Slickensides on the west and east contacts indicate movement between the enclosing wall rock and the limestone. Several other faults and shear zones are exposed in the quarry walls and in roadcuts to the west. The limestone is contained in a sequence composed predominantly of black carbonaceous shale, but including a considerable amount of ribbon chert and minor amounts of greenstone and graywacke. These rocks are believed to be of Permian age and have been tentatively assigned to the Trafton sequence. The limestone is cut by numerous calcite veinlets, which stand out in relief on weathered surfaces. No fossils were seen.

Popoff (1949a, p. 6) suggested that a continuation of the limestone might lie under an increasing thickness of overburden in a low ridge about 40 feet wide extending 1,000 feet to the north from the quarry, as the limestone bodies in this area are more resistant than the enclosing bedrock and commonly stand up as knolls and ridges. However, shale overlies the limestone on the quarry face, and the limestone appears to plunge down to the north under bedrock overburden.

About 1,000 feet to the northeast is a second area of limestone outcrop. It consists of two exposures—one, near a slough of the North Fork of the Stillaguamish River, which looks very much like a buried boulder and might be limestone float; and a second, which lies about 350 feet to the northwest and 150 feet above the river. At this latter locality, poorly exposed knobs of limestone project up through soil and drift over an area of about 500 square feet. The limestone is similar in appearance to that exposed in the quarry. It has not been developed.

Calcareous shales crop out in streambeds to the northwest of the limestone and are cut by calcite veinlets. They have been called limestone, but are too impure to be of economic value.

Quality.—The limestone is a high-calcium type.

Chemical analyses of Jack limestone

Sample no.	Location	Sample length (feet)	$CaCO_3$	Loss on ignition	CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3	P	S
1/ S1	West side of quarry -----	18.0		43.6	55.1	0.4	0.2	0.1	0.2	0.016	0.004
1/ S2	East side of quarry -----	7.5		43.0	54.0	0.4	2.0	0.1	0.3	0.023	0.002
1/ S3	East side of quarry -----	26.6		43.6	55.1	0.4	0.4	0.1	0.1	0.027	0.002
1/ S4	Center of quarry -------	26.5		43.6	55.4	0.4	0.2	0.1	0.1	0.052	0.000
1/ S5	Outcrop ? near slough ---			43.8	55.6	0.4	0.2	0.2	0.1	0.015	0.004
1/ S6	Undeveloped outcrop to north --------			43.5	55.5	0.3	0.5	0.2	0.4	0.038	0.001
2/	Sec. 16, north of Jack deposit. Calcareous shale	Composite	24.6	11.74	15.16	1.30	63.94	2.14	5.94		

1/ Popoff (1949a, p. 7).
2/ Unpublished private analysis.

Ownership and development.—The present owner of this property is unknown. The deposit was owned in 1945 by J. A. Jack, and was operated by him from October 1941 until some time before 1949. Production was irregular, 22 tons a day being produced in March of 1943 and about 4,000 tons being produced per year. Most of the limestone was shipped to Northwestern Glass Company, of Seattle, but in 1943 about 50 tons per week was also being sent to Longview, Wash., for pulp mills, and previously some had been shipped to a pulp mill at Anacortes. Agricultural stone was supplied to local farmers, and a mill for crushing and grinding was located at the quarry. Rock was hauled by truck and stored in bunkers at the

community of Bryant, to the west. A 7½-mile truck haul was required. An unpublished geological report on the property that was circulated in the local area states that the deposit was of a size suitable for a cement plant, but this was certainly not the case, as the deposit is now exhausted. It was not a particularly profitable operation. The second outcrop area to the north has not been investigated sufficiently to determine its size, but it is probably too small to be of economic value.

References.—Guard (1943, unpublished field notes), Mathews (1947, p. 44-45), Popoff (1949a, p. 6-7), Danner (1957, p. 204).

Skagit Power Line Deposit

Location, size, and accessibility.—The Skagit Power Line deposit is along the City of Seattle Skagit Power Line right-of-way in the north center of sec. 10, T. 31 N., R. 6 E., approximately 10 miles from the town of Arlington by road, the last 2 miles of which is on the Skagit Power Line right-of-way. The outcrop is at an altitude of about 625 feet, on a relatively flat hilltop between Bear Creek and Porter Creek in brushy logged land. The limestone forms a bed that is exposed for about 100 feet in a north-south direction and is at least 50 feet wide.

Geology and description.—The deposit is a poorly exposed limestone body consisting of discontinuous weathered knobs 1 to 2 feet high and small solution depressions. The greatest vertical exposure is 6 feet. Limestone is in contact with shale, sandstone, and conglomerate on the west, but on the east an area covered with glacial drift over 100 feet wide separates the eastern limit of limestone exposure from that of other types of bedrock. A brief exploration to the north and south did not reveal any additional limestone outcrops. The limestone is gray in color and dense or oölitic-organoclastic in texture. It is of Permian age and contains abundant fusulinid fossils.

Quality.—The quality is unknown, but the limestone is probably of a high-calcium type similar to that of all the other Permian limestones in the area.

Ownership and development.—The property is owned by Seattle City Light. There has been no development, and the deposit appears too small to be of economic value. However, its true size is unknown. It probably could not be developed because of the danger of damage to power lines overhead.

References.—Popoff (1949a, p. 7), Danner (1957, p. 218).

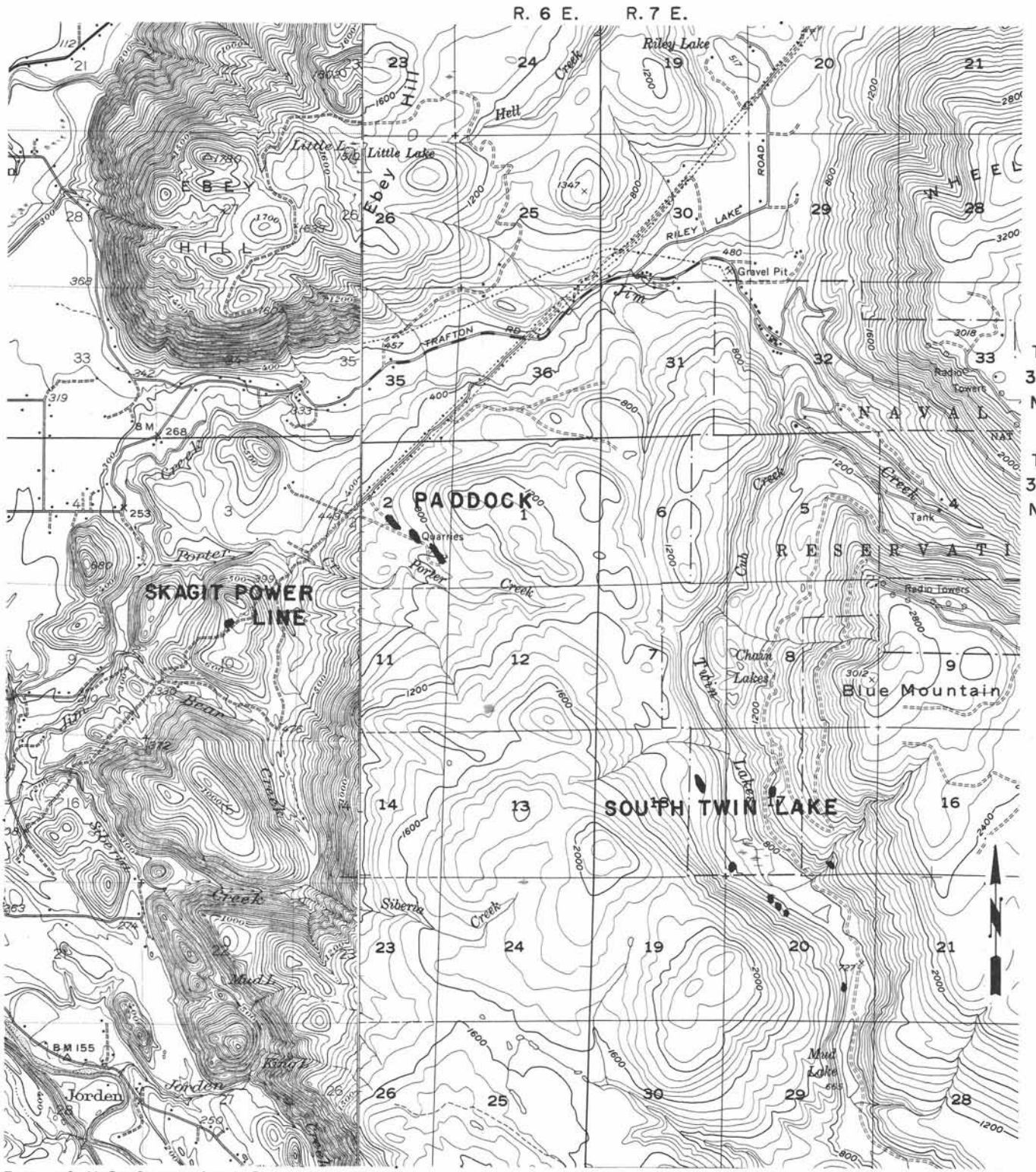
Paddock (Morcrop) Deposit

Location, size, and accessibility.—The Paddock, or Morcrop, limestone deposit is in the SE¼ sec. 2, T. 31 N., R. 6 E., about 7 miles east of the town of Arlington and a few hundred feet south of the City of Seattle Skagit Power Line road, 1½ miles west of Jim Creek.

The deposit consists of at least 14 lenses of limestone, the largest of which was about 375 feet long and had a maximum width of 125 feet. It produced a little over 100,000 tons of high-calcium limestone. The other bodies are smaller, and most of them contain only a few thousand tons or less. The deposit is accessible by 5 miles of paved road connecting with the Arlington-Darrington highway near Trafton and by about 2 miles of gravel-surfaced road. The area is hilly and is covered with dense second-growth trees and brush.

Geology and description.—The deposit consists of a sequence of limestone lenses interbedded with argillite, ribbon chert, graywacke, and volcanic rocks exposed along a northwest-southeast strike for a distance of 3,250 feet. When development of the property began, only a few knobs of limestone were visible projecting through glacial drift and soil. It was thought then that the outcrops might be connected and compose a continuous bed. Subsequent stripping has shown the outcrops to represent mostly separate individual bodies. In some cases they may have been continuous beds when deposited, but they are now separated by faulting.

The most northerly outcrop consists of dark bluish gray limestone exposed about 675 feet northwest of the main quarry, 120 feet west of the quarry road, and about 350 feet east of the Skagit Power Line. The outcrop extends over an area of about



Part of U.S. Geological Survey maps of
Marysville quadrangle and Granite Falls quadrangle

1 ½ 0 1 2 3 4 MILES

CONTOUR INTERVAL 80 FEET
DATUM IS MEAN SEA LEVEL

FIGURE 150. — Index map showing limestone deposits of the Twin Lakes area.

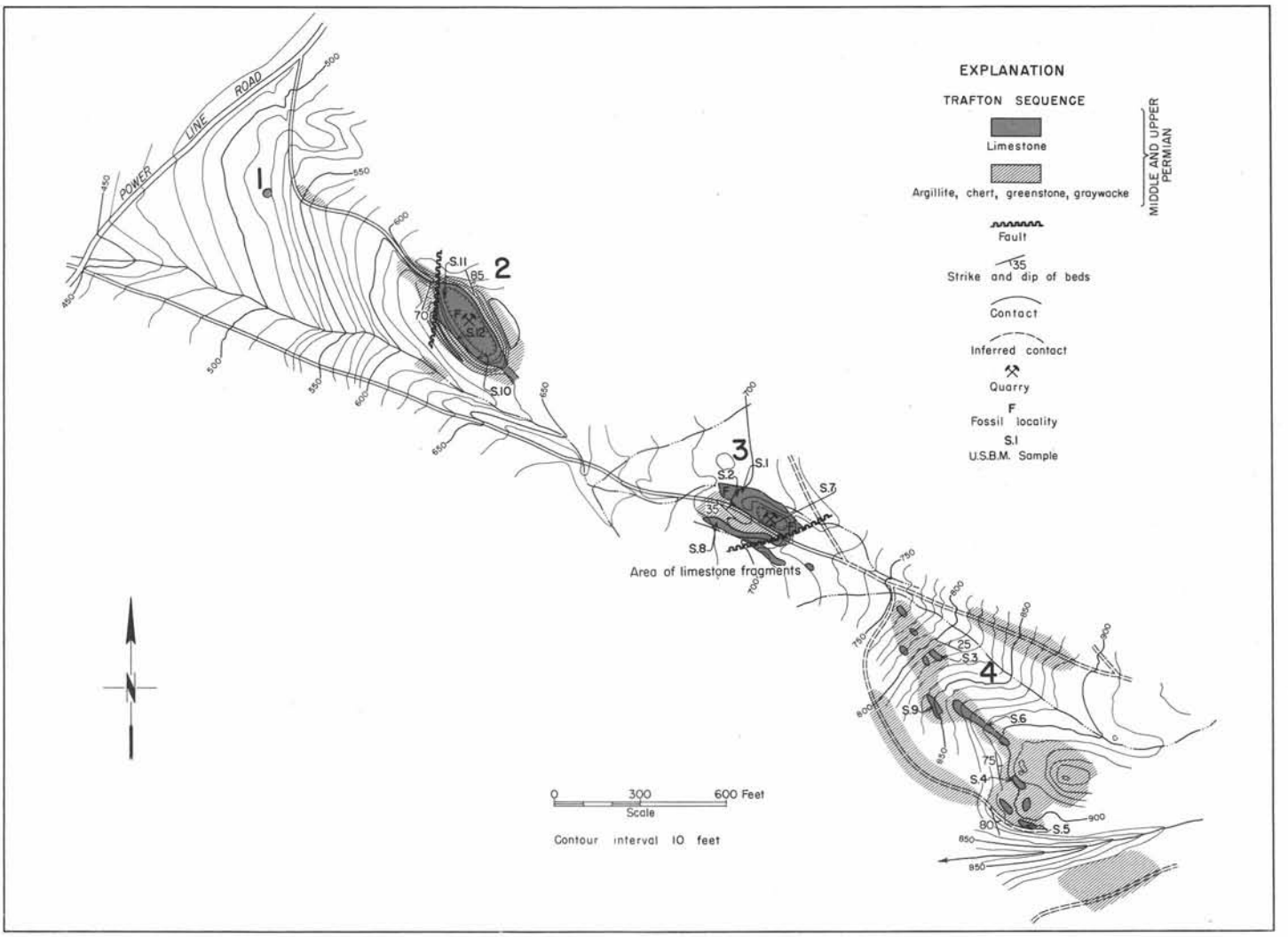


FIGURE 151.—Paddock (Morcrop) deposit. SE$\frac{1}{4}$ sec. 2, T. 31 N., R. 6 E. Geology by W. R. Danner. Base map modified from Figure 2, U.S. Bureau of Mines Report of Investigations No. 4393, by C. C. Popoff, 1949.

60 square feet and is surrounded by soil and glacial drift. It is reported that limestone was encountered in the roadbed of the quarry road 120 feet east of this outcrop when the road was under construction, but the gravel surfacing used on the road covered the outcrop and it is not now visible.

The second outcrop from the north—and also the largest—was quarried for several years, and most of the limestone has now been removed. It was about 375 feet long and had a width of from 20 feet at the south end to a maximum of about 125 feet in the middle. A north-south-trending fault cuts it off at the north end. It appears to pinch out to the south and narrows with depth. Carbonaceous sandstones and conglomerates and altered tuffs underlie the limestone. Ribbon chert, chert breccia, and argillite overlie it.

The limestone strikes northwest-southeast and dips steeply to the northeast. It is mostly dark bluish gray to black in color and is cut by many veinlets of white calcite. Some parts of the limestone are massive and break into large blocks, whereas other parts are fractured and break into small fragments.

The limestone is roughly stratified; a dense limestone forms the lower parts. In the middle of the sequence it grades upward into beds composed in large part of the shells of fusulinids. The upper part of the limestone is formed of light-colored organoclastic and oölitic limestone composed in part of crinoid debris and only a few fusulinids. The fusulinids Neoschwagerina

FIGURE 152.—Northern quarry of the Morcrop Lime Company on the Paddock deposit. View looking southwest, 1955.

brevis, Schwagerina, Pseudodoliolina oliviformis, Neoschwagerina morcropensis, Verbeekina americana, and Dunbarula (Boultonia) cascadensis have been described from this quarry. John W. Skinner (written communication, Sept. 1955) has also found Cancellina. The locality contains in addition other fossils, such as small gastropods, crinoid debris, algal fragments, and the formaninifers Climacammina and Pachyphloia.

The third outcrop is about 800 feet farther south and consists of two limestone beds separated by a body of greenstone and sheared argillite as much as 100 feet in thickness. The limestone-bearing sequence is exposed in a quarry and strikes northwest-southeast and dips about 35°-40° NE. A fault striking about N. 25° E. and dipping 55° NW. cuts the sequence at the south side of the quarry and displaces the limestone a few feet to the south. The fault zone is about 6 feet wide and is filled with gouge and coarsely crystalline milky white calcite. The lower limestone bed is exposed for a width of about 30 feet. Its lower contact is concealed by soil. The upper limestone is about 85 feet thick and about 300 feet long. It pinches out to the north and is faulted out to the south. Its lower part is composed of organoclastic-oölitic limestone containing numerous algal fragments and the worn shells of transported fusulinids. Upward it grades into a dense limestone containing numerous fusulinids. The fusulinids Neoschwagerina, Verbeekina, Cancellina, Yabeina, and Pseudodoliolina have been found in this limestone, along with fragments of calcareous algae.

During quarrying operations on this outcrop in 1954, a small cave big enough for a man to enter was encountered and subsequently destroyed. A small stream disappears under the limestone at the southeast side of the outcrop, and another small stream issues at the north end, indicating the possibility that other small caves may exist at depth.

A flat swampy area lies to the south of the outcrop area. Scattered over its surface are numerous limestone fragments of unknown origin. They may represent remnants of a former extension of the limestone to the west, or they may be limestone float that has been carried out onto the flat in some manner from the slightly higher outcrop area to the northeast.

The fourth area of limestone outcrops lies about 450 feet to the south on a hillside and consists of at least 11 small blocks or lenses of limestone, the largest of which is about 250 feet long and 25 feet wide. Discontinuous blocks of limestone can be traced along strike for about 900 feet. The limestone-bearing sequence of this fourth outcrop area strikes northwest-southeast and dips 25°-80° NE. A considerable amount of faulting is evident, and it is possible that many of the limestone bodies are fault blocks or tectonic lenses. The limestone is bluish gray to light gray and is noticeably lighter in color than that in the other outcrop areas. Crinoid debris and fusulinids similar to those contained in the other outcrops are common. The surrounding bedrock consists of ribbon chert, cherty argillite, and greenstone.

The limestone of the Paddock deposit is of late middle Permian age and contains a fusulinid fauna not found at any other locality in the United States.

Quality.—The limestone is of a high-calcium type averaging about 98 to 99 percent calcium carbonate. This is probably the best quality limestone to be found in western Washington.

