BUILDING STONE of WASHINGTON

By WAYNE S. MOEN

Washington Department of Conservation
Division of Mines and Geology

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INTRODUCTION

The fact that Washington contains an abundant supply of many different building stones was brought to the attention of the public by George A. Bethune, first State Geologist, in his first report on Washington mineral resources, published in 1890. Enthusiastically Bethune stated, "As usual, our bountifully endowed commonwealth, rich in everything, is wealthy in the possession of the finest building, dimension, and rubble stone of nearly every known variety from the finest of marbles to the sturdiest of granites and sandstones." Although over 70 years have passed since Bethune made this statement, the building stone deposits of Washington are far from being depleted, and many of them are much more accessible than they were in the late 1800's.

Each year the use of stone in commercial and residential construction increases, representing an important segment in the development of the State's mineral resources. The increasing use of stone in the construction of buildings is due largely to an influence of styling in which the stone is used for ornamental rather than structural purposes. As residential construction increases, more builders are using unfinished natural stone. A recent style trend has been to design wall areas with almost any uncut stone so that the color and texture of the mass is attractive. Even common talus or field stone may be used for this purpose, but the effectiveness of such stonework depends to a large degree upon the skill of the stonemason. Crude stone, with its irregular shape, is hard for the ordinary brickmason to lay.

Although Washington stone is used in the construction of many buildings, much stone continues to be shipped into the State from well-established stone producers as far away as Vermont and Georgia.

For the benefit of those who are interested in the building stones of Washington, this report discusses the stones that have been or are being quarried for building purposes. In addition to a general discussion of the different stones, the distribution of the major rock units from which various stones have been quarried and the locations of the quarries are shown on a series of maps.

The term "building stone" as used in this report refers to stone used in buildings mainly for its decorative purposes; it does not include common aggregate, ballast, riprap, etc. Building stone includes dimension stone, which is sold in blocks or slabs of specific shapes and usually of specific sizes, as contrasted with crushed, broken, or pulverized stone. Dimension stone includes cut stone, rough building stone, ashlar (hewn or squared stone), rubble, monumental stone, paving blocks, curbing, and flagging.

It is not the purpose of this report to describe that phase of the stone industry concerned with quarrying methods or the processes used in the finishing of stone. Quarrying and stone finishing require special equipment and trained personnel. Much has been written on these subjects, and for the convenience of the reader several reports covering quarrying methods and stone finishing are listed in the selected references of this report.

GENERAL HISTORY

Since the earliest settlement of the State, Washington stone has been used in buildings, monuments, road building, curbing, bridges, culverts, and as flagging stone for sidewalks. In the first comprehensive report on the building and ornamental stones of Washington, published in 1903, Solon Shedd reported on 26 quarries that were producing stone. At that time granite, marble, sandstone, basalt, tuff, and serpentine were being quarried from deposits in 10 of the State's 39 counties.

From these quarries came granite that was used in the construction of Federal buildings in Portland, classrooms and administrative buildings at the University of Washington in Seattle, office buildings in downtown Seattle, and street curbings and gutters in many Washington cities. Sandstone quarries produced stone for the State Capitol building, which was built in Olympia in 1901, and for many important buildings in the larger cities of Washington as well as for buildings in cities along the west coast as far south as San Francisco. From the marble quarries of Stevens County came various colors of marble used to finish the interiors of buildings and for monumental purposes.

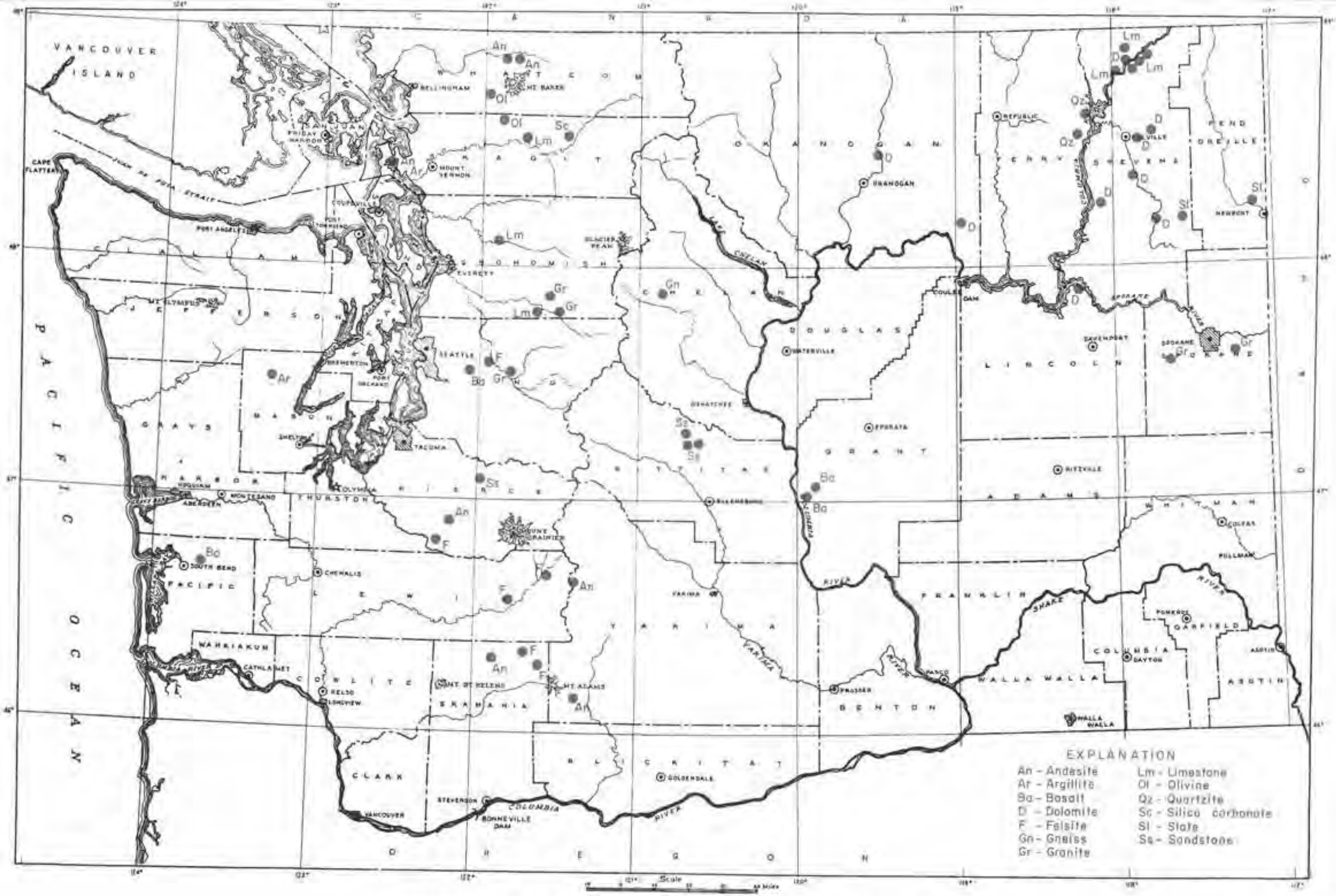

FIGURE 1.—Building stone quarries of Washington (1963).

Although a few of the quarries were operated for many years, most of them were opened to supply temporary markets and have long since been abandoned. To date (1964), no fewer than 250 quarries have at one time or another produced building stone. When compared with the well-established stone quarries of the eastern states, the building stone quarries of Washington are small. With the exception of the Wilkeson sandstone quarry, which is the oldest and largest operating building stone quarry in the State, the quarries are operated by only two or three men, mostly on a part-time basis.

In 1963, building stone was produced from 52 quarries that are widely scattered throughout the State. The major production consisted of marble from Stevens County, granite from Spokane and King Counties, sandstone from Pierce and Kittitas Counties, and basalt from Grant and Yakima Counties. Other types of building stone produced in 1963 consisted of andesite, felsite, dolomite, limestone, quartzite, gneiss, and slate. The locations of the quarries that were operated in 1963 are shown in Figure 1.

PRODUCTION AND VALUE

The earliest available production figures, which are for 1912, report $99,095 in sandstone, granite, and basalt as having been produced (Patty and Glover, 1921, p. 136-147). For most years, accurate figures on the total production of building stone are not available. Production figures published by the United States Bureau of Mines for stone include stone used in concrete aggregate, riprap, roadstone and ballast, and limestone used for cement production and for agricultural, metallurgical, and chemical purposes. Some production figures are withheld to avoid disclosure of individual company confidential data. Based on available information, an estimate of the quantity and value of production of Washington building stone, which includes dimension stone, flagstone, rubble, rough building stone, terrazzo, and roofing chips, is as follows for 1961 through 1963:

Year	Short tons	Value (wholesale-processed)
1961	17,321	$432,023
1962	26,174	581,384
1963	93,213	618,171

These figures represent less than 1 percent of the total stone production of Washington, which in 1962 was 12,749,000 tons and in 1963 was 12,934,000 tons.

TABLE 1.—Average wholesale values of Washington building stones 1961 through 1963

Material and form	Value per short ton
SANDSTONE	
Rough construction	$50.00
Rubble	25.00
Sawed	55.00
Dressed	182.00
Flagging	27.00
GRANITE	
Monumental, rough	20.00
Monumental, dressed	25.00
Rough construction	20.00
MARBLE	
Dimension	18.00
Rough construction	19.00
Terrazzo	18.00
Roofing granules	18.00
LIMESTONE	
Rough construction	18.00
BASALT	
Rough construction	12.00
Rubble	20.00
Flagging	11.00
QUARTZITE	
Rough construction	21.00
Flagging	40.00
ANDESITE	
Rough construction	21.00
FELSITE	
Rubble	30.00
QUARTZ	
Rough	7.00
SLATY ARGILLITE	
Flagging	35.00
OLIVINE	
Rough	5.00

The average quarry and processed prices for Washington building stone range from lows of around $4.00 per ton for rough andesite at the quarry to a high of about $185.00 per ton for dressed sandstone. Rock used in the manufacture of crushed stone for terrazzo and roofing chips sells for an average of $5.00 per ton at the quarry; after crushing, the wholesale market price ranges from $13.00 to $20.00 per ton, depending on the size and color of the granules. For comparison, the price of common riprap and road metal in 1963 was $1.30 to $2.50 per ton.

Average wholesale values for building stone sold in Washington from 1961 through 1963 are shown in Table 1.

FORMS OF BUILDING STONE

The forms of unfinished natural stone used most commonly in construction are field stone, rough building stone, rubble, and flagging. Although ashlar also is a common form of building stone, most of it cannot be classed as an unfinished stone because it generally has sawed or planed surfaces. Cut or finished stone is a form of building stone consisting of blocks that have been accurately shaped and sized, and surface tooled.

Field Stone

Field stone, often overlooked as a building stone, consists of loose stone that is scattered over the ground surface by natural processes. Most field stone has

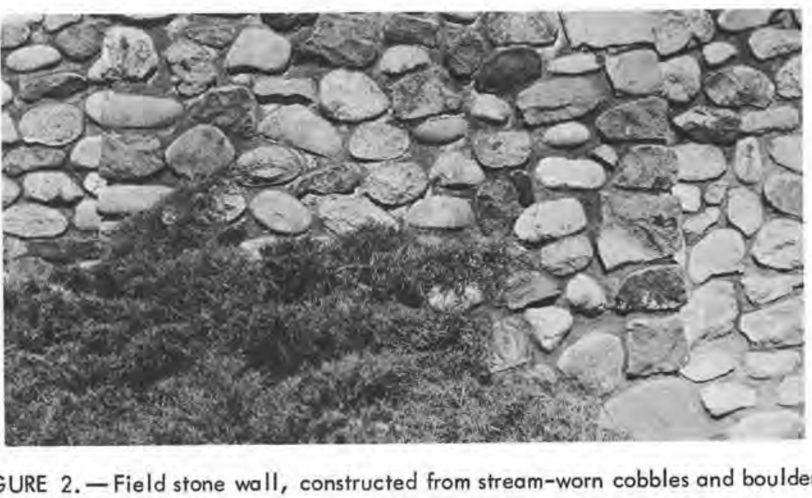

FIGURE 2.—Field stone wall, constructed from stream-worn cobbles and boulders.

acquired a rounded shape through attrition during transportation by stream or glacial action. Having originated from different sources, field stone provides many different sizes and types of rock, ranging from pebbles of white quartz to boulders of black basalt. It is perhaps one of the cheapest forms of stone to obtain, as conventional hard-rock quarrying methods are not required to mine it.

The most common uses of field stone are in fences, retaining walls, and partial or entire walls of buildings (Fig. 2).

Rough Building Stone

Rough building stone is the crudest form of building stone. It consists of stone of various shapes and sizes that is removed from a quarry without further processing; often some sorting is undertaken to grade the rock according to shape and size. Rock that is massive and lacks cleavage planes is generally preferred for rough building stone, as it retains its rough form during handling. Rocks commonly quarried for this form of building stone are andesite, basalt, rhyolite, granite, gneiss, limestone, marble, silica-carbonate rocks, tuff, sandstone, and quartzite.

Rough building stone is generally used for retaining walls or in walls of buildings where a rough natural stone finish is desired (Fig. 3). The size of the

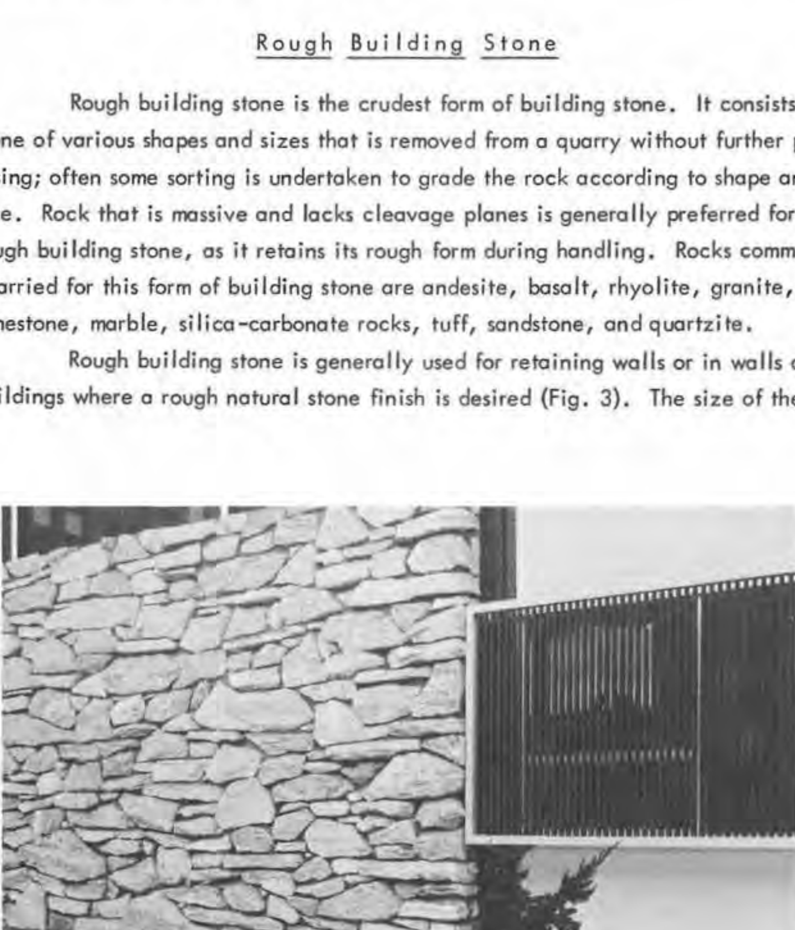

FIGURE 3. — Rough building stone wall. Note how recessed mortar accentuates the shape of the fragments of gneiss.

stone used in the construction of walls ranges from 6 to 30 inches in maximum dimension. However, to create a balanced structure the general rule often followed by stonemasons is that the exposed area of the largest stone should not exceed by five times the size of the smallest.

FIGURE 4. — Limestone rubble wall.

Rubble

Rubble, another crude form of building stone, consists of irregular rock fragments, each of which has one essentially flat face. When laying rubble, the flat face is exposed, which provides a somewhat flat surface to the finished wall (Fig. 4). In general, the discussion on rough building stone also applies to rubble.

Flagging (flagstone)

Flagstone consists of thin rock slabs used for walks, driveways, patios, hearths, and wall veneer (Fig. 5). Although sawed slabs are sometimes used, the stones that split into thin slabs are preferred because of their natural appearance. Flagstone slabs are commonly 1 to 3 inches thick, depending upon the toughness of the stone; thinner slabs used on walkways and roadways may crack under heavy loads. Slate flagging, because of its toughness, is cut as thin as 3/8 inch.

FIGURE 5.—Quartzite flagging wall. (Photo by G. W. Thorsen.)

Most flagstone consists of sandstone, siltstone, and slate; however, volcanic rocks, quartzite, and limestone when flaggy (cleavage plates 1/2 to 4 inches thick) are commonly quarried in Washington. Granitic rocks can also be used as flagstone if rock can be found that splits into the required thicknesses. Sheeted granite sometimes satisfies this requirement.

Unlike rubble and rough building stone that in most cases is removed with a minimum of quarry work, flagstone requires special care to remove the rock in thin sheets. In addition to the initial work of stripping and exposing a working face in a quarry, much hand work is required in separating the stone, and careful stacking may be required to minimize breakage (Fig. 9, p. 25).

Ashlar

Ashlar consists of rectangular blocks of stone having sawed, planed, or natural surfaces, contrasted with cut blocks that are accurately sized and surface tooled (Bowles, 1934, p. 24). Ashlar is laid in courses, but to achieve an effective

FIGURE 6. — Sandstone ashlar wall.

pattern most ashlar is laid as random ashlar, consisting of blocks of several sizes having irregular and unequally spaced joints (Fig. 6). Two, three, or more unit heights may be used.

Unlike rubble, rough building stone, and flagging that may be prepared for the market by using standard rock-quarrying equipment, the production of ashlar requires a rock saw of one type or another and usually a hydraulic stone shear. However, when stone is available that possesses natural cleavage planes of desired thickness, sawing or shearing may not be required.

Ashlar most commonly consists of sandstone, limestone, and marble; only minor amounts of felsite are used. Although other types of ashlar are available on the market, they are supplied by out-of-state producers.

Crushed Stone

Crushed stone includes all stone that after quarrying has been reduced to smaller fragments, usually by means of mechanical crushers. Although crushed stone is used in large amounts for such purposes as concrete aggregate, railroad track ballast, road metal, and poultry grit, the crushed stone referred to in this report is only that used for terrazzo, roofing granules, exposed aggregate, and reconstituted stone.

In general, stone that is to be crushed should be dense, strong, and homogeneous; it should tend to break into suitably shaped fragments. Limestone, marble, dolomite, serpentine, and quartz satisfy these requirements and are commonly used as crushed stone in Washington.

Terrazzo

Terrazzo consists of marble granules embedded in a cement mortar, the whole of which is surface machined and polished to a high-gloss finish. Many floors of commercial buildings have terrazzo floors; such floors are usually laid and surfaced in place. Terrazzo may also be precast in tiles or slabs and used to finish walls. Attractive murals for use in commercial buildings are sometimes prefabricated of terrazzo in this manner.

Terrazzo surfaces consist of 1/4-inch to 1-inch fragments bound by a cement mortar; the common mixture is about 70 percent chips to about 30 percent mortar. The effectiveness of terrazzo is achieved by the size, shape, and color of the rock fragments and the color of the mortar.

Rock fragments used for terrazzo should all have approximately the same degree of denseness and hardness so as to take a uniform polish. They should be free of dirt, silt, mica, organic matter, and other foreign substances. The fragments are graded commercially according to size; the common commercial sizes are: No. 1, 3/16 to 1/4 inch; No. 2, 3/8 to 7/16 inch; and No. 3, 1/2 to 5/8 inch.

In Washington the mining of rock for terrazzo fragments is carried out mainly in Stevens County. The rock is crushed into the required sizes at plants near Northport, Addy, Valley, and Chewelah. These plants, which have supplied fragments in colors of white, black, gray, brown, green, and red to markets in the United States and Canada, are as follows:

International Stone Co., Inc.
711 Hutton Bldg.
Spokane, Wash. 99204
Plant at Addy

Manufacturers Mineral Co.
P. O. Box 3543
Seattle, Wash.
Plant at Chewelah

Peter Janni & Sons
Box 333
Northport, Wash.
Plant south of Northport

Northwest Marble Products Co.
Chewelah, Wash.
Plant at Chewelah

North American Nonmetallics, Ltd.
2775 W. Broadway
Vancouver 8, B.C., Canada
Plant at Valley

Granules of rocks other than marble may be used in terrazzo, but because of their hardness the cost of sawing, grinding, and polishing is greater than that of marble. Granite, quartz, basalt, argillite, and brightly colored volcanic rock have been used in terrazzo.

Roofing Granules

Rock roofs are impervious to rain and snow, have long life spans, rank high in fire resistance, and have low maintenance costs. Because of its insulating quality through the reflection of sunlight, white crushed stone is used widely as roofing material. However, in recent years the trend has been toward colored stone roofs for styling purposes.

On built-up roofing, which consists of alternating layers of asphalt-impregnated felt and roofing asphalt, rock granules are spread over the top coating of tar, which hardens and holds the granules in place.

