.2.2. Engineering Properties of Sedimentary Rocks. The shearing resistance, crushing strength, and hardness of clastic sediments depends for the most part on the degree of consolidation and cementation.

1.3. METAMORPHIC ROCKS. These rocks are the result of profound changes in both igneous and sedimentary rock. There are two principal types of metamorphism, Igneous and Dynamic. Igneous is caused by direct contact with hot igneous rocks and the water, steam, and other gasses that come from them. Dynamic is caused by movement of the crust of the earth, compression, downward pressure, and the action of water providing the resulting rock changes go further than mere compaction and cementation.

1.3.1. Common Metamorphic Rocks and Their Properties.

GNEISS.—Gneiss is a banded rock of granite composition, containing quartz, feldspar, and mica. Their banded structure enables the rock to be split into more or less parallel surfaces allowing its use in the construction of tough walls and some road surfaces.

SCHISTS.—Schist has much finer texture than gneiss and possess a well marked cleavage. Unlike gneisses, their bands are mineralogically alike causing treacherous rock slips in quarries, rock cuts, and in tunnels if unsupported on steep or vertical faces.

SLATE.—Slate is a fine grained, hard, and dense rock, which was formed by the metamorphism of shale. It splits easily into thin layers which cut across bedding planes. The most important feature of slate is its cleavage which makes it valuable for roofing. Although not recommended, it can be used as a road material if absolutely necessary.

QUARTZITE.—For the most part, quartzite is metamorphosed sandstone. The grains of feldspar, hematite, chlorite, muscovite, and other minerals are present as impurities and give the rock a pink, brownish, or red brick color. Although similar in appearance to grainy limestones, quartzite's are much harder. Quartzite is not used as building stone due to shattering during jointing, but when crushed, become an excellent material for concrete work, railroad ballast, and road work.

MARBLE.—Marble is the result of the metamorphism of limestone and dolomite. When crushed and used as an aggregate, marble has the same value as limestone.

1.3.2. Engineering Properties of Metamorphic Rocks. It is impossible to generalize the engineering properties of metamorphosed rocks. Most gneisses are hard and tough and have high crushing and shearing strengths. Most schists are highly anisotropic and attention should be given to their cleavage orientation. Also, many schists are very soft and unusable for high unit loading.

1.4. IDENTIFICATION OF COMMON ROCKS.

1.4.1. Moh's Hardness Scale. Rocks that fall between 5 and 7 on the Moh's hardness scale (see chart A) are most suitable for construction use. Below 5 on the scale is too soft and above 7 is too hard to crush. This scale does not indicate an exact hardness. The number 9 is not three times as hard as the number 3. It only means that any mineral can scratch all those beneath it in the scale and can be scratched by all those above it. Two minerals of the same number will scratch each other.

1.4.2. Expedient Scale. In the absence of the Moh's scale, a hardness test can be done in the field using the Expedient Scale. This is a simple test, if a file scratches the rock, the rock is below 6.5 hardness. If the rock scratches the file, the rock is above 6.5 hardness. If the rock scratches a knife blade or glass, but not the file, the rock hardness is between 5.5 and 6.5.

1.4.3. Taste Test. Most minerals that are readily soluble in water have a distinctive taste, Halite, for instance, can be identified quite easily because of its salty taste. A good rule of thumb to follow is, if it tastes salty, it is not good for construction. It will erode quickly.

1.4.4. Color. The color of a mineral is not always a dependable guide, since some minerals, quartz for example, occur in a bewildering array of color without any perceptible change in their composition. A few minerals are reasonably constant in their color and in these cases color can be considered, more or less, an identifying property.

1.4.5. Tenacity. Tenacity is the term to describe the
behavior of a mineral when an attempt is made to break, hammer, cut, bend, or crush it. A mineral is brittle if it breaks or powders easily, malleable if it flattens under the hammer, tough if its resistance to being torn apart under a blow or great strain, flexible if it bends and remains bent after the pressure is released, and elastic if when bent it recovers its original position upon release of pressure.

1.4.6. Acid Test This test is used most effectively in the identification of carbonates. Any acid plus a carbonate will produce an effervescent reaction. Hydrochloric acid is the most common used.

Chart A

Moh's Scale of Hardness

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Hardness</th>
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<tbody>
<tr>
<td>Talc</td>
<td>1</td>
</tr>
<tr>
<td>Gypsum</td>
<td>2</td>
</tr>
<tr>
<td>Calcite</td>
<td>3</td>
</tr>
<tr>
<td>Flourite</td>
<td>4</td>
</tr>
<tr>
<td>Apatite</td>
<td>5</td>
</tr>
<tr>
<td>Feldspar</td>
<td>6</td>
</tr>
<tr>
<td>Quartz</td>
<td>7</td>
</tr>
<tr>
<td>Topaz or Beryl</td>
<td>8</td>
</tr>
<tr>
<td>Corundum</td>
<td>9</td>
</tr>
<tr>
<td>Diamond</td>
<td>10</td>
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</table>

Expedient Scale

<table>
<thead>
<tr>
<th>Material</th>
<th>Hardness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel file</td>
<td>6.5</td>
</tr>
<tr>
<td>Knife blade or window glass</td>
<td>5.5</td>
</tr>
<tr>
<td>Copper coin</td>
<td>3.0</td>
</tr>
<tr>
<td>Fingernail</td>
<td>2.5</td>
</tr>
</tbody>
</table>