Chemical analyses of Paddock limestone[1/]

Sample no.	Sample length (feet)	Loss on ignition	CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3	P	S	Free carbon
S1	Horizontal, 15.5	43.6	55.5	0.5	0.3	0.06	0.0	0.048	0.009	0.02
S2	Horizontal, 18.0	43.2	52.9	0.0	1.2	0.4	0.2	0.091	0.014	0.03
S3	Horizontal, 10.0	43.4	54.7	0.3	0.9	0.4	0.3	0.011	0.015	
S4	Horizontal, 10.5	43.6	54.8	0.7	0.6	0.2	0.2	0.006	0.014	
S5	Vertical, 3.0	43.7	55.5	0.4	0.3	0.1	0.0	0.007	0.014	
S6	Vertical, 5.0	43.5	55.4	0.5	0.6	0.2	0.0	0.003	0.007	
S7	Vertical, 10.0	43.4	54.8	0.6	0.7	0.2	0.1	0.015	0.016	0.04
S8	Vertical, 7.0	43.3	54.9	0.8	0.7	0.1	0.0	0.062	0.012	0.03
S9	Vertical, 6.0	43.4	55.0	0.6	0.5	0.1	0.0	0.007	0.007	
S10	Vertical, 10.0	43.5	55.3	0.5	0.5	0.2	0.0	0.005	0.004	
S11	Horizontal, 13.0	43.5	54.1	1.4	0.6	0.2	0.0	0.065	0.005	
S12	Vertical, 9.0	43.4	54.3	0.6	0.7	0.1	0.1	0.011	0.003	

1/ Popoff (1949a, p. 7).

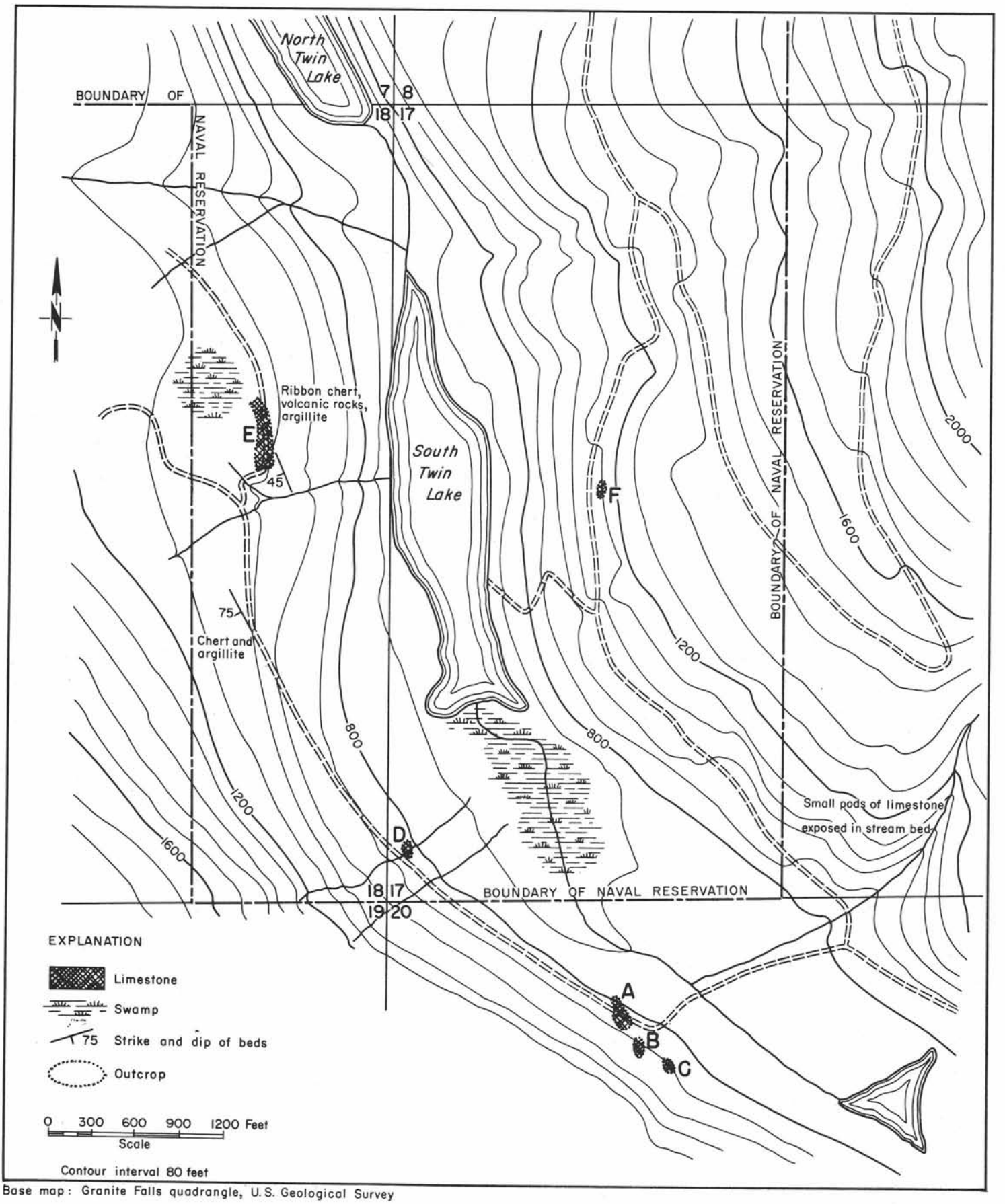
Ownership and development.—The Paddock limestone deposit is on State land controlled by the Washington Department of Natural Resources. The limestone was discovered prior to 1943 by the late William S. Paddock, of Arlington, and leased by him from the State. It was mapped and sampled in 1946 by the U.S. Bureau of Mines and named by them the Twin Lakes deposit, which name has been dropped by the writer to avoid confusion with similar limestone bodies in the vicinity of Twin Lakes, to the south. In 1947 a quarry was opened by the Morcrop Lime Company as a source of agricultural limestone. Pits were opened on the two largest outcrops, and the southern group of outcrops were stripped. Overlying glacial drift and soil were removed from the limestone by hydraulic methods. The largest limestone body was considered to be exhausted in 1956 and was abandoned by the company. In 1960 the property was reopened and was being leased from the State Department of Natural Resources by the Western Lime Company, of 621 West Division Street, Mount Vernon, Wash., John Koetje, owner. At most, only a few thousand tons remain in this deposit.

References.—Guard (1943, unpublished field notes), Green (1948, p. 28), Popoff (1949a, p. 5-6), Thompson and others (1950, p. 48), Banta (1956, p. 28), Danner (1957, p. 211-218), Libbey (1957, p. 211-218).

South Twin Lake Deposits

Location, size, and accessibility.—The South Twin Lake limestone deposits are in the E½ sec. 18, the W½ sec. 17, and the NW¼ sec. 20, T. 31 N., R. 7 E., on the east and west sides of South Twin Lake and on the west side of the valley to the south of the lake. The occurrence consists of six widely scattered lenses of limestone, the largest of which is exposed for a length of about 400 feet north-south and a width of 80 feet, and the smallest of which is 15 feet wide east-west and 20 feet long.

The limestone outcrop on the east side of South Twin Lake is accessible by about 5 miles of graveled road from the headquarters of the Jim Creek Naval Reservation. It was accessible at one time by a logging road from the south, but a bridge has been washed away just south of the section boundary. The limestone outcrops on the west side of the lake and the valley to the south are accessible by 4½ to 6 miles of logging road from the Granite Falls highway. The last 1.3 miles of this road is in poor condition. The area is hilly, logged land covered with dense second-growth trees and brush.



Base map: Granite Falls quadrangle, U.S. Geological Survey

FIGURE 153.—South Twin Lakes deposits. Secs. 17, 18, and 20, T. 31 N., R. 7 E. Geology by W. R. Danner. Base map from U.S. Geological Survey Granite Falls quadrangle.

Geology and description. — The deposits consist of at least six lenticular bodies of limestone interbedded in a sequence of ribbon chert, volcanic rocks, and argillite of Permian age. The Permian sequence is exposed in a north-south, glacier-scoured valley that at one time was temporarily occupied by the North Fork of the Stillaguamish River. Graywacke, slate, phyllite, and chert of Jurassic and Early Cretaceous age are exposed to the east and west on areas of higher ground. The Permian sequence strikes northwest-southeast and dips steeply to the southwest.

Outcrop A is exposed for about 125 feet along and in the roadbed of the logging road on the west side of South Twin Lake and about 60 feet farther northwest below the road. It sticks up through soil and glacial drift as a knob about 30 feet high, and the contacts with bedrock are not exposed. Black slate crops out along the logging road to the north and south. The limestone is light gray to white in color and medium crystalline in texture.

Outcrop B is about 100 feet to the south and west up the hillside from A. Its exposure forms a small cliff, and it appears to strike almost east-west. The outcrop is about 120 feet long and approximately 30 to 40 feet wide. The limestone is light gray to white in color and medium crystalline in texture.

Outcrop C is about 100 feet south and east of outcrop B and forms a small cliff outcrop about 20 to 30 feet high and about 100 feet long north-south. It is similar in color and texture to outcrops A and B.

The hillside above contains outcrops of slate and ribbon chert, and talus of this composition lies on the brush-covered slopes between the outcrops, effectively concealing any possible connections between outcrops A, B, and C. It is thought by the writer that they are separate bodies.

Outcrop D lies about 1,500 feet to the northwest, in a small creekbed on the east side of the logging road. It forms a narrow ridge about 20 feet long north-south, 10 feet high, and 15 feet wide extending across the creek valley. The limestone is similar in color and texture to that at outcrops A, B, and C. A few outcrops of black contorted ribbon chert are present in the vicinity.

Outcrop E is about 4,000 feet north of D and is exposed on both sides of the east fork of the west side-South Twin Lake logging road. Limestone is exposed in low parallel northwest-southeast-striking, glacier-polished ridges. Areas covered with low brush occur between the outcrops. The relief is about 10 feet.

Limestone exposures occur across the strike for a width of at least 80 feet and along the east side of the logging road for about 330 feet and the west side for a distance of 420 feet. The outcrops disappear in a swampy drift-covered area to the west and northwest. The limestone is underlain by ribbon chert and pillow lavas that strike about N. 20° W. and dip from 40° SW. to vertical.

The limestone is gray in color and organoclastic and crystalline in texture. It is less crystalline that that in other outcrops in the vicinity, and on its weathered surfaces are visible outlines of small gastropod fossils and the fusulinids Schwagerina and Pseudodoliolina of late Permian age.

Outcrop F is on the east side of South Twin Lake, above the main logging road leading south. It crops out as a knoll 35 to 40 feet high, 50 feet wide, and about 90 feet long. It is strongly jointed, and where weathered breaks into large slabs. It is light gray in color and medium crystalline in texture. No contacts with bedrock are visible.

In a creekbed east of the Navy reservation border are well-exposed outcrops of volcanic rocks, tuffs, black argillites, and ribbon cherts dipping mostly toward the west and cut by numerous small faults. Limestone lenses 2 and 3 feet in length and up to a foot in thickness are common interbedded in the sequence.

Quality. — No chemical analyses are available for these limestone bodies, as they were not examined during this investigation. They are free of dikes of volcanic rocks and contain very little visible chert. It is thought that they are probably high-calcium limestones.

Ownership and development. — Outcrops D, E, and F, in secs. 17 and 18, are within the boundaries of the Jim Creek Naval Radio Station Reservation. Outcrops A, B, and C, in sec. 20, are on lands of the Scott Paper Company. There has been no development. Outcrops A, B, and C combined contain about 6,500 tons of limestone visible at the surface. Outcrop F might contain over 100,000 tons, but needs to be drilled to determine its depth. It could be quarried easily, starting at its south end.

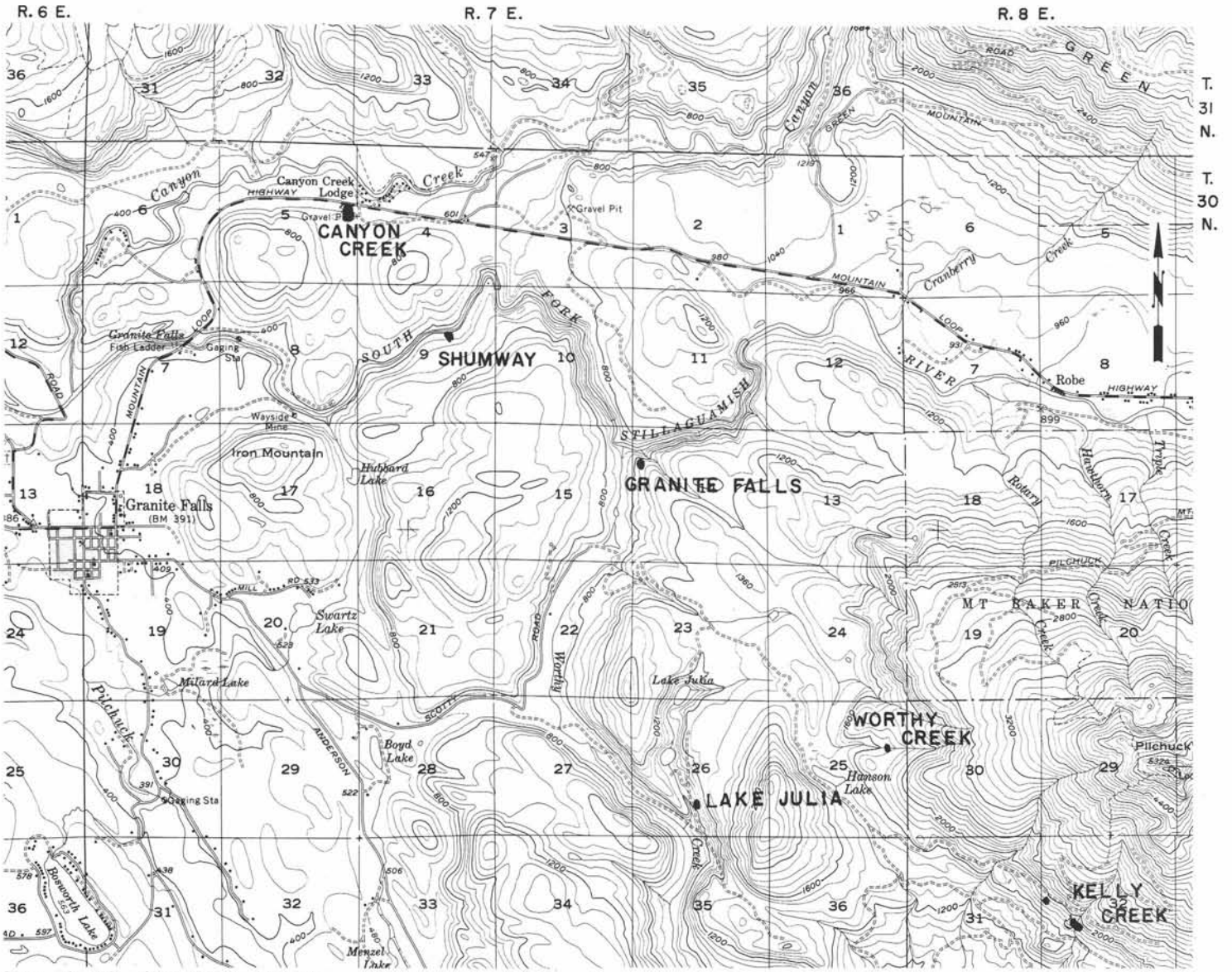
Reference. — Danner (1957, p. 214-222).

Limestone South of South Twin Lake

Just north of Mud Lake, on an old logging road going up the hillside to the west and where the first switchback turns north, a block of limestone is interbedded in glacial drift in a roadcut. About 40 feet to the west on a hillside covered with dense brush is a limestone outcrop 10 feet long north-south, 5 feet wide, and about 1½ feet high. West of this, on the next switchback of the logging road higher up on the hillside, is a boulder(?) of limestone embedded in the side of the road. It may actually be part of a small limestone body sticking up through the glacial drift.

Canyon Creek Lodge Quarry

Location, size, and accessibility. — About 3 miles northeast of the town of Granite Falls, on the south side of the highway in the central eastern part of the E½ sec. 5, T. 30 N., R. 7 E., is a deposit of limestone of late Permian age. The



Part of U.S. Geological Survey map of Granite Falls quadrangle

1 ½ 0 1 2 3 4 MILES

CONTOUR INTERVAL 80 FEET
DATUM IS MEAN SEA LEVEL

FIGURE 154. — Index map showing deposits of the Granite Falls-Mount Pilchuck area.

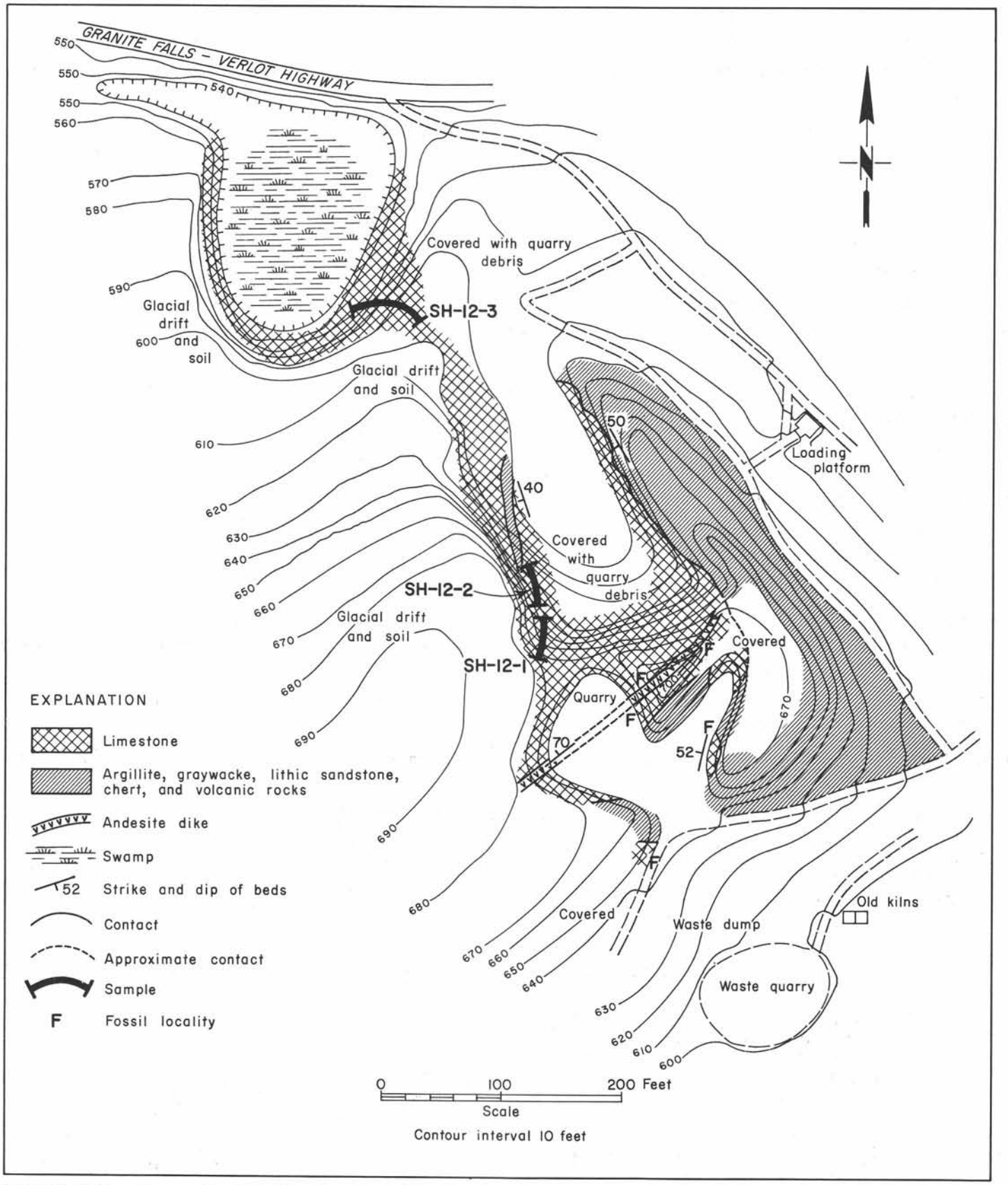


FIGURE 155.—Canyon Creek Lodge deposit. E½ sec. 5, T. 30 N., R. 7 E. Geology by W. R. Danner, C. L. Smith, E. A. Adams, and C. F. Royse, Jr. Compass and tape survey.

deposit lies just southwest of the Canyon Creek Lodge and is shown on the Granite Falls quadrangle of the U.S. Geological Survey as a gravel pit. The occurrence consists of a lenticular body of limestone about 700 feet long and as much as 200 feet wide that has been quarried extensively. The quantity of limestone remaining is unknown but is estimated to be as much as 100,000 tons.