Granules for built-up roofs should be opaque to the sun's rays, clean, dry, and hard. Cleanness and dryness are essential in order to insure complete adhesion. Opacity protects the tar from being melted by the sunlight, and hardness inhibits attrition between the granules.

The color, shape, and texture of the granules are other important characters of roofing granules. The color should be uniform and pleasing to the eye and should resist fading. Although white has been popular for many years, subdued tones of green, red, pink, brown, and gray are becoming popular, especially for the modern residential buildings. Where appearance is of little or no importance, any granule that meets the basic requirements may be used.

Normal sizes for standard roofing granules range from 1/8 to 3/4 inch. On low-pitch roofs, rock fragments as large as 3 inches in maximum dimensions are sometimes placed over the standard-size granules to provide a textural effect created by shadows.

Roofing granules, as sold by roofing-material dealers, are priced according to the size and color of the granule. The average price is about $18.00 per ton.

Exposed Aggregate

Exposed aggregate is the term used for a cement-bound aggregate that, through the combination of color, size, shape, and texture of the exposed rock fragments, creates a pleasing appearance (Fig. 7). Unlike terrazzo, which is

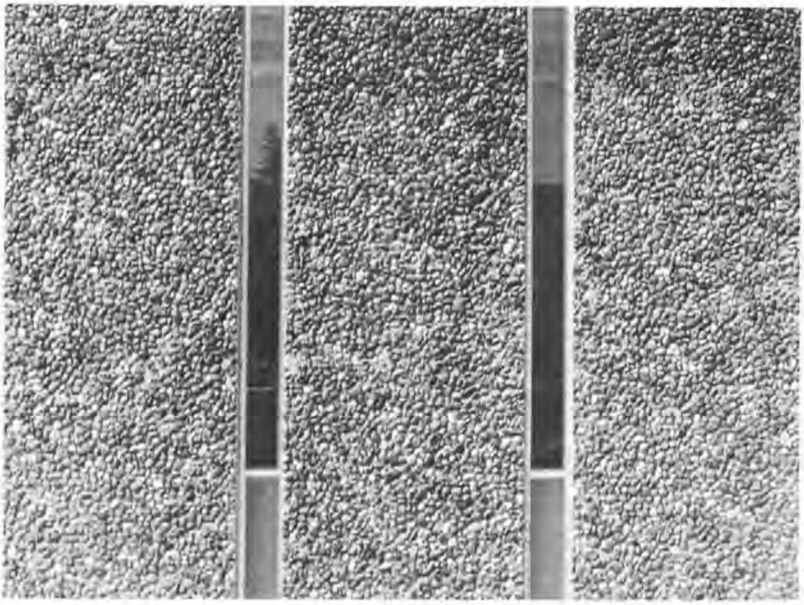

FIGURE 7.—Exposed aggregate panels. Panels are about 16 feet high and 5 feet wide.

machined and surface polished to provide a smooth surface, exposed aggregate is intentionally left in its rough form. Like roofing chips, fragments for exposed aggregate should be dense, hard, and clean. Opacity is not essential, as the fragments are bonded together by a cement that is not affected by the heat of the sun.

Varieties of marble, granite, and quartz are commonly used as exposed aggregate, but any rock may be used to achieve the desired finish if the rock is resistant to weathering. Inasmuch as exposed aggregate is used mainly for exterior wall panels, rocks containing minerals that stain are usually avoided.

Reconstituted Stone

A recent trend, especially in the construction of precast panels, is to cast different-size fragments of one specific stone type into a slab and polish the slab so that it resembles a massive natural continuous stone panel. Such panels in reality are man-made breccias. Although close examination of the finished panels will reveal the individual fragments, when viewed from a distance the fragments are indiscernable.

Whereas careful selection of a stone would be required to obtain large stone slabs free of natural defects such as dikes and inclusions, reconstituted stone slabs are free of imperfections. It is also possible to manufacture large reconstituted stone panels from attractive stone that, because of jointing, was previously limited in size to the slab that could be cut and polished.

To date, attractive panels of granite and marble have been used in the construction of walls for commercial buildings. However, there is no reason why other attractive stones cannot be used for this purpose.

Landscape Rock

Rock that is used by landscape gardeners to create a desired effect in the landscape is considered landscape rock. The modern style trend is to utilize rock to decrease the lawn area and to achieve a natural setting about a building. Such landscaping usually harmonizes with the design of modern buildings, many of which contain stonework on their exterior surfaces.

No attempt will be made to describe landscaping technique in this report, as it is a skill that must be developed. However, the desirable properties of

FIGURE 8. — Field stone used as landscape rock.

landscape rock will be pointed out to aid the layman in the selection of these rocks.

Physical properties that should be considered in the selection of landscape rock include shape, size, color, and durability. The shape of a rock is one of the more important features of landscape rock. Shapes range from well-rounded glacier- and stream-worn boulders to angular fragments that are typical of rock found in talus slides or as broken quarry rock. In size, landscape rock may consist of small fragments of crushed rock and stream pebbles, or rocks so large that the use of a mobile crane may be required to set them in place. The color of landscape rock does not seem to be as important as that of building stone. Many rocks that are used for landscaping purposes lack the distinct colors of freshly quarried building stone, but are characterized by subdued colors that are typical of rock that has been exposed to many years of weathering. To achieve a natural look, weathered rock is used in many landscaping jobs. As in the case of exterior building stone, landscape rock should be durable. Those rocks that are low in clay minerals are generally resistant to weathering of the type that tends to break the rock down. The general appearance of an outcrop or a rock fragment serves as a guide toward the selection of a durable rock. Rocks that tend to retain their form over many years of weathering are usually resistant to the existing climatic conditions. Rocks that show signs of slaking or are in the process of disintegrating due to the breakdown of the rock-forming minerals should be avoided.

Fortunately, most of the rock that is used as building stone in Washington is suitable for use as landscape rock. These rocks include granite, diorite, quartz, andesite, basalt, felsite, gneiss, schist, sandstone, quartzite, marble, limestone, and olivine. Thus, large areas of the State provide many varieties and excellent sources of landscape rock.

AREA COVERAGE OF BUILDING STONE

The area a given weight of building stone will cover depends mainly on the thickness of the pieces of stone. Rough building stone and rubble that have nearly equal dimensions yield the smallest coverage, whereas flagstone, which is flat, yields the greatest. Inasmuch as most stone is sold on a per ton basis, the specific gravity of a stone is sometimes a determining factor in estimating coverage. When working with the building stones of Washington the specific gravity factor may usually be disregarded, because most of the stones have similar weights.

The approximate coverage of the common forms of building stones is shown in Table 2.

TABLE 2.—Area coverage of stone

Form of stone		Average coverage (sq ft per ton)
Field stone		40 - 50
Rough building stone		40 - 55
Rubble		40 - 55
Ashlar		40 - 60
Flagging	1/4 in - 1/2 in	220 - 290
	1/2 in - 1 in	165 - 220
	3/4 in - 1-1/2 in	100
	1-1/2 in - 2-1/2 in	80

ACQUISITION OF BUILDING STONE

As common as rock is in Washington, it all belongs to someone, and to legally remove it requires the consent of the owner. Land on which stone occurs may be owned by individuals, the State, or the Federal Government.

Stone on privately owned land is the property of the owner of the mineral rights, who may not necessarily be the owner of the surface rights. In selling the land, one of the earlier owners may have retained the mineral rights to the land. Often a search of title is necessary to determine the owner of mineral rights to a particular property.

Stone on State-owned land belongs to the State and, if not subject to an existing mineral lease, it may be purchased or leased from the State. The price for stone of the types used for building purposes usually ranges from 25 cents to $1.00 per ton. Such prices are determined by the district administrator for the Department of Natural Resources and are based on the fair market value of the stone.

Although most rocks within the national forests are considered common and subject to purchase, some rocks have properties that make them locatable under the mining laws. According to George Abbott, formerly solicitor, U.S. Department of the Interior:

> Any deposit that has characteristics giving it a special economic value above and beyond the value of the normal deposit of widespread

> occurrence is not a "common variety." Examples of this are: stone that is naturally cleavable into blocks or impervious to water, and, thus, especially suitable for building purposes; sand that has characteristics making it particularly valuable for glass making or sand blasting; and limestone valuable for cement or metallurgical processes. . . . On the other hand, if the only uses for the deposit are for fill, aggregate, or road surfacing, it would probably be deemed a common variety and subject to purchase as a material rather than a locatable mineral.

Common stone suitable for building purposes can be purchased at a small charge from the Federal Government. Such purchases are for personal uses and cannot exceed $1,000 per year. If the stone is to be mined for commercial uses, it is subject to lease and is to be mined at a fixed price on a per ton basis.

As an aid to the public in the determination of general land ownership in the State, the Washington Division of Mines and Geology has published a free information circular on land ownership (Moen, 1962).

EXAMINATION OF STONE DEPOSITS

The selection of small amounts of building stone for specific jobs need not be complicated; it involves determinations of pleasing color and texture, strength, and durability. However, if a deposit of rock is being considered for the purpose of commercial development, a more detailed appraisal of the deposit is needed. Such a study should be carried out by a consultant who is familiar not only with geology but also with the various phases of the stone industry. The proper appraisal of a stone deposit is usually beyond the training of the average individual, but publications are available that will aid in the examination of deposits. One such publication is "Geologic Appraisal of Dimension-Stone Deposits" (Currier, 1960).

When examining a deposit of stone for its building stone possibilities, many features must be considered. The following brief outline lists some of the important factors to note when examining a deposit or quarry:

TABLE 3. — General considerations for quarry examinations

General Features

- Location
- Ownership
- History of past operation
- Trade name of stone, if established
- Climatic conditions
- Topography of land

TABLE 3. — General considerations for quarry examinations — Continued

Geologic Features

Formation name
Distribution of formation
Type of rock
Physical properties of rock:

Color, texture, strength, hardness, toughness, porosity and absorption, insulation, reflection

Structural features
Cleavage and fractures
Thickness of deposit of favorable rock
Weathering:

Depth and nature

Overburden:

Nature and thickness

Economic Factors

Reserves
Markets
Access
Transportation
Labor supply

GENERAL QUARRYING METHODS

In Washington, building stone is mined wholly from open-pit quarries. These quarries range in size from small, one-man operations to large quarries that may employ as many as 30 men. The small quarries may not be much more than 50 feet in length, having a working face less than 20 feet in height. A large quarry, such as the Wilkeson sandstone quarry, may be over 700 feet long and have a working face several hundred feet high. Regardless of the size of the quarry, the operator is faced with the problem of removing the stone at a minimum cost.

In opening a new quarry, overburden may present the first problem. In the mountainous rocky terrain of Washington many quarries are started on outcrops of rock that have no overburden. This eliminates the problem of having to strip overburden from the rock surface. Stripping, if required, may be accomplished by hydraulic methods or by use of a dragline scraper or a bulldozer. The hydraulic method consists of washing away the overburden with a stream of water under pressure. This is a very effective low-cost method, if water and a disposal area for overburden are available. Scraping away the overburden by means of a dragline scraper or a

FIGURE 9. — Building stone quarry in quartzite. Note quartzite flagstones on pallet in lower right foreground.

bulldozer is common practice. Sufficient room for the storage of the overburden may present a problem in areas of low relief, but on hillside operations the overburden can be used to build up a flat working area adjacent to the quarry.

After the overburden has been removed, the next step in opening a quarry is to obtain a working face on a solid ledge. Inasmuch as most of the stone quarries in Washington are on hillsides, holes are drilled along the side of the hill above the proposed working level and the mass of stone is broken loose by explosives. For use as rubble and rough building stone, the stone is sorted according to size and shape. By using properly spaced charges, the initial blast can supply much stone for these uses. The larger masses of dislodged stone are broken to smaller fragments by sledging or by drilling and shooting the mass with small charges of powder.

If the stone is to be worked into squared blocks, wedging or sawing is used. Wedging consists of driving steel wedges into evenly spaced drill holes that have been drilled along a straight line. The wedges are sledged lightly back and forth along the line until the stone fractures. Wedging is also used to remove large blocks of stone from the quarry face.

Sandstone, which is usually softer than igneous rock, may be split by driving steel points along a line until a fracture develops. In working the more indurated sandstones, a square-faced steel tool can be struck successive blows along a line until a fracture occurs.

Sawing is accomplished by gang saws or continuous wire saws. A cutting grit, such as sand, steel, or corundum, and water is fed to the saw blades, and the stone is cut by abrasion. Blocks of different thicknesses are obtained by adjusting the distance between the blades of the gang saw or the wires of the wire saw.

Handling large blocks of stone is by no means easy, considering that a cubic yard of stone weighs about 2 tons. In large quarries the stone is handled by derricks that are capable of lifting masses of stone weighing as much as 50 tons. Smaller masses may be moved by front-end loaders on tractors, fork lifts, or power shovels. A few quarries require no lifting devices at all, for the stone is in small enough pieces to be moved by hand.

PHYSICAL PROPERTIES OF BUILDING STONE

Although innumerable deposits of rock of the types used for building stone occur throughout the State, only a small percentage of them contain rock that meets the requirements of a good building stone. The desirable physical properties of building stone differ according to use. Strength and durability appear to be the principal considerations, but color and texture are also important, especially if the stone is to be used for ornamental purposes.

In general, a rock considered for building purposes should meet the following requirements:

1. Uniform texture and grain size
2. Attractive color
3. Freedom from cracks and lines of weakness
4. Splits easily in one or two planes
5. Free of minerals that upon weathering cause deterioration and surface staining
6. Workability

Strength

A rock consists of one or more minerals, and it is the physical properties of these rock-forming minerals that largely determine the strength and durability of the rock. However, in a sedimentary rock the cement that binds the individual grains together also determines the rock's strength and durability.

Many unaltered rocks are very strong and capable of sustaining loads for most building purposes. Most of the rocks used for building purposes have crushing strengths of more than 3,000 psi (pounds per square inch), as compared with concrete, which has crushing strengths that range from 2,000 to 3,750 psi. Strengths for Washington stone as reported by Shedd (1903, p. 134-135) are as follows:

Material	Range (psi)
Granite	10,730 - 16,610
Sandstone	3,270 - 11,070
Marble	6,280 - 24,510
Basalt	30,000 - 46,000

For comparison purposes, crushing strengths as reported by Currier (1960, p. 28) on stones from many different localities throughout the country are:

Material	Range (psi)
Granite	17,000 - 37,000
Sandstone	5,000 - 20,000
Marble	8,000 - 27,000
Limestone	2,600 - 28,000
Quartzite	16,000 - 45,000
Serpentine	11,000 - 28,000

In general, the crushing strengths for crystalline rocks such as igneous and metamorphic rocks are greater than those for stratified sedimentary rocks.

Hardness and Workability

The hardness and texture of the minerals that make up a rock determine the hardness and workability of the rock. Many minerals are as hard or harder than steel (5.5 on Mohs' scale of hardness), and their presence makes a rock difficult to work. The common rock-forming minerals and their hardnesses are presented in Table 4.

Although a rock may be composed mainly of hard minerals, if the grains are cemented with soft minerals the rock may be worked with ease. Thus a quartzose sandstone in which the mineral grains have a hardness of 7 may be readily worked if the cementing agent is calcite, which has a hardness of 3. Should the cementing agent be quartz, the stone would be difficult to work.

TABLE 4.—Hardness of common rock-forming minerals

Mineral	Mohs' scale
Actinolite-tremolite	5 - 6
Augite	5 - 6
Biotite-muscovite	2.5 - 3
Calcite	3
Dolomite	3.5 - 4
Hornblende	5 - 6
Magnetite	5.5 - 6.5
Olivine	6.5 - 7
Orthoclase-plagioclase	6
Pyrite	6 - 6.5
Pyrrhotite	4
Quartz	7
Volcanic glass	7

The workability of igneous rocks depends on the interlocked texture of the minerals that make up the rock. Rocks in which the minerals crystallized at essentially the same time generally have a well-interlocked internal texture, whereas minerals that crystallized out at several stages provide a poorly interlocked texture. Granite is characterized by a poorly interlocked texture, and gabbro possesses a well-interlocked texture. Increased interlocking of the minerals in a rock that originally possessed a poorly interlocked texture may be accomplished by the agents of metamorphism. Through metamorphism the rock becomes recrystallized.

Color

Many stones used for decorative purposes in building are selected because of their color. The color of a rock is due mainly to the color of the predominant mineral but also is influenced by the rock's texture. Texture is the size, shape, and arrangement of the component particles. In the fine-textured rocks there is more blending of the colors to give a uniform effect. However, as grain size increases, the color becomes more difficult to describe. The blending of the separate colors is often achieved only when viewing the rock from a distance.

The surface finish of a stone also affects its color. On many stones, polished surfaces show darker tones, and tooled surfaces show lighter tones than the natural stone.

Some building stone changes color after exposure of a fresh surface. This change in color is due mainly to the oxidation of ferrous iron. Such a color change is not always detrimental, for only through weathering are some delicate colors achieved. However, it should be determined whether a change in color of a stone is accompanied by the formation of detrimental minerals that would tend to weaken the stone. Some of the common colors are caused by the presence of the following metals and minerals:

Green - chromium, nickel, and copper stain; ferrous iron
Red and pinks - various amounts of hematite or manganese oxides
Browns - mixtures of iron oxides (ferric iron)
Black and grays - mainly carbonaceous matter

The stone trade has not established standard color specifications, and for this reason the color assigned a particular stone seldom gives an accurate description of the stone's true color. Trade names are usually based on the general color of the stone, as "Alpine green," "Midnight black," "Silver white," "Sunset red," "Silver shadow," etc. Many such names are highly imaginative and are chosen because of their commercial appeal.

Should a more exact color designation for a particular stone be desired, standard color charts should be consulted. Two such charts are the "Rock-Color Chart" distributed by the National Research Council, Washington, D.C., and "Methods of Designating Colors," National Bureau of Standards, Research Paper 1239. Standard color charts are also included in Webster's Unabridged Dictionary, which is available for reference at most libraries.

Alteration

The susceptibility to alteration through chemical weathering of the rock-forming minerals varies greatly among different rocks. Some minerals are generally stable to adverse weathering conditions, whereas others readily break down under normal weathering. In general, alteration by which iron oxide and clay minerals are formed is detrimental to a rock, but alteration that results in minor sericitization, chloritization, or epidotization is usually harmless (Currier, 1960, p. 64).

Iron oxides are not always detrimental to building stone, for these oxides give many of the stones their red, brown, and green colors as well as attractive patterns that are created by stains. Pyrite, which commonly alters to iron oxide, may, however, cause unsightly rusty spots and streaks. This is especially noticeable on the light-colored fine-grained rocks such as felsite. However, a few scattered grains of pyrite should not cause concern when selecting a rock for exterior building purposes.

The feldspars, which are the main rock-forming minerals in granite and many sandstones, are slowly altered to clay minerals. This alteration is more pronounced in rocks subjected to the action of ground water, which contains acids and carbon dioxide, than it is in those exposed to normal atmospheric moisture. The alteration of fresh feldspar in exterior building stone does not appear to be appreciable and detrimental, because the alteration proceeds at a rate that is barely discernible in the lifespan of the average building.

The common alteration products of the main rock-forming minerals are shown in Table 5.

TABLE 5.—Common alteration products of the main rock-forming minerals

Actinolite, tremolite → Talc
Augite → Secondary hornblende (uralite), epidote, chlorite, and biotite
Biotite → Chlorite and iron oxide
Calcite (generally stable)
Dolomite (generally stable)
Hornblende → Chlorite, biotite, epidote, and calcite
Magnetite → Hematite, limonite, and geothite
Olivine → Antigorite, chrysotile, and iddingsite
Orthoclase, plagioclase → Kaolinite, sericite, and quartz
Pyrite → Hematite, limonite, and geothite
Pyrrhotite → Limonite
Quartz (generally stable)
Volcanic glass → Palagonite and montmorillonite

The ability of a rock to resist alteration and to withstand weathering is generally indicated in the appearance of the outcropping rock. Rocks that form bold outcrops and tend to retain their sharp angular edges are more resistant to weathering and are usually suitable as exterior building stone.

Porosity and Absorption

Porosity is a measure of the volume of pore space in a rock, and absorption refers to the amount of liquid absorbed upon immersion. The pore space in a rock determines the rock's absorption of water, which is an important factor in the susceptibility to frost action and chemical weathering. In Washington, especially west of the Cascade Mountains, building stones used for exterior purposes are subjected to large amounts of moisture. For this reason the porosity and absorption should be considered in selecting a building stone for use in this area.

In general, rocks of compact textures possess low porosities; such rocks are: granite, marble, andesite, basalt, quartzite, and slate. Sandstone and limestone may be loosely compacted and have high porosity or be highly compacted and have low porosity. Tuffs in general have highly porous textures.

