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A GUIDE FOR THE PRELIMINARY EVALUATION OF ROCK FOR ROAD SURFACING

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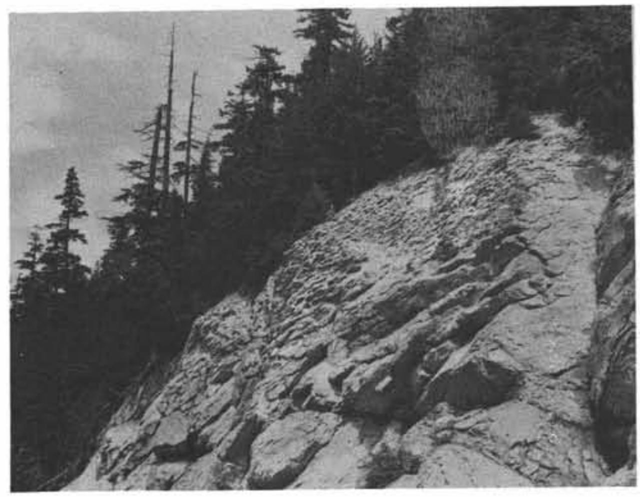
INTRODUCTION

Availability of good road-surfacing rock is of prime importance in logging operations. It is especially important in areas of high rainfall, such as the Willapa Hills and the foothills of the Cascade and Olympic Mountains, where good rock is needed to construct a stable year-around road surface. A problem facing the logging-road builder in the Willapa Hills and Olympic Peninsula areas is that good competent rock is scarce. If good rock is not available locally, the operator may have to haul in rock from somewhere else, raising his logging costs.

Because potential problems related to a scarcity of good rock can occur locally almost anywhere, the forester who is working in any given area should be alert to the occurrences of potential rock sources. No one probably has a better knowledge of a local area than the forester who is implementing the various plans related to forest practices; that is, working up timber sales, checking logging compliance, surpervising planting, etc. During all of these phases, the forester should map the location of potential rock sources.

It is possible that the forester may not be able to fully evaluate a rock occurrence for its suitability as a source of road material, but there are some simple tests and observations that can be made in the field that could help in the evaluation process. Simplified rock identification charts have been included as tables 1, 2, and 3 for the individual who has had a class in beginning geology, but it should be kept in mind that the kind of rock being considered is not as important as its observable physical properties. Even the best rock can be rendered useless by deep thorough weathering. There are some generalizations that can be made about rocks and their suitability as road metal that are related to their origin. Assuming the rocks are unweathered, igneous rocks (formed by cooling from a molten magma, see table 1) will usually be a better source of road metal than sedimentary rocks (formed from material deposited by water or air, see table 2) and metamorphic rocks (their texture or composition has been changed by application of heat and(or) pressure, see table 3). It must be remembered that this is a generalization and may not always be true. For instance, both limestone and dolomite, which are sedimentary rocks, and quartzite and marble, which are



Example of how good rock can be weathered to bad rock in the same outcrop. Note massive jointing of rocks in lower part of outcrop, which would make good road rock. See how the rock gradually grades upward into almost platy-jointed, soft, weathered rock, which would not be suitable for road rock.

metamorphic rocks, can make superior road metal. Tuff (indurated ash) on the other hand is igneous in origin but usually makes poor road rock because it normally breaks down too easily. This discussion is limited to rocks to be used for road surfacing, not ballast, fill material or concrete or bituminous aggregate. Quality requirements for ballast and fill are not nearly so high as for the actual gravel road surface. Requirements for concrete and bituminous aggregate, on the other hand, may be much higher. The most common rocks will be discussed individually later.

The two things that control a rock's usefulness as a road metal are its physical characteristics and mineral composition. Mineral composition is beyond the scope of this paper so only physical characteristics that are easily observable in the field and generally the most important controlling factors for rock use are discussed in this report.