The deposit is adjacent to the paved Granite Falls-Verlot highway and is about 4 miles from the town of Granite Falls by road. It is at an altitude of about 600 feet on a relatively flat terrace between the South Fork of the Stillaguamish River on the south and Canyon Creek on the north. The terrain is logged-off land covered with a dense second growth of trees and brush.

Geology and description.—The deposit consists of a poorly exposed lenticular body of limestone striking northwest and dipping 40°-65° SW. Its outcrop forms a topographically higher area projecting through surrounding terrace gravels. Bedrock composed of lithic siltstone, tuff, and cherty argillite crops out on the east side of the deposit in the quarry faces and roadcuts and underlies the limestone. To the west the limestone is overlain by as much as 20 feet or more of fluvial glacial gravels.

The limestone at the south end of the occurrence appears to be folded into a small anticline cut by a fault on its east limb. Structure in the remainder of the deposit appears to be homoclinal.

The north end of the outcrop disappears beneath alluvium and glacial drift as it becomes lower in altitude. Guard (1943) reported that geophysical studies indicated that limestone covered by 2 to 9 feet of overburden extended to the north about 300 feet beyond the highway.

The limestone outcrop disappears under overburden to the south also, but indications are that it pinches out or plunges beneath bedrock in this direction.

A dike of green porphyritic basalt 2 to 4 feet thick cuts the limestone. It strikes N. 40°-50°E. and dips 70° NW., and has recrystallized the limestone within an inch or two of its contact.

The limestone is gray to dark gray in color and is cut by numerous calcite veinlets. The texture appears to be dense in hand specimen, but in thin section it is seen to be made up largely of limestone fragments, oölites, pellets, and fossil debris. In the vicinity of the basalt dike the limestone is a coquina of large fusulinid tests composed mostly of the genus Yabeina but containing also Schwagerina and Codonofusiella. Fragments of calcareous algae are also common. This quarry is the site of the first Permian fossil locality discovered in western Washington and contains the youngest marine Permian fauna known in the United States.

The limestone body appears to reach a maximum thickness of approximately 50 feet. Some faulting may have occurred along its undulating eastern contact with the underlying tuffaceous sedimentary rocks. Stringers of coal are present both in the underlying sedimentary rocks and in the limestone. A spring of water heavily impregnated with iron oxide issues from the southeast wall of the quarry and flows across its floor.

Chemical analysis of Canyon Creek Lodge limestone[1/]

Calcium carbonate	97.06	Manganese	0.025
Magnesium carbonate	0.66	Fluorine	0.002
Calcium carbonate equiv.	97.84	Phosphorus	0.008
Aluminum	0.04	Zinc	0.0010
Iron	0.08	Vanadium	0.0008
Potassium	0.002	Boron	0.0003
Sulfur	0.03	Copper	0.00005
Sodium	<0.001	Molybdenum	0.00028
Silicon	0.20	Cobalt	<0.0001

1/ Chichilo and Whittaker (1961, p. 141).

Chemical analyses of Canyon Creek Lodge limestone

Sample	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
1/		98.43		43.86	55.12	Trace	0.22	Trace	
1/		97.22		44.00	55.44	0.42	0.61	0.13	
2/		98.1					0.2	1.4	
3/ Sh 12-1	40	96.52	0.919	43.19	54.23	0.44	1.11	0.29	0.017
3/ Sh 12-2	40	94.96	2.069	42.88	53.35	0.99	1.51	0.68	0.006
3/ Sh 12-3	60	92.79	4.78	43.13	52.13	2.29	1.21	0.27	0.022
3/ Sh 12-4	Single hand specimen	97.45	1.02	43.41	54.75	0.49	0.67	0.27	0.005
3/ Sh 12-5	Single hand specimen	77.32	20.27	44.82	43.44	9.70	0.78	0.97	0.009

1/ Shedd (1913, p. 232).
2/ Hodge (1944, p. 57).
3/ Samples collected for this report, Mark Adams, analyst.

Quality.—The quality of the Canyon Creek limestone is variable; there are relatively high areas of magnesium oxide and some siliceous impurities. Hodge (1938, p. 61) states:

> The quality of the rock at the surface is much better than below. There seems to be a gradual blending into the country rock which makes it difficult to sort in the quarry. Only the material from above the upper third is being quarried, as the remainder is too impure for paper mill consumption.

Ownership and development.—Parts of the deposit are owned by several individuals, but the largest part is owned by Mrs. Joe Moeller, who lives north of the highway east of the quarry. The history of early operations is unknown. Norum (1910) reports three old limekilns on the property in 1910, and that the quarry was shut down. The quarry was leased to the Everett Lime Company prior to 1936 and was operated by that company until sometime after 1943. In 1952 it was operated intermittently by Mineral Processors, Inc., of Granite Falls. Recently it has been leased by Leslie Miller, of Gold Bar, Wash. Three main pits have been established. Hodge (1938) states:

> The area around the quarries has been thoroughly prospected without success. This deposit is a small lens of rather indifferent quality and short life. Mr. Johnson, the quarry foreman, figured that about 200,000 tons have been removed, and his estimate, as well as that of the U.S. Engineers, indicates a maximum of 200,000 tons remaining, of which only a portion is suitable for paper mill use.
>
> Attempts have been made to burn this limestone for lime without any particular success, according to Mr. Johnson. His explanation is that the rock is too dense. When crushed to the proper size for burning, the limestone is altered to CaO only on the outside and the inside remains $CaCO_3$.

The annual production of limestone is stated (Hodge, 1944, p. 58) to have been about 75,000 tons, most of which went to paper mills in Everett. Much waste rock has been used for surfacing local logging roads. Guard (1943) reports that some limestone was shipped to a pulp mill at Bellingham. He gives the March 1943 production as 3,500 tons and the average production as 2,750 tons per month. In 1943, Guard estimated the deposit to contain 415,500 tons of limestone. The limestone is used now for agricultural stone, fluxstone, iron stone, building stone, calcium carbide, sugar refining, rock wool,

and golf course rocks. The lower quarry, adjacent to the highway and below its level, is flooded. To the southeast of the quarry area are the ruins of at least two old limekilns.

References.—Norum (1910, p. 19), Shedd (1913, p. 230-232), Glover (1936, p. 58), Hodge (1938, p. 59-63; 1944, p. 57-58), Anderson (1941, p. 189-202), Northern Pacific Railway Co. (1941, unpublished notes), Broughton (1942, p. 55), Thompson and Wheeler (1942, p. 700-711), Guard (1943, unpublished field notes), Mathews (1947, p. 44), Thompson and others (1950, p. 48), Danner (1957, p. 223, 273), Valentine (1960, p. 55).

Shumway Quarry

Location, size, and accessibility.—The Shumway limestone deposit is on the south side of the old railroad grade of the Monte Cristo Branch of the Northern Pacific Railway, about 3 miles northeast of the town of Granite Falls. It is in the SW¼NE¼ sec. 9, T. 30 N., R. 7 E., on a gently sloping area near the top of the hill on the south side above the cliffs of the gorge of the South Fork Stillaguamish River.

A quarry, now abandoned, about 170 feet long, 40 to 50 feet wide, and 60 to 80 feet deep was developed on the limestone, and, except for a few hundred tons remaining on the quarry walls and at the south end, the deposit appears to be mostly exhausted. It can be reached by driving about ¼ mile north of Granite Falls, then east about 1½ miles on the road to the Wayside mine, and by hiking from there on the railroad grade about 1¼ miles east and northeast to the quarry. The area is covered with second-growth trees and dense brush.

Geology and description.—The limestone forms a lenticular body interbedded with ribbon chert and cherty argillite of Permian age. Outcrops extend 30 to 40 feet south of the quarry rim. The limestone is gray in color and contains stringers of brown argillaceous material, crystalline to organoclastic in texture, and in places contains fusulinids of the genera *Yabeina* and *Schwagerina*, indicating a late Permian age.

A vertical basalt dike 6 to 8 feet thick and striking N. 50° W. divides the limestone into two parts 60 feet from the northeast end of the quarry, and the dike is pierced by a tunnel that gives access to the north and south parts of the quarry. Small solution cavities are found in the quarry walls.

Quality.—Most of the limestone quarried was high in calcium.

Chemical analyses of Shumway limestone

Sample	Location	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3
1/	Unknown --------	98.43				0.80	0.60	1.15	
								R_2O_3	
2/	Unknown --------	98.1	Trace				0.2	1.4	

1/ Landes (1902, p. 187).
2/ Eckel (1913, p. 362).

Ownership and development.—The deposit is on a 15-acre tract owned by J. L. Shumway. A quarry was started there about 1899 by the Canyon Lime and Cement Company, and production was about 60 tons of limestone per day. Limestone was shipped to Seattle and to Everett for use as flux in a smelter. A kiln of 100 tons capacity was constructed adjacent to the Everett-Monte Cristo railroad tracks, and limestone was transported to the top of the kiln by small cable cars. It is reported that approximately 30,000 tons of limestone was burned in this kiln. Production ceased some time prior to 1936, and

now (1963) the floor of the quarry is filled with water and the area of the deposit is covered with a dense growth of trees and brush. A few thousand tons of limestone appears to remain at the south end of the quarry.

References.—Landes (1902, p. 187; 1906, p. 380), Norum (1910, p. 19), Shedd (1913, p. 232), Glover (1936, p. 58), Hodge (1938, p. 64), Northern Pacific Railway Co. (1941, unpublished notes, p. 14), Broughton (1942, p. 54), Guard (1943, unpublished field notes), Thompson and others (1950, p. 48), Danner (1957, p. 224).

Granite Falls Quarry

Location, size, and accessibility.—The Granite Falls limestone deposit is in the NW¼ sec. 14, T. 30 N., R. 7 E., at an altitude of about 800 feet on a hillside above the South Fork of the Stillaguamish River. It is on a ridge between two small streams and is about 4 miles directly east of the town of Granite Falls. The deposit was quarried many years ago and is now (1963) considered to be exhausted. The old quarry can be reached by following the black-topped Anderson Road southeast from the town of Granite Falls about 2 miles to the intersection with the gravel-surfaced Scotty Road, then by continuing on Scotty Road about 3 miles to the SW. cor. sec. 15 and a large pond. By going north about 1 mile from Scotty Road on the east side of this pond and following an old logging road to the gorge of the Stillaguamish River, one can reach the limestone by climbing eastward up the heavily brush-covered hillside to the quarry. Thick second-growth trees and brush cover the area, and the limestone deposit is so small that it can be found only with great difficulty.

Geology and description.—The deposit consists of a small pod of limestone on which a quarry about 100 feet long and 70 feet wide was developed. Most of the limestone has been removed. The limestone appears to dip under argillite eastward into the hillside, and its extension to the south is cut off by a fault. The limestone is gray in color and partly crystalline in texture. No fossils were found, but the limestone is very similar in appearance to Permian limestones found to the north and south along strike. The deposit contains a few small solution cavities.

Quality.—Unknown.

Ownership and development.—The owner of this deposit is unknown. The limestone was quarried some time prior to 1910, and was transported by a cable tram across the Stillaguamish River to a shipping bin on the north bank of the river, where it was loaded onto cars of the Everett and Monte Cristo Railroad. It is not known whether any quarrying was done after that time, but the quarry has been abandoned for many years and is considered to be exhausted.

References.—Norum (1910, p. 19), Glover (1936, p. 58), Northern Pacific Railway Co. (1941, unpublished notes, p. 14), Broughton (1942, p. 55), Danner (1957, p. 225), Halliday (1963, p. 111).

Stillaguamish Canyon Deposit

Small lenses of limestone crop out in a sequence of argillite, volcanic rocks, and chert exposed at the east end of the canyon of the South Fork Stillaguamish River in secs. 11 and 14, T. 30 N., R. 7 E. The largest outcrop found was only about 2 feet thick.

Lake Julia Deposit

Location, size, and accessibility.—The Lake Julia limestone deposit is in the SE¼SW¼ sec. 26, T. 30 N., R. 7 E., in a roadcut on the east side of an old logging road leading from Lost Valley to the small lake south of Lake Julia.

The deposit is very small, being only about 15 feet long, 5 feet wide, and exposed vertically for not quite 25 feet. It is accessible by about 5½ miles of road from the town of Granite Falls, the last 3/4 mile of this being abandoned logging road.

Geology and description.—The deposit is a small lenticular body of crystalline limestone interbedded with argillite and volcanic rocks. It strikes northwest-southeast and dips steeply to the east. Contacts with the enclosing rock indicate

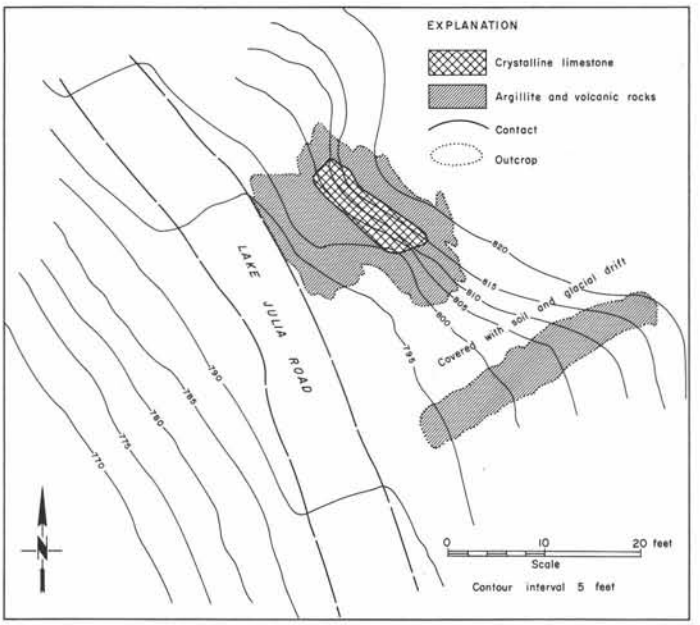


FIGURE 156.—Lake Julia deposit. SE¼SW¼ sec. 26, T. 30 N., R. 7 E. Geology by W. R. Danner. Compass and tape survey.

that the limestone may widen at depth. No fossils were found, but the deposit is thought to be of Permian age and is enclosed in rocks believed to be part of the Permian Trafton sequence.

Quality.—The quality of the limestone is unknown. There are no visible impurities on weathered surfaces.

Ownership and development.—The owner is unknown, and there has been no development. The deposit is too small to be of economic value. If it increases in size at depth, its location on a steep bedrock hillside would require underground mining.

Menzel Lake Deposit

An outcrop reported by Newcomb (1952, p. 37) as a "vuggy limestone" is northeast of Menzel Lake in the central part of sec. 33, T. 30 N., R. 7 E. The rock outcrop mentioned is not a true limestone exposure but rather a jagged, vertical-walled ridge composed of chalcedonic quartz, magnesium carbonate, serpentine, fault gouge, iron oxide, and chlorite. Similar silica-carbonate rocks occur at other places in western Washington.

References.—Newcomb (1952, p. 37), Danner (1957, p. 381).

Mount Pilchuck Area

Rocks of the Permian Trafton sequence crop out over a large area west, south, and possibly on the north side of Mount Pilchuck and contain several small lenses of limestone.

WORTHY CREEK DEPOSIT

About ½ mile northeast of Hansen Lake on the west side of Mount Pilchuck, in sec. 25, T. 30 N., R. 7 E., limestone float occurs in the bed of the headwaters of the south fork of Worthy Creek. Only one limestone outcrop was found exposed in the creekbed. It consists of a limestone lens 6 feet by 4 feet in area interbedded in argillite. The limestone is dark bluish gray to gray in color and finely crystalline in texture. Boulders of limestone float occur higher up in the streambed and indicate that other limestone bodies are to be found in the vicinity. It is likely that there are several small limestone bodies at present undiscovered in this densely forested area.

HEATHER LAKE OCCURRENCE

Small boulders and fragments of coarsely crystalline white limestone occur on a talus slope at the southwest side of Heather Lake on the cliffs composing the north side of Mount Pilchuck, in secs. 21 and 28, T. 30 N., R. 8 E., on lands of the Mount Baker National Forest. The source of the limestone is apparently high up on the cliffs, but no limestone outcrops could be seen. Several of the specimens contained interbedded argillaceous and siliceous material, indicating a rock of poor quality.

KELLY CREEK DEPOSIT

Finely crystalline limestone with interbedded chert crops out in the bed and banks of a small canyon through which Kelly Creek flows in the SW¼ sec. 32, T. 30 N., R. 8 E., at an altitude of about 1,700 feet. The outcrop is on a steep slope

over which Kelly Creek pours in a waterfall. The size of the deposit is not known, but the limestone bed is at least 50 feet long, 5 to 10 feet thick, and thins to the southeast. It strikes northwest-southeast and appears to dip northeastward. An abandoned logging road is about 150 feet below and 400 feet south of the limestone outcrop.

About 1,500 feet to the northwest of this limestone bed another limestone body crops out at an altitude of about 1,900 feet (Robert Wiebe, oral communication, Dec. 1962). It is about 10 feet wide, but its length is unknown. It is exposed at the top of a cliff. Thin sections of this limestone were seen to contain abundant specimens of calcareous algae and minute fusulinids. The large fusulinid Misellina is abundant and indicates a Leonardian (middle Permian) age for the deposit.

Limestone float occurs along logging roads and in streambeds in secs. 31 and 32, on the south side of Mount Pilchuck.

Liberty Mountain Deposit

Shedd (1913) reported limestone about 25 miles east and north of Granite Falls at the western base of Liberty Peak on Bopeep Creek, which is a stream flowing into Canyon Creek. The limestone occurs closely associated with igneous rock and, as far as could be determined, is very limited in extent. The deposit shows well-marked stratification, individual layers having a thickness in some cases of several feet. It is finely crystalline and dissolves in hydrochloric acid with the exception of a very small amount of an almost black substance.

The occurrence was not visited during the present investigation. It is in relatively inaccessible mountainous terrain on lands of the Mount Baker National Forest.

Reference.—Shedd (1913, p. 231, 233).

Green Mountain Occurrence

Thin limestone beds interbedded with ribbon chert, phyllites, and arkose are reported to crop out on the eastern end of Green Mountain and the ridge to the east. (Joseph Vance, oral communication, 1956).

Marble Peak Deposit

Location, size, and accessibility.—The Marble Peak limestone deposit is in the E½ sec. 30, T. 30 N., R. 10 E., in Marble Gulch and on the north side of Marble Peak, between altitudes of 3,200 and 5,000 feet. The deposit consists of small lenses of limestone, generally not much more than 50 feet long and 10 feet thick. The area can be reached by about 22 miles of black-topped road east of the town of Granite Falls and then by about 3 miles of trail climbing up the steep mountainside to the outcrop area. The deposits are in steep mountainous country that has subalpine vegetation.