The ranges in porosity for various stones as reported by the U.S. Bureau of Standards (Kessler and others, 1940) are as follows:

Material	Volume (percent)
Granite	0.4 - 3.84
Marble	0.4 - 2.1
Slate	0.1 - 1.7
Quartzite	1.5 - 2.9
Sandstone	1.9 - 27.3
Limestone	1.1 - 31.0
Cast stone (manufactured)	6.7 - 32.7

The ranges in porosity of selected Washington stones as reported by Shedd (1903, p. 136-137) are:

Material	Volume (percent)
Granite	0.36 - 0.69
Sandstone	1.82 - 5.36
Marble	0.03 - 1.32
Tuff	4.64 - 7.86

A rough determination can be made of the suitability of a stone for building purposes by measuring the absorption and the weight of the stone (Ralph Clark, written communication, 1964). As shown in Figure 10, rocks that weigh less than 101 pounds per cubic foot and have an absorption of 15 percent or greater

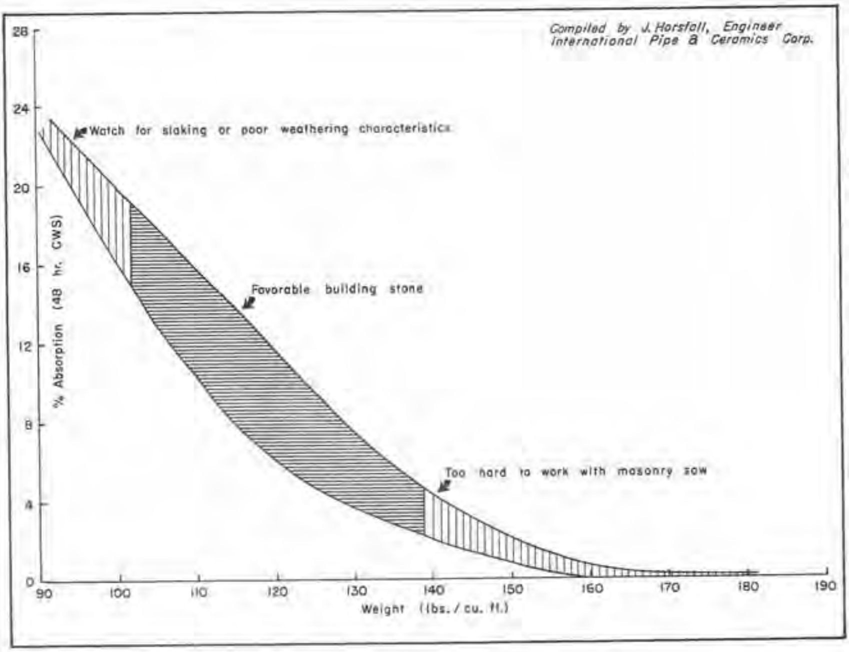

FIGURE 10. — Evaluating building stone based on weight and absorption.

may slake or have poor weathering characteristics. Rocks having weights greater than 138 pounds per cubic foot have very little absorption, but generally they are too hard to work with a masonry saw. In some stone work this may be a disadvantage.

It should be pointed out that the selection of a stone for building purposes based solely on weight and absorption is no substitute for actual testing but serves as a guide for a quick evaluation of a building stone.

In testing the absorption of a rock specimen the following procedure should be followed:

1. The specimen may be a cube, prism, cylinder, or any regular form having its smallest dimension not under 2 in and greatest dimension not over 3 in, but the ratio of volume to surface area should be not less than 0.3 nor greater than 0.5. All surfaces should be reasonably smooth; saw or core drill surfaces are considered satisfactory.

2. Specimens should be dried for 24 hr in a ventilated oven at a temperature of 105°± C. After drying, specimens should be cooled in the room for 30 min and weighed to the nearest 0.02 g.
3. The specimen should be completely immersed in filtered or distilled water at 20°±5° C for 48 hr. At the end of this period the sample should be surface dried with a damp cloth and weighed to the nearest 0.02 g.
4. The percentage of absorption by weight for the specimen is calculated as follows:

   Absorption by weight, percent: $\frac{B-A}{A} \times 100$ where: A is the weight of the dried specimen and B is the weight of the specimen after immersion.

TESTING OF BUILDING STONE

Standard tests for natural building stone have been adopted by the American Society for Testing Materials, 1916 Race Street, Philadelphia, Pa., 19103. All stones are not covered by these specifications, but the Society is in the process of preparing standards to cover most of the common building stones. Standard methods of test that are presently (1963) available from the Society at 50 cents each are:

Compressive strength of natural building stone (C170-50)

Absorption and bulk specific gravity of natural building stone (C97-47)

Modulus of rupture of natural building stone (C99-52)

Abrasion resistance of stone subjected to foot traffic (C241-51)

Combined effect of temperature cycles and weak salt solutions on natural building stone (C218-48T)

Weather resistance of natural slate (C217-58)

Roofing slate (C406-57T)

Water absorption of slate (C121-48)

Flexure testing of slate (C120-52)

Although laboratory procedures have been devised to test building stone, the average individual is not equipped to perform these tests. Should it be desired to have specific tests run on stone specimens, the following commercial testing laboratories in the Northwest are available to do this type of work:

Inland Analytical Laboratories, Inc.
N. 118 Browne Street
Spokane, Wash. 99201

Northwest Testing Laboratories
4115 N. Mississippi Avenue
Portland, Oreg. 97217

Northwest Laboratories
200 James Street
Seattle, Wash. 98104

Washington Testing Laboratories, Inc.
N. 130 Stone Street
Spokane, Wash. 99202

COMMON BUILDING STONES OF WASHINGTON

The classification of rocks as used by petrologists is by no means simple, and in most cases a microscopic examination is required to properly identify a rock. At times, chemical and X-ray methods may be employed to establish the name of a specific rock-forming mineral, which in turn determines the rock name.

A megascopic examination can provide a general name for a rock until a more detailed examination can be made. However, a general rock name is usually all that is required for a rock that is to be used as building stone. Most of the rocks used for building stone in Washington are listed in the rock charts in the appendix of this report. Because the classification of rocks as used by petrologists is too detailed to be used by the building stone industry, the industry through many years of usage has adapted names for several principal classes of rocks to fit its needs. Realizing the need for standard rock names for the building stone industry, the American Society for Testing Materials (1952), through its Committee on Natural Building Stones, adopted the following classes, which include 26 petrological varieties of rock (Currier, 1960, p. 7):

1. Granite (Includes gneiss, gneissic granite, syenite, monzonite, granodiorite.)
2. Limestone (Includes calcite limestone, dolomite, magnesian [dolomitic] limestone, travertine.)
3. Marble (Includes calcite marble, dolomite marble, onyx marble, travertine marble, serpentine marble, verd antique.)
4. Sandstone (Includes bluestone, conglomerate, freestone, quartzite.)
5. Slate
6. Greenstone
7. Basalt and trap rock

Included in this classification are rocks that occur and are utilized as building stone in Washington. However, several building stones of this State do not fall within this classification; these rocks are discussed under the heading, "Miscellaneous Stone." Basalt and traprock are included under volcanic rocks. Although greenstone does occur in Washington, its color and texture are such that it is not in demand as building stone. Some stone that is called "greenstone" by stone producers is in reality green andesite.

Granite

Granite is one of the major rocks of Washington; it occurs in 22 of the State's 39 counties. Since the opening of the first granite quarries in the late 1800's, at least 20 quarries have produced granite at one time or another (Table 6). These quarries have never operated on as large a scale as have the granite quarries of the eastern states, and most production has been sporadic, granite having been produced only when there was a demand for the stone.

In eastern Washington, for many years granite has been quarried near Medical Lake, in Spokane County, for use as monumental and building stone. Fort Wright, near Spokane, and some of the first buildings at the University of Washington and Washington State University were constructed from this granite. From the Snake River area of Whitman County, granite was quarried to build the United States Customs House in Portland.

Granite quarries in western Washington produced stone as early as 1900 from the Index area of Snohomish County and near Baring, in King County. This stone was used for curbing and paving blocks on the streets of Seattle, as monumental stone, and for flagging and building purposes.

In recent years the production of granite for uses other than monumental stone and building stone has declined until at present (1964) only five quarries remain in part-time production (Table 7).

Geology and Distribution

Specifically, the term "granite" refers to a definite rock type, but the term as used in the building and monumental trades includes true granite, granodiorite, quartz monzonite, quartz diorite, and gneiss (pronounced "nice"). Dark igneous rocks, classified petrographically as diorite, gabbro, or diabase, are commonly used as dimension stone—chiefly for monumental stone—and are called black granites.

TABLE 6. — Granite quarries of Washington that have produced in the past

Quarry	County	Location Sec. (T. R.)	Product
Manson	Chelan	15 (28-21E)	Dark-red granite worked by Columbia Granite Co.
Boring Granite Works	King	1 (26-10E)	----------
Landsburg	King	19 (22-7E)	----------
Patrick O'Hara	King	7 (22-11E)	----------
Camp Union	Kitsap	8 (24-1W)	Dioritic rock.
Green Mountain	Kitsap	21 (24-1W)	Coarse-grained diabase worked by Bremerton Monument Co.
Brewster	Okanogan	12 (30-24E)	White granite worked by Columbia Granite Co.
Methow River	Okanogan	8 (31-22E)	Light-gray gneissic granite worked by Columbia Granite Co.
Pateros	Okanogan	20 (30-24E)	Light-gray granite worked by Columbia Granite Co.
Ellis	Snohomish	20 (27-10E)	Light-gray granodiorite used as architectural and monumental stone.
Soderberg	Snohomish	19-(27-10E)	----------
Darrington	Snohomish	Near Darrington	Coarse-grained dark-colored rock containing iridescent labradorite crystals.
Fish Lake	Spokane	32 (24-42E)	----------
Little Spokane River	Spokane	34 (27-42E)	Light-gray granite worked by Washington Monumental and Cut Stone Co.
Washington Monumental and Cut Stone Co.	Spokane	17 (24-41E)	Light-gray granite used as architectural and monumental stone.
Giles & Peat	Spokane	18 (24-41E)	----------
Granite Point	Whitman	13, 14 (13-43E)	----------

TABLE 7. — Granite quarries of Washington that were producing in 1964

No.	Name of operation	Property location	Product
1.	Alberg & Associates, Inc. 1919 Fifth Ave. Seattle, Wash. 98101	KING COUNTY North Bend area SW$\frac{1}{4}$NE$\frac{1}{4}$ sec. 5, (23-8E)	Medium-gray diorite for rough building stone and landscape rock.
2.	Hemphill Brothers, Inc. 201 Boren North Seattle, Wash. 98109 Baring quarry	KING COUNTY Near Baring Sec. 2, (26-10E)	Light-gray granite, mainly for poultry grit.
3.	Miller Lime Co. P. O. Box 166 Gold Bar, Wash. 98251	SNOHOMISH COUNTY Gold Bar area SW$\frac{1}{4}$ sec. 8, (27-10E)	Light-gray granite for rough building stone, flagging, and landscape rock.
4.	Empire Granite Co. P. O. Box 273 Dishman, Wash. 99213	SPOKANE COUNTY Near Dishman Secs. 19 and 20 (25-44E)	Light-gray granite in the form of monumental, architectural, rough building stone, and crushed stone.
5.	Keene & Son Medical Lake, Wash. 99022 Morris quarry	SPOKANE COUNTY Near Medical Lake SE$\frac{1}{4}$ sec. 8, (24-41E)	Light-gray granite in the form of monumental and architectural stone.

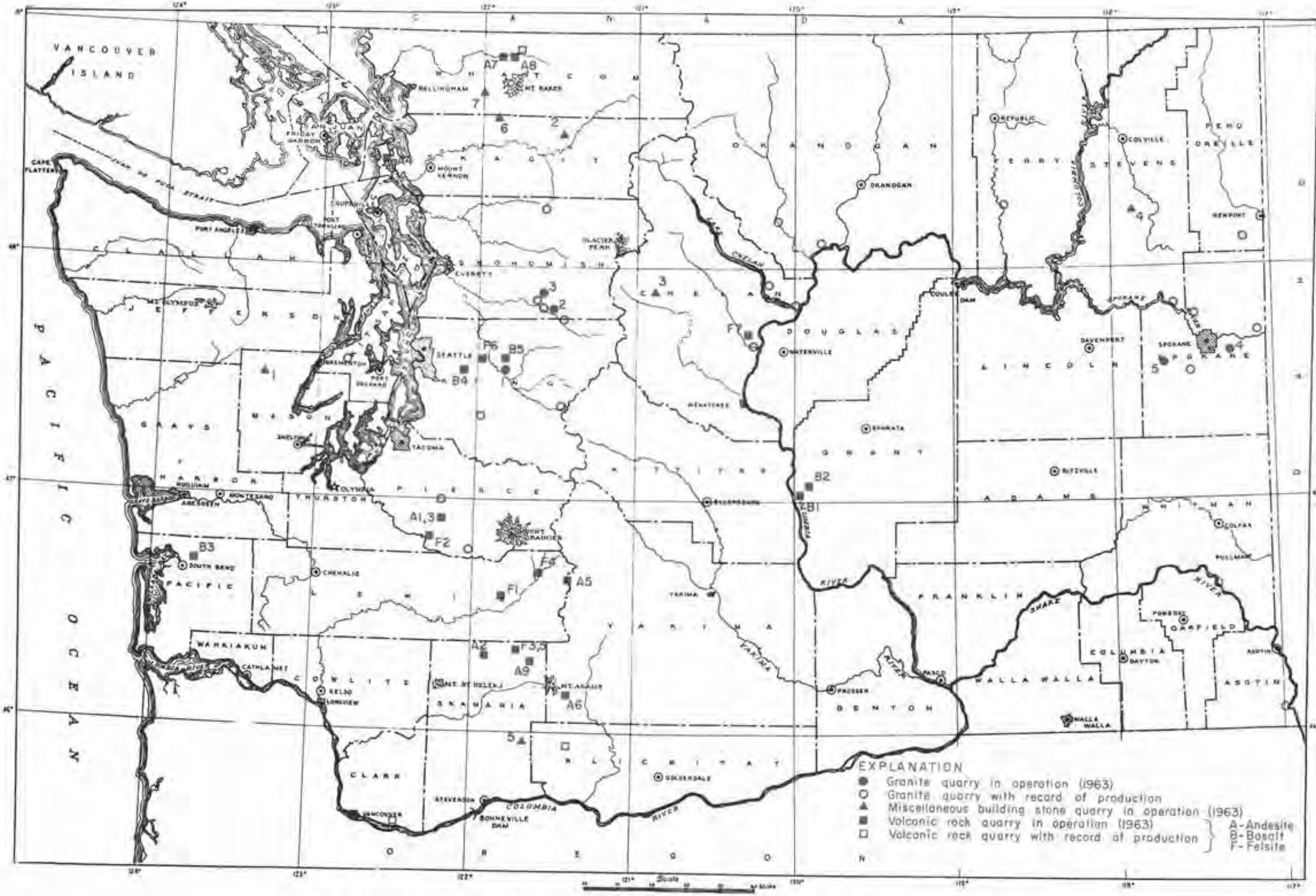

FIGURE 11.—Granite, volcanic rock, and miscellaneous building stone quarries.

Granite, by definition, is an equigranular plutonic rock that contains over 10 percent quartz, two-thirds or more potash feldspar, and small percentages of biotite, hornblende, and other ferromagnesian minerals. Quartz monzonite is similar to granite, except that the potash feldspar is one-third to two-thirds the total feldspar, and the remaining feldspar is oligoclase-andesine. The percentage of dark minerals is usually higher than in granite. In granodiorite, only 10 to 33 percent of the total feldspar is orthoclase or microcline. Quartz diorite contains over 10 percent quartz, less than 10 percent potash feldspar, over two-thirds plagioclase feldspar, and minor amounts of hornblende and biotite. Any of these rocks that exhibit foliation are classed as gneiss.

Granitic rocks occur most commonly in batholithic bodies or smaller igneous bodies such as laccoliths, stocks, and thick sills and dikes that are associated with batholiths. Granite is considered to have originated from magmas or from the recrystallization of pre-existing rocks during metamorphism without a molten stage. Slow crystallization tends to produce coarse-grained textures, and rapid crystallization produces fine-grained textures.

All granite crystallized beneath the surface of the earth, but through crustal movements such as folding and faulting, and subsequent erosion, many granite masses are now exposed. Because granites characteristically are formed and later exposed in mountain belts, the distribution of the granitic rocks of Washington is mainly in the mountainous areas of the State, particularly in the northern ranges. This northern belt of granitic rocks consists of the Chelan, Colville, Kaniksu, Mount Stuart, and several smaller batholiths that have a combined area of nearly 8,000 square miles. The most extensive exposures of granitic rocks occur in Whatcom, Skagit, Snohomish, King, Chelan, Okanogan, Ferry, Stevens, Pend Oreille, and Spokane Counties. Smaller bodies crop out in Pierce, Lewis, Clark, Skamania, Yakima, and Whitman Counties (Fig. 12).

Physical Properties

Although granite and its related rocks cover large areas in Washington, only a small part of these rocks possess physical properties that make them suitable for building stone.

Texture.—Texture denotes the size and arrangement of the mineral grains. Uniform grain size is usually required in granites for building or ornamental stone uses. According to grain size, granites are classified as fine, medium, and coarse grained. In medium-grained granites the feldspars are about a quarter of an inch across.

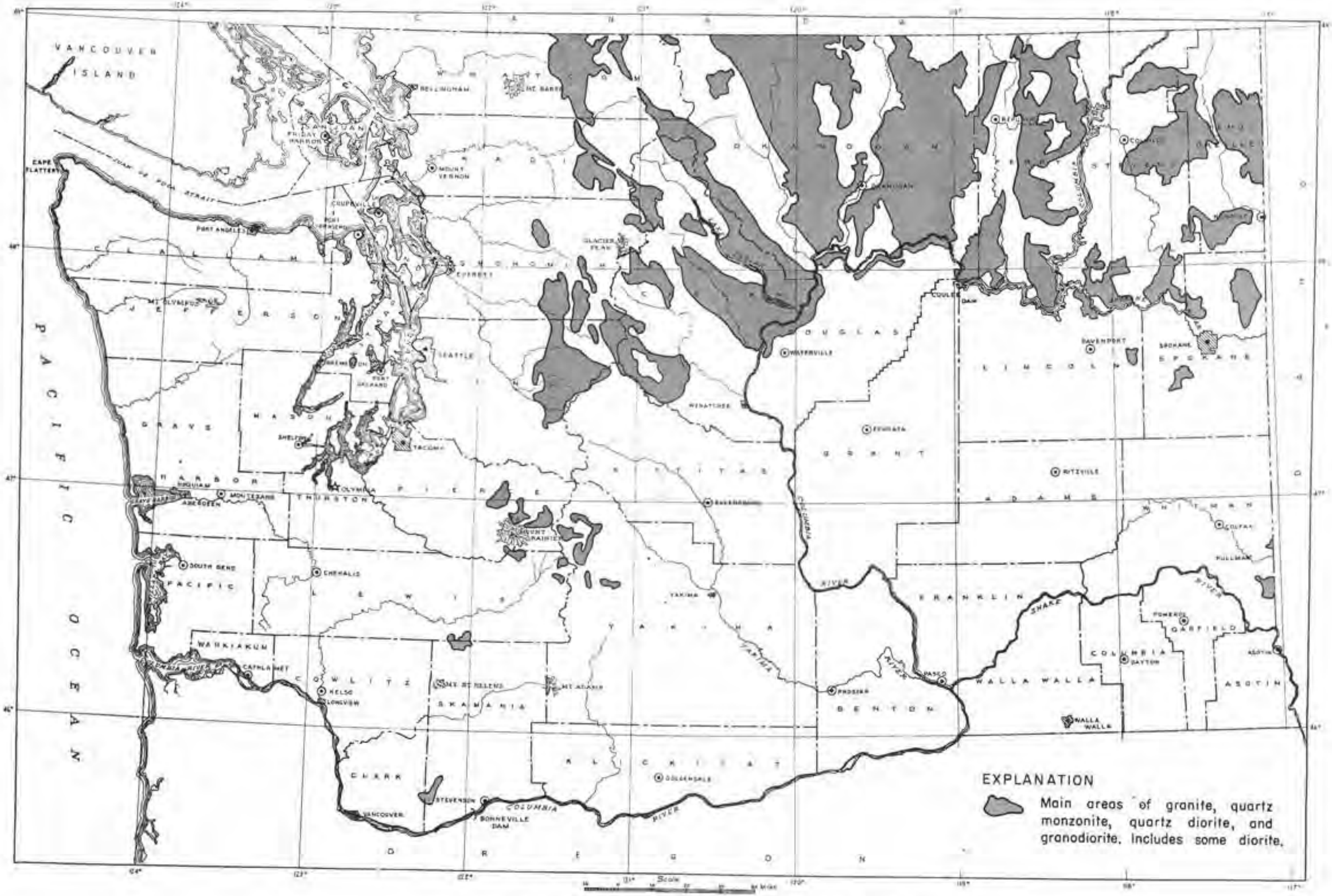

FIGURE 12. — Distribution of granitic rocks.

The distribution of the mineral grains is as important as their size. In order to give uniform color and texture, the light- and dark-colored minerals should be evenly distributed throughout the rock. Many deposits of granite do not display homogeneity, which makes them unsuitable for monumental stone and most building purposes.

Color. — Granite may be white, light gray, pink, red, or olive green. The light color of granite is due mainly to the predominance of feldspar and quartz. Other minerals, especially the amphiboles, pyroxenes, and micas, tend to modify the color and produce a darker stone. In Washington the granite is predominantly light to medium gray; however, some red granite has been produced from quarries near Lake Chelan.