ACKNOWLEDGMENTS

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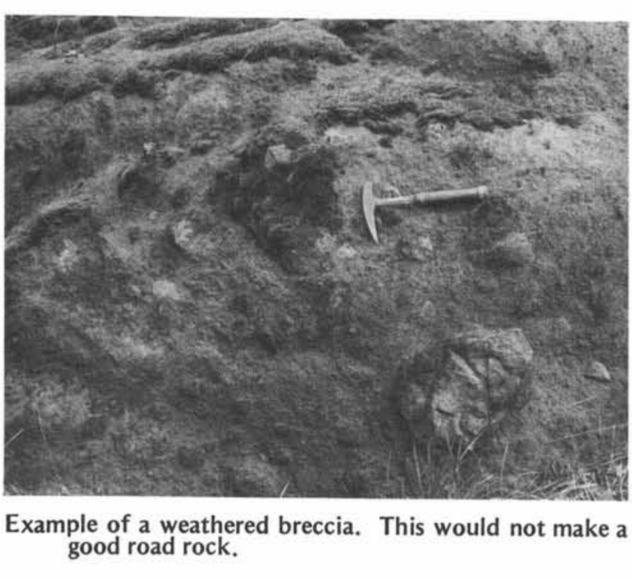
PHYSICAL CHARACTERISTICS OF ROCKS

The physical characteristics of a rock that can easily be observed or tested in the field are resistance to weathering, toughness, texture, fracture, jointing, hardness, and porosity. Each one, in its own way, adds to or detracts from a rock's suitability as road metal.

Resistance to weathering. – Resistance to weathering is an excellent clue as to whether a rock will make good road metal. Weathering is the process by which rocks are broken down by chemical and mechanical processes. In western Washington the most active process is the decomposition of rocks by ground water. In eastern Washington it is by mechanical processes, such as frost wedging. A rock that stands out as a bold outcrop, especially in western Washington, will be resistant to weathering and a candidate for road rock. If the bedrock is covered by deep overburden or fine rock rubble that has been produced by weathering, chances are the rock will not be suitable for road metal.

Toughness. – Toughness has to do with the amount of force, which must be applied in a blow, to break a rock. It is a direct function of the way crystals interlock in igneous rock and how well the individual grains of a sedimentary rock are cemented. In a metamorphic rock, it can be a function of either crystal orientation or cementation depending on the rock type. The harder it is to break the tougher the rock is, and in most instances the better road metal it will make. Fresh unaltered basalt is a good example of a tough rock. One usually has to really pound it with a hammer to break it.

Texture. – Texture relates to the size of grains or crystals that make up a rock and can be determined with the unaided eye. As a rule of thumb, the coarser the texture the weaker the rock. The differences in the coefficient of expansion between different rock grains



Example of a weathered breccia. This would not make a good road rock.

Example of an unweathered breccia. This would be good for road rock.

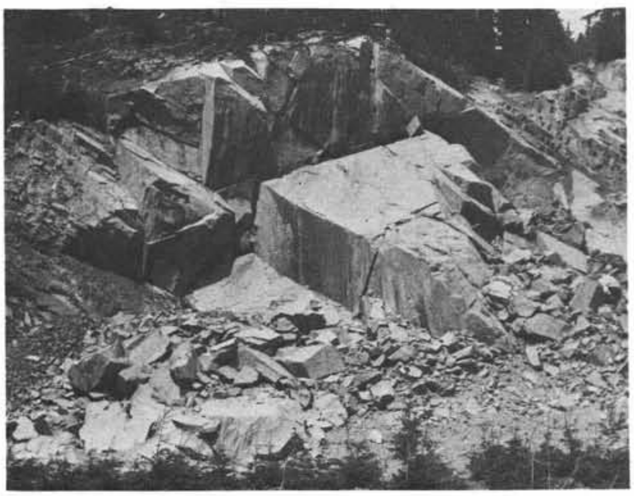
in the case of sedimentary and some metamorphic rocks, and different mineral crystals in igneous and some metamorphic rocks, can impart a weakness to the rock as a whole. It should be pointed out that if the rock is very coarse grained, like a conglomerate or pegmatite, and is going to be crushed, the problems related to coefficient of expansion are pretty well eliminated. The stress caused by crushing will cause failure along the weakest surfaces, which are the boundaries of crystals and clasts (a clast is an individual grain, pebble, or cobble in sedimentary rock). This will result in each crushed fragment being fairly homogeneous.

The fact that large grains or fragments and crystals tend to weaken a rock does not necessarily mean that the finer the grain a rock has the better it will be for road surfacing. Other factors such as fracture, jointing, hardness, and porosity must be considered also.

Fracture. – The term fracture relates to the kinds of surfaces that are produced when a rock is broken. Rocks that have uneven irregular surfaces when broken are more suitable for road surfacing than rocks that break along smooth surfaces. The rough uneven surfaces will provide much better binding qualities. The type of fracture a rock has is easily determined by simply breaking the rock and observing the nature of the broken surfaces. For instance, thin bedded rocks will most often break along bedding planes which produces a smooth fracture surface. Massive rocks, rocks that lack bedding or are thick bedded, when broken, will most likely produce an irregular fracture surface.