Geology and description.—Valentine (1949) describes limestone in sec. 31 as two 20-foot beds separated by 6 feet of sandstone. In sec. 30, just above the 3-mile trail marker on the east side of Marble Gulch, numerous boulders of light-gray crystalline limestone occur in a creekbed. Their outcrop source is unknown. To the south, on the steep face of Marble Peak, are several small lenses of crystalline limestone. The largest seen by the writer was estimated to be about 10 feet thick and a little more than 50 feet long.

Quality.—Unknown.

Ownership and development.—The ownership of the limestone is unknown. The deposit is on lands of the Mount Baker National Forest and is probably too small and remote to be of economic value.

References.—Valentine (1949, p. 50), Danner (1957, p. 455-456).

King Lake Occurrence

A few fragments of gray, finely crystalline limestone are in talus material below steep cliffs on the west side of King Lake, in the NE¼ sec. 27, T. 31 N., R. 6 E. Argillite boulders in the talus contain small masses of limestone only a few cubic inches in volume.

Lost Lake Deposit

One small lens of argillaceous limestone less than 1 ton in size is exposed in an abandoned road-metal quarry in the SE$\frac{1}{4}$ sec. 25, T. 31 N., R. 6 E. Fossils of the pelecypod genus Buchia in similar-appearing rock nearby indicate a Late Jurassic age.

Whitehorse Ridge Area

CLIMAX AND HI HI CLAIMS

Location, size, and accessibility.—The Climax and Hi Hi limestone claims are in the NE$\frac{1}{4}$ sec. 25, T. 32 N., R. 8 E., at altitudes of between 2,970 and 3,420 feet on the steep northeast face of Whitehorse Ridge. The deposits are about 23 miles east of Arlington and 5 miles west of Darrington; they can be reached by going south on a gravel-surfaced road about 1$\frac{1}{4}$ miles from the Arlington-Darrington highway to the start of a trail. The last $\frac{1}{4}$ mile of the road is steep and rough and in many places impassable to ordinary cars. The trail, overgrown in places, is about 2$\frac{1}{2}$ miles in length to where a branch trail leads to the Climax claim. The branch trail is almost obliterated by vegetation, and the main trail disappears in an area of devils club, alder, and salmonberry a short distance above. A cabin on the claim is now in ruins. Both claim areas are covered with a dense growth of brush and are exceedingly difficult of access. The area contains rock slides and a few patches of virgin timber.

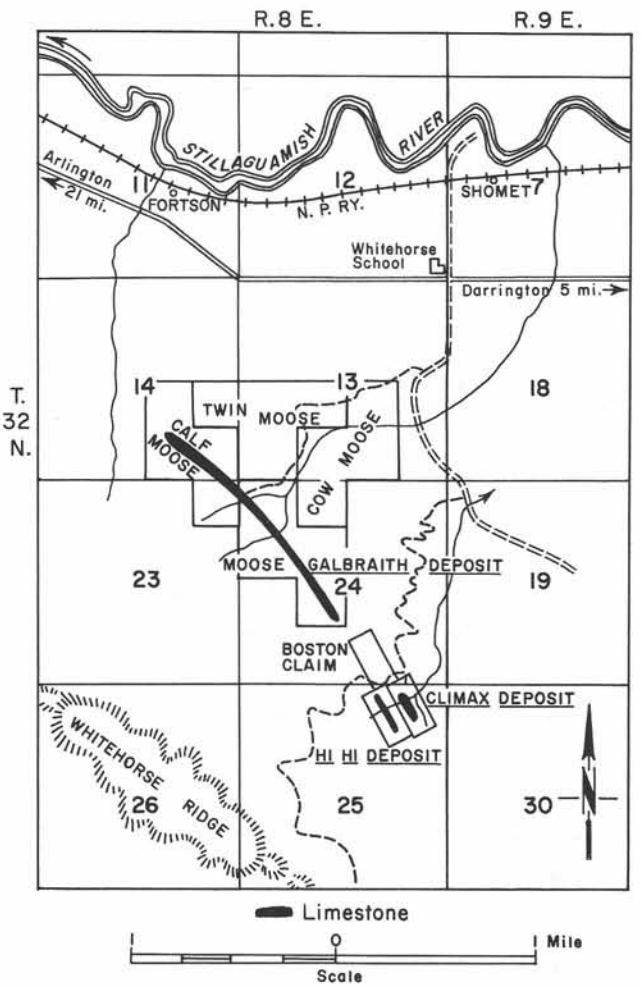


FIGURE 157.—Index map showing limestone deposits of the Whitehorse Ridge area. Modified from Figure 1, U.S. Bureau of Mines Report of Investigations No. 4510.

The Climax deposit is at least 600 feet in length and 100 feet in thickness. The Hi Hi deposit is parallel and 600 feet to the west and 350 feet above the Climax. According to Popoff (1949b), the Hi Hi is about 1,100 feet long and as much as 30 feet wide.

Geology and description.—The Climax claim contains a lenticular limestone body striking about N. 25° W. and appearing to dip steeply to the northeast. Its western contact dips southwest into the steep hillside and was described as a fault by Popoff (1949b, p. 5). A band of orange-stained sheared rock about 1 foot thick marks the trace of this fault. Thin sheets of andesite have been intruded along the bedding planes, and near the east contact of the deposit one of these is about 20 feet thick. Andesite underlies and overlies the limestone, and some of it shows poorly developed pillow structure. The best exposures of the limestone are in small creekbeds. The limestone is bluish gray in color, is cut by numerous white calcite veinlets, and has a finely crystalline texture. Parts of the limestone that have a sugary-appearing texture are usually high in magnesium. Secondary silica in the form of jasperoid is present in many exposures. The limestone bed is reported to persist for more than $\frac{1}{2}$ mile, but no outcrops were found to the north, and the buff-colored cliffs to the south were not examined by the writer.

According to Popoff (1949b), the Hi Hi deposit lies about 500 feet above and 600 feet west of the Climax. The Hi Hi

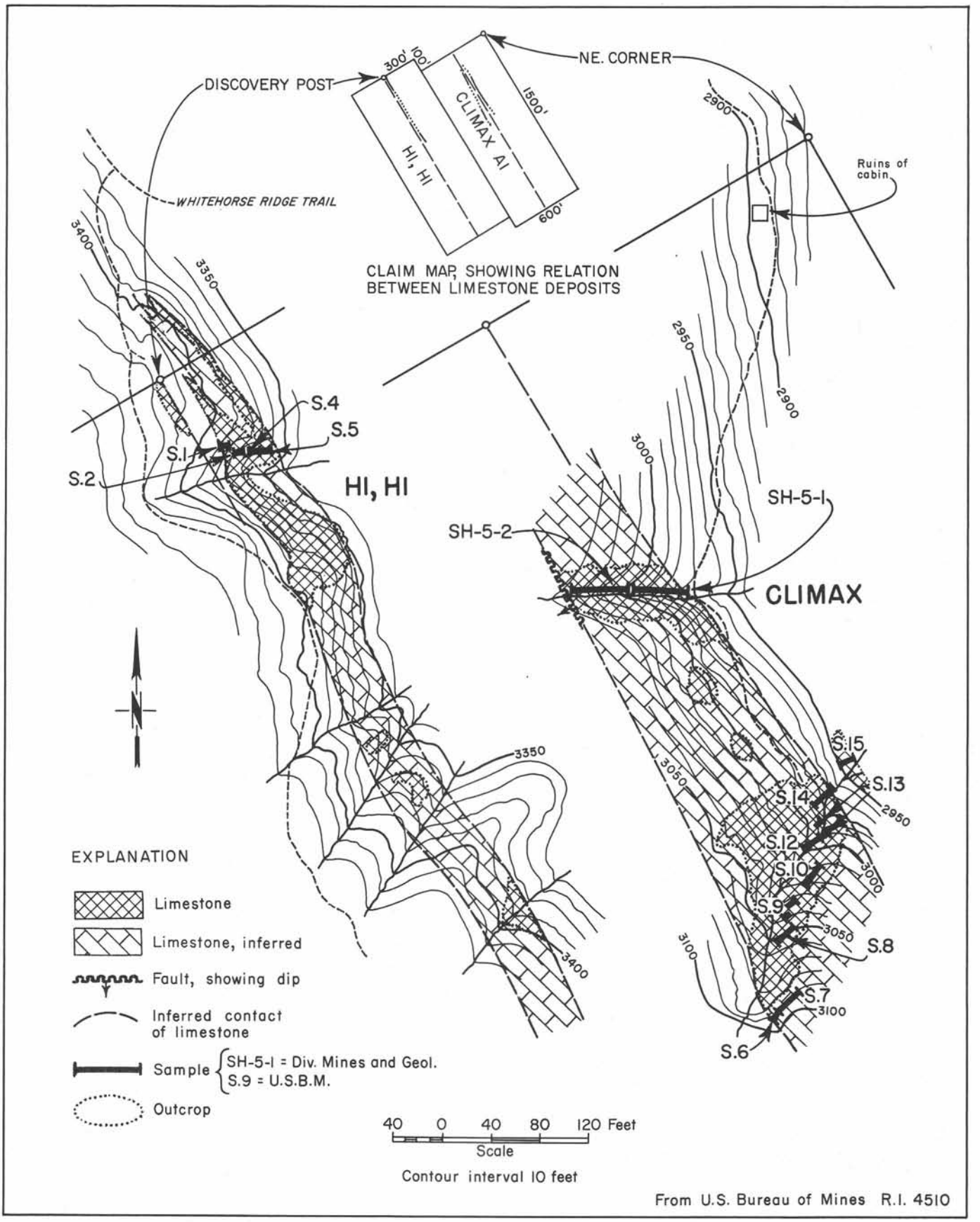


FIGURE 158.—Climax and Hi Hi deposit. NE¼ sec. 25, T. 32 N., R. 8 E. Reprinted from U.S. Bureau of Mines Report of Investigations No. 4510. Geology by C. C. Popoff, slightly modified by W. R. Danner.

Chemical analyses of Climax limestone

(Mark Adams, analyst)

Sample no.	Location	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
Sh 5-1	Streambed, east	35	87.95	11.95	43.29	48.85	5.72	1.75	0.50	0.004
Sh 5-2	Streambed, west	35	88.94	10.74	43.17	49.97	5.14	1.11	0.49	0.006

Chemical analyses of Climax limestone[1/]

Sample no.	Horizontal footage		Percent							
	Limestone	Rock	Loss on ignition 950° C.	CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3	P	S
Main body:										
S 6 ----------	7.0		43.6	55.0	0.6	0.5	0.1	0.0	0.005	0.031
S 7 ----------	24.0		41.5	46.0	5.3	4.9	0.7	1.1	0.007	0.048
S 8 ----------	12.2		44.1	50.4	4.4	0.6	0.1	0.0	0.003	0.008
S 9 ----------	13.0		43.8	53.6	1.8	0.6	0.1	0.0	0.003	0.009
S 10 ----------	23.0		44.0	51.9	3.0	0.7	0.1	0.0	0.003	0.005
S 11 ----------		2.0	12.0	Not determined		42.5	0.1	16.3	0.077	
S 12 ----------	19.8		43.4	55.3	1.4	1.2	0.2	0.2	0.004	0.030
S 13 ----------	9.0		44.4	49.5	5.0	0.6	0.2	0.0	0.004	0.043
S 14 ----------	20.0		42.8	49.1	4.3	2.3	0.4	0.7	0.005	0.039
Average of samples nos. 6-10 and 12-14	128.0		43.2	50.6	3.4	1.8	0.28	0.35	0.004	0.027
East of main body:										
15	14.0		43.1	54.9	0.5	1.1	0.2	0.0	0.003	0.012

1/ Popoff (1949b, p. 7).

Chemical analyses of Hi, Hi limestone[1/]

Sample no.	Horizontal footage		Percent						
	Limestone	Rock	Loss on ignition 950° C.	CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3	P
S 1	13.0		32.2	2/ 41.0		24.3	0.6	1.1	
S 2	6.4		34.5	2/ 43.9		18.9	0.6	1.1	
S 3		2.0	6.3	Not determined		45.4	8.6	16.1	
S 4	9.5		33.3	2/ 42.4		22.3	0.4	0.5	
S 5	6.8		35.0	46.8	0.8	13.0	1.7	2.6	0.014
Average of samples nos. 1, 2, 4, & 5			33.44	2/ 43.15		20.65	0.76	1.22	

1/ Popoff (1949b, p. 8).

2/ Estimated combined CaO - MgO.

deposit could not be reached during the present investigation. Popoff (1949b) describes it as:

> . . . a lenticular body about 30 feet thick striking S. 25° E. and dipping about 65° NE. It may be traced throughout a strike length of 1,100 feet. A persistent andesite sheet several feet thick has been intruded along the bedding, thereby separating the body into two members. The beds are siliceous limestone of uniform appearance; they contain about 20 percent SiO_2.

Specimens of limestone float from a creekbed below the Hi Hi claim are composed of banded and partly silicified limestone. Poorly preserved crinoid and coral remains are visible in some specimens. The limestone is light gray to buff where silicified and is crystalline in texture. Volcanic rocks form high cliffs above the limestone. A few overgrown and partly filled depressions west of the Climax claim along the main Whitehorse Ridge trail resemble sinkholes.

Quality.—The limestone of this deposit has a relatively high magnesium content, which would be detrimental for its use as cement rock or for most chemical uses.

Ownership and development.—The property consists of at least two unpatented claims formerly owned by the late Sam Grabe and R. E. and B. B. Kragnes, of Edmonds, Wash. There has been no development. The high altitude, relatively small size, and high magnesium and silica contents make this deposit uneconomic under present conditions.

Reference.—Popoff (1949b, p. 1-8).

GALBRAITH DEPOSIT

Location, size, and accessibility.—The Galbraith limestone deposit, consisting of the Calf Moose and Moose claims, is in the SE¼ sec. 14, NE¼ sec. 23, and W½ sec. 24, T. 32 N., R. 8 E., on the steep northeast-facing slopes of Whitehorse Ridge at an altitude of between 2,000 and 2,600 feet. The deposit is exposed in scattered outcrops along a strike length of at least 2,000 feet through a vertical range of 250 feet. Its width appears to range from 150 to 450 feet, though outcrop is not continuous across the width.

Access to the area is difficult because of the overgrowing of the old trails. The claims are about 23 miles east of Arlington and about 5 miles west of Darrington. The claims can be reached by following a graveled road about ½ mile south from the Arlington-Darrington highway along the boundary between sec. 13, T. 32 N., R. 8E. and sec. 18, T. 32 N., R. 9 E. This road bends to the southwest, and a short distance beyond this bend is a driveway into a farmyard. A trail starts from the southwest corner of the farmyard and follows up a low ridge for about ½ mile to an old railroad grade, which is followed about ½ mile almost to its end near the base of Whitehorse Ridge. About 150 to 200 feet short of the end of the grade, a faint trail leads off to the left and switchbacks steeply up the mountainside for at least 1½ miles. If the trail is not found, one can climb directly up the steep mountainside, going to the right or left of about five cliffs at different altitudes up the slope.

The upper area of the deposit is covered with virgin timber, whereas the lower parts are covered with dense second-growth trees and brush. It is rumored that this area will be logged within a few years; if that is done, the logging roads will make the limestone more accessible.

Geology and description.—The deposit consists of what is believed to be a long lenticular body of limestone striking about N. 35° W. and dipping down the steep slope 80° NE. It has been traced at least 2,000 feet along the strike. A map by J. L. McPherson published by Popoff (1949b, p. 4) shows the deposit extending almost 7,000 feet, but Joseph Vance (oral communication, Dec. 1962) reported that he did not find a continuation of the outcrop in the southern fork of Moose Creek. Exposures are so poor on the surface that it cannot be proven that the limestone is continuous along either strike or width. However, an adit 400 feet long driven across the width of the limestone in the Calf Moose claim shows continuous limestone except for six "impure beds, dikes, or sills." Popoff (1949b, p. 5), describes intrusive andesite sills ranging in width from 1 inch to 16 feet, together with bands of siliceous material comprising about 10 percent of the rock exposed by the Moose adit.

Guard (1943) describes the adit as being 373 feet long and trending S. 45° W., and states that it cuts a calculated true width of 76 feet of limestone. The adit is 1,200 feet west and 300 feet above an old cabin, now in ruins. Twenty feet of greenish graywacke was intersected 40 feet from the face. Guard noted attitudes of N. 61°-75° E. on limestone in the

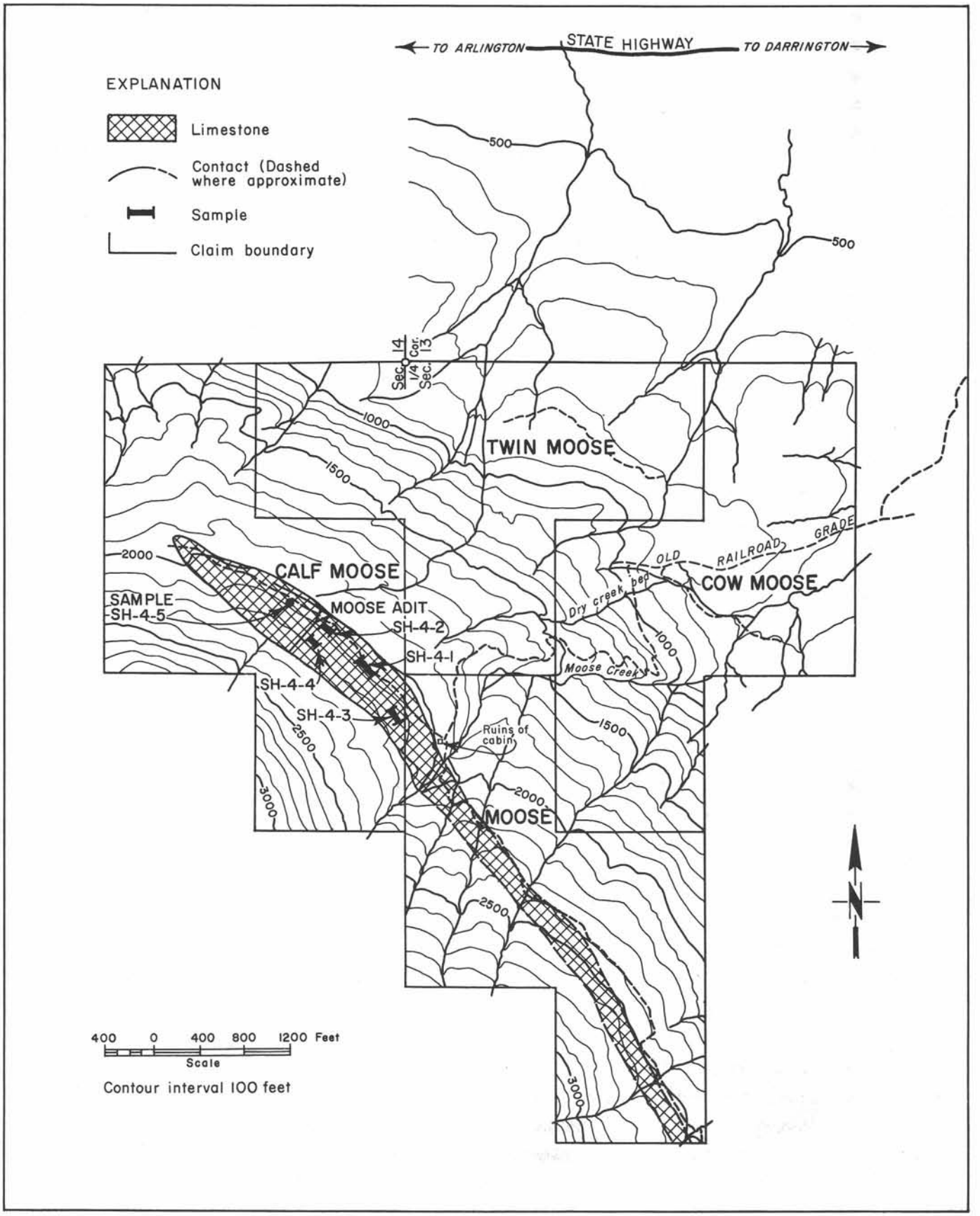


FIGURE 159.—Galbraith deposit. SE¼ sec. 14, NE¼ sec. 23, and W½ sec. 24, T. 32 N., R. 8 E. Reprinted from Figure 2, U.S. Bureau of Mines Report of Investigations No. 4510, by C. C. Popoff. Modified slightly by W. R. Danner.

adit and a dip of about 24° SE. However, east of the portal of the adit, on the surface, he reports a strike of N. 82° W. and a dip of 74° S. These attitudes suggest internal folding of the limestone, but nowhere is bedding good enough so that such structures can be seen. Guard (1943) reports a large vertical solution crevice about 75 feet from the portal of the adit.