Hardness. — Because most of the minerals in granite have hardnesses of about 6 and 7 (Mohs' scale of hardness), granite is a moderately hard stone. The higher the percentage of quartz in granite, the greater is the hardness of the rock. Some granites shatter readily, and others are tough and difficult to break by blasting and wedging. According to Shedd (1903, p. 143), the crushing strength of Washington granites ranges from 10,730 to 16,610 psi (pounds per square inch). The crushing strengths of granites from Wisconsin are as great as 43,973 psi; however, for all ordinary building uses a strength of 5,000 psi is considered satisfactory (Bowles, 1934, p. 28). If used strictly for a facing stone, the strength factor is less important.

Porosity and weight. — The porosity of granite is low as compared with sedimentary rocks. The pore space in average granite ranges from 0.10 to 0.50 percent. Although the pore space is small, the average granite contains about 0.80 percent water and can absorb as much as 0.2 percent more (Bowles, 1934, p. 105). The porosity of Washington granite from four locations, as reported by Shedd (1903, p. 136), ranges from 0.969 to 1.843, which is above the average for granite.

The weight of granite varies according to the rock's mineral content. The light-colored granites weigh from 160 to 170 pounds per cubic foot, whereas the dioritic rocks that contain more mafic or dark-colored minerals weight as much as 185 pounds per cubic foot.

Varieties

Granites are named for their most prominent mafic mineral, accessory mineral, distinct color, or texture and structure. The name may be as simple as "pink granite" or more detailed, such as "gray schistose hornblende granite."

The names of granites derived from texture and structure are probably the most confusing to the layman. Porphyritic granite is granite that has large grains in a fine-grained groundmass. Orbicular granite contains nodules composed of the dark-colored mafic minerals. Granite that contains intergrowths of quartz and microcline, which resemble the script used in Arabic writings, is known as graphic granite. Other granites exhibit a banded arrangement of light and dark minerals; these are called gneissic granites.

Desired Qualities

Granite and its related rocks must possess certain physical properties and structural features to make them suitable for dimension and building stone. Chemical composition does not appear to be of economic significance, but an attractive color and a uniform texture are most desirable. In granites that are to be used for structural and ornamental purposes, segregations of dark-colored minerals, such as mica and hornblende, and inclusions of dark rock fragments usually are undesirable. These imperfections usually stand out boldly on polished surfaces, but in unpolished stone, such as rubble and flagging, segregations and inclusions may be permissible.

Narrow dikes, either as dark bands of diabase or white bands of aplite, traverse many granites. The presence of these dikes detracts from the appearance of these rocks when used for structural or ornamental purposes.

Joints or cracks exist in most masses of granite; these may or may not be desirable. If closely spaced or irregular in direction, excessive waste may result. The most easily quarried granites contain two straight major joint sets 10 to 40 feet apart, intersecting at right angles and one set vertical. The quarry is usually opened to follow the vertical joints.

Some granite bodies exhibit sheeting. Sheeting consists of closely spaced joints that are essentially parallel to the ground surface. Near the surface the joints are closely spaced, but at depth they become progressively father apart. Excellent flagging is obtained from some sheeted granite.

Although granite is resistant to weathering, the action of chemical and mechanical weathering over many years may cause disintegration to depths of as much as 10 feet. The resulting weathered granite is weak and punky and is known as disintegrated granite. In Washington, where glacial erosion has been extensive, most granite outcrops tend to be free of thick disintegrated zones.

Unlike sedimentary rocks such as limestone and sandstone, in which the thickness of the beds often determines the depth to which a deposit may be worked, granites can usually be considered to extend to depths beyond which quarry operations are impractical.

Uses as Building Stone

The principal use of granite in Washington is as riprap and poultry grit. Small amounts of granite are still used as monumental and architectural stone, flagging, rubble, roofing chips, and exposed aggregate, but the onetime market for paving stone and curbing no longer exists.

Cotter (1964) reports that 753,186 short tons of granite, valued at $32,795,665, was produced in the United States in 1963. States of the Appalachian district from Maine to Georgia were the chief producers of dimension granite. In the West, small tonnages of granite were produced in Colorado, California, and Washington. Washington ranked 19th among the states in production for 1963, producing 30 short tons, valued at $600.

In 1963 the production of monumental and architectural granite was confined to one quarry, in Spokane County. Rubble, flagging, and rough building stone continue to be mined from scattered small quarries in the State. However, production is sporadic and production figures are not available.

Although the production of granite in Washington during 1963 for use as building and monumental stone was small, the production of granite, mainly for riprap and chicken grit, was about 14,000 short tons, worth $82,000.

Marble, Limestone, and Dolomite

The term "marble" is used loosely in the stone industry and in most instances includes all rocks that consist mainly of calcium carbonate (marble and limestone) or calcium-magnesium carbonate (dolomite). As the ability to take a good polish is one of the main commercial assets of marble, all calcareous rocks capable of taking a polish are classed as marble. Even serpentine rocks, which contain little calcium or magnesium carbonate but are attractive and capable of taking a good polish, are a commercial substitute for true marble.

Geology

In a geologic sense, the term "marble" is restricted to limestone or dolomite that has been recrystallized by heat or pressure into a metamorphic rock. During metamorphism the grains of the calcite or dolomite grow larger and any impurities that were present in the original rock tend to be segregated into knots or spread out into wavy streaks. The streaking of the marble produces the varicolored "marbling" of many ornamental marbles.

TABLE 8. — Marble quarries of Washington that have produced in the past

Quarry	County	Location Sec. (T. R.)	Product
Spokane Marble Co. ----	Pend Oreille	32 (30-43E)	Ornamental and decorative marble in black, white, and tones of green.
Chewelah Mottled Marble Co.	Stevens --	16 (32-40E)	Dolomite in different tones of red.
Columbia Marble and Onyx Co.	--- do ---	7, 8 (32-41E)	White and gray, medium-grained dolomitic marble.
Columbia River Marble and Lime Co.	--- do ---	22, 27 (39-39E)	Light-gray to black marble.
Colville Marble Co. ----	--- do ---	North Fork Mill Creek	White to black marble.
Crystal Marble Co. -----	--- do ---	26, 27, 34, 35 (34-38E)	White to black marble.
Evergreen Serpentine Co.	--- do ---	35 (33-39E)	--
Florentine Marble Co. --	--- do ---	12 (38-38E)	Light-gray, fine-grained marble.
Great Western Marble Co.	--- do ---	14, 32 (33-40E)	White to dark-red, fine-grained dolomite.
Green Mountain Marble Co.	--- do ---	13 (31-40E)	Green fine-grained marble.
Jefferson Marble, Mining & Milling Co.	--- do ---	13 (37-39E)	Produced ornamental and decorative marble in white and tones of brown and blue.
Keystone Marble Co. ---	--- do ---	1, 12 (37-39E)	White to black and pinkish marble; coarse to fine grained.
North American Marble & Onyx Co.	--- do ---	24, 25 (31-38E) 12, 19 (31-39E)	Dolomite and serpentine in tones of green, red, and white.
Northwestern Marble Co.	--- do ---	30 (32-40E) 18 (32-41E)	Dolomite in white and tones of green, blue, brown, and yellow.
Pacific Coast Marble, Tiling, & Manufacturing Co.	--- do ---	18 (31-41E)	Siliceous dolomite with prevailing colors of white, green, and sienna.
Royal Serpentine Marble Co.	--- do ---	9 (32-41E)	Siliceous dolomite with prevailing green color.
Standard Marble-Onyx Co. (Tulare quarry)	--- do ---	13 (35-39E) 18 (35-40E)	Gray and white, fine- to coarse-grained dolomite.
Toronto Marble Co. ----	Pend Oreille	20 (38-43E)	White to dark blue and cream-colored marble.
U.S. Marble Co. ------	Stevens --	8, 9 (31-39E)	Serpentine in shades of green.
Washington State Marble Co.	--- do ---	12 (31-39E) 6, 7 (31-40E)	Siliceous dolomite in tones of pink and green.

Most of the calcium carbonate rocks of Washington have been recrystallized to some degree, and petrographically can be classed as marble. However, many of these marbles do not approach the quality of the marbles of the eastern states.

"Marble" as used in this report refers to marble, limestone, and dolomite that are used as building stone in Washington.

Distribution of Deposits

As shown in Figure 13, the marble quarries of the State are confined mainly to Stevens and Pend Oreille Counties, in northeastern Washington.

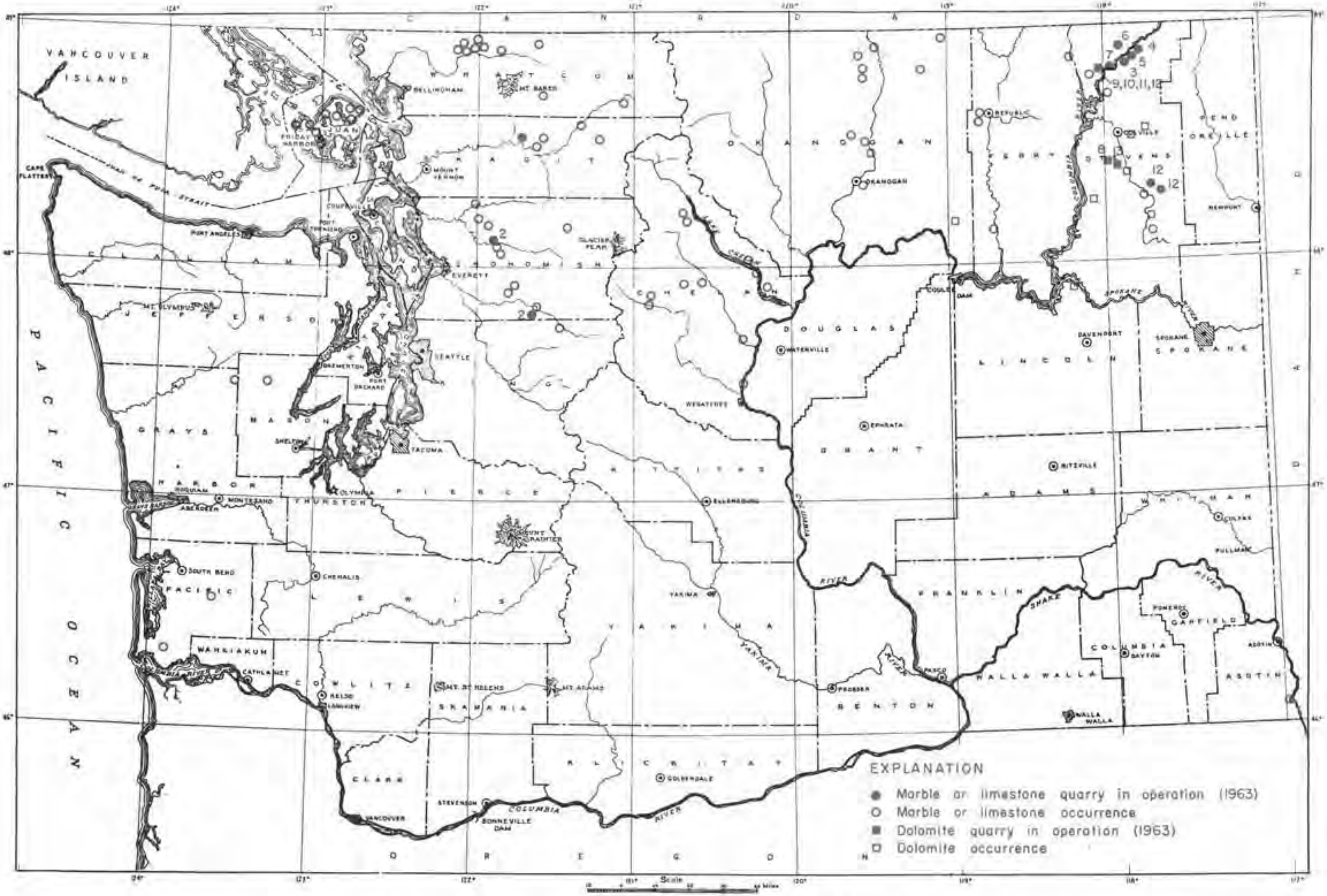

FIGURE 13.—Marble, limestone, and dolomite quarries.

TABLE 9. — Marble, limestone, and dolomite quarries of Washington that were producing in 1963

No.	Name of operation	Property location	Product
1.	Scheel Stone Co. 3314 Harbor Ave. S.W. Seattle, Wash. 98126	SKAGIT COUNTY Concrete area S½ sec. 4, (35-8E) Dewey Smith lease	Travertine as rubble.
2.	Miller Lime Co. P. O. Box 166 Gold Bar, Wash. 98251	SNOHOMISH COUNTY Gold Bar area SE¼ sec. 16, (27-9E) Granite Falls area SE¼NE¼ sec. 5, (30-7E)	White to gray, medium- to coarse-grained marble in the form of rough building stone, rubble, terrazzo, and roofing chips. Crushing plant east of Gold Bar.
3.	Joseph A. Janni 826 Red Apple Road Wenatchee, Wash. 98801	STEVENS COUNTY Northport area SE¼NE¼ sec. 13, (39-39E)	Ashlar, flagging, and rubble. Limestone, white to pale yellow-white, fine to medium grained, massive to platy, and slightly dolomitic.
4.	Peter Janni & Sons Box 333 Northport, Wash. 99157	STEVENS COUNTY Northport area SE¼ sec. 7, (39-40E)	Rubble, ashlar, rough building stone, terrazzo, and roofing chips. Limestone, white to cream white to light gray, medium grained, moderately well bedded.
5.	John Marty Rice, Wash. 99167	STEVENS COUNTY Northport area SE¼SW¼ sec. 18, (39-40E)	Rubble, ashlar, and flagging. Limestone, white, gray, cream, and light blue. Well-developed bedding planes ½ to 12 inches thick.
6.	Gordon Lavigne Chewelah, Wash. 99109	STEVENS COUNTY Northport area SE¼ sec. 35, (40-38E)	Flagging and rubble. White, medium-grained limestone.
7.	Don Lewis Chewelah, Wash. 99109	STEVENS COUNTY Northport area SE¼ sec. 3, (38-38E)	Flagging and rubble. White to cream, flaggy to blocky limestone.
8.	Madsen's Quarries Route 3, Box 124 Colville, Wash. 99114	STEVENS COUNTY Addy area Sec. 26, (34-38E)	Rough building stone and rubble. White to bluish-gray crystalline dolomite.
9.	Everett Merrill Kettle Falls, Wash. 99141	STEVENS COUNTY China Bend area NW¼ sec. 3, (38-38E) Denny quarry	Flagging consisting of white to light-cream marble.
10.	Northwest Stone 2414 - 46th N.E. Sumner, Wash. 98390	STEVENS COUNTY China Bend area NW¼ sec. 34, (39-38E)	Rubble and flagging. White to light-cream, fine- to medium-grained marble containing light-gray to greenish-gray banding in part.
11.	Northwest Marble Products Chewelah, Wash. 99109	STEVENS COUNTY Quarries northwest of Northport and near Chewelah	Rubble, stucco dash, terrazzo, and roofing chips in various colors. Crushing plant at Chewelah.
12.	North American Non-Metallics, Ltd. P. O. Box 227 Valley, Wash. 99181	STEVENS COUNTY Quarries southwest of Northport and near Valley	Rubble, stucco dash, terrazzo, and roofing chips. Marble, dolomite, and serpentine in white, and tones of gray, red, black, green, and brown. Crushing plant at Valley.
13.	International Stone Inc. 711 Hutton Building Spokane, Wash. 99204	STEVENS COUNTY Quarries in several parts of the County	Ashlar, rubble, rough building stone, terrazzo, and roofing chips. Marble, limestone, and dolomite in various colors. Crushing plant at Addy.

In Okanogan County several deposits occur west of the Okanogan River, and in western Washington the marble occurs mainly in Whatcom, Skagit, San Juan, and Snohomish Counties.

As early as 1902 no fewer than 20 marble quarries were in operation in Stevens County alone (Table 8). However, in 1963 only 13 companies or individuals in the State were producing marble for building purposes (Table 9), but some companies were producing from as many as 15 quarries.

The general distribution of geologic units that are made up mainly of marble, limestone, and dolomite, as well as those that contain minor beds of these rocks, is shown in Figure 14. In eastern Washington, mining occurs on several extensive marble, limestone, or dolomite beds, whereas in western Washington, mining of marble and limestone is confined to smaller, separate deposits.

Physical Properties

Composition.—A calcite marble may contain from 95 to 100 percent calcium carbonate. A dolomite marble contains approximately 54 percent calcium carbonate and 46 percent magnesium carbonate. Marble comprising mixtures of calcite and dolomite may have compositions anywhere between these extremes.

Impurities are present in practically all marbles, the most common being silica, iron oxide, manganese oxide, alumina, and sulfur. Pyrite (FeS_2) is the most common iron-bearing impurity and occurs as scattered crystals or as bands and lenses in the marble. Silica in the form of quartz (SiO_2) may cause knots or bands in the marble. The quartz may also be introduced into a bed of marble and fill cavities and cracks. Because of their hardness, which impairs workability, both pyrite and quartz are impurities that are generally condemned in marble for uses that involve polishing of the stone. Pyrite is also detrimental because of the brown iron oxide staining caused by oxidation of the mineral.

Compared with other rocks, marble is soft; the hardness of marble is 3 and of dolomite is 3.5 to 4. The presence of impurities such as silica (hardness 7) may increase the hardness of marble greatly. Because of pore space the actual weight of marble ranges from 165 to 180 pounds per cubic foot, which is less than the theoretical weight.

Color.—One of the more important physical properties of marble is its color. If composed of pure calcite or dolomite, the marble will be white; variations from white are due to admixtures of foreign substances. Black and grayish shades are caused by carbonaceous matter, usually in the form of fine-grained graphite. Reddish colors are due mainly to manganese oxides or to hematite, and yellow or cream are caused by grains of limonite. In Washington the most common color of marble is white or gray; however, the marbles of Stevens County occur also in hues of green, red, brown, black, and yellow. Like most of the marble that is quarried in the United States, the marbles of Washington show very little color alteration after exposure to sunlight or weather.

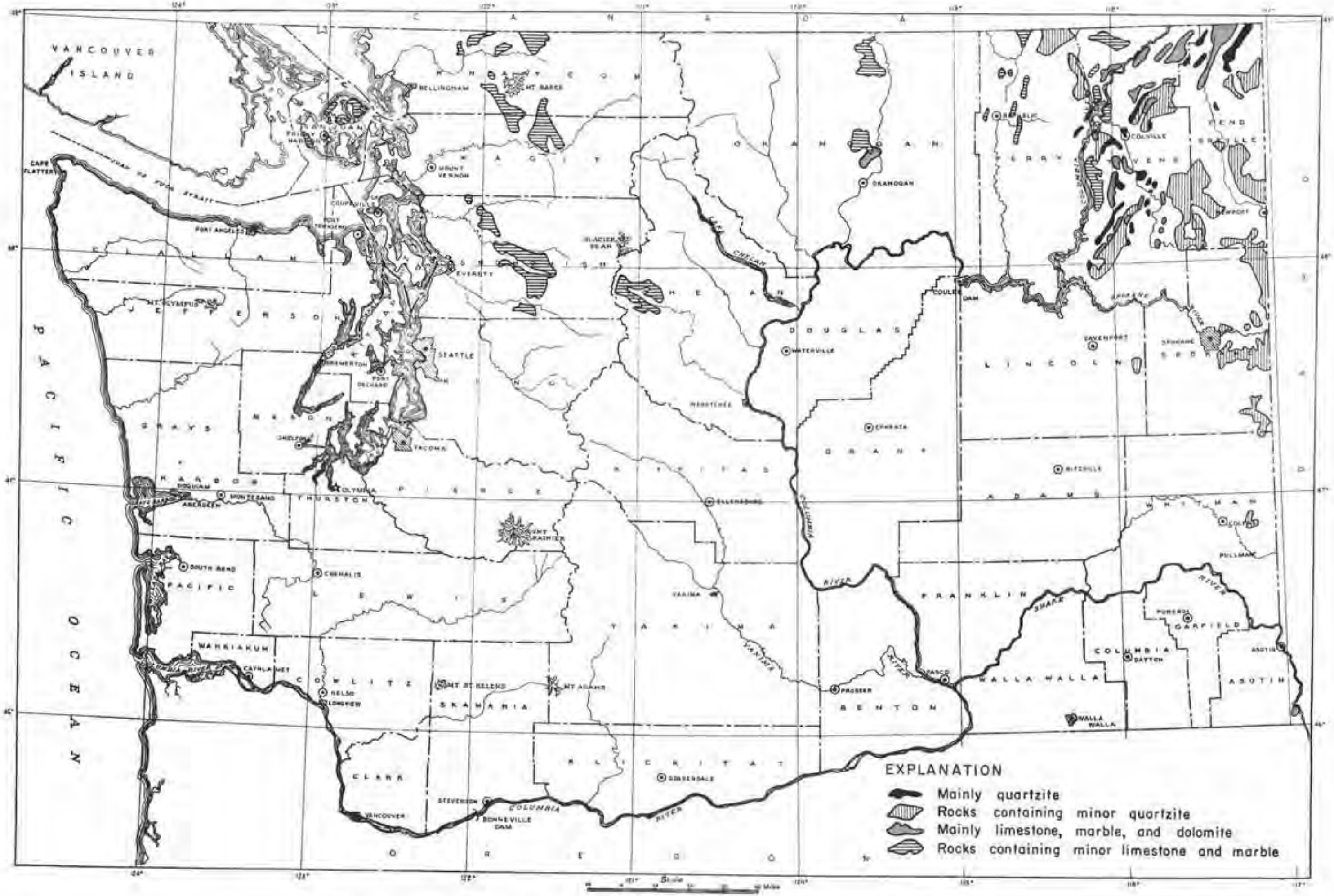

FIGURE 14. — Distribution of marble, limestone, dolomite, and quartzite.