Jointing. – Joints are the natural cracks that exist in the rock as it occurs in nature, and for all practical purposes all rock is jointed. The joints are formed by stresses in the earth's crust related to folding, faulting, and cooling. They are usually most abundant at the surface where burial pressure has been released. Joints can make

Example of platy jointing. This would not make a good road rock.



Example of blocky jointing. This would make a good road rock.

Example of columnar jointing. This would make a good road rock.

If an axe blade will scrape up powder from the rock, it means the rock has a lot of soft minerals in it and probably would not be a good road rock.

quarrying easier when they occur in the right pattern or at an optimum spacing, thus reducing blasting and crushing costs. When they are too closely spaced, however, they have the same effect as fracturing in that they produce too many smooth surfaces on the crushed rock fragments.

Hardness. — Although hardness is a function of mineral composition, the knowledge of exact mineral content is usually not overly important for a rock to be used as road metal or riprap. What one is looking for most of the time simply is whether the rock is hard or soft. If the rock is soft, in all probability some of the original minerals have been altered to clay, clay minerals were part of the rock when it was first formed, or the rock is made up of soft minerals other than clay. In any case, a soft rock could mean problems for road metal use.

One of the simplest tests for hardness is to scrape the rock with an axe blade. If the blade peels or powders rock material up from the rock, it means the rock has a fair amount of clay or other soft minerals in it. Another test is to strike the rock in question with considerable force using a geology pick, hammer, or the poll of an axe. If you get a "thud" or a sound similar to hitting a log, the rock is probably loaded with clay or other soft minerals and will be of questionable value as road metal. On the other hand, if the blow produces a "ringing" or sharp "crack," the minerals that make up the rock are hard and unaltered and the rock will probably be satisfactory for road surfacing. Unfortunately, as in so many things, there are exceptions to this rule of thumb. Both limestone and dolomite have a hardness that is much softer than an axe blade but, because their crystal structure is so tight, they hold together and make a suitable road metal.

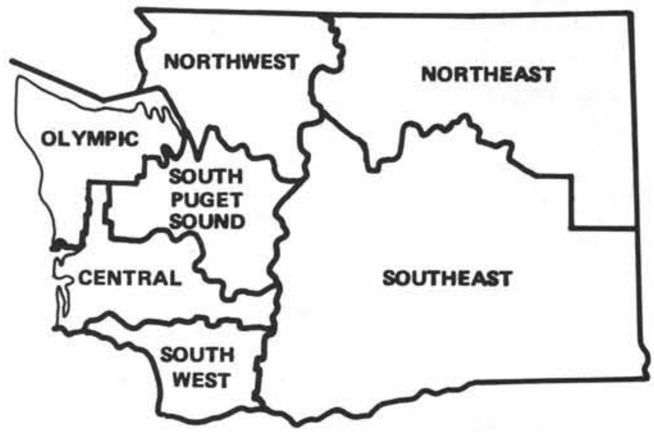
It is common to find volcanic and sedimentary rocks that grade from hard to soft (from unaltered to altered) in the same quarry in western Washington. Often a rock will be weathered and altered and useless at the surface but a few feet into the outcrop it will be hard and usable. Sometimes a rock that produces a slight "ring," which means it has some clay or other soft mineral in it, may make suitable road metal. The clay acts as a binder for the larger fragments and produces a durable road surface. However, this material may be subject to frost heave, or expansion and fail, causing surface breakup.

Porosity. – The amount of pore space in a rock can usually be determined by looking at a rock with the unaided eye or with the help of a hand lens. The pore space is the space between the grains, rock fragments, or crystals that make up the rock. Normally the higher the pore space in a rock the less valuable it is as a road rock. In a sedimentary and fragmented rock, high pore space means a lack of cementing material which means the rock will lack strength or toughness. In igneous rocks, pore space is usually the result of gas bubbles being trapped in the rock as it cooled. These gas cavities are called vesicles and when they become numerous they can lower the value of the rock as a road metal. The differences in the value of vesicular rocks are exemplified by scoria or volcanic cinder, which occur in the Glenwood area, in Klickitat County, and make fair road metal, and pumice which is poor road rock.

Example of scoria. Note the vesicles (small gas bubbles) in the rock. If the rock contained more holes, it would be considered volcanic cinder. Too many vesicles would lower the value of the rock as a road metal.