The limestone is light gray to black in color and weathers to gray or dark blue gray. Its weathered outcrops have a remarkably smooth solution surface. The limestone is cut by numerous white calcite veinlets and black stylolites. Chert is rare, and there are a few small stringers of limonitic shaly material. Tiny white spots believed to be clusters of dolomite crystals are common, and rock in the dump at the entrance to the Moose adit is a gray sugary-textured magnesian limestone.

The slope on the deposit is generally steep along the lower part and more gentle at higher altitudes. Outcrops are more continuous on the steeper slopes than on the more gentle ones. No sinkholes were seen, but a few outcrops show down-slope solution channels.

Bedding is not readily apparent in the outcrop, and the limestone is remarkably uniform and massive in appearance. No traces of fossils were seen, either in hand specimen or thin sections, nor are any oölites present. All the limestone is finely crystalline in texture. Petrographically, it does not resemble any of the Paleozoic limestones of western Washington but does resemble some of the massive Triassic limestones of Vancouver Island. It is underlain by greenstones, and lower down

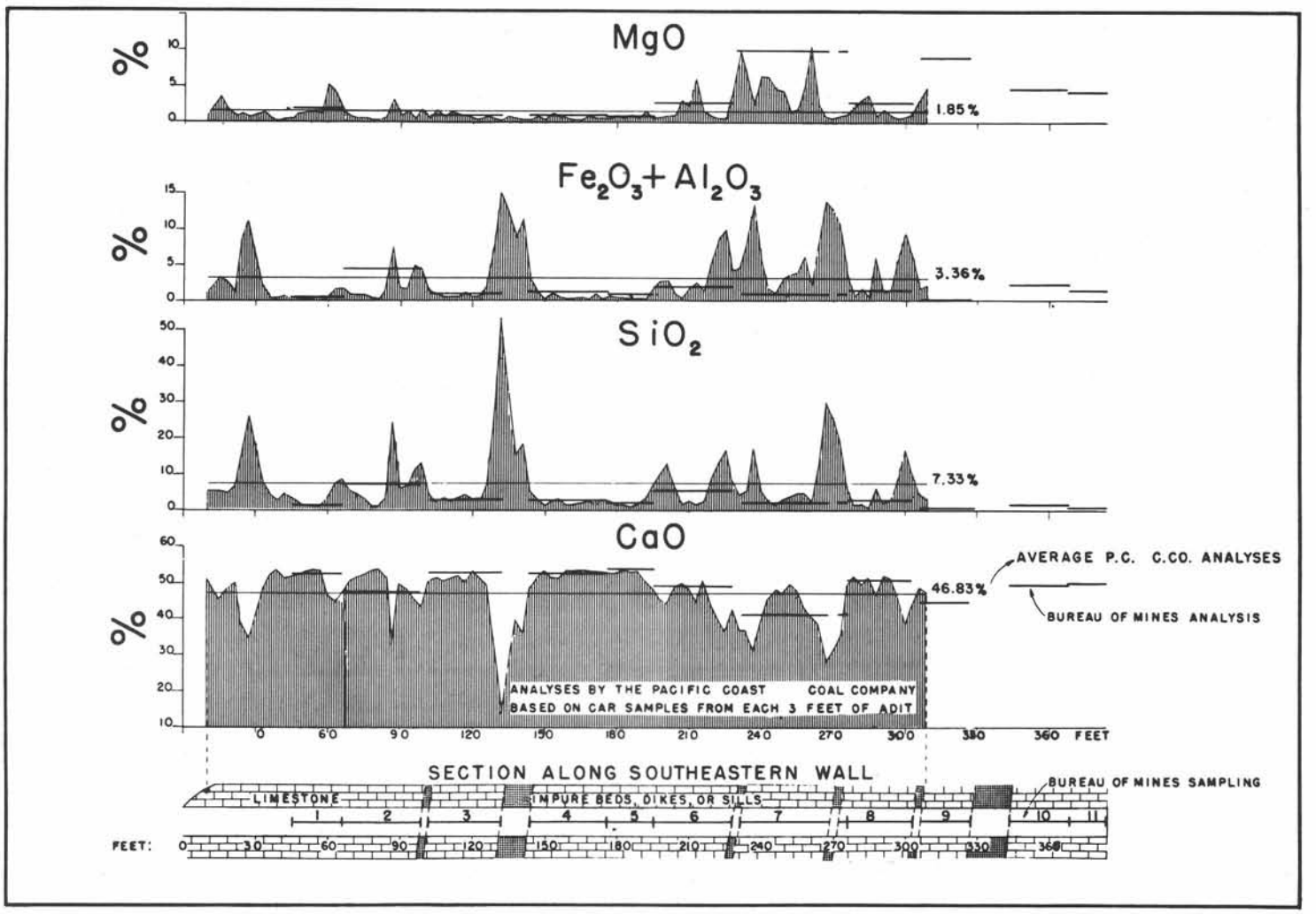


FIGURE 160.—Graph showing analyses by the U.S. Bureau of Mines and the Pacific Coast Company of samples from the Moose adit. Reprinted from Figure 4, U.S. Bureau of Mines Report of Investigations No. 4510.

the mountain by a sequence of argillites striking about N. 35° W. and having a prominent breakage surface that may be bedding, dipping 65° SW.

Quality.—The limestone is variable in composition and has areas high in magnesium.

The exposed limestone in the Moose adit sampled by the U.S. Bureau of Mines was of two types. The unit first penetrated contains 51.1 percent CaO and 1.56 percent MgO over a width of 167 feet. The second unit is magnesian limestone containing 46 percent CaO and 6.97 percent MgO across a width of 130 feet.

Chemical analyses of Galbraith limestone

(Mark Adams, analyst)

Sample no.	Location	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
Sh 4-1	Halfway between cabin and adit -	100	95.12	3.15	42.87	53.44	1.51	1.40	0.48	0.004
Sh 4-2	Above and east of adit ----------	Composite	95.97	0.71	42.29	53.92	0.34	2.70	0.36	0.005
Sh 4-3	Outcrop at adit --	40	92.70	5.43	42.78	52.08	2.60	1.71	0.39	0.004
Sh 4-4	South above adit	Gray limestone, hand specimen	97.91	0.75	42.58	55.01	0.36	1.36	0.40	0.005
Sh 4-5	Northwest of adit	Black limestone, hand specimen	97.95	0.81	42.51	55.03	0.39	1.43	0.52	0.006

Chemical analyses of Galbraith limestone[1]

Sample no.	Footage From	Footage To	Width (feet) Limestone	Width (feet) Rock[2]	Percent: Loss on ignition 950° C.	CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3	P	S
Moose adit - southeast wall (from assumed hanging wall to foot wall)												
	0.0	46.0				not sampled						
BM 1 ---------	46.0	66.0	20.0		43.0	52.7	1.9	1.6	0.3	0.3	0.009	0.050
2 ---------	66.0	98.1	32.1		38.1	47.5	1.6	7.5	1.4	3.1	0.021	0.276
	98.1	101.3		3.2								
3 ---------	101.3	131.5	30.2		41.7	52.8	1.0	3.3	0.4	0.6	0.012	0.179
	131.5	143.0		11.5								
4 ---------	143.0	176.0	33.0		41.6	52.6	1.1	2.9	0.5	0.8	0.011	0.252
5 ---------	176.0	195.5	19.5		42.2	53.7	0.9	2.2	0.4	0.5	0.008	0.157
6 ---------	195.5	227.5	32.0		40.4	49.2	2.7	5.3	0.9	1.2	0.016	0.214
Weighted average, samples 1-6 ----			166.8		40.9	51.1	1.56	4.07	0.69	1.19	0.012	0.195
	227.5	230.6		3.1								
7 ---------	230.6	267.1	36.5		43.8	41.3	11.5	2.0	0.5	0.5	0.011	0.111
	267.1	272.1		5.0								
7a --------	272.1	274.6	2.5		43.8	41.3	11.5	2.0	0.5	0.5	0.011	0.111
8 ---------	274.6	302.7	28.1	5.0	41.9	50.8	2.8	2.9	0.5	1.1	0.014	0.052
	302.7	306.1		3.4								
9 ---------	306.1	327.3	21.2		44.4	45.0	9.1	0.9	0.1	0.1	0.007	0.018
	327.3	343.0		15.7		7.75	0.50	57.39	[3] 28.28			
10 ---------	343.0	368.5	25.5		42.5	49.6	4.6	1.9	0.4	0.7	0.010	0.190
11 ---------	368.5	384.5	16.0		43.1	50.4	4.2	1.2	0.3	0.5	0.009	0.077
Weighted average, samples 7-11 ---			129.8		43.1	46.7	6.97	1.90	0.39	0.60	0.010	0.094
Weighted average, samples 1-11 ---			296.6		41.9	49.2	3.9	3.1	0.56	0.9	0.012	0.154
Pacific Coast Coal Co., Average 98 samples:												
	27.0	330.0	303.0			46.83	1.85	7.33	[3] 3.36			

[1] Popoff (1949b, p. 6). [2] Andesite, siliceous material, etc., not sampled. [3] Combined Al_2O_3 - Fe_2O_3.

Ownership and development.—The Galbraith deposit was patented in 1910 by Galbraith Bros. and Associates, Seattle, under the name of Moose and Calf Moose association placer claims. At the same time, two adjacent claims on a "cement-clay" deposit were patented. In 1926 the Galbraith deposit was leased and partly explored by the Pacific Coast Coal Company. At the present time (1963) the property is owned by the Wall Street Dock Company, C. H. Todd, agent, Seattle.

The only development was the cutting of the Moose adit and several small surface trenches. The adit is about 6 feet high and 4 feet wide and has the remains of a rail line on its floor. The entrance is gradually being blocked by fallen trees and debris. The part of the property examined contains at least 5 million tons of limestone, but the deposit may be much

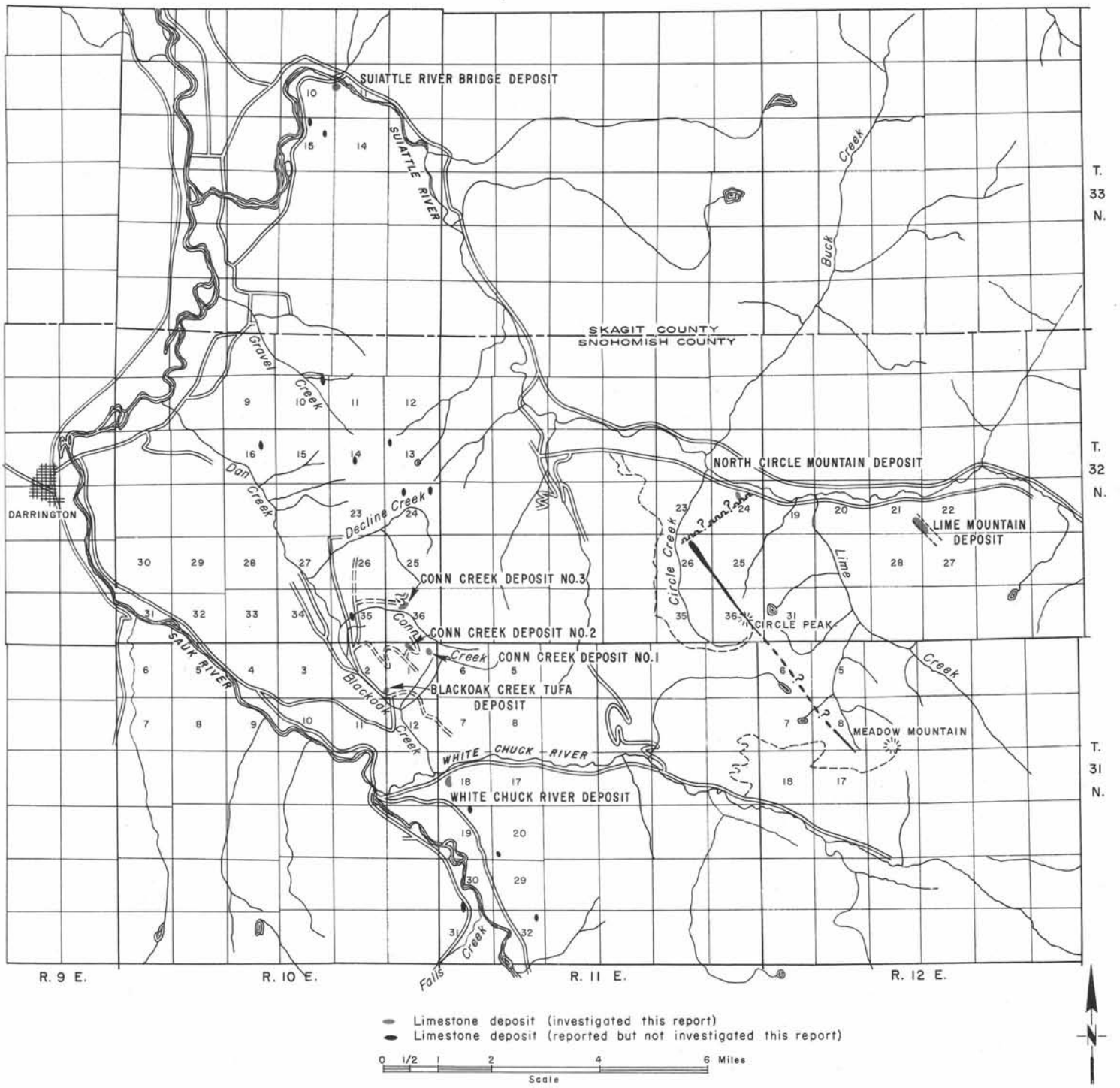


FIGURE 161.—Index map of limestone deposits east of Darrington. Base map by U.S. Forest Service.

larger. However, the high magnesium content would be harmful for cement and chemical uses. Overburden is thin on the lower part of the deposit but may increase to several feet at higher altitudes on the more gentle slopes. The deposit in general presents excellent quarry sites.

References.—Glover (1936, p. 58), Hodge (1938, p. 58-59), Northern Pacific Railway Co. (1941, unpublished notes, p. 14), Broughton (1942, p. 55), Guard (1943, unpublished field notes, p. 14), Hodge (1944, p. 57), Popoff (1949b, p. 1-8), Libbey (1957, p. 88-89).

OTHER LIMESTONE DEPOSITS IN THE WHITEHORSE RIDGE AREA

Popoff (1949b, p. 8) states: "Several other outcrops belonging to the same belt of limestone rocks have been found in the area between the Galbraith and Climax deposits. In general, these outcrops evidently are small-scale repetitions of the deposits described." Joseph Vance (oral communication, Dec. 1962) reports small pods of limestone on the south side of Whitehorse Ridge and limestone float in the bed of French Creek to the west.

Conn Creek Deposit No. 1

Location, size, and accessibility.—The Conn Creek No. 1 limestone deposit is in the NE¼ sec. 1, T. 31 N., R. 10 E., at an altitude estimated to be 3,500 feet on the steep west slope of the ridge between the Dan Creek-Blackoak Creek valley on the west and the valley of Conn Creek on the east. It consists of a small ridgelike knob of limestone having a 100-foot-high cliff outcrop on the west, extending northwest-southeast for a distance of about 260 feet, and showing an outcrop width of about 100 feet.

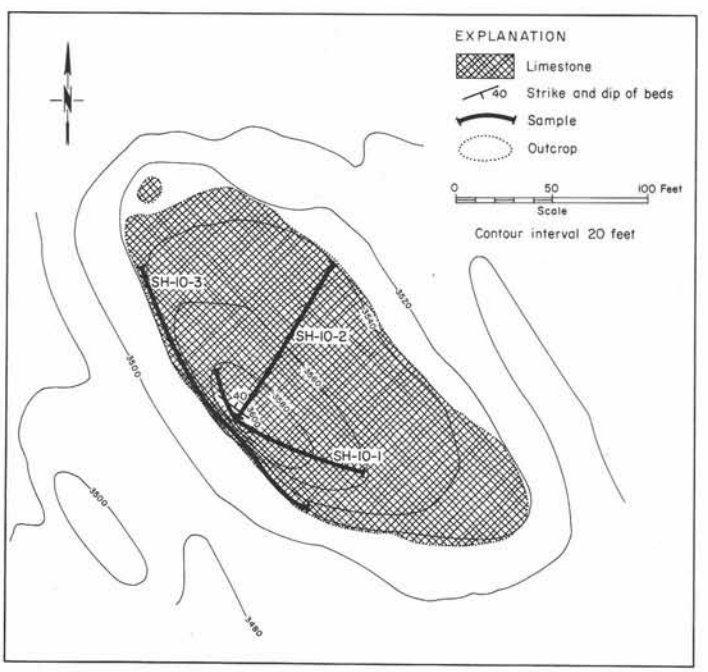


FIGURE 162.—Conn Creek No. 1 deposit. NE¼ sec. 1, T. 31 N., R. 10 E. Geology by C. F. Royse, Jr. and C. L. Smith. Compass and tape survey.

The deposit can be reached by following a logging road for about 9 miles from its intersection with the Sauk River road 7 miles south of Darrington. The deposit is about 1,500 feet northwest on the hillside above the logging road.

Geology and description.—The deposit consists of a massive to bedded sequence of argillaceous limestone exposed on a hillside. The outcrop forms a cliff 100 to 122 feet in height along its west side. The limestone strikes about N. 50° W. and dips 40° NE. It is dark gray blue in color and dense to organoclastic, oölitic, and crystalline in texture. A few large crinoid stems were found in limestone float below the outcrop.

Much of the limestone appears to be argillaceous. It forms a lenticular body in a sequence of graywacke, slate, and conglomerate cut by dikes of andesite. Phyllite crops out down the hillside from the deposit, and the limestone-bearing rocks appear to be in the upper plate of a thrust fault.

Quality.—The limestone is impure and argillaceous.

Ownership and development.—The outcrops are on lands of the Mount Baker National Forest. There has

Chemical analyses of Conn Creek No. 1 limestone

(Mark Adams, analyst)

Sample no.	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
Sh 10-1	75	94.46	0.54	42.32	53.07	0.26	2.60	0.81	0.026
Sh 10-2	100	93.27	0.69	41.76	52.40	0.33	3.96	1.12	0.034
Sh 10-3	160	94.87	0.54	42.62	53.30	0.26	2.50	0.88	0.009

been no development, and the deposit is too small and remote to be of economic value under present conditions. It needs to be explored in order to determine more accurately its size.