Texture. — The texture of marble depends on the size, uniformity, and arrangement of its grains. The individual grains are large enough to be distinguished with the unaided eye and commonly are described as fine, medium, and coarse. According to Bowles (1934, p. 173), the Vermont marbles are graded into six classes, based on grain sizes, that range from extra fine (0.06 mm) to extra coarse (0.50 mm). However, in some Washington marbles the grains are as much as 5 mm in diameter.

Varieties

Marbles are classed in three groups. The first group contains those marbles that have been formed through the recrystallization of limestone. Most commercial marbles are of this type.

The second group comprises the onyx marbles, which consist of deposits of calcium carbonate that have not been recrystallized by metamorphism. True onyx marble is formed by the deposition of calcium-rich cold-water solutions, commonly in limestone caves. Travertine, which is precipitated from hot springs, generally does not take a fine polish and is classed as a limestone rather than a marble.

The third group includes verd antiques. They consist mainly of serpentine, a hydrous magnesium silicate, and are predominantly dark green. Many verd antique marbles contain streaks or veins of white calcite. Unlike true marble, which originated as accumulations or precipitation of calcareous material on the beds of seas, serpentine is a product of the alteration of ultrabasic igneous rocks.

Uses as Building Stone

Marble is used mainly for monuments and buildings, interior decoration, and statues. Verd antique marble is used as surfacing on the exterior walls of business buildings. In the past, marble from the Washington deposits was used mainly for monuments, interior and exterior decoration of buildings, terrazzo chips, rubble, and rough building stone. At present (1964), most of the marble mined in the State is crushed for terrazzo and roofing granules. Other uses include ashlar, rough building stone, and rubble.

Production figures are not available for the total marble produced in Washington during 1963. However, a rough estimate indicates that about 13,000 tons of marble, dolomite, and limestone having a wholesale value of around $244,000 was produced. Washington ranked ninth among the states as a producer of dimension marble.

Sandstone

The sandstone of Washington that has been quarried as building stone occurs mainly on the western slopes of the Cascade Mountains (Fig. 15). From 1889 to 1935, large amounts of sandstone were produced from 21 quarries in Whatcom, King, Pierce, and Thurston Counties to be used in the construction of buildings in the larger cities along the west coast.

In Olympia, Washington, the building now called the Old State Capitol Building was built of sandstone quarried from the Chuckanut and Tenino quarries; however, the present Legislative Building and several other buildings on the State Capitol grounds are of sandstone from the Wilkeson quarry. Other prominent buildings constructed from Washington sandstone include the Rhodes department store, Seattle Post-Intelligencer Building, and Dexter Horton Building, in Seattle; the U.S. Customs House, Port Townsend; several University of Puget Sound buildings, Tacoma; and the Cathedral of St. John the Evangelist, Spokane.

By 1935 the use of sandstone for structural purposes in buildings declined, the natural stone having been replaced by brick, concrete, and terra cotta. Because of the decreasing demands, only the quarries near Wilkeson, in Pierce County, and at Tenino, in Thurston County, remained in production.

At present (1964) only three quarries in Washington produce sandstone commercially for building purposes, mainly in the form of ashlar, flagstone, and rubble. The sandstone quarry at Wilkeson is the State's oldest and major producer and is a continuous producer of attractive structural and ornamental building stone.

The past producers of Washington sandstone are shown in Table 10, and the present producers (1964) in Table 11.

Geology and Distribution

Sandstone is a consolidated sedimentary rock composed of mineral and (or) rock fragments that range in size from 0.062 to 2.00 mm. In Washington the sandstones used for building purposes are composed mainly of quartz, feldspar, mica, and rock fragments that are cemented by iron oxide, silica, calcite, and clay. The predominance of light-colored minerals such as quartz and feldspar places most of these sandstones in a class known as arkoses (Appendix A, page 77).

Most sandstones occur in beds that were originally deposited as sand on the bottoms of fresh-water lakes or salt-water seas. The sands were usually deposited with beds of gravel and clay, which later became consolidated to form conglomerate and shale.

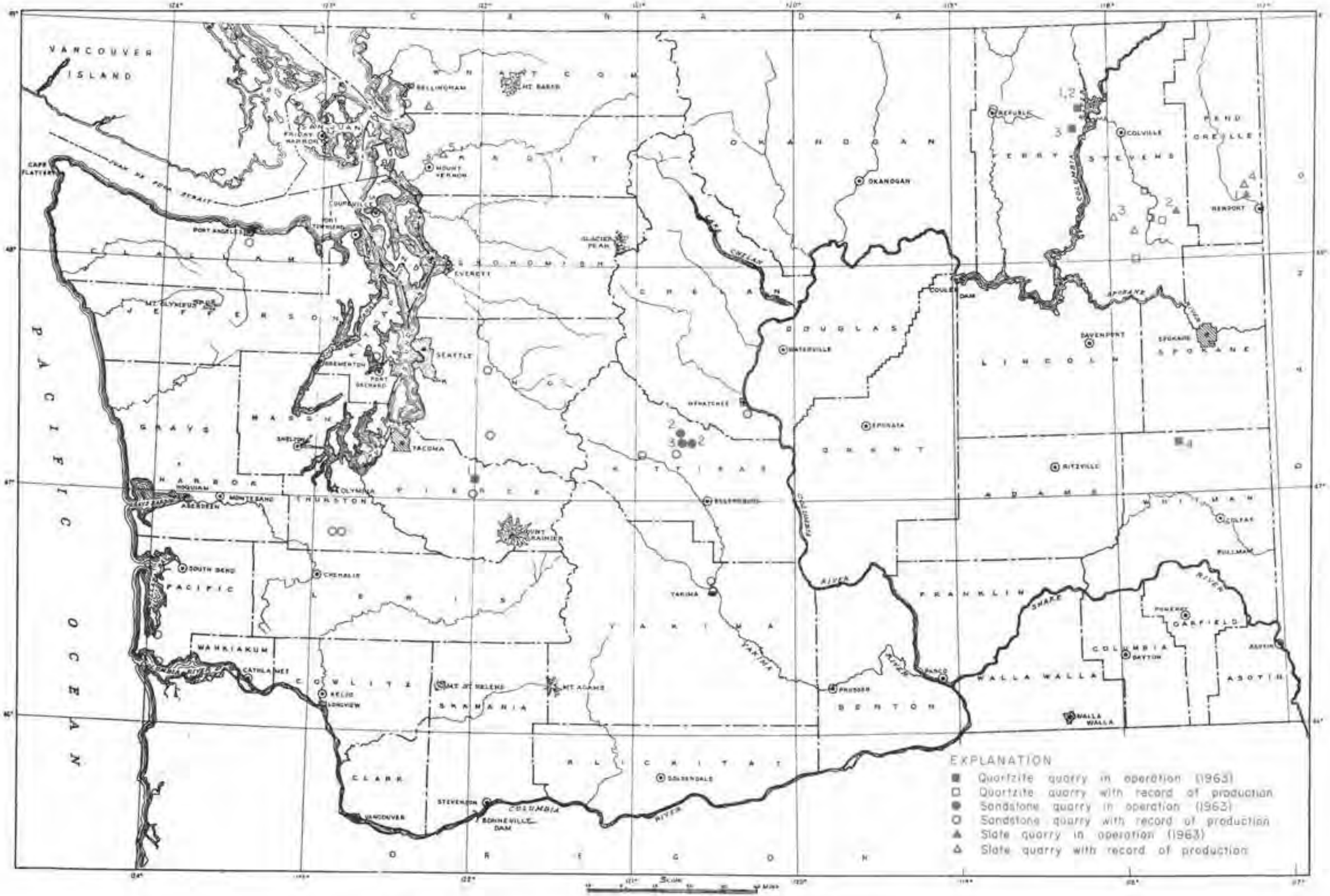

FIGURE 15.—Sandstone, quartzite, and slate quarries.

TABLE 10.—Sandstone quarries of Washington that have produced in the past

Quarry	County	Location Sec. (T. R.)	Uses
Clarkston ----------	Asotin ----	8 (10-46E)	Building stone.
Prosser ----------	Benton ----	5 (8-25E)	----- Do. ----------
Wilkeson-Wenatchee Stone Co.	Chelan ---	21 (22-20E)	----- Do. ----------
Port Angeles --------	Clallam --	(30-6W)	----- Do. ----------
Wiseman-McGillis ----	Ferry -----	1½ miles north of Republic	----- Do. ----------
Eureka (Cumberland) --	King -----	28 (21-7E)	----- Do. ----------
Preston ----------	King -----	21 (24-7E)	----- Do. ----------
Cle Elum ----------	Kittitas ---	Northeast of Cle Elum	----- Do. ----------
Swauk Flag Rock Inc. --	Kittitas ---	36 (21-17E)	----- Do. ----------
McGowan ----------	Pacific ---	Near McGowan	----- Do. ----------
C. B. Hicks --------	Pierce ----	20 (18-5E)	Flagging.
Reid Harbor --------	San Juan --	27, 28 (37-4W)	Building stone.
Sucia Island --------	San Juan --	(38-2W)	Building stone and paving blocks.
Alaska Barge Co. -----	San Juan --	24 (37-3W)	----------
Humphrey Head -------	San Juan --	1 (35-2W)	----------
Tenino Stone Co. -----	Thurston --	19 (16-1W)	Building stone and paving blocks.
Hercules ----------	Thurston --	20 (16-1W)	Building stone and grindstones.
Chuckanut Stone Co. --	Whatcom --	13, 24 (37-2E)	Building stone and paving blocks.
Howard ----------	Yakima ---	Near Selah	Building stone.
Yakima ----------	Yakima ---	Near Yakima	----- Do. ----------

TABLE 11.—Sandstone quarries of Washington that were producing in 1964

No.	Name of operation	Property location	Product
1.	Wilkeson Cut Stone Co., Inc. 1117 - 2nd Avenue Bldg. Seattle, Wash. 98104	PIERCE COUNTY Quarry at Wilkeson Sec. 27, (19-6E)	Ashlar, hearths, sill and coping, patio stone, special cut pieces, and sculptured stone. Buff to tan, medium-grained arkosic sandstone.
2.	J. Jack Kirsch Route 2 Cle Elum, Wash. 98922	KITTITAS COUNTY Lion Gulch of the Liberty area Sec. 24, (21-17E) Sec. 6, (20-18E)	Ashlar, rubble, and flagging. Medium- to fine-grained arkosic sandstone in shades of gray, green, red, and brown.
3.	Larry Brighton and A. E. Reid Route 2 Cle Elum, Wash. 98922	KITTITAS COUNTY Lion Gulch of the Liberty area NW¼ sec. 1, (20-17E)	Ashlar and rubble. Medium- to fine-grained arkosic sandstone in shades of gray, green, and brown.

Although originally the beds of sandstone were deposited as flat-lying or nearly flat-lying beds, post-depositional folding and faulting related to mountain building caused many of the beds to be deformed. Some beds of sandstone may be tilted as much as 90° from their original position; however, this does not condemn them for quarry sites. Other beds may be so highly fractured that they are not suitable for use as building stone.

Inasmuch as probably all of Washington was at one time or another covered by seas, the sandstone deposits are widespread. However, many of these sandstone deposits are deeply buried and others have been removed by erosion. Of the sandstone deposits that have been geologically mapped, at least 2,000 square miles, or about 3.0 percent of the total land area of Washington, contains formations from which sandstone for building purposes has been quarried (Fig. 16). Because sedimentary rocks vary in their physical properties even within the same bed, it should not be construed that the sandstone-bearing units shown in Figure 16 are composed mainly of stone suitable for building purposes. Only small parts of these units contain sandstones suitable for quarrying.

Physical Properties

Only the harder sandstones are used as building stone. The most desirable sandstone should be hard enough to resist weathering but soft enough to quarry economically. Ideally, the sandstone should be uniformly cemented so as to be free of hard and soft spots that affect the workability of the stone.

Hardness and texture. — The hardness of sandstone depends chiefly on the hardness of the mineral grains that make up the stone. The hardness is also influenced to some extent by the cementing agent that binds the grains together. Sandstone cemented by silica tends to be harder that that cemented by calcite.

The grains of a sandstone may be well rounded to angular, depending upon the extent to which they were worked prior to deposition. In a very fine-grained sandstone the individual grains are barely distinguishable to the unaided eye, and in a very coarse sandstone the grains may be as much as 2 mm in diameter. The medium- to coarse-grained sandstones, the grains of which range from 0.25 to 1.0 mm, are most commonly used for building stone. Uniformity of grain size is one of the desirable features to be considered in a sandstone.

Color. — Many sandstones are quarried for their pleasing colors. Blue or gray sandstone is usually avoided, as it contains ferrous sulfides or ferrous carbonates that after exposure to weathering gradually assume a buff or red color (Bowles, 1934,

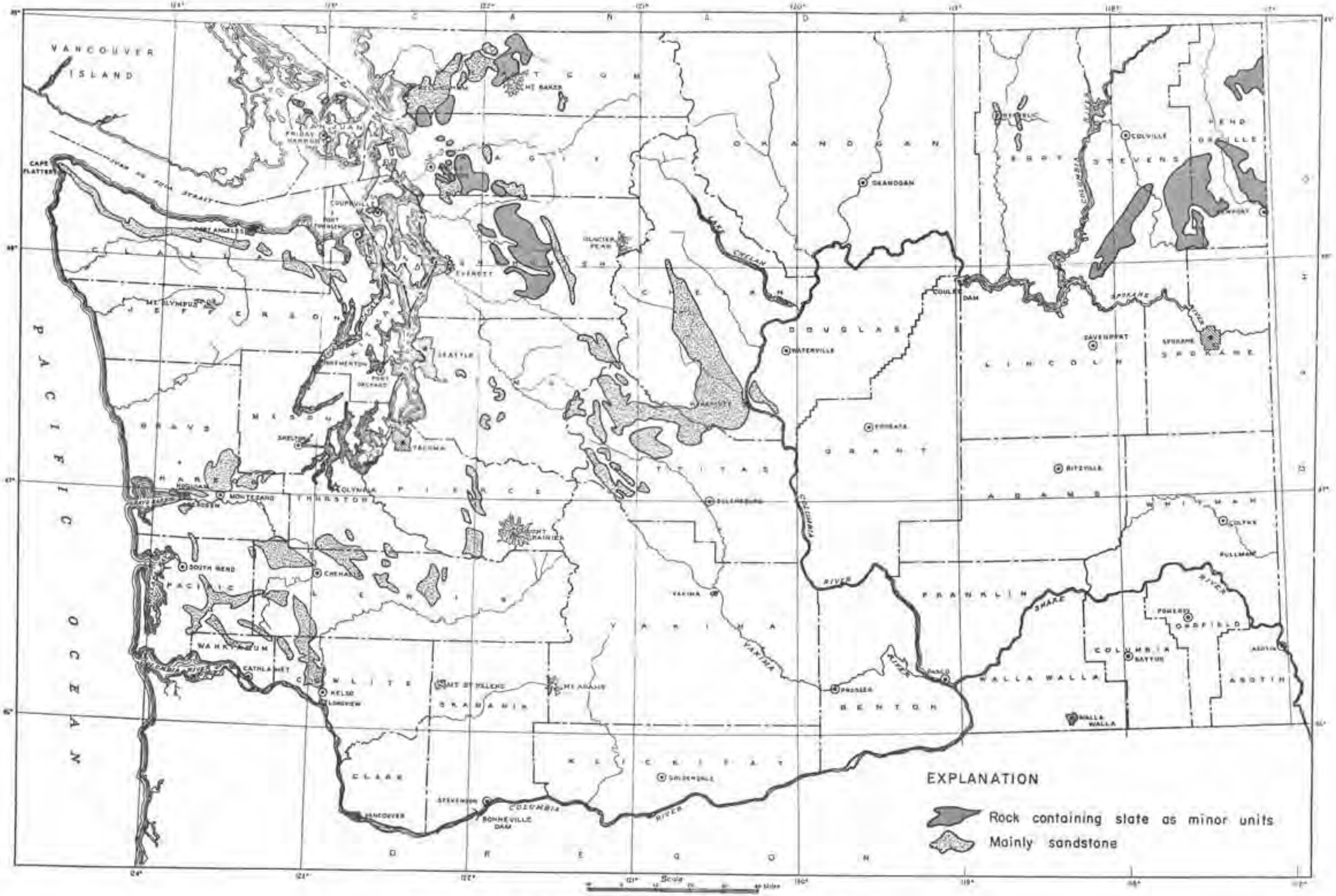

FIGURE 16. — Distribution of sandstone and slate.

p. 69). The deeper shades of red, brown, yellow, or buff are generally permanent, as they are caused by the stable iron oxides such as hematite and limonite.

For large buildings in which the sandstone forms a structural part of the building, a uniform color is generally desirable. However, with the increasing use of sandstone as an ornamental building stone, varicolored stones are being more widely used because of their pleasing color effects.

Porosity and strength. — Sandstone is generally more porous than most of the other common building stones; the porosity ranges from 2 to 15 percent in commercial sandstone. The porosity of Washington sandstones ranges from 1.73 percent in the Nanaimo sandstone of Stuart Island to as much as 18 percent in the Tenino sandstone. The weight of most Washington sandstone ranges from 136.83 to 166.61 pounds per cubic foot (Shedd, 1903, p. 136).

The crushing strengths of Washington sandstones that have been quarried for building stone range from 3,270 to 11,070 psi. Bowles (1934, p. 28) reports that for most uses a stone that will sustain a crushing strength of 5,000 psi is considered satisfactory.

Structure. — The structures of sedimentary rocks are the larger features of the rocks and are those characteristics that are best seen in the outcrops. Some common structures of sandstone are bedding planes, graded bedding, crossbedding, concretions, and jointing.

Bedding, or stratification, is one of the common features of sedimentary rocks. Some common terms applied to bedding are:

Fissile — beds less than 2 mm in thickness

Platy or shaly — beds 2 to 10 mm in thickness

Slaty or flaggy — beds 10 to 100 mm in thickness

Massive — beds more than 100 mm in thickness

The sandstone most commonly used for building stone is quarried from the massive beds; however, the flaggy beds provide a source for flagstone.

Graded bedding is marked by a gradation in the size of the grains, which usually range from coarse at the bottom of a bed to fine at the top. In some instances the change in grain size is accompanied by a change in color of the sandstone. Crossbedding is a name applied to the arrangement of laminations of beds transverse or oblique to the main planes of stratification. It consists of inclined, commonly lenticular beds between the main bedding planes.

Concretions occur in many sandstones and range from small pellet-like objects 1/8 inch in diameter to great spheroidal bodies as much as 10 feet in diameter. Concretions form by the accumulation of mineral matter about some nucleus after the deposition of the sediments. A fossil leaf, shell, or bone is commonly the center around which a concretion is built. Concretionary sandstones are avoided for building stone because they impair the workability of the stone and detract from its beauty.

Most sandstones are traversed by joints and seams that probably originated through compression or torsional strains in the earth's crust. Such joints and seams are usually perpendicular to the bedding planes and generally occur in two or more sets. Quarry operations are greatly facilitated when the joints occur in two vertical sets at right angles and spaced from 10 to 40 feet apart.

Uses as Building Stone

Sandstone can be used for both exterior and interior construction. Because of its homogeneity and resistance to weathering, it is excellent for exterior construction. Most sandstone used in the construction of walls is laid in the form of ashlar (Fig. 6, p. 16); however, attractive walls of rubble are also being used increasingly in the construction of modern residential buildings. Other common uses of sandstone are in fireplaces, chimneys, and as flagging for walks and patios.

From the sandstone that is presently (1964) being quarried in Washington comes ashlar, hearthstones, sill and coping stones, patio stone, flagging, rubble, and cut and sculptured stone. The quarries that produced sandstone for building purposes in 1964 are listed in Table 11, on page 51, and their locations are shown in Figure 15, on page 50.

In 1963 the production of dimension sandstone in the United States was 412,214 tons, valued at $11,442,710. Of the states, Washington ranked 8th, having produced 4,200 tons, worth $202,310.

Quartzite

Physical Properties

In common usage the term "quartzite" refers to a sandstone composed mainly of quartz grains that have been recrystallized through the agents of metamorphism. An important feature of quartzite is the tendency for fracture surfaces to break through the grains rather than around them. Although quartzite consists essentially of quartz, other minerals such as feldspar, carbonate minerals, mica, pyroxene, amphibole, iron oxides, and garnet may be present.