A GENERAL EVALUATION OF COMMON ROCKS FOR USE AS ROAD METAL

This discussion assumes that the rocks being considered are fresh and unweathered. Once a rock has been weathered its value as a road metal or road surfacing material tends to diminish. It needs to be pointed out, however, that, in some cases, a little bit of clay in a rock can be useful because it acts as a binder and holds the larger fragments together. The one serious drawback to this situation is that the clay will absorb moisture and, if subjected to freezing weather the clay will break apart, which in turn will cause the breakup of the road surface.



Map of Washington showing Department of Natural Resources administrative areas.

Igneous Rocks
(see table 1)

Granite, diorite, and gabbro. – All of these rocks will make a good road surfacing rock. They occur in all Areas except the Olympic.

Rhyolite, andesite, and basalt. – All of these rocks will make a good road surfacing rock. Some basalts when very fresh have unusually sharp fracture edges and points that can easily cut and puncture tires. Basalt occurs in all Areas, andesite occurs in all Areas except the Olympic, and rhyolite occurs in South Puget Sound, Southwest, and Northeast Areas.

Felsite and trap. – Makes good road rock. Same warning about fracture edges that applies to basalt applies to black varieties of trap. Trap occurs in all areas; felsite occurs in all Areas except the Olympic.

Obsidian. – This is volcanic glass and would be an extremely poor road rock. Its fracture edges are as sharp as a knife and would cut up tires most severely. Fortunately it is not very common in Washington State.

Basalt glass. – Same problem as obsidian.

Scoria. – This is full of vesicles but can make an acceptable road rock. Occurs in Southwest and Southeast Areas.

Pumice. – This is a very weak rock and would make a generally poor road surface material. Occurs in Southeast, Southwest, and Northeast Areas.

Tuff. – Generally will make a poor road rock in western Washington because it weathers and breaks down so rapidly in a wet climate. If hard and indurated, it might be more acceptable in eastern Washington but it has little strength. Occurs in South Puget Sound, Southwest, Southeast, and Northeast Areas.

Breccias. – Will generally be an acceptable road rock both where it has been totally cemented and has low porosity and where it is poorly cemented and has a high porosity. Where the porosity is high it will tend to break up faster, especially in western Washington where the rainfall is high and water can penetrate the pores.

Cinders. – Generally will make an acceptable road rock. Occurs in Southwest and Southeast Areas.

Sedimentary Rocks
(see table 2)

Conglomerate. – Will usually make acceptable road rock. Occurs in all Areas.

Tillite. – There are no recognized tillites in Washington State. Because of its mineralogical makeup, it would be a poor road rock.

Sandstone. – Suitability of sandstones are variable. In the Olympic Peninsula and Willapa Hills area they are cemented by tuff (volcanic ash). The tuff is weak and weathers rapidly allowing the sandstone to break down. Most of the sandstones in the Cascade Mountains and eastern Washington will make a fair road rock. The key factor is what they are cemented with. Occurs in all Areas.

Siltstone. – Poor road rock. Occurs in all Areas.

Shale. – Poor road rock. Occurs in all Areas.

Claystone. – Poor road rock. Occurs in all Areas.

Limestone. – Good road rock. Occurs in Northeast and Northwest Areas.

Dolomite. – Good road rock. Occurs only in Northeast Area.

Chert, jasper, flint, and agate. – Poor road rock. Although these are hard rocks, their fracture edges are usually as sharp as a knife and would cut tires to shreds. Chert is the only one that occurs in enough quantity in the state that it could be used as a road metal. The areas of its occurrence are very limited, however. Chert occurs in Northwest and Northeast Areas.

Coal. – Poor road rock. Occurs in Southwest, Southeast, South Puget Sound, and Northwest Areas.

Coquina. – Acceptable road rock. Limited occurrences in Southwest Area.

Diatomite. – Very poor road surfacing. Extremely weak. Occurs only in Southeast Area.

Metamorphic Rocks
(see table 3)

Quartzite and metaconglomerate. – Good road rock. Occurs only in South Puget Sound and Northeast Areas.

Argillite. – Might be acceptable locally as a road rock but generally will be poor. Will fracture into small flat fragments. Occurs in South Puget Sound, Southeast, Northwest, Olympic, and Northeast Areas.

Marble. – Good road rock. Occurs only in Northwest and Northeast Areas.

Slate. – Generally will be a poor road rock because it will fracture into small flat pieces. Occurs only in Northwest and Northeast Areas.

Phyllite. – Poor road rock. Occurs in Northwest, Southeast, and Northeast Areas.