Reference.—Vance (1957, p. 204-205).

Conn Creek Deposit No. 2

Location, size, and accessibility.—The Conn Creek No. 2 limestone deposit is in the NE¼NW¼ sec. 1, T. 31 N., R. 10 E., in a logging road cut on the west side of the ridge between the Dan Creek-Blackoak Creek valley and the valley of Conn Creek. It is a small deposit about 220 feet long and 15 feet wide.

The limestone is accessible by about 8½ miles of logging road from the intersection with the Sauk River road 7 miles south of Darrington.

Geology and description.—The deposit is a small lenticular bed of coarsely crystalline carbonate. It strikes N. 30° W., and dips 50°-60° SE., and pinches out at both ends. It is dark gray on fresh surfaces and weathers to a dark golden brown color. The coarse crystals and veinlets of calcite stand out in relief on weathered surfaces.

Quality.—The limestone is high in magnesium.

Chemical analysis of Conn Creek No. 2 limestone

(Mark Adams, analyst)

Sample no.	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
Sh 9-1	220	54.06	37.70	42.17	30.26	18.04	2.80	6.51	0.003

Ownership and development.—The deposit is on lands of the Mount Baker National Forest. There has been no development, and it is too small to be of any economic value.

Conn Creek Deposit No. 3

Location, size, and accessibility.—The Conn Creek No. 3 limestone deposit is in the NW¼ sec. 36, T. 32 N., R. 10 E., on the mountainside north above Conn Creek. It consists of 7 isolated outcrops, the largest of which are about 25 to 50 feet wide and 125 feet long. The deposit is accessible by about 9 miles of logging road from the intersection with the Sauk River road 7 miles south of Darrington. The area has been logged recently.

Geology and description.—The deposit consists of several small outcrops of cherty limestone interbedded with chert. Rocks in the general area have been tightly folded and intensively sheared, and poor exposures make it difficult to determine

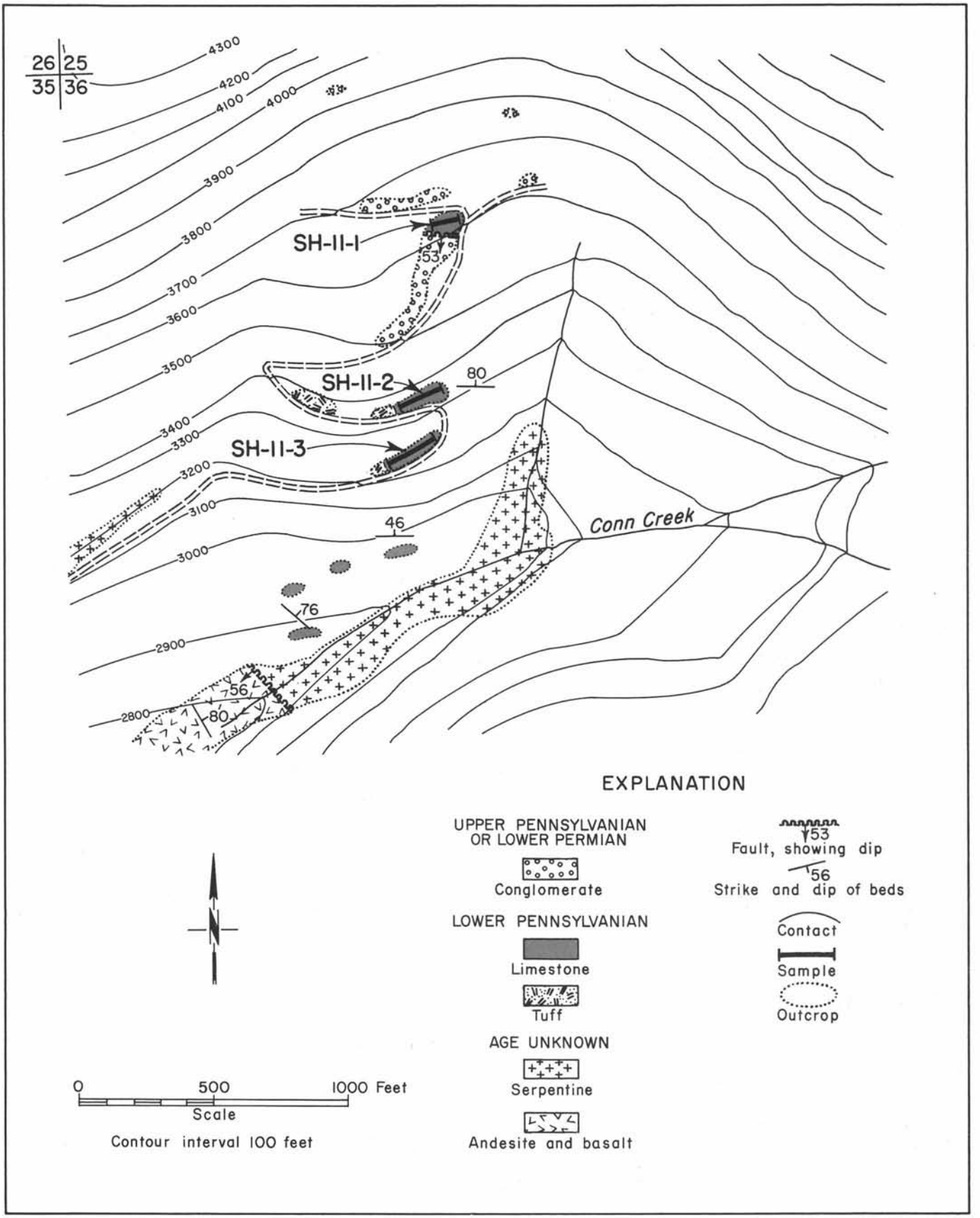


FIGURE 163.—Conn Creek No. 3 deposit. NW¼ sec. 36, T. 32 N., R. 10 E. Geology by C. L. Smith and C. F. Royse, Jr. Base map from U.S. Geological Survey Glacier Peak quadrangle.

the shape and size of the limestone bodies. In most places the limestone appears to strike northwest-southeast and dip steeply to the north. It is interbedded with tuff and appears to be overlain unconformably by conglomerate. Numerous blocks of limestone float in Conn Creek contain large crinoid columnals typical of the Early Pennsylvanian age limestones of northwestern Washington, but the crinoid stems are not commonly visible in the outcrops north up the mountainside.

Most of the exposures consist of alternating beds of gray cherty limestone, ½ inch to 26 inches thick, and gray-brown chert ¼ inch to 8 inches thick. Some of the limestone is brown colored, and most of it appears to be crystalline or organoclastic in texture.

Quality.—The limestone is cherty and argillaceous and is quite variable in composition.

Chemical analyses of Conn Creek No. 3 limestone

(Mark Adams, analyst)

Sample no.	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
Sh 11-1	75	90.47	1.19	40.51	50.83	0.57	6.50	0.76	0.025
Sh 11-2	100	78.12	0.62	34.79	43.89	0.30	19.08	1.57	0.030
Sh 11-3	100	75.88	0.73	33.75	42.63	0.35	20.99	1.83	0.049

Ownership and development.—The area is on lands of the Mount Baker National Forest. There has been no development, and the occurrence is too small, impure, and remote to be of economic value under present conditions.

References.—Vance (1957, p. 204-205), Smith (1961, p. 62-74).

Other Limestone Deposits Near Darrington

The following information on limestone occurrences was furnished by Professor Joseph Vance, of the University of Washington:

A limestone outcrop is reported to occur in approximately the NE. cor. sec. 10, T. 32 N., R. 10 E., in a small tributary of Gravel Creek on the west side of Prairie Mountain. It is reached by about 1 hour of hiking upstream from a logging road.

A small lens of limestone crops out in the bed of Conn Creek in the W½ sec. 35, T. 32 N., R. 10 E.

A limestone lens about 30 feet thick crops out on the ridge crest south of Prairie Mountain in sec. 13, T. 32 N., R. 10 E.

In sec. 14, T. 32 N., R. 10 E., thin lenses of limestone 2 to 3 feet thick are exposed on the hillside.

In sec. 24, T. 32 N., R. 10 E., two small limestone bodies are exposed on the ridge south of Prairie Mountain. One, 8 to 10 feet in thickness, is exposed on the ridge crest, and another, about the same size, is exposed to the west a little below the ridge crest.

Whitechuck River Deposit

Location, size, and accessibility.—The Whitechuck River limestone deposit is in the NW¼ and SW¼ sec. 18, T. 31 N., R. 11 E., in a roadcut and south up the steep hill above the Whitechuck River road. It consists of an outcrop belt at least 300 feet long, 30 to 70 feet in width, and exposed vertically for at least 120 feet. The deposit can be reached by driving on a good gravel-surfaced road 22.6 miles from the Sauk River bridge at Darrington and then 1.4 miles east on the Whitechuck River logging road. The exposures up the steep hillside are covered with very dense second-growth trees and brush.

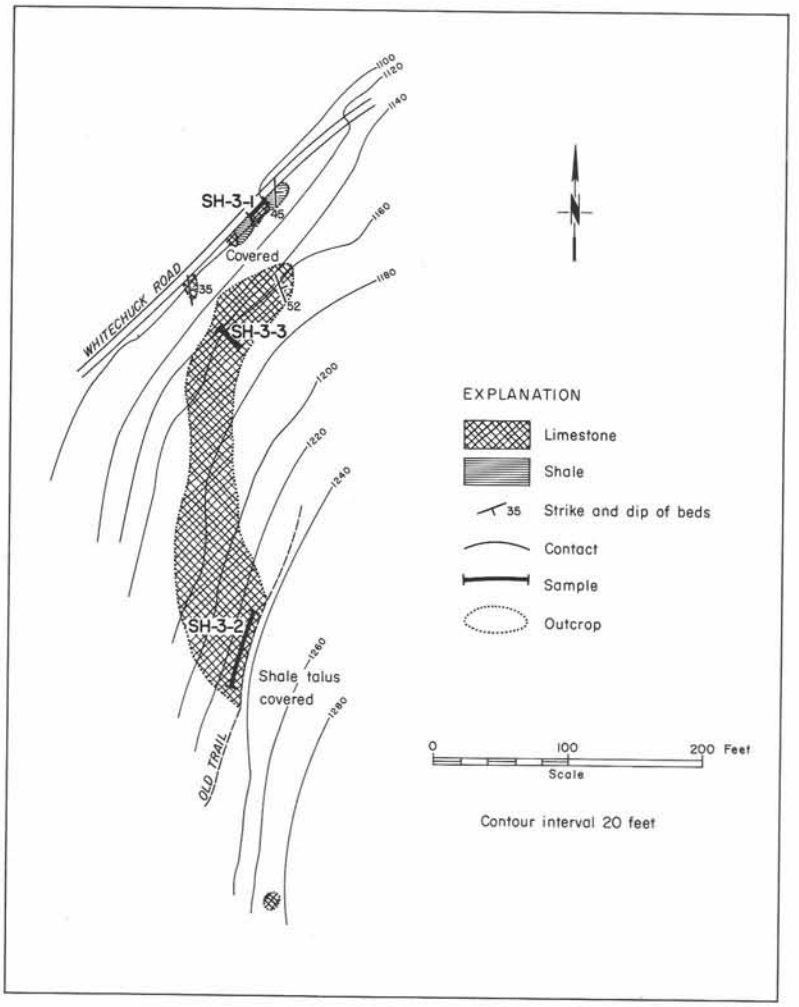


FIGURE 164.—Whitechuck River deposit. NW¼ sec. 18, T. 31 N., R. 11 E. Geology by W. R. Danner and C. F. Royse, Jr. Compass and tape survey.

Geology and description.—The limestone of this deposit is poorly exposed in a roadcut but forms prominent vegetation-covered cliffs to the south up the hillside. The limestone is dark blue gray in color on fresh surfaces and weathers to light blue gray. It is an argillaceous limestone, oölitic and finely crystalline in texture, and interbedded with shale. Except for one small outcrop found under the roots of a fallen tree 140 feet south of the main outcrop area, the limestone extension along strike is concealed on a steep talus- and vegetation-covered hillside. The limestone strikes northwest-southeast to north-south and dips 30°-55° NE.

In the roadcut the following section is exposed:

Top of section	Ft
Thin-bedded shale	4
Interbedded limestone and shale	8
Clastic limestone	2½
Crystalline limestone	3
Shale	15
Argillaceous limestone	4
Covered interval	42
Calcareous shale and clastic limestone	4

The deposit may be lenticular in shape, pinching out to the north and south. It resembles in appearance the Lower Pennsylvanian limestones to the north and is probably correlatable with them.

The roadcut exposure is not typical of the limestone higher up on the hillside to the south. The southern exposures contain very little shale and appear to consist of a more massive body of limestone, more uniform in composition and of better quality.

Quality.—The limestone is quite variable in composition along strike.

Chemical analyses of Whitechuck River limestone

(Mark Adams, analyst)

Sample no.	Location	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
Sh 3-1	Roadcut (2-ft. intervals)	13	64.89	1.96	30.17	36.46	0.94	28.68	3.36	0.041
Sh 3-2	Southwest end of outcrop ------	20	92.84	1.00	41.44	52.16	0.48	4.03	1.46	0.024
Sh 3-3	Central part of deposit ------	60	92.32	0.73	40.90	51.87	0.35	5.20	1.39	0.022

Ownership and development. — The deposit is on lands of the Mount Baker National Forest. There has been no development, and it is too small and remote to be of economic value under present conditions.

References. — Guard (1943, unpublished field notes), Vance (1957, p. 205).

Other Limestone Outcrops Near Whitechuck River

Professor Joseph Vance (oral communication, Dec. 1962) reports small limestone outcrops about 12 feet thick to the south along strike with the Whitechuck River deposit. These are in the NE¼ sec. 19, SW¼ sec. 20, and NE¼ sec. 32, T. 31 N., R. 11 E. To the west, on Falls Creek road in the SE¼ sec. 31, T. 31 N., R. 11 E., is a limestone bed, averaging about 15 feet in thickness, that is associated with chert.

Circle Peak Deposit (North Part)

Location, size, and accessibility. — The north part of the Circle Peak limestone occurrence is in the N½ sec. 24, T. 32 N., R. 11 E., on the steep mountain slope south of Suiattle River about 0.9 mile east of Circle Creek. It consists of a bed of crystalline limestone from 60 to 75 feet in width that is exposed in scattered outcrops for a length of at least 550 feet and has a vertical exposure of at least 300 feet.

It is accessible by a good gravel-surfaced logging road 13.8 miles in length from the intersection of the Darrington-Concrete-Suiattle River roads, or can be reached by a little over 26 miles of road from the town of Darrington. The logging road on the south side of the Suiattle River cuts across the strike of the deposit.

Geology and description. — The deposit consists of a bed of coarsely crystalline limestone underlain and overlain by mica and pyroxene schist. The limestone strikes about N. 10°-15° W. and dips 45°-60° SW. Several interbeds of schist are within the limestone, and thin beds of crystalline limestone are within the underlying and overlying schists.

In a roadcut the limestone appears to be free of dikes, but on the steep slope to the south of the road it is transected by many dikes, and in some places 50 to 60 percent of the limestone outcrop is dike rock. The dikes consist of finely crystalline quartz, finely crystalline plagioclase, plagioclase and quartz, and plagioclase-quartz-biotite. Few of the dikes are more than 1 foot thick.

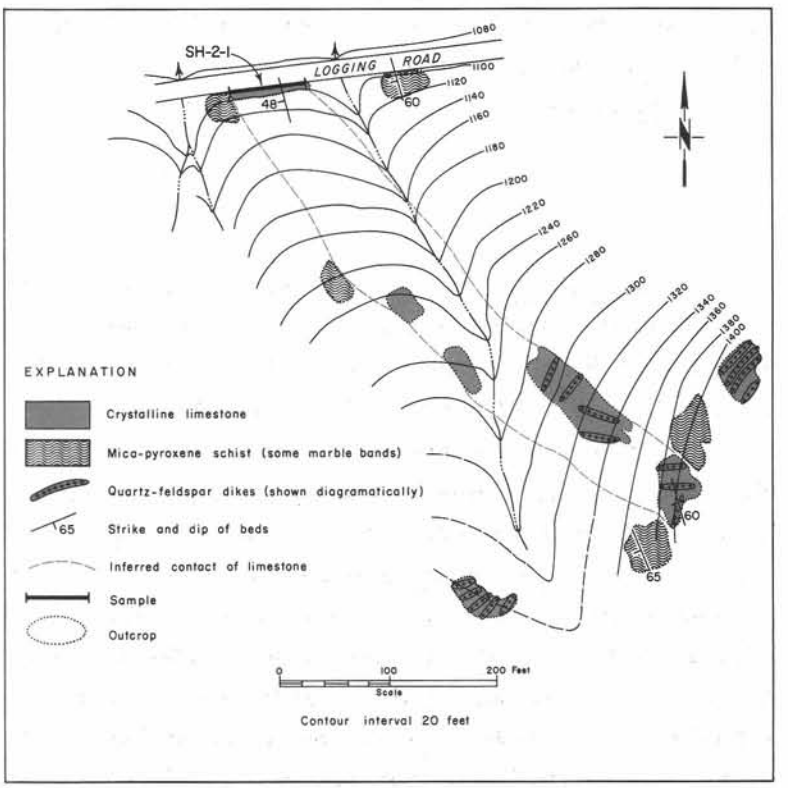


FIGURE 165. — Circle Peak deposit, north part. Reconnaissance geologic map by W. R. Danner and C. F. Royse, Jr. Compass and tape survey.

The limestone is medium to coarsely crystalline in texture and white to light gray in color. It is strongly jointed and breaks into slabs. Up the hillside, solution has enlarged some of the joints to as much as 2 to 5 inches in width, and these extend 3 to 4 feet vertically down into the outcrop. The limestone commonly contains tiny crystals of pyrite and flakes of graphite.

The extent of the limestone up the steep slope is unknown, but it is reported to extend only a few hundred feet. It is poorly exposed and is covered with a dense growth of vegetation.

Quality.—Chip samples were taken at 4-foot intervals in the roadcut, where the best appearing limestone is exposed. The limestone is high in silica and magnesium.

Chemical analysis of Circle Peak limestone (north part)

(Mark Adams, analyst)

Sample no.	Location	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
Sh 2-1	Roadcut (4-ft. intervals)	75	74.88	3.15	34.52	42.07	1.51	20.53	1.73	0.027

Ownership and development.—The deposit is on lands of the Mount Baker National Forest. It was staked about 1959 by J. Vance and R. Ellis, of Seattle, as the La Vache claim. There has been no development, and the deposit is too remote and of too poor quality to be of economic value.

Reference.—Vance (1957, geologic map).

Circle Peak-Meadow Mountain Deposit

Location, size, and accessibility.—The Circle Peak-Meadow Mountain limestone deposit is a northwest-southeast-striking bed of crystalline limestone in secs. 25, 26, and 36, T. 32 N., R. 11 E., and in secs. 5, 6, and 8, T. 31 N., R. 12 E. It is believed to crop out along the ridge of Circle Peak southeastward to the ridge west of Meadow Mountain at altitudes between 4,000 and 5,900 feet for a distance of almost 5 miles. The thickness varies from less than 100 feet to as much as 800 feet. It is relatively inaccessible but can be reached by about 9 miles of steep trail from the logging road on the south side of the Suiattle River about 23½ miles from Darrington. The Meadow Mountain part of the outcrop can be reached by 5 to 6 miles of trail and about ½ mile of travel without trail from the Whitechuck River road 31 miles from Darrington.