TABLE 12.—Quartzite quarries of Washington that were producing in 1963

No.	Name of operation	Property location	Product
1.	Columbia Quartzite Quarry N. 2706 Morton Street Spokane, Wash. 99207	FERRY COUNTY Kettle Falls area SW¼ sec. 2, (36-37E)	Ashlar, flagging, and rubble. Light-gray quartzite containing silvery mica flakes on cleavage surfaces. Some surfaces stained brown to yellowish-brown by oxides of iron.
2.	Kifers Mica Rock Quarry Route 1 Kettle Falls, Wash. 99141	FERRY COUNTY Kettle Falls area SW¼ sec. 2, (36-37E)	Stone, same as above. Stone cleavable into ½- to 12-inch thicknesses and available in slabs as much as 4 by 6 feet in area.
3.	Kettle Falls Quartzite Pete and Jeff Molenberg Kettle Falls, Wash. 99141	FERRY COUNTY Bangs Mountain area SE¼ sec. 1, (35-36E) P & J placer claims	Flagging. Light-gray micaceous quartzite containing brownish-yellow iron oxide staining on some cleavage surfaces. Average thickness of slabs about 1 inch.
4.	Hole In The Ground Quarry H. C. Bach St. John, Wash. 99171	WHITMAN COUNTY Rock Lake area SW¼ sec. 14, (20-41E)	Flagging. Medium-gray quartzite containing brownish-yellow iron oxide staining on cleavage surfaces.

A quartzite composed wholly of quartz is usually white or light gray, but impurities in the original sandstone or those introduced through metamorphism give quartzite different colors or banded effects. Since quartzite is composed mainly of quartz having a hardness of 7, it is hard and tough and it can be cut and polished with about the same ease as granite. Although quartzite generally is massive, some beds have distinct bedding that provides cleavage planes for the quarrying of sheets, plates, and blocks.

Distribution

The quartzite formations of Washington occur mainly in the northeastern part of the State, in Ferry, Stevens, and Pend Oreille Counties (Fig. 14, p. 47). They form a northeastward-trending belt that extends from the Canadian border on the north to Roosevelt Lake on the south. A major geologic unit of this belt is the Addy Quartzite (Cambrian), which is confined to Stevens and Pend Oreille Counties. For the most part, the Addy Quartzite consists of gray, white, and buff, medium- to thick-bedded quartzite, but minor reddish and maroon beds are also present.

In Ferry County, quartzite is not as extensive as in Stevens and Pend Oreille Counties and occurs mainly in the eastern half of the county. This quartzite is commonly interbedded with dolomitic and calcitic marble, lime-silicate gneiss, and amphibolite. Mica is a common accessory mineral of much of the quartzite and occurs on many bedding planes. Oxidation of the mica produces attractive stains in shades of yellow, brown, and red on bedding and cleavage planes.

Elsewhere in the State, quartzite units are, for the most part, small and unattractive for use as building stone. Most of these units are too small to be shown in Figure 14, on page 47, and to date they have not been quarried as commercial building stone.

Uses as Building Stone

Although the quartzites of northeastern Washington have been the source for only a small amount of building stone in the past, the market for attractive quartzite is growing. Several quarries near Kettle Falls produce platy mica quartzites mainly as flagging (Fig. 9, p. 25). These quarries are listed in Table 12, and their locations are shown in Figure 15, on page 50.

Slate

High-grade slates are among the most durable rocks on the earth. Bowles (1934, p. 232) states that slate tombs, which are believed to have been constructed about 500 B.C., are still in good condition. Also, a slate-roofed chapel in England is still in use after 1,200 years of constant exposure to the weather.

Physical Properties

Slate that is used as building stone is a hard, durable, microcrystalline, metamorphic rock having good cleavage in one direction. Its most common color is blue black, but it also occurs in hues of green, red, purple, and gray. Some slate contains crystals of pyrite, and other slate contains inclusions of silicate minerals that give it a knotted appearance. These and other minerals are objectionable in slate because they prevent smooth splitting.

Slates have their origin in sedimentary deposits consisting mainly of clay. Through consolidation the clay becomes shale, a laminated rock that consists of consolidated clay particles. Acted upon by the metamorphic agents of heat and (or) pressure, the shale is converted into slate. This results in the mica and chlorite, which were formed by metamorphism, assuming positions with their flat surfaces oriented in positions parallel with each other. This parallelism of mineral grains gives the slate its cleavage that permits it to be split easily in one direction. Continued metamorphism of slate results in the formation of phyllite and mica schist.

TABLE 13.—Slate quarries of Washington

No.	Name of operation	Property location	Remarks
1.	International Stone Inc. 711 Hutton Building Spokane, Wash. 99204	PEND OREILLE COUNTY Newport area SW¼ sec. 21, (32-45E) Felsman quarry	Blue-black, slaty to platy argillite with reddish-brown to yellowish-brown iron oxide staining on many cleavage surfaces. Minor quartz veins and pyrite cubes as much as 1 inch across are present. Produced in 1962, mainly flagging.
2.	W. B. Moorhead Box 575 Chewelah, Wash. 99109	STEVENS COUNTY Upper Cottonwood Creek area SW¼ sec. 6, (31-42E) Little Joe claims	Medium-gray, slaty to platy argillite with yellowish-brown iron oxide staining on cleavage surfaces. Produced in 1962, mainly flagging.
3.	Waterman-Symington Slate Co.	STEVENS COUNTY Waits Lake area NW¼ sec. 19, (31-39E) Slate quarry	Blackish-gray to dark-green slate used for roofing slate and flagging. Last record of production, 1956.
4.	Bennion Colorok	PEND OREILLE COUNTY No Name Lake area SE¼ sec. 5, (32-45E)	Blue-black, slaty to platy argillite with yellowish-brown iron oxide staining on cleavage surfaces. Similar to stone at Felsman quarry and used mainly as flagging. Last record of production, 1951.
5.	Sedro Woolley	SKAGIT COUNTY Sedro Woolley area Center sec. 36, (35-4E)	Blue-black slaty argillite having moderately flat, smooth cleavage. Quarried in the past for riprap, but suitable in part for flagging.
6.	Pilchuck River	SNOHOMISH COUNTY Echo Lake area Sec. 17, (29-8E)	Road cuts expose slate of good quality. No record of production from this area.

Distribution

Good slate is the least abundant building stone in Washington. Although slate has been mined from several deposits in the State, it cannot be considered good-quality slate; it is more properly mica slate or phyllite. Almost all the building slate used in Washington comes from Vermont or Pennsylvania.

The deposits of slate that have been or are being mined in Washington are confined to the metamorphic rocks of the northeastern counties. These rocks are among the oldest of the State and consist mainly of schist, phyllite, quartzite, argillite, dolomite, and marble. The slaty rocks are most commonly confined to the phyllite and argillite units, the general distribution of which is shown in Figure 16, on page 53.

In western Washington, slate has not been quarried commercially for building purposes; however, minor slate beds do occur in several rock units. Slaty rock near Sedro Woolley has been utilized for riprap, but parts of the deposit are suitable as flagging. Slate of good quality is also reported (Northern Pacific Railway Company, 1941) near Echo Lake in Snohomish County, but it has yet to be developed. Rocks of the type that contain minor slate beds are extensive in northwestern Washington; however, most of them are poorly exposed because of dense vegetation and abundant overburden.

To date (1964), slate or slaty rock has been produced from four deposits in Washington, all of which are in northeastern Washington (Table 13). The highest quality slate was quarried by the Waterman-Symington Slate Company from a deposit west of Waits Lake, in Stevens County. The last recorded production from this quarry was in 1956.

Although slaty rock was produced from two quarries in 1962 (Table 13), the material is not true slate. The stone from these operations consists of iron oxide-stained slaty argillite and siltstone. Some attractive flagging has been produced on a small scale from these operations.

Uses as Building Stone

The largest use of slate has been for roofing purposes, and for such use it should split readily into plates from three-sixteenths to one-quarter inch in thickness. Standard slates range in area from 6 by 10 inches to 4 by 24 inches.

Slate is also used for ornamental flagging in sidewalks, patios, carports, and as fireplace hearths. For flagging it should be from 1 to 3 inches in thickness, depending on use. Size is not critical, as various sizes in irregular outline are used to provide pleasing patterns. Figure 5, on page 15, shows how flagging can create an effective pattern from various shapes and sizes of stone.

Volcanic Rocks

An examination of the geologic map of Washington shows that volcanic rocks are the most abundant rocks in the State. Roughly 60 percent of the total land area of the State contains volcanic bedrock, which in places exceeds 10,000 feet in thickness. Most of these rocks consist of basalts that are commonly dark gray to black and are the least preferred rock for building stone. However, many of the andesites, which occur in tones of green and gray, as well as the felsites, which are white to tan in color, provide a wide variety of stone suitable for building purposes.

Although volcanic rocks lack the natural cleavage of sedimentary rocks, and are not capable of taking a polish like granite and marble, some are well suited for rough building stone and rubble. In general, color and texture are the main

TABLE 14. — Basalt building stone quarries of Washington that were producing in 1964

No.	Name of operation	Property location	Product
1.	J. E. Houplin P. O. Box 456 Des Moines, Wash. 98016	GRANT COUNTY Vantage area Sec. 29, (18-23E) Cathedral quarry	Dark-gray to black basalt in the form of rubble and flagging.
2.	Scheel Stone Co. 3314 Harbor Ave. S.W. Seattle, Wash. 98126	GRANT COUNTY South of Burke Junction	Dark-gray to black basalt in the form of ashlar and rubble.
3.	H. G. Runyon Raymond, Wash. 98577	PACIFIC COUNTY Raymond area Center sec. 23, (14-9W)	Dark-gray to black basalt in the form of rubble.
4.	Sunset Quarries, Inc. 9718 - 42nd Street Seattle, Wash. 98105	KING COUNTY Issaquah area W$\frac{1}{2}$NW$\frac{1}{4}$ sec. 5, (23-6E)	Gray to dark-green basalt in the form of rough building stone.
5.	Alberg & Associates, Inc. 1919 Fifth Ave. Seattle, Wash. 98104	KING COUNTY North Bend area SW$\frac{1}{4}$NE$\frac{1}{4}$ sec. 5, (23-8E)	Dense black basalt in the form of rough building stone.

factors considered in the use of volcanic rocks for building stone, as most volcanic rocks are resistant to weathering and capable of supporting loads well beyond building requirements.

Volcanic rocks such as basalt and andesite are most widely used in Washington as riprap, ballast, concrete aggregate, and roadstone. In 1963 about 11 million tons of basalt and andesite was used for these purposes. During this same time about 70,000 tons of these rocks, valued at $89,000, was sold as dimension stone.

Geology and Distribution

Volcanic rocks are a class of igneous rocks that have been extruded on the earth's surface or intruded near the surface. Most rocks of this type formed as surface flows and as accumulations of volcanic rock fragments; however, other bodies of volcanic rocks occur as injected dikes and sills.

Because volcanic rocks cooled rapidly, many of their mineral grains are so small that their outlines are not visible to the unaided eye. This fine grain size ofthe rocks makes the megascopic classification of them difficult. In general, the light-colored rocks are called felsite and the dark-colored rocks "trap." To properly name a volcanic rock, the percentage of quartz and feldspar as well as the type of feldspar must be determined. Also, the names of some volcanic rocks depend upon accessory minerals.

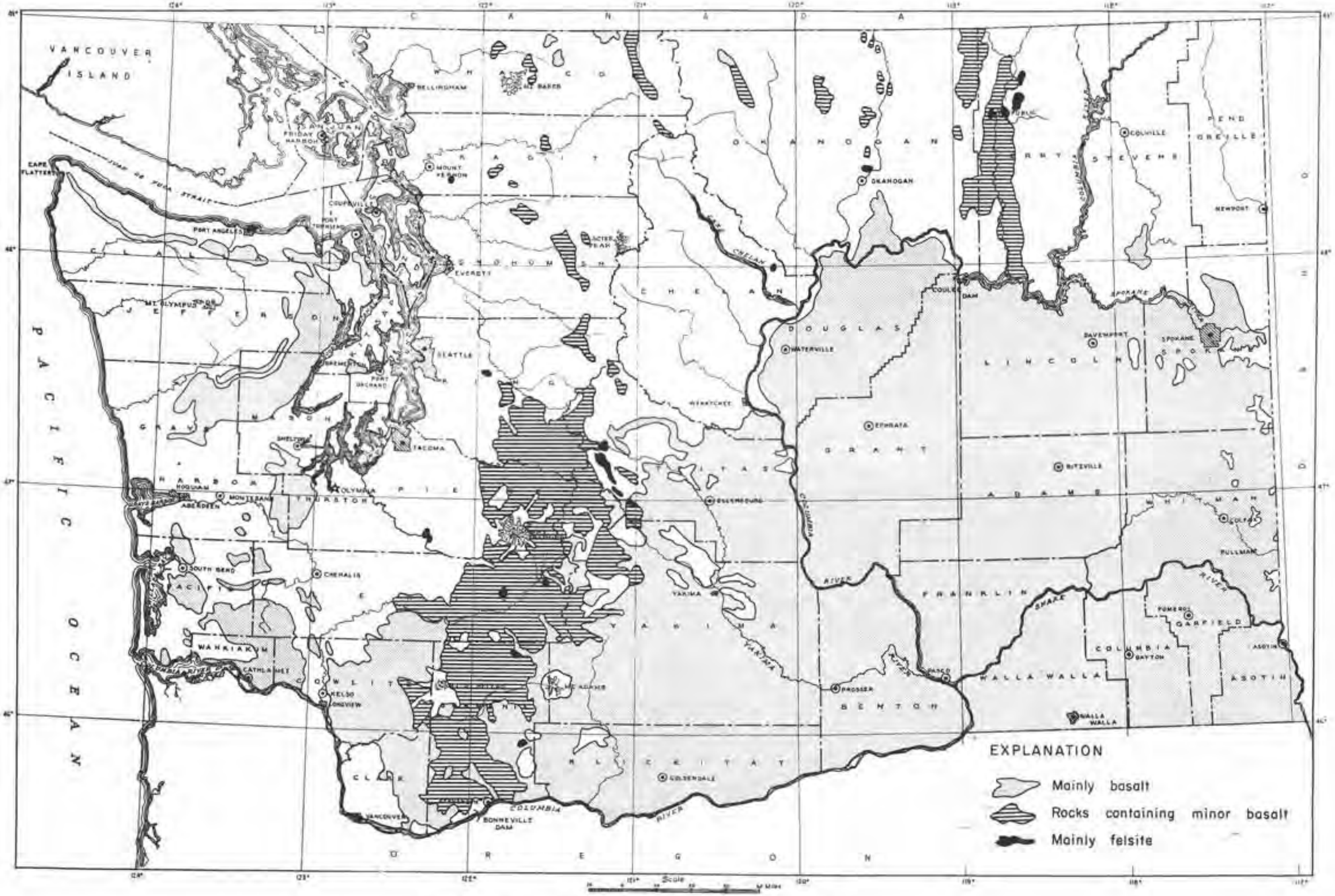

FIGURE 17.—Distribution of basalt and felsite.

TABLE 15. —Andesite quarries of Washington that were producing in 1964

No.	Name of operation	Property location	Product
1.	Gilbertson Landscape Construction Star Route, Box 21 Eatonville, Wash. 98328	PIERCE COUNTY Eatonville area SW¼NW¼ sec. 30, (17-5E)	Rough building stone and rubble from gray, greenish-gray, and bluish-gray andesite.
2.	Cascade Slate Cullen Campbell Route 6 Olympia, Wash. 98501	SKAMANIA COUNTY Randle area Sec. 35, (10-7E)	Ashlar and flagging from platy and flaggy medium-gray andesite.
3.	Dave Elmore Star Route, Box 25 Eatonville, Wash. 98328	PIERCE COUNTY Eatonville area N½SW¼ sec. 30, (17-5E)	Rough building stone and rubble from greenish-gray, bluish-gray, and medium-gray andesite.
4.	Island Frontier Landscape Construction Co. Dave Taggart Route 3, Box 522 Anacortes, Wash. 98221	SKAGIT COUNTY Deception Pass area E½ sec. 13, (34-1E)	Rough building stone and rubble from bluish-green andesite. Stone similar to Shuksan Stone.
5.	Heatherstone Co. P. O. Box 626 Steilacoom, Wash. 98388	YAKIMA COUNTY White Pass area SE¼ sec. 36, (14-11E)	Ashlar, rubble, and flagging from platy and blocky medium-gray andesite. Marketed as Heatherstone.
6.	Mount Adams Sheet Rock Quarry Joe Marston 9400 N.E. Mason Street Portland, Oreg. 97220	YAKIMA COUNTY Mount Adams area SW¼ sec. 27, (8-11E)	Flagging from gray andesite.
7.	Scheel Stone Co. 3314 Harbor Ave. S.W. Seattle, Wash. 98126	WHATCOM COUNTY Shuksan area Sec. 6, (39-8E)	Rough building stone and rubble from bluish-green andesite. Marketed as Shuksan Stone.
8.	Wells Creek Quarry Gordon Pullar 2241 Woburn Street Bellingham, Wash. 98225	WHATCOM COUNTY Shuksan area NW¼ sec. 5, (39-8E)	Rough building stone and rubble from bluish-green andesite. Marketed as Shuksan Stone.
9.	W. F. Taylor and Harold Wasson 410 Sixth Ave. W. Renton, Wash. 98055	SKAMANIA COUNTY Mount Adams area (East Canyon Creek) Sec. 2, (9-9E)	Rough building stone and rubble from maroon and gray andesite tuffs.

Volcanic rocks occur in every county of the State, and the deposits range in size from small dikes or sills to extensive flows that completely cover several counties. The flows occur most extensively in southeastern Washington, underlying the physiographic province known as the Columbia Plateau. Other large flows occur in southwestern Washington and as a belt that partly surrounds the Olympic Mountains. The distribution of basalt and andesite, which represent the major rock types, is shown on Figures 17 and 18.

Basalt

Basalt is a fine-grained volcanic rock that is composed mainly of plagioclase and pyroxene. In addition, olivine, potash feldspar, and glass may be present. The plagioclase, which makes up two-thirds or more of the total feldspar, is of the calcic variety.

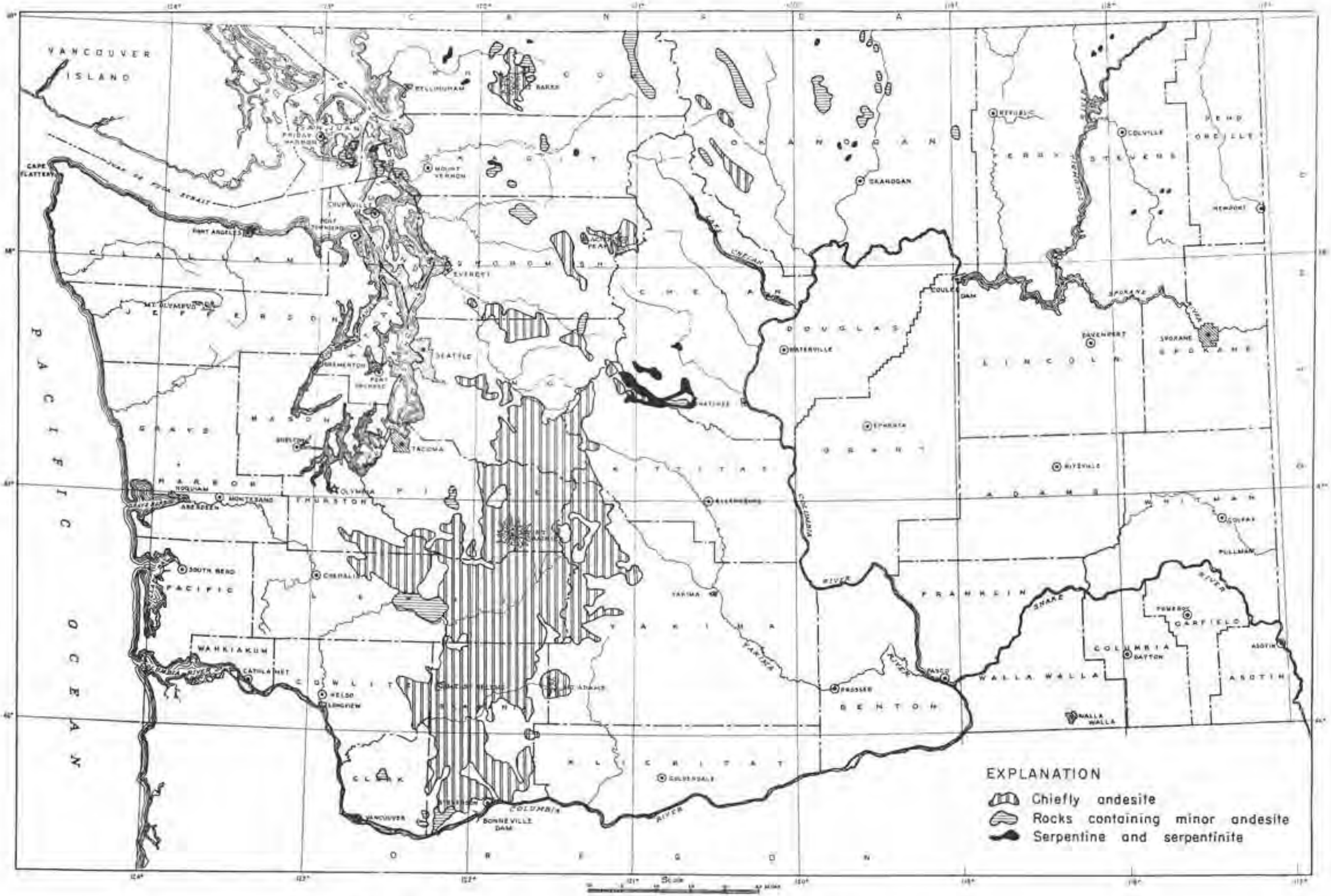

FIGURE 18. — Distribution of andesite and serpentine.