Schist. – Poor road rock. Usually has abundance of soft flaky minerals, like mica, that are weak. Occurs in Northwest, Northeast, and Southeast Areas.

Gneiss. – Varies in value. Where crystalline like a granite, it is a good road rock. Where it has a lot of flaky minerals like mica, it will be a poor road rock. Occurs only in Northwest, Northeast, and Southeast Areas.

TABLE 1. – *Igneous rock classification chart*

Mode of occurrence	Texture	Light-colored minerals predominate	Light- and dark-colored minerals about equal	Dark minerals predominate
Rocks that cooled below the earth's surface	Coarse-crystal grains, easily seen with unaided eye	Granite	Diorite	Gabbro
Rocks that cooled at the earth's surface	Fine crystals, need magnifying glass to see crystals clearly	Rhyolite	Andesite	Basalt
		Felsite (light-colored lava)		Trap (dark-colored lava)
Lava surfaces, volcanic cones, areas around cones	Glassy	Dense – obsidian Coarsely vesicular – scoria Finely vesicular, fibrous – pumice		Basalt glass
Crudely to well-stratified layers; volcanic cones	Fragmental	Fine fragments – ash and tuff Coarse fragments – breccia and cinders		

TABLE 2. – *Sedimentary rock classification chart*

Origin	Texture	Composition	Remarks	Loose, uncompacted form	Rock name
Deposited as grains or fragments by streams, glaciers, or wind	Coarse grained; most fragments over 2 mm in diameter	Fragments of other rocks	Usually poorly layered	Gravel	Conglomerate
			Chaotic, heterogeneous mixture of clay, sand, and gravel	Till	Tillite
	Medium grained; 1/16 to 2 mm in diameter. Grains can be seen with unaided eye	Quartz, feldspar, or rock fragments	Well layered; may have ripple marks and cross-bedding. Occasionally contains fossils	Sand	Sandstone
	Fine grained; grains less than 1/16 mm in diameter. Grains can be seen only with magnifying glass or microscope	Very fine particles of quartz, clay, and mica	Layered in thick massive beds to thin platy beds. Often contains fossils	Loess, silt, mud, or clay	Siltstone (if gritty)
					Shale (if not gritty and in thin platy beds)
					Claystone (if not gritty and in thick beds)
Precipitated from water	Fine to coarse grained. Made up of crystals, usually less than 1 mm in diameter	Calcite	Effervesces with acid; often contains fossils	Lime mud	Limestone
		Dolomite	Effervesces with acid only when powdered	Lime mud	Dolomite
		Quartz	Hardness of 7, will scratch steel of knife blade; conchoidal fracture	Silica gel	Chert (usually gray)
					Jasper (usually red)
					Flint (usually brown)
					Agate (banded)
Organic	Coarse to fine grained	Plant remains	Brown to black, burns	Peat	Coal
		Calcite seashells	Mass of broken and unbroken shells cemented together; fine to coarse grained	Shell bed	Coquina
		Opaline diatom skeletons	Chalklike, white, fine grained	Siliceous mud	Diatomite

TABLE 3. – *Metamorphic rock classification chart*

Texture		Outstanding feature	Original rock	Metamorphic rock
Fragmental		Rock breaks through the grains as well as through the cementing material. Usually composed mostly of quartz and has hardness of 7	Sandstone Conglomerate	Quartzite (medium-grained fragments) Metaconglomerate (coarse-grained fragments)
Dense		Commonly dark colored; hard, showing conchoidal fracture	Claystone and siltstone	Argillite
Granular		Effervesces with acid in either solid or powdered form. Formed by recrystallization of limestone or dolomite. Has a hardness of 3 to slightly more	Limestone and dolomite	Marble
Foliated (laminated)	Slaty	Has very good rock cleavage. Breaks into thin flat plates or slabs. When struck with a hammer it has a ring to it	Shale, siltstone, and claystone	Slate
	Phyllose	Same as slate except that the rock cleavage surfaces have a mica coating or sheen	Shale, siltstone, and claystone	Phyllite
	Schistose	Platy minerals are all oriented in one direction. Minerals are packed together like a shuffled deck of cards; that is, they overlap one another	Shale, siltstone, sandstone, claystone, basalt, and others	Schist (rock name prefixed by most abundant or characteristic mineral; for example, mica schist, garnet schist)
	Gneissose	The minerals have moved together into alternating light and dark bands. Good crystalline texture; appears very much like an intrusive igneous rock. Commonly the bands are contorted or twisted	Sandstone, shale, conglomerate, claystone, granite, basalt, and others	Gneiss