Geology and description.—Little is known about this deposit. Joseph Vance (oral communication, Dec. 1962) supplied the following information. The limestone is crystalline and occurs interbedded in a sequence of gneisses and schist. It appears to thicken northward from less than 100 feet west of Meadow Mountain to 800 feet on Circle Peak. North of Circle Peak the limestone may be faulted to the east, and the Circle Peak north deposit could be its northward, displaced extension. On Circle Peak the limestone strikes northwest-southeast and dips from 75° W. to vertical. To the south it dips from 85° E. to vertical. It is not known with certainty to be continuous for 5 miles, but is believed to extend for this distance.

Quality.—Unknown.

Ownership and development.—The limestone is on lands of the Mount Baker National Forest. There has been no development, and the deposit is too remote and inaccessible to be of economic value under present conditions. The high altitude of the deposit in an area of heavy winter snowfall would limit quarrying to a brief late summer period.

Reference.—Vance (1957, geologic map and field notes).

Lime Mountain Deposit

(Description by G. W. Thorsen, Geologist,
Washington Division of Mines and Geology)

Location, size, and accessibility.—The Lime Mountain deposit is in the SE¼ sec. 21 and SW¼ sec. 22, T. 32 N., R. 12 E., at the northerly tip of the long northwest-trending ridge forming Lime Mountain. Scattered cliff outcrops occur in a belt about ½ mile wide and traceable for a horizontal distance of at least 1,500 feet, from 1,400 feet to more than 3,000 feet in altitude. The property is approximately 28 miles by road (7 miles paved) from the rail siding at the "Three Rivers' Mill" near Darrington, and is about 75 miles by road to seaport facilities at Everett. It is reached by following the paved road toward Rockport northeast out of Darrington. About 7 miles from the ranger station at the edge of town, the road crosses the Sauk River, then turns northward. At this point a good graveled road continues straight ahead up the Suiattle River valley to a junction with a road to the right about 17.2 miles from the Darrington Ranger Station. This road crosses the Suiattle River on a concrete bridge, then continues eastward up the Suiattle for another 10.6 miles, to a point where the Box Mountain road branches to the right. Above the first switchback (about ½ mile), crystalline limestone and other metasedimentary rocks are exposed in a new roadcut.

The property consists of 14 unpatented mining claims (Lester 1 to 14), on steep slopes broken by scattered cliffs. Vegetation consists largely of fir and cedar trees as much as 3 feet in diameter and very little underbrush.

Geology and description.—The limestone is fairly coarse grained (grains 1/8 to 1/4 inch across) and is extremely light gray or "off-white" in color. In only one narrow zone was any dense fine-grained material found, and this may be a healed fault. The outcrops in the area are the faces of scattered cliffs that are largely calcareous and can be found for about ½ mile across the regional strike. These cliffs range from 10 to more than 50 feet in height and from 5 to more than 150 feet in width.

All the cliffs are randomly cut by irregular aplite dikes that are generally 1 to 3 inches across but, in places, as much as 1 foot across. In only a few places are these dikes more than 10 to 15 feet apart, and most dikes are closer. The dike material probably makes up from 1 to 5 percent of the rock. In some places, minor amounts of extremely fine pyrite grains are disseminated within the limestone. Thin streaks of graphite also occur in places. The exposures in roadcuts along new sections of the Box Mountain road display more interbedded siliceous sediments than do the cliffs higher up, but this difference

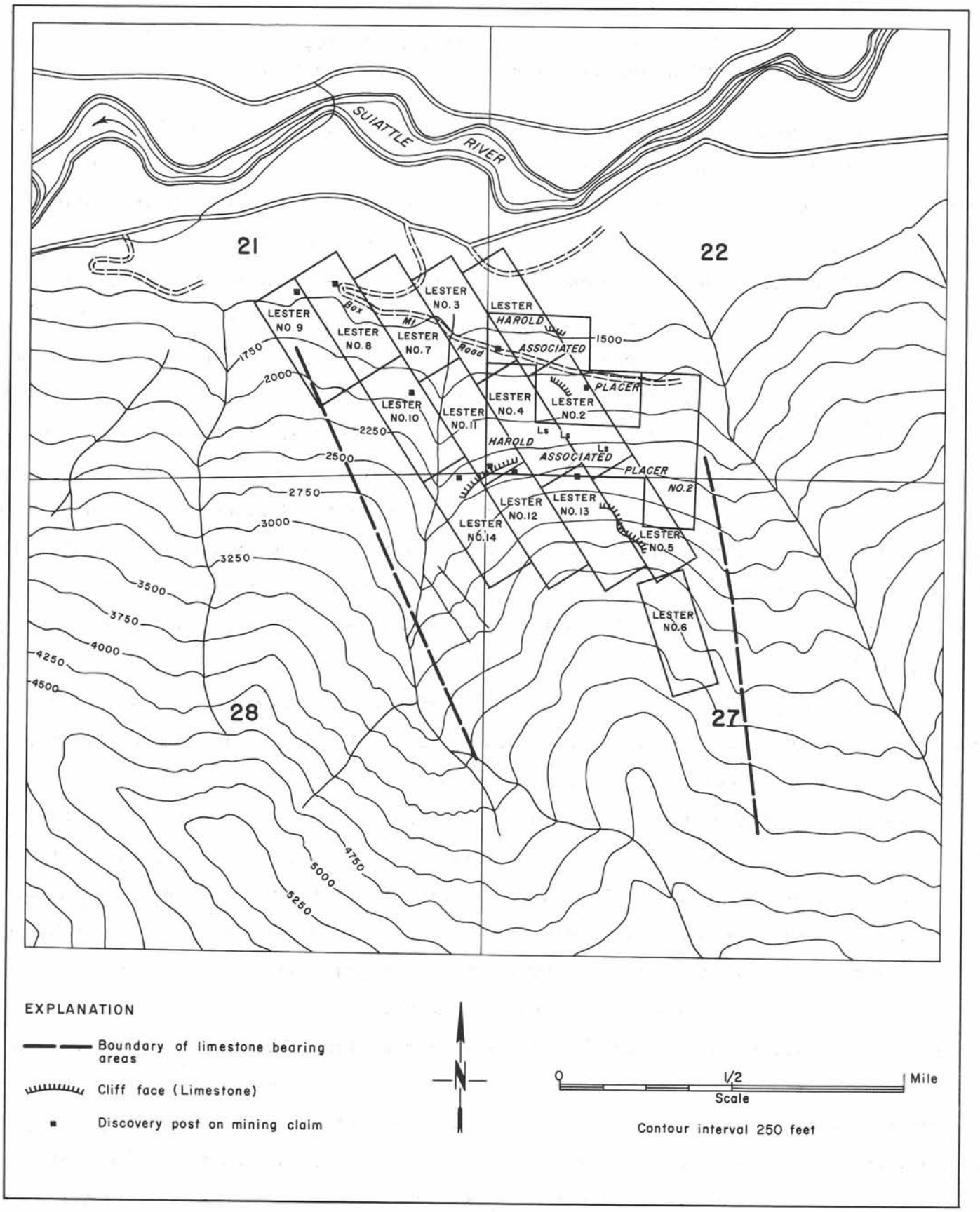


FIGURE 166.—Lime Mountain deposit. Secs. 21, 22, 27, and 28, T. 32 N., R. 12 E. Topography adapted in part from U.S. Geological Survey Glacier Peak quadrangle. Claim locations from map of John Newman.

may be only apparent. It could be due to differential weathering rather than facies change.

The ½-mile-wide calcareous zone appears to strike about N. 20° W. and to dip very steeply to the west. It was followed from about 1,400 feet to more than 3,000 feet in altitude, and claims on limestone are said to continue much higher.

The trend of the zone lines up roughly with the long high ridge that forms Lime Mountain. If the zone is continuous, it should have good exposures in the meadows above tree line.

Quality.—The limestone is of variable composition, but the one sample tested appears to be of fair quality. The presence of numerous dikes would make it difficult to obtain good-quality rock in large quantities.

Chemical analysis of Lime Mountain limestone

Sample	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
1/	100	96.28	---	43.29	54.10	<0.001	1.36	1.20	<0.001

1/ Analysis by Northwest Testing Laboratories, Seattle, for State of Washington.

Ownership and development.—The 14 claims were staked on the property early in 1962 by Harold G. Butler, 1725 W. Glenview, Portland 25, Oreg., and Lester Hathaway. Interested persons should contact the Darrington Limestone Co., Box 512, Darrington, Wash. The deposit is on lands of the Mount Baker National Forest.

(End of report by Thorsen)

Other Limestones in the Suiattle River Area

Small lenses of limestone are reported to occur along the north side of the Suiattle River opposite Milk Creek in about the south part of sec. 30, T. 32 N., R. 14 E.

Sultan Deposit

Location, size, and accessibility.—Sultan limestone deposit is in part in the NE¼NW¼ sec. 14 and in part in the SE¼SW¼ sec. 11, T. 27 N., R. 8 E., on a hilly area south of the Skykomish River and about 2 miles due south of the village of Startup. The deposit contains an estimated 600,000 tons of mixed limestone and chert in about equal parts. Outcrops are 650 to 2,000 feet from a good logging road that is about 7 miles in length, starting 1½ miles southwest of the town of Sultan. The deposit lies in rough hilly country at altitudes between 880 and 1,050 feet above sea level. The area is covered with dense second-growth trees and brush.

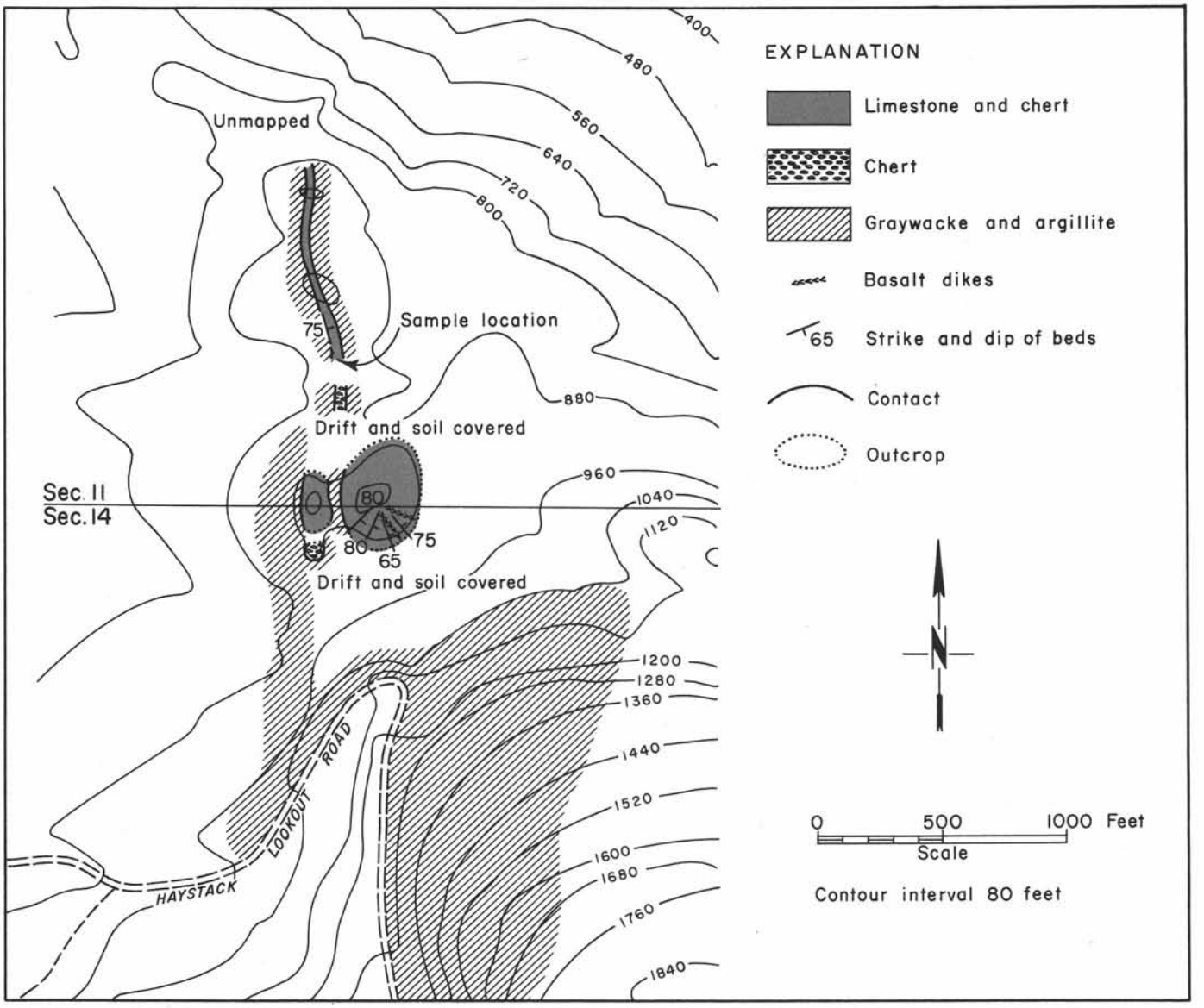


FIGURE 167.—Sultan deposit. NE¼NW¼ sec. 14 and SE¼SW¼ sec. 11, T. 27 N., R. 8 E. Geology by W. R. Danner. Base map modified from U.S. Geological Survey Index quadrangle.

Geology and description.—The first known discovery of this occurrence was by a geology student of the University of Washington, Richard Goldsmith, who brought some samples of it to the University in the spring of 1949. The deposit is a band of thin interbedded limestone and chert layers trending northwest-southeast and dipping steeply to the east. The northern part of the deposit forms an outcrop along the crest of a northwest-trending ridge and ranges from 20 to 80 feet in width, traceable for at least 750 feet and possibly farther. It is exposed vertically for more than 25 feet. The deposit consists of alternating layers of gray chert and bluish-gray limestone. Individual limestone layers range in thickness from 1 inch to 24 inches, and chert layers from ½ inch to 12 inches. One 22½-foot section that was measured in detail included 135 inches of limestone and 133 inches of chert.

Graywacke and argillite border the deposit on both sides. A second outcrop of limestone is about 400 feet to the south and consists of a double-peaked hill; the major parts of both sides of the hill apparently are underlain by limestone and

chert interbeds. A narrow band of argillite crops out in the saddle between the peaks. The east peak of the hill contains the largest body of limestone, estimated to be about 325 feet wide east-west and 400 feet long. It is about 100 feet in height. Limestone and chert form about equal amounts of the bedrock, but there appears to be less chert on the east side of the peak. Two basalt dikes 2 to 3 feet thick cut the limestone and chert on the southeast side of the hill. The limestone is variable in attitude, striking both northeast and northwest and dipping steeply to the east.

FIGURE 168.—Alternating ribbon chert and limestone. View looking north at southern end of northern outcrop of Sultan deposit.

The west peak of the hill is smaller and contains a body of limestone about 100 feet wide east-west, 200 feet long, and exposed vertically for at least 75 feet. It dips steeply to the east and is underlain by argillite. About 100 feet to the south, at a lower altitude, is a small benchlike outcrop consisting mostly of chert but containing a little limestone.

Between the hill with two peaks and the long ridge outcrop to the north is a low saddle containing one poorly exposed mass of chert.

The chert in the Sultan deposit appears to be largely of primary origin, and it forms a rhythmic pattern of alternate deposition with the limestone. Several hundred feet to the west of this deposit is an outcrop consisting of nothing but ribbon chert, and several thousand feet to the east are limestone outcrops containing only minor quantities of chert. There appears to be a small amount of replacement of the chert by limestone along the limestone-chert contacts.

Both the limestone and chert contain poorly preserved remains of radiolarians. Although no diagnostic fossils have been found, the similarity of the enclosing graywacke and argillite to that of the fossiliferous Nooksack Group to the north, along the Sultan River, has led to the belief that the sequence is of Jurassic or Early Cretaceous age. The ribbon cherts bear a strong resemblance to those of the Franciscan Formation of California. Agglutinated tubes of the fossil worm(?) Terebellina palachei have been found in silty argillites to the south and east. This same fossil is common in Tertiary rocks of the Olympic Mountains, so that a Cenozoic age cannot be ruled out for this deposit.

Quality.—The deposit averages about 50 percent chert and 50 percent limestone in outcrop. Analyses of individual specimens of limestone and chert from the south end of the western outcrop indicate almost 20 percent silica in the limestone and over 35 percent calcium carbonate in the chert.

Chemical analyses of Sultan limestone and chert

(Analyses by Ideal Cement Company, T. Baldwin, analyst)

Sample	Sample length	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3	Na_2O	K_2O
Chert	Hand specimen	35.60	----	15.38	20.00	Trace	62.00	0.66	1.23	0.08	0.02
Limestone	Hand specimen	79.29	----	34.83	44.55	Trace	19.21	0.66	1.18	0.06	0.02

Ownership and development.—The deposit is believed to be on lands of the Washington State Forest Board. There has been no development. The property has good quarry sites, but the average composition of 50 percent chert in thin interbeds would make it useless, except possibly for use as a cement rock to be blended with more pure limestone. However, the chert-limestone combination would present difficulties in crushing.

Reference.—Danner (1957, p. 358-363, 400-404).

Reported Occurrences of Limestone, Sultan-Gold Bar Area

WALLACE LAKE OCCURRENCE

A graywacke breccia cropping out on the hillside above the northeast end of Wallace Lake, in the SE¼ sec. 17, T. 28 N., R. 9 E., contains fragments of gray oölitic limestone as much as 6 inches in diameter.

Reference.—Danner (1957, p. 363, 365).

SULTAN RIVER OCCURRENCE

Limestone is reported to occur in sec. 8, T. 28 N., R. 8 E., but no outcrop of it was found. Much of this area is underlain by weathered dioritic intrusive rocks.

References.—Danner (1957, p. 359), Valentine (1960, p. 55).

SULTAN AREA OCCURRENCE

Limestone is reported to crop out in sec. 19, T. 28 N., R. 8 E., but none was found. The area is underlain by graywacke and argillite, probably of Mesozoic age, that could contain limestone.

Reference.—Valentine (1960, p. 55).

WALLACE FALLS AREA

Limestone float is common in the vicinity of Wallace Falls, in the NW¼ sec. 34, T. 28 N., R. 9 E. It is probably derived from an outcrop above Wallace River to the northeast, in sec. 22.

References.—Danner (1957, p. 359), Valentine (1960, p. 55).

Wallace River Deposit

Location, size, and accessibility.—The Wallace River limestone deposit is in the SE¼ sec. 22, T. 28 N., R. 9 E., in a stream valley on the north side of Wallace River, at an estimated altitude of 2,700 feet. The deposit consists of a lenticular bed of limestone about 600 feet long, 50 to 100 feet in thickness, and exposed vertically for over 250 feet. About half of the limestone has been removed by erosion, and it is estimated that a minimum of 500,000 tons remains. The deposit is accessible by about 9 miles of road climbing 2,410 feet in elevation, 2½ miles of which is county road, and 6½ miles of which is logging road via Wallace Falls. The area has been logged in recent years, and when visited by the writer in 1956 the deposit was well exposed.

Geology and description.—The deposit is a lenticular body of gray, dense-appearing but finely crystalline limestone exposed in the bottom and sides of a narrow stream canyon. It strikes N. 15°-20° W. and dips on the average 40°-45° NE. The limestone is underlain by brown phyllitic graywacke, which in turn is underlain by coarser graywacke. A thick bed of black to gray iron oxide-stained argillite overlies the limestone.