Fine-grained, dense lavas or dike rock containing over 40 percent mafic minerals and usually black in color are called "trap" by stone producers. Although "trap" is not recognized by petrographers as a proper name for any rock, it is often used by geologists as a field name for dense black volcanic rocks until the proper geologic name is determined (Appendix B, page 78).

Many basalts are very hard, dense, and have a uniform, very fine-grained groundmass. If larger crystals of the rock-forming minerals occur in the fine-grained groundmass, the rock is classed as a basalt porphyry. Other basalts contain round cavities called vesicles that range from 1/25 inch to as much as 1/2 inch in diameter. If the basalt is made up of at least 50 percent vesicles, it is known as scoria. A common structural feature of basalts is columnar jointing, which is produced by shrinkage of the lava during cooling. The columns occur as pillars at right angles to the surfaces of the flows, commonly making it difficult to obtain very large blocks of basalt. However, well-developed jointing in many basalts facilitates quarrying operations. Platy structure, in which the basalt breaks into thin plates or shells, is also present in basalts. This structure sometimes produces excellent flagging.

Although dark gray and black are the most common colors of basalt, alteration of the iron-bearing minerals of the rock often produces shades of green and red. The dark varieties are not particularly attractive as building stone, but iron oxide stains on the fracture surfaces of some basalts produce colorful stone in tones of brown, yellow, and red that may be used in the construction of rubble walls.

As abundant as basalt is in Washington—underlying approximately 28,000 square miles of land surface—only five quarries produced basalt mainly for building stone in 1964 (Table 14, page 60). This basalt was produced mostly in the form of rough building stone and rubble. Many other basalt quarries exist in the State, but they supply stone used mainly for road surfacing, riprap, and fill.

Andesite

Andesite is the second most abundant volcanic rock in Washington and underlies about 4,700 square miles of land surface. Although it is not as abundant as basalt, it is the volcanic rock most commonly used for building stone. It is probably because of andesite's lighter colors that this rock is preferred over basalt. The common forms of andesite used for building purposes are flagging, rough building stone, and rubble.

Mineralogically, andesite is similar to basalt except that the plagioclase is sodic instead of calcic. The texture may be dense or glassy, but andesites are characteristically porphyritic rocks. Plagioclase, pyroxene, hornblende, and sometimes biotite occur as distinguishable crystals in a very fine-grained groundmass.

As in basalt, columnar jointing is common in andesite. Also, well-developed flaggy and platy jointing of some andesites makes them suitable for flagstone and natural ashlar.

The most common colors of andesite are gray, greenish gray, and bluish gray. However, some attractive tones of green occur in the andesites of northwestern Washington. One such stone is a bluish-green andesite known locally as Shuksan Stone.

At present (1964), andesite is being mined for use as building stone from 9 quarries in western Washington (Table 15, page 62). Common uses for the stone include flagging, natural ashlar, rough building stone, and rubble.

Felsite

Fine-grained, light-colored volcanic rocks that contain less than 20 percent mafic minerals are called felsite by stone producers. The term "felsite" is also commonly applied to light-colored volcanic rocks that give few if any indications to the unaided eye of their actual mineralogical composition (Appendix B).

When examined in detail, felsite may be seen to be composed mainly of potash feldspar, which is usually the predominant feldspar, and plagioclase and quartz. Hornblende, biotite, muscovite, pyroxene, and feldspathoids may be present as accessory minerals. It is the predominance of the light-colored feldspar and quartz that gives the felsite its light color.

Felsite includes rhyolite, trachyte, phonolite, quartz latite, and latite. However, through alteration some basic igneous rocks such as andesite and dacite assume a light color; these, too, are often called felsite.

Because of their light color, felsites are susceptible to staining, especially by the oxides of iron, which are common alteration products of the mafic minerals. The brown, red, or yellow stain of iron oxide is usually confined to the near-surface rocks or to the rock adjacent to joints. Closely spaced joints in some felsites provide a wide variety of staining patterns that make attractive building stone. Although felsite is not nearly as extensive as basalt and andesite, it possesses a wider variety of textures and colors that make it desirable as a building stone.

TABLE 16. — Felsite building stone quarries of Washington that were producing in 1964

No.	Name of operation	Property location	Product
1.	Cascade Ornamental Building Stone, Inc. Route 3 Randle, Wash. 98377	LEWIS COUNTY Randle area Secs. 29 and 32, (13-8E)	Ashlar, rubble, rough building stone, and mantels. Light-gray, tan, and yellowish-brown latite(?). Finishing plant east of Randle; stone marketed as Cascade Stone.
2.	La Grande Canyon Quarry Don Murphy Box 188 Eatonville, Wash. 98328	PIERCE COUNTY La Grande area E½SE¼ sec. 33, (16-4E)	Rough building stone and rubble from tan to dark brownish-tan latite(?).
3.	William J. Scalf Box 753 Randle, Wash. 98377	SKAMANIA COUNTY Upper Cispus River area Sec. 18, (10-9E)	Rough building stone and rubble from light-gray to tan rhyolite.
4.	Wild Rose Claims J. W. Gorrell and W. L. Rowland Packwood, Wash. 98361	LEWIS COUNTY Upper Cowlitz River area SE¼ sec. 29, (14-10E)	Rough building stone from buff to tan rhyolite.
5.	Rainbow Mines John Looney Randle, Wash. 98377	SKAMANIA COUNTY Upper Cispus River area NE¼ sec. 18, (10-9E)	Rough building stone from light-gray to tan moderately altered massive dacite(?)
6.	Snoqualmie Stone, Inc. 3215 E. 123rd Seattle, Wash. 98125	KING COUNTY Preston area NW¼SW¼ sec. 21, (24-7E)	Rough building stone and rubble from yellowish-brown iron oxide-stained buff felsite.
7.	M & C Enterprises, Inc. J. W. Melrose, Pres. Box 226 Mukilteo, Wash. 98275	CHELAN COUNTY Crum Canyon area	Rough building stone and rubble from yellowish-brown iron oxide-stained buff felsite.

To date, felsite has been quarried in Washington for rough building stone, rubble, ashlar, and mantels. Most of the production of this stone has come from the Daybreak quarry of Cascade Ornamental Building Stone, Inc., in eastern Lewis County.

The distribution of the larger felsite bodies of the State is shown in Figure 17, page 61, and the quarries from which felsite has been produced are listed in Table 16.

Volcanic Breccia and Tuff

Volcanic breccia consists of sharply angular fragments of volcanic rock in a matrix of finer grained interstitial volcanic ash or fragmental country rock. The size of the larger fragments should exceed 1.5 inches in diameter; if they are smaller, the rock is classified as a tuff (Appendix A, page 77).

The material of breccias and tuffs generally has the same composition as the igneous rock from which they were derived. However, nonvolcanic materials may be present, especially if the rock formed in bodies of water. The predominant rock or mineral of the breccia or tuff indicates its composition. Typical varieties include: rhyolitic breccia, basaltic breccia, felsitic breccia, and pumiceous tuff.

When fragments of one color occur in a contrasting matrix, some attractive stone may result. Volcanic breccias are associated with the volcanic rocks of the State, but to date they have not been utilized to any extent as building stone. This is because most of them lack the texture or color desired to make an attractive stone.

A small amount of tuff has been quarried as building stone in Washington. One such deposit occurs in the East Canyon Creek area of Skamania County (Table 15, page 62). At this locality the tuff occurs in tones of red and gray. The tuff with the red matrix contains white to dark-red pumice fragments, and the medium-gray tuff contains light-gray to black pumice fragments.

Although deposits of tuff may be the source of attractive stone, the stone is not ideally suited for exterior stone work in western Washington, where moisture is excessive. The high absorption of porous tuffs promotes alteration, and slaking may result. However, if used for interior ornamental stone there appears to be no disadvantage in the use of tuff other than the one that it will not take a good polish.

Some tuffs become so well cemented that they lose their ashy fragmental appearance and resemble igneous rocks. This is especially true of the light-colored acidic tuffs, and many felsites are in reality indurated tuffs. These tuffs are commonly well suited for use as building stone.

Miscellaneous Stone

Washington has other occurrences of stone that are being used for building purposes, but not to the extent of the more common stones thus far discussed in this report. Generally, the production of these stones has been small and erratic; however, the use of unusual stone often provides a pleasing contrast to the common varieties of brick and stone that are generally used in building construction.

Gneiss, schist, and the green-stained silica carbonate rocks have been used mainly as rough building stone, and, because of their unusual textural and structural features, as well as their colors, they produce attractive walls. Quartz is used mainly in crushed form for roofing chips and exposed aggregate; and olivine, though used very little as a building stone in the past, is finding more use as rough building stone for walls.

Schist and Gneiss

Schist is a closely layered metamorphic rock that splits easily between layers. It is the alignment of the platy minerals in schist that gives schist its splitting property. Although slate also has splitting properties, it differs from schist in that the minerals are very fine-grained and usually indistinguishable to the unaided eye as compared with the coarser mineral grains that make up a schist (Appendix C, page 79).

TABLE 17. — Miscellaneous building stone quarries of Washington that were producing in 1964

No.	Name of operation	Property location	Product
1.	Robert Bartholet 1306 Langridge Ave. Olympia, Wash. 98501	MASON COUNTY Lake Cushman area	Ashlar and rubble from light-gray to maroon argillite.
2.	Scheel Stone Co. 3314 Harbor Ave. S.W. Seattle, Wash. 98126	SKAGIT COUNTY Marblemount area NE¼ sec. 30, (36-11E)	Rough building stone and rubble from green-stained silica-carbonate rock.
3.	Scheel Stone Co. 3314 Harbor Ave. S.W. Seattle, Wash. 98162	CHELAN COUNTY Lake Wenatchee area W½ sec. 33, (28-16E) Silver Lace quarry	Rough building stone from gneissic and schistose quartz-feldspar rock containing silvery mica on surfaces.
4.	Lovejoy Mining & Leasing Co. Vic Lovejoy Chewelah, Wash. 99109	STEVENS COUNTY Addy area NE¼ sec. 24, (33-39E)	White quartz for roofing granules and exposed aggregate.
5.	Vernon Beeks Trout Lake, Wash. 98650	SKAMANIA COUNTY Trout Lake area NE¼ sec. 11, (5-9E)	Rough building stone and rubble from siliceous tuff. Tuff is gray and white, containing various patterns in yellow, orange, and brown.
6.	Omega Mining, Inc. 411 Maritime Bldg. Seattle, Wash. 98104	SKAGIT COUNTY Twin Sisters Mountain area Sec. 3, (36-7E)	Crude and crushed olivine.
7.	Olivine Corp. 1015 Hilton Bellingham, Wash. 98225	WHATCOM COUNTY Twin Sisters Mountain area Sec. 35, (38-6E)	Crude and crushed olivine. Crushing plant at Bellingham.

A typical schist is made up of quartz and (or) feldspar, and platy minerals such as biotite, muscovite, chlorite, talc, and graphite. Usually (because of their color and crystal habit), the platy or micaceous minerals are more conspicuous than the quartz and feldspar. Tabular and prismatic minerals also occur in schists, and they, too, tend to become segregated into layers.

Schists are named according to their most abundant minerals. As an example, a schist rich in biotite would be a biotite schist; a schist containing garnets and mica would be a garnet-mica schist. Many varieties of schist occur in Washington, but the most common of these are mica schist and graphite schist.

Washington schists are typically dark green to black, due to the abundance of dark minerals. However, garnet schists occur in tones of red and brown. Because of their subdued colors, most of the schists quarried for building stone in this State are used because of structural and textural features that make them attractive.

Gneiss, like schist, is a metamorphic rock, but the rock is coarsely banded as a result of the different minerals segregating into bands. Each band may consist of several different layers.

TABLE 18. — Green-stained rocks of Washington

No.	Name of deposit	Deposit location	Remarks
1.	Garnierite -----------	CHELAN COUNTY Sec. 20, (23-17E) Sec. 19, (23-18E)	Nickel-stained silica-carbonate rock associated with serpentine.
2.	Peshastin ------------	CHELAN COUNTY SW¼SW¼ sec. 1, (22-17E)	Nickel-stained zone 200 to 800 feet wide in quartz, calcite, and magnesite.
3.	Peshastin Creek -------	CHELAN COUNTY SW¼ sec. 19, (23-18E)	Nickel-stained ledge of chalcedonic quartz and silica-carbonate rock 150 to 200 feet wide.
4.	Red Rock ------------	KITTITAS COUNTY NW¼NW¼ sec. 20, (19-15E)	Nickel- and chromium-stained silica-carbonate rocks in zone 100 to 150 feet wide.
5.	Browns Lake ----------	OKANOGAN COUNTY SW¼ sec. 6, (34-26E)	Chromium-stained quartzite associated with serpentine.
6.	Section Twelve -------	OKANOGAN COUNTY NE¼ sec. 12, (32-30E)	Nickel staining of fracture surfaces of crushed quartz lode 4 feet wide.
7.	Cultus Mountain ------	SKAGIT COUNTY SE¼ sec. 22, (34-5E)	Zones of nickel- and chromium-stained silica-carbonate rocks in graphite schist.
8.	Diobsud Creek ------- (Germaine)	SKAGIT COUNTY NE¼ sec. 30, (36-11E)	Nickel-stained silica-carbonate rock associated with quartz phyllite. Quarried for building stone by Scheel Stone Co., Seattle.
9.	La Conner -----------	SKAGIT COUNTY SE¼ sec. 35, (34-2E)	Nickel-stained silica-carbonate rock associated with schist.
10.	Scott ----------------	SKAGIT COUNTY Center sec. 5, (34-5E)	Nickel-stained silica-carbonate rock in zone 25 feet wide.
11.	Anderson ------------	SNOHOMISH COUNTY N. line sec. 4, (29-7E)	Nickel-stained silica-carbonate rock.
12.	Granite Falls --------	SNOHOMISH COUNTY Center W½ sec. 33, (30-7E)	Nickel-stained silica-carbonate rock in zone 25 feet wide.

Gneiss is composed predominantly of feldspar and quartz; hornblende and biotite are probably the next most common minerals in it. Gneiss also is named after the most common minerals that make up the rock. Common varieties are: quartz gneiss, biotite gneiss, hornblende gneiss, and garnet gneiss. Other gneisses are named after the rock from which they appear to have originated. Granite gneiss, monzonite gneiss, and diorite gneiss represent some of these.

Like that of schist, the color of most of the Washington gneisses leaves something to be desired; they are commonly white to dark green. Therefore, textural and structural features are the basis for selecting many gneisses as building stone.

To date (1964), very little gneiss in Washington has been used as building stone (Table 17). However, from a deposit near Lake Wenatchee, muscovite gneiss has been quarried for use as rubble in walls of buildings. The silvery color of the muscovite combined with unusual textures and banding creates a distinctive building stone (Fig. 3, p. 13). Similar gneisses probably occur in other parts of the gneiss belts of the State and should not be overlooked as possible sources of building stone.

Most schists and gneisses are products of metamorphism and are related to mountain building. In Washington the rocks are confined mainly to the mountains of the northern Cascades and the Okanogan Highland province. Much of the schist and gneiss is in the mountainous areas of the State, especially in the more remote areas of the northern Cascades, and therefore is not easily accessible. The general distribution of the larger masses of schist and gneiss is shown in Figure 19.

Green-Stained Rock

Rocks that contain stains or coatings of secondary green minerals have proved to be the source of attractive building stone. Three such rocks are the copper-, nickel-, and chromite-stained rocks that occur in several mineralized areas of the State.

The most common green stain is that of the secondary copper mineral malachite, which is emerald, grass, and dark green. This stain is common to copper-bearing ores and may be found as coatings on the rocks of copper-bearing outcrops or often on the waste rocks of copper mine dumps. Inasmuch as the secondary copper minerals are difficult to process, much of this material was discarded during mining operations as waste or was stockpiled for future uses.

The secondary nickel mineral garnierite is commonly associated with the silica-carbonate rocks found in serpentines and ultrabasic rocks. Although these nickel-bearing rocks are not of economical value for their nickel, they are colorful, strong, resistant to weathering, and well suited for ornamental building stone purposes. The nickel-stained silica-carbonate rocks occur in many different tones of green, but pale green and emerald green seem to predominate.

The general distribution of serpentine masses that might possibly contain silica-carbonate rocks is shown in Figure 18, page 63, and the general locations of the larger known occurrences of the green-stained rocks are presented in Table 18. To date (1964), only one quarry, near Marblemount, has supplied this stone for commercial purposes, this being the Germaine property, on Diobsud Creek.

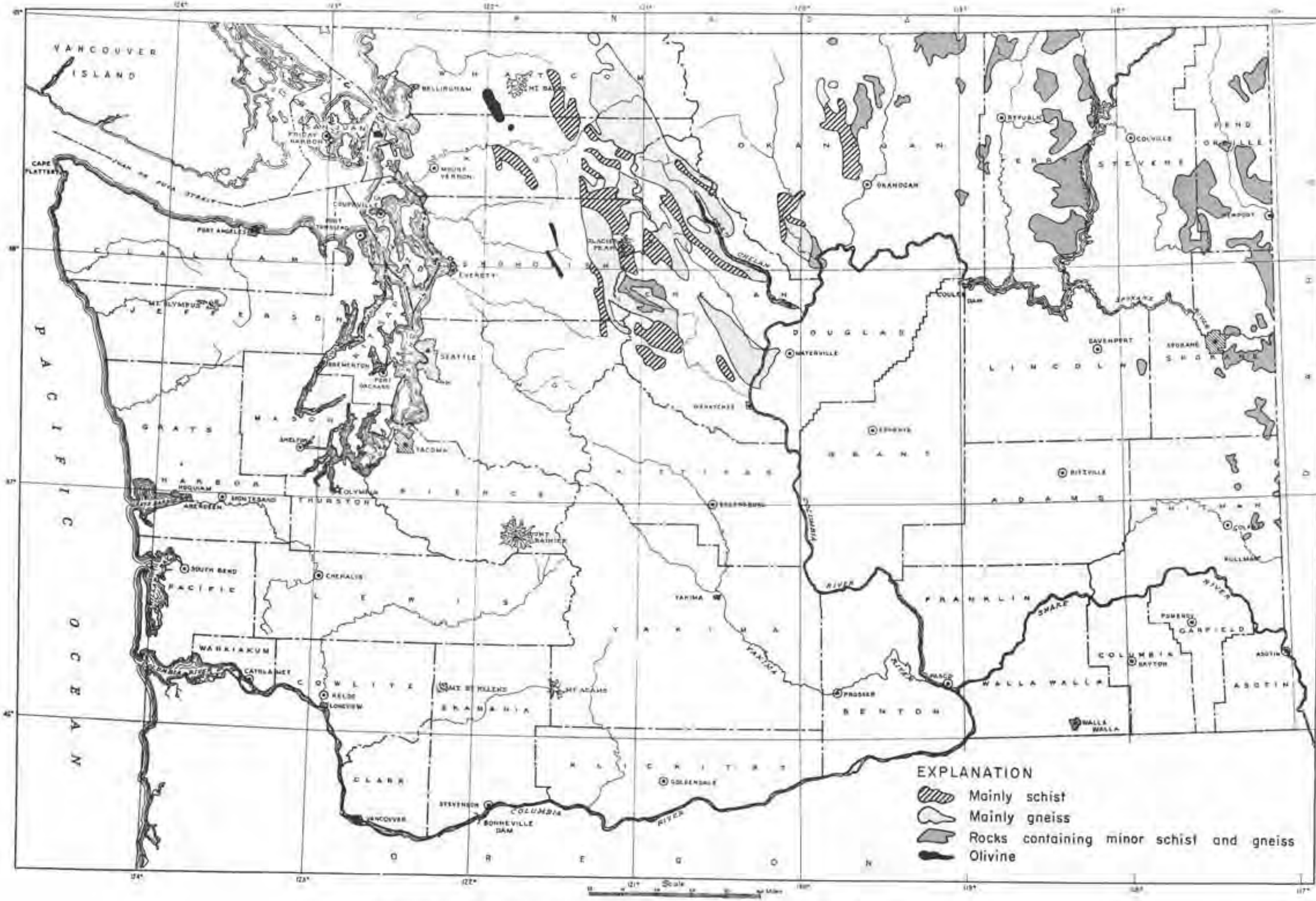

FIGURE 19. — Distribution of schist, gneiss, and olivine.

Although secondary copper and nickel minerals are two of the most common minerals responsible for green stains in rocks, the chromium mineral mariposite, which is a chromiferous mica, also imparts a light apple-green color to some rocks. Chromium-stained rocks are comparatively rare but should not be overlooked as a possible source of green building stone.

Near Browns Lake, in Okanogan County, a chromite-stained quartzite forms several outcrops of green rock (see Browns Lake in Table 18, page 69). This occurrence has never been quarried but appears to be well suited as a decorative building stone. Other occurrences of chromium-stained rock occur in Washington (Table 18), but it is not known whether they are suitable for building stone.

Olivine

The magnesium-iron silicate mineral olivine, named for its olive-green color, forms several extensive outcrop areas in Washington. Rather than being an opaque green, like many green volcanic rocks, pure olivine is semitransparent.

Olivine is generally massive and lacks natural splitting planes. Because of the massive nature of olivine, it is generally used as rough building stone or rubble.

Although it is possible to find large masses of almost pure olivine (dunite), much of the olivine in Washington contains varying amounts of chromite, enstatite, and serpentine. The chromite usually occurs as distinct black grains, whereas the enstatite and serpentine are green. Excessive amounts of these impurities generally make the olivine unsuitable for building stone.

The largest bodies of olivine in the State occur in Whatcom, Skagit, and Snohomish Counties (Fig. 19). To date, only a minor amount of the olivine has been used as building stone; this has been used by individuals for small jobs. The main use for the stone continues to be for crushing to produce foundry sand.

Quartz

Deposits of quartz, which range in size from thin hairlike stringers of no economic value to large deposits of several million tons that are mined for their high silica content, occur in many parts of the State. The deposits that are considered to have commercial potentials are confined to the northern half of Washington (Fig. 20).

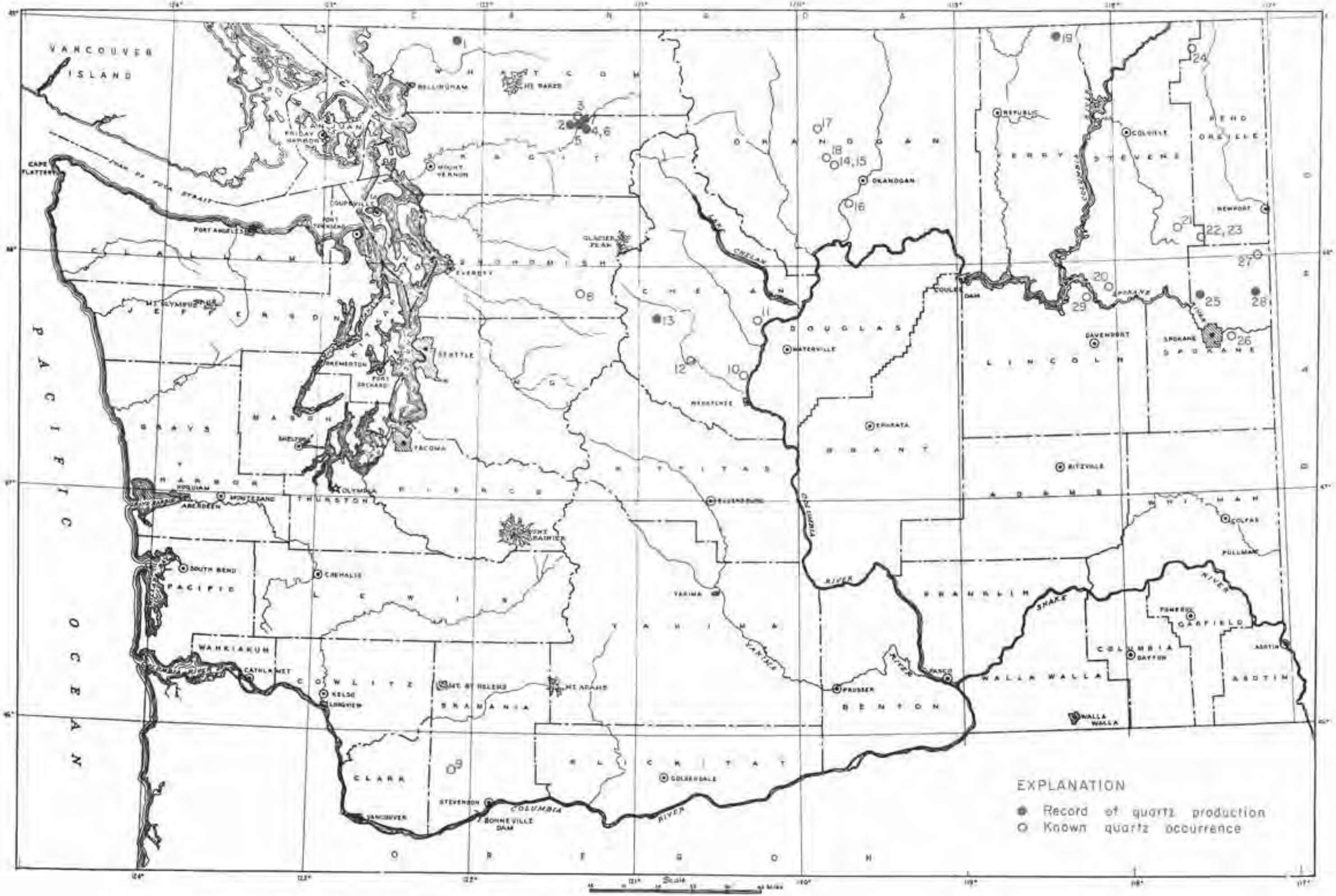

FIGURE 20. — Quartz deposits and quarries.

TABLE 19. —Selected quartz deposits of Washington

No.	Name of deposit	Deposit location	Remarks
		WHATCOM COUNTY	
1.	Olympic	SE¼ sec. 17, (40-5E)	Body of massive white quartz with minor iron oxide staining.
		SKAGIT COUNTY	
2.	Bacon Creek	Secs. 16 and 17, (36-11E)	Several large quartz lenses in schist.
3.	Doris	Sec. 4, (36-11E)	Body of massive white quartz, 50 by 100 feet.
		SNOHOMISH COUNTY	
4.	Pressentin	Center W½ sec. 15, (36-11E)	Several lenses of quartz in schist.
5.	Scheel	Sec. 16, (36-11E)	White quartz vein.
6.	Silica Camp	Sec. 15, (36-11E)	Large quartz lens in schist.
7.	Stoner	SW¼SE¼ sec. 10, (36-11E)	Massive white quartz lens 90 feet wide and 300 feet long.
8.	Good Luck	SW¼ sec. 21, (28-11E)	Quartz pegmatite 500 feet long and 50 to 100 feet wide.
		SKAMANIA COUNTY	
9.	Yacolt	Sec. 13, (4-5E)	A 4½-foot quartz vein in andesite.
		CHELAN COUNTY	
10.	Burch Mountain	W½ sec. 4 and NE. cor. sec. 5, (23-20E)	Several quartz veins; largest, 25 feet wide and 800 feet long.
11.	Harris Creek	NE¼ sec. 33, (27-20E)	Quartz outcrop 40 feet wide and 150 feet long.
12.	Leavenworth	Center sec. 10, (24-17E)	Body of pegmatitic quartz in diorite.
13.	Merritt	SE¼ sec. 6, (26-16E)	Lens of white pegmatitic quartz in schist.
		OKANOGAN COUNTY	
14.	Howell	SE¼NW¼ sec. 6, (33-25E)	Massive quartz.
15.	Loup Loup	W½ sec. 29, (34-25E)	Large uniform deposit of white quartz.
16.	Malott	SE¼ sec. 22, (32-25E)	Three pegmatite dikes of white quartz.
17.	Snow White	S½ sec. 36, (36-23E)	Body of pegmatitic quartz.
18.	Buck Mountain	NE¼ sec. 21, (34-24E)	Several bodies of pegmatitic quartz.
		FERRY COUNTY	
19.	Independent Mountain	Sec. 22, (40-35E)	Good grade of quartz reported on 4 claims.
		STEVENS COUNTY	
20.	Big Smoke	SW¼ sec. 31, (28-38E)	Large pegmatitic quartz body.
21.	Bald Mountain	NE¼ sec. 2, (30-41E)	Quartz vein 10 to 125 feet wide traceable for several thousand feet.
22.	Blue Grouse Mountain	S½ sec. 15, (30-42E)	Large body of quartz.
23.	Steinmetz	Sec. 24, (30-42E)	Large quartz vein reported to contain 3 million tons.
		PEND OREILLE COUNTY	
24.	Sauvola	E½ sec. 15, (39-42E)	Quartz vein or pegmatitic quartz traceable for 2,000 feet.
		SPOKANE COUNTY	
25.	Denison	NE¼ sec. 14, (27-42E)	Segregation of pegmatitic quartz in granite. Quarried in past by Pacific Silica Co.
26.	Dishman	SW¼ sec. 20, (25-44E)	Lens of quartz in granite.
27.	Glander	NW¼ sec. 24, (29-45E)	Large body of massive quartz.
28.	Quartz Mountain	NW¼ sec. 35, (28-45E)	Large body of massive quartz, some iron oxide staining.
		LINCOLN COUNTY	
29.	Egypt	SE¼ sec. 6, (27-37E)	Large deposit of massive quartz.

Quartz is one of the most common minerals and consists of silicon dioxide (SiO_2). It has a hardness of 7, weighs around 165 pounds per cubic foot, and is one of the most stable rock-forming minerals. Quartz is most commonly white, but it may also be smoky, rose colored, or clear.

Quartz often contains metallic minerals which, when altered, cause the otherwise white quartz to become stained. When quartz is used as building stone, the rusty stain of iron may be objectionable but the green stains of copper and nickel are often desired.

As a building stone, quartz in large fragments is used mainly as rough building stone or rubble. When a dark contrasting mortar is used, attractive walls may be constructed from quartz. Other common uses for quartz include roofing chips and exposed aggregate.

Inventory of Washington Minerals - Part I, Nonmetallic Minerals (Valentine, 1960, p. 92-93), lists 37 occurrences of massive quartz in 13 counties. Those occurrences that might have possibilities as building stone are listed in Table 19 of this report.

SUMMARY

In the foregoing discussion of the building stones of Washington it has been pointed out that a wide variety of rocks occur in the State, many of which are suitable for building purposes. Inasmuch as most stone is used for ornamental purposes, the color and texture of the stone appear to be the most important considerations in the selection of a building stone. However, if used for exterior purposes the stone should be able to resist alteration, which may cause deterioration and often a change in color of the stone. Almost all of the rock in Washington that has been used for building purposes is capable of bearing loads well in excess of the minimum requirements for safe construction.

Building stone on public domain, which includes the national forests, may in some cases be obtained without cost by locating a mineral claim. However, stones of common varieties on public domain are subject to purchase from the U. S. Government. Building stone on State and private land must be purchased from the owner of the mineral rights, who may not necessarily be the owner of the surface rights.

Much building stone is available as field stone or talus and as such does not require costly quarrying methods for removal. However, other rock that may be suitable for use as building stone may occur in outcrops that will require blasting for removal. If cleavage planes and joints are present in the rock, it is often possible to obtain building stone by breaking down the rock with hammers and wedges instead of blasting.

Markets do exist for attractive building stone, but, as in the sale of most nonmetallic minerals, in most instances the seller must find or possibly create a market for the stone.

APPENDIX A

MEGASCOPIC CLASSIFICATION OF COMMON SEDIMENTARY ROCKS [1]

ESSENTIAL MINERALS	CHEMICAL ROCKS	CLASTIC ROCKS			
	Precipitates from aqueous solutions	Grains not recognizable with unaided eye (<0.062 mm)	Fine to coarse grained (0.062 - 2.0 mm)	Very coarse grained (>2.0 mm)	
				Rounded fragments	Angular fragments
		UNCONSOLIDATED			
		Clay, mud, loess, ash	Sand and grits	Gravel, boulder deposits, and till	
		CONSOLIDATED			
Calcite	Limestone Tufa Travertine	Limestone		Limestone conglomerate	Limestone breccia
Clay minerals	---------------	Siltstone, shale, and argillite	---------------	---------------	---------------
Dolomite	Dolomite	Dolomite		Dolomite conglomerate	Dolomite breccia
Quartz	Chert, flint	---------------------	Quartzose sandstone	Quartz pebble conglomerate	Quartz breccia
Quartz, feldspar, kaolinitic clay	---------------	---------------------	Arkose	Arkosic conglomerate	Arkosic breccia
Quartz, feldspar, rock chips, micaceous or chloritic clay	---------------	---------------------	Graywacke	Graywacke conglomerate	Graywacke breccia
Volcanic ejecta (Glass and rock fragments)	---------------	Tuff (<32 mm)		Agglomerate (>32 mm)	Volcanic breccia (>32 mm)

[1] Modified from: Field, Richard M., 1947, p. 32.

Note: > means greater than
< means less than

APPENDIX B

MEGASCOPIC CLASSIFICATION OF IGNEOUS ROCKS[1]

		LIGHT-COLORED ROCKS			DARK-COLORED ROCKS		
		Felsic minerals dominant		Ferromagnesian minerals abundant		Feldspar absent	
		Quartz, present	Quartz, absent	Hornblende, conspicuous	Pyroxene, conspicuous	Without olivine	With olivine
Phaneritic Batholiths, laccoliths, stocks, thick dikes, and sills	Nonporphyritic	Granite Aplite Pegmatite	Syenite	Diorite	Gabbro Diabase	Pyroxenite Hornblendite	Peridotite
	Porphyritic	Granite porphyry	Synenite porphyry	Diorite porphyry	Gabbro porphyry		
Aphanitic Dikes, sills, surface flows, margins of larger masses	Porphyritic	Felsite porphyry		Basalt porpiiyry Melaphyre			
	Nonporphyritic	Felsite		Basalt Trap		Very rare rocks	
Glasses Surface flows, margins of dikes and sills, welded tuffs	Porphyritic	Vitrophyre Obsidian porphyry Pitchstone porphyry		Rare			
	Nonporphyritic	Obsidian - black Pitchstone - resinous Perlite - concentric fractures Pumice - finely cellular					
Fragmental igneous rocks	Volcanic ash, tuff, breccia, agglomerate, etc.						
Color Index[2]		10	15	25	50	95	

[1] From: Wahlstrom, E. E., 1960, p. 304.

[2] Color Index: Percentage of dark-colored minerals.

APPENDIX C

MEGASCOPIC CLASSIFICATION OF METAMORPHIC ROCKS[1]

MINERALS	NONDIRECTIONAL STRUCTURE		DIRECTIONAL STRUCTURE (Lineate or Foliate)			
	Contact metamorphism		Regional metamorphism			
	Dense	Granular	Slaty	Phyllitic	Schistose	Gneissic
Quartz	--------	Quartzite	------	-----	--------------	--------------
Quartz and mica	--------	--------	------	-----	Quartz schist	--------------
Contact metamorphic minerals (cordierite, andalusite, quartz, feldspar, and mica)	Hornfels	Hornfels	------	-----	--------------	--------------
Chlorite	--------	--------	Slate	Phyllite	Chlorite schist	--------------
Mica	--------	--------	Slate	Phyllite	Mica schist	Mica gneiss
Mica with quartz and (or) feldspar	--------	--------	Slate	Phyllite	Schist	Gneiss
Hornblende	--------	Amphibolite	------	------	Hornblende schist or amphibolite	Hornblende gneiss or amphibolite
Calcite	Marble	Marble	------	------	--------------	---------------
Dolomite	Marble	Marble	------	------	--------------	---------------
Calcium-bearing silicates (garnet, epidote, vesuvianite, wollastonite, diopside, scapolite, and calcite)	Skarn	Skarn	------	------	--------------	Skarn
Serpentine	--------	Serpentine	------	------	Serpentine	---------------
			Grain size increases →			

[1] From: McKinstry, H. E., 1948, p. 608.

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GLOSSARY

Aphanitic. Having a texture so fine that the individual grains or crystals cannot be distinguished with the unaided eye.

Ashlar. Rectangular blocks having sawed, planed, or rock-faced surfaces, contrasted with cut blocks that are accurately sawed and surface tooled.

Ballast. Broken stone, gravel, sand, etc., used for keeping railroad ties in place.

Batholith. A huge intrusive body of igneous rock. Minimum size, 40 square miles in outcrop.

Bedding. Plane of stratification. The surface marking the boundary between a bed and the bed above or below it.

Bluestone. Refers to sandstones that are thinly bedded and readily cleaved, irrespective of color.

Building stone. Includes all stone that is used for structural or ornamental purposes in part of a structure.

Chloritization. Metamorphic alteration of other minerals into chlorite.

Concretion. A spheroidal or discorded aggregate formed by the segregation and precipitation of some soluble mineral like quartz or calcite around a nucleus, which commonly is a fossil.

Dense. Compact; individual grains not readily distinguishable; distinct cleavage lacking.

Dike. Tabular mass of igneous rock that fills a fissure in pre-existent rocks.

Dimension stone. Masses of stone prepared for use in the form of blocks of specific shapes and usually of specific size.

Epidotization. The production of epidote in a rock by metamorphism.

Exposed aggregate. Term applied to concrete aggregate that is purposely exposed for its color or texture in cast slabs or driveways and walks.

Fault. A break or dislocation in the continuous strata or masses of rock, which results in the offsetting of the units.

Felsite. A general commercial term for very fine-grained light-colored igneous rocks.

Field stone. Loose stone scattered by natural processes over the ground surface.

Fissile. Capable of being split, as schist, slate, and shale; beds less than 2 mm thick.

Flagging. Rock that splits into thin slabs. Used mainly for walks, driveways, patios, and wall veneer around small commercial buildings and residences.

Flaggy. Strata from 10 to 100 mm thick.

Fold. An undulation or wave in stratified, layered, or folded rock.

Foliation. The laminated structure resulting from the segregation of different minerals into layers.

Freestone. A type of sandstone that carves easily with no splitting tendencies in any one direction.

Gneissic. Coarse-grained, in the range of one to several millimeters. Cleavable on rough surfaces, if at all. If composed of more than one mineral, the minerals are more or less segregated into separate bands or lenses.

Granite. Commercial use of the term granite includes not only true granite but also granite gneiss, syenite, quartz monzonite, granodiorite, quartz diorite, and diorite. Black granite includes those dark igneous rocks that are classified petrographically as gabbro, diabase, anorthosite, and pyroxenite.

Granular. Individual grains readily distinguishable; distinct cleavage lacking.

Graphic. In petrology, characterized by the mutual interpenetration, commonly in parallel orientation, of the crystals of two minerals; said of the texture of some igneous rocks.

Igneous rock. Rock made by the solidification of molten matter that originated within the earth.

Laccolith. Lens-shape mass of igneous rock intrusive into layered rocks. Typically, a laccolith has a flat bottom and a domed top and is more or less circular in ground plan.

Mafic. High in magnesia and iron and correspondingly low in silica; usually dark colored.

Magma. Molten rock matter together with its dissolved gas or vapor.

Marble. A metamorphic rock composed essentially of calcite and (or) dolomite, generally a recrystallized limestone. Also includes verd antiques, which consist chiefly of serpentine.

Massive. Strata more than 100 mm thick, free from minor joints and laminations; also hard to split.

Metamorphic rock. A rock that through the agencies of heat, pressure, and (or) chemical solutions has been changed in texture and composition.

Metamorphism. A change in texture or mineralogical composition of a rock, usually brought about by heat, pressure, or chemically active solutions.

Orbicular. Containing spheroidal aggregates of megascopic crystals, generally composed of two or more of the constituent minerals.

Petrology. Study of rocks, particularly igneous rocks.

Phaneritic. Having a texture so that individual grains or crystals can be seen with the unaided eye.

Phyllitic. Cleavable on smooth surfaces. Coarser than slate, but grains and flakes discernible with difficulty by the unaided eye.

Platy. Strata from 2 to 10 mm thick.

Plutonic. Of igneous intrusive origin. Usually applied to sizable bodies of intrusive rock rather than to small dikes and sills.

Porphyritic. Texture in an igneous rock characterized by larger crystals in finer grained groundmass.

Riprap. Stones thrown together without order or matrix in a foundation or retaining wall. Riprap for special applications must meet certain requirements as to size and durability.

Rough building stone. The crudest form of building stone, consisting of irregular rock fragments.

Rubble. A crude form of building stone, consisting of irregular rock fragments, each having at least one essentially flat surface.

Schistose. Coarser than phyllite. Grains and flakes clearly visible. Cleavage surfaces rough and parallel to the platy minerals that show alignment.

Sedimentary rock. Rock that originated as a sediment. The sediment may have been transported by wind, water, or ice and carried in the form of solid particles (sand, gravel, clay) or in solution (some calcareous sediments). Sedimentary rocks have been indurated by cementation.

Sericitization. The development of sericite in schists and other rocks, due to metamorphism.

Sheeting. The development, in rock formations, of small, closely spaced parallel fractures.

Sill. Intrusive sheet of igneous rock parallel with the layers enclosing it.

Skarn. Rock resulting from contact metamorphism and characterized by calcium silicates such as garnet and pyroxene (alternative term—tactite).

Slaty. Cleavable on smooth, usually lustrous surfaces, commonly at an angle to bedding. Grains so fine that individual grains are not distinguishable except in thin section under the microscope.

Stock. An intrusive body like a batholith, but smaller; i.e., less than 40 square miles in outcrop.

Stone. Sometimes synonymous with rock, but more properly applied to individual blocks, masses, or fragments taken from their original formation or considered for commercial use.

Strip. Removal of overburden or waste material. Also, elongate or linear pieces of cut stone.

Talus. A heap of coarse broken rock at the foot of a cliff.

Terra cotta. Hard, usually unglazed earthenware.

Terrazzo. A type of concrete in which chips or fragments of stone, usually marble, are mixed with cement and are ground to a flat surface, exposing the chips, which take a high polish.

Texture. Size, degree of uniformity, and arrangement of the constituent mineral grains of a rock.

Trap rock. A general commercial term for very fine-grained black igneous rocks.

Vesicle. A small cavity in an aphanitic or glassy igenous rock, formed by the expansion of a bubble of gas or steam during the solidification of the rock.

Wedging. Breaking down rock with hammers and wedges instead of by blasting.