The limestone appears to be unfossiliferous in hand specimen, but thin sections show irregular objects that might be recrystallized fossil debris, distorted shells, or oölites. On weathered surfaces some of the limestone shows a finely laminated bedding. No chert, dikes, or other impurities were seen.

The limestone is thought to be Late Jurassic or Early Cretaceous in age, and the enclosing graywacke-argillite sequence is correlated with the Nooksack Group of Whatcom County. The supposed fossil worm tube Terebellina palachei is common in rocks near Wallace Falls, and different species of Buchia are found along strike a few miles to the northwest.

The limestone has been recrystallized, due at least in part to compression and in part to the intrusion of the Index Granodiorite to the east and south. A few small solution channels and crevices penetrate the limestone outcrops.

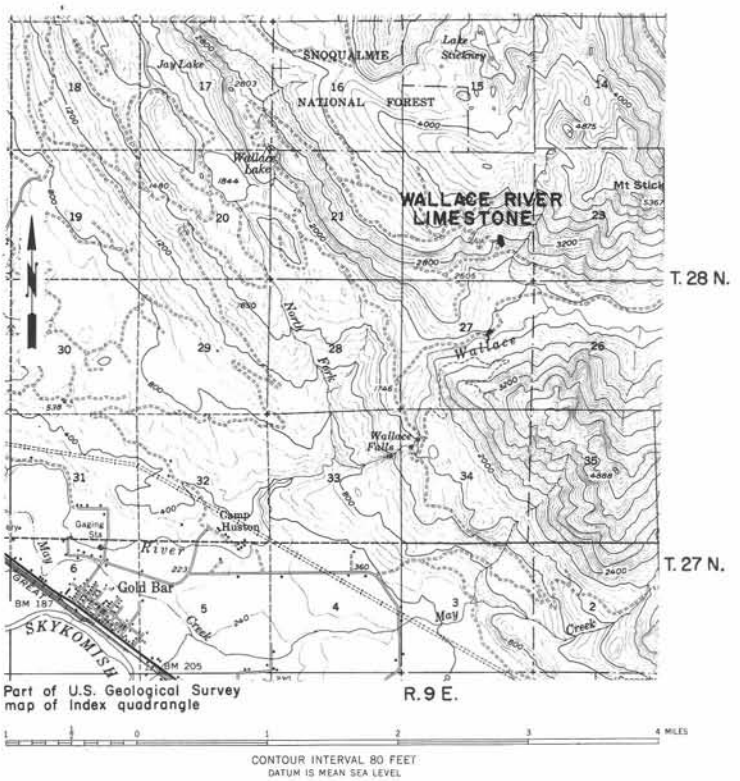


FIGURE 169.— Index map showing location of Wallace River deposit.

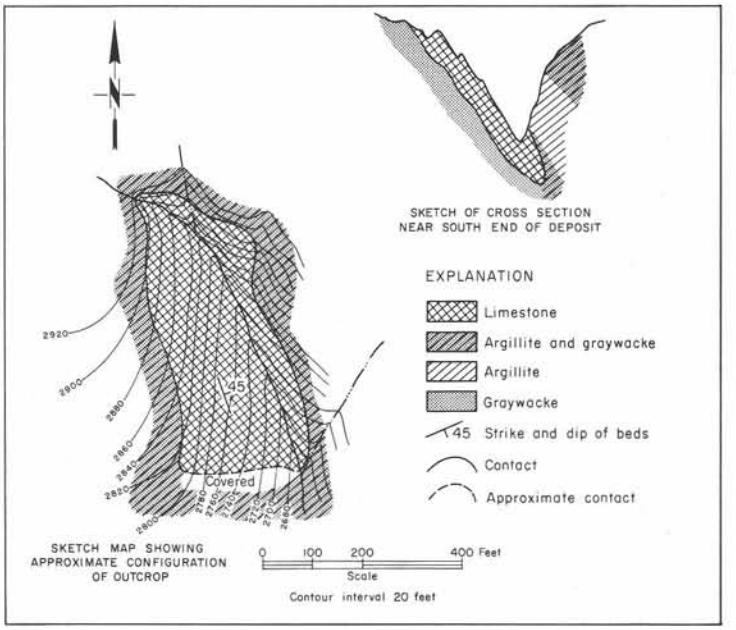


FIGURE 170.—Wallace River deposit. SE¼ sec. 22, T. 28 N., R. 9 E. Sketch map by W. R. Danner. Deposit not surveyed.

Quality.— The quality of the limestone is unknown. It has no visible impurities.

Ownership and development.— The owner is unknown, and there has been no development. The deposit was first reported and shown to the writer by Leslie Miller, of Gold Bar. This deposit might support a small operation, but its quality should be tested. Outcrops look large, but most of the deposit is simply a slab of limestone dipping roughly parallel to the east-dipping slope of the west side of the canyon on which it is situated.

Gold Bar Deposits

Location, size, and accessibility.—The Gold Bar limestone deposits are in the SE¼ sec. 16 and SW¼ sec. 15, T. 27 N., R. 9 E., in hilly country lying south above the Skykomish River between Crystal Creek on the west and Proctor Creek on the east. The property consists of three small areas of limestone lenses, the largest of which is about 200 feet long and has a maximum width of 50 to 60 feet. Two of the areas contain quarries and are accessible by a road starting about 3 miles east from the town of Gold Bar on U.S. Highway 2 at the entrance to the property of the Miller Lime Company. Area No. 1 and area No. 2 can both be reached by about 1½ miles of road from the highway. Outcrop area No. 3 (Crystal Creek) formerly could be approached to within about 450 feet on one outcrop by a logging road approximately 1.6 miles in length from the highway, but 3,000 feet of this road is now overgrown and impassable. The outcrops lie at altitudes between 660 and 970 feet above

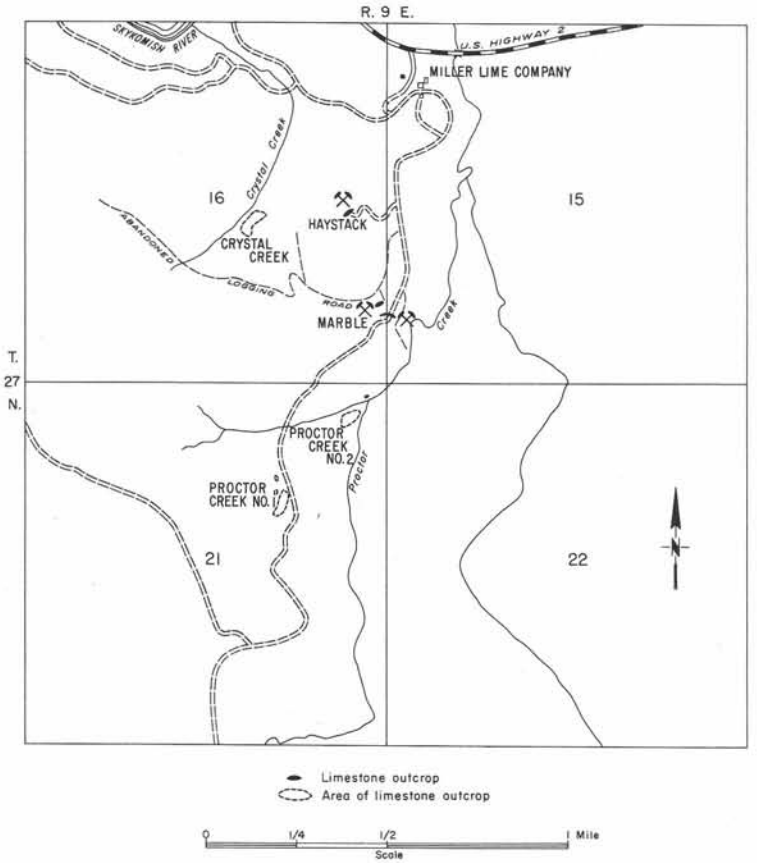


FIGURE 171.—Index map of the Gold Bar limestone deposits. T. 27 N., R. 9 E.

sea level in hilly, logged terrain covered with dense second-growth trees and brush. Gold Bar is a station on the main line of the Great Northern Railway 61 miles from Seattle. The deposit is $2\frac{1}{2}$ miles east of Gold Bar.

Geology and description.—The Gold Bar deposits consist of small lenticular beds of limestone interbedded in a thick sequence of graywacke, argillites, and volcanic rocks believed to be of Late Jurassic or Early Cretaceous age. Fragments of echinoid spines, pelecypod shells, and poorly preserved radiolarians have been found in the limestone, but nothing diagnostic has been located or identified. The agglutinated worm tube(?) fossil Terebellina palachei is common in argillites of this sequence in the vicinity of the limestone, particularly in exposures in the bed of Proctor Creek, to the east.

The sequence is highly folded and cut by numerous faults, and it has not been possible to determine the stratigraphic succession nor the position of the limestone horizon in the section. It is not known whether there is more than one limestone horizon or whether all the outcrops represent a single zone. Ribbon chert is common underlying, overlying, or interbedded with the limestone.

Dikes of andesite, granodiorite, and other igneous rocks cut the sequence in several places, and where these have penetrated the limestone they have recrystallized it. The minerals wollastonite and pyrite have formed in the limestone near where it has been intruded by these dikes.

Where not recrystallized, the limestone is black to gray on fresh surfaces and light bluish gray on weathered surfaces. It is mostly oölitic in texture; only minor parts are dense. A breccia composed of gray limestone fragments from about $\frac{1}{4}$ inch to 1 inch in diameter in a dark-gray to black matrix is found in areas No. 1 and No. 2. It usually occurs as a layer from 1 to 3 feet thick interbedded in the normal limestone. Most of the limestone is well bedded.

AREA NO. 1, HAYSTACK QUARRY

Area No. 1, the Haystack Quarry, consists of a series of limestone outcrops striking northeast-southwest across a small ridge. Exposures extend for about 200 feet along the strike and have a maximum width of 60 feet. The limestone is well bedded and contains several bodies of chert, including one layer about 3 feet thick. A stratigraphic thickness of about 30 to 40 feet of limestone is exposed, including a bed of limestone breccia. The sequence strikes northeast-southwest and dips on the average 20°-40° SE. Several normal faults cut the deposit, but they have a displacement of only a few feet. Andesite dikes are common.

It is possible that additional limestone will be found in this area along the strike to the north and south in terrain covered by glacial drift. The drift ranges from a few inches to several feet in thickness and overlies much of the limestone being quarried in the Haystack.

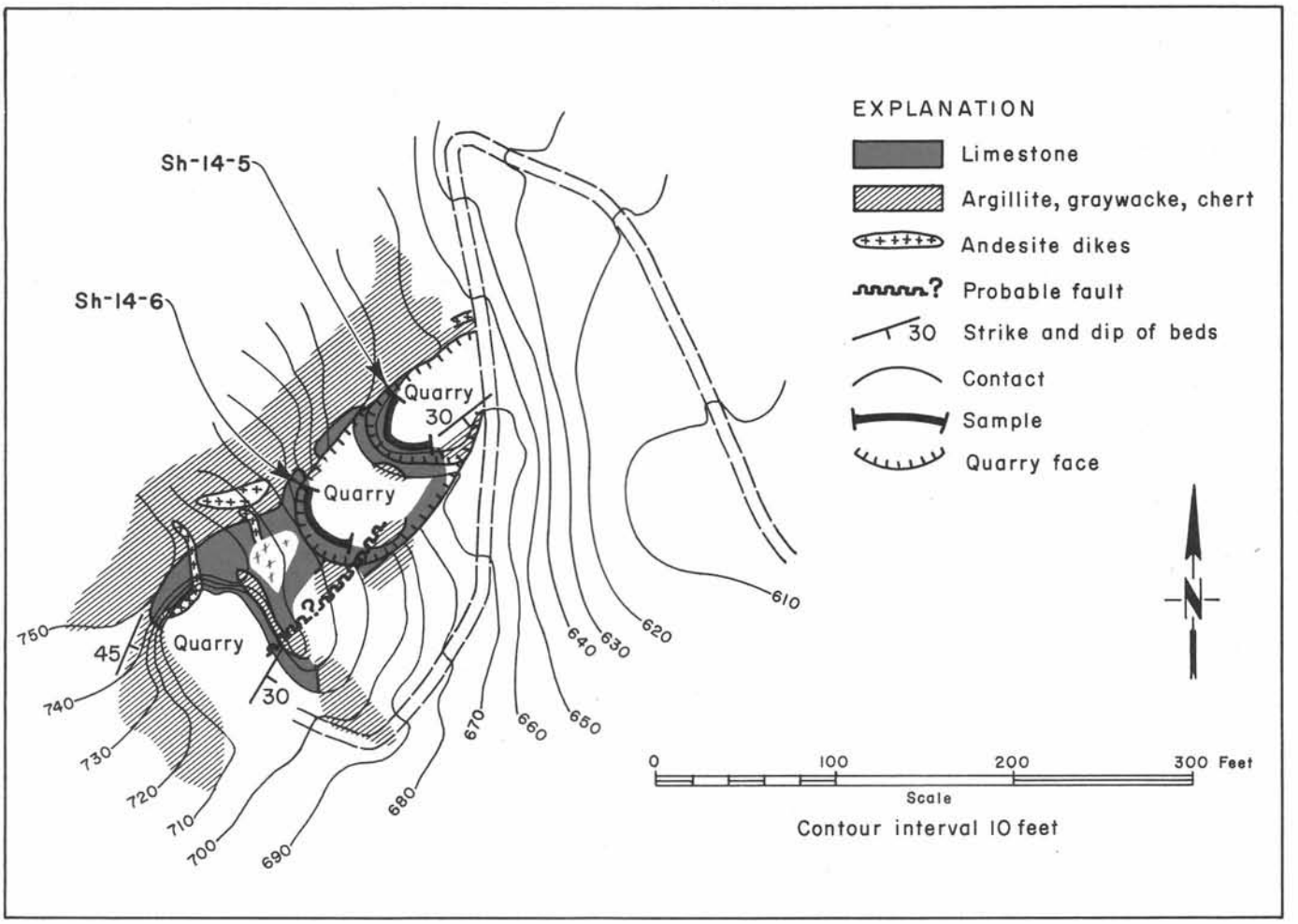


FIGURE 172.—Haystack quarry area. SE¼ sec. 16, T. 27 N., R. 9 E. Geology by W. R. Danner, E. A. Adams, and C. L. Smith. Compass and tape survey.

FIGURE 173.—Haystack quarry, north end. View looking southwest, 1960. Interbedded ribbon chert and limestone overlie limestone with minor amounts of ribbon chert.

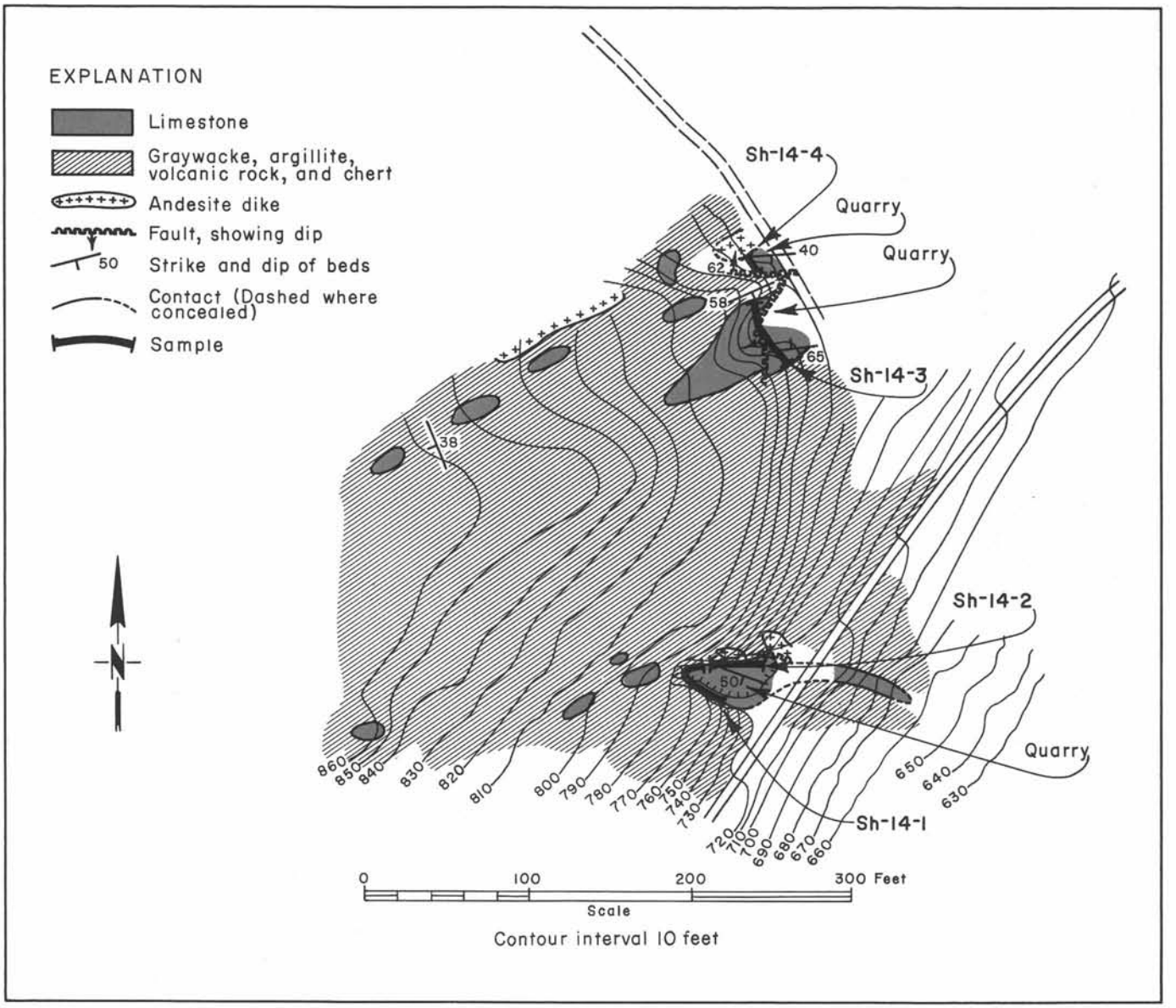


FIGURE 174.—Marble quarry area. SE¼ sec. 16 and SW¼ sec. 15, T. 27 N., R. 9 E. Geology by W. R. Danner, E. A. Adams, and C. L. Smith. Compass and tape survey.

AREA NO. 2, MARBLE QUARRY

The Marble quarry outcrop area consists of two relatively large lenticular limestone bodies and several small pods along the trend of the strike. The northern body is exposed for a length of about 100 feet, is trianglular in shape, and has a maximum width of about 42 feet. It is cut by a gently west-dipping fault that is exposed in the quarry face from the east rim nearly to the floor of the west side. A steep west-dipping normal fault on the west side of the quarry has dropped a part of the limestone to form a second small outcrop, cut on its west side by a large dike of andesite.

To the southwest are five small lenses of limestone, most of which are not more than 10 feet thick and 20 to 30 feet in length. The limestone is overlain and underlain by contorted argillite and is underlain in places by chert. Wollastonite has developed in the limestone near its contact with the andesite dike and is also present in some of the smaller limestone bodies. Glacial drift, soil, and vegetation cover much of the outcrops.

The southern part of the quarry area is on the steep east face of a hillside above the west side of the valley of Proctor Creek. The main limestone outcrop is a lenticular body about 150 feet long, striking almost east-west and dipping about 50° S. It is underlain and overlain by chert, argillite, and volcanic rocks. Locally, the north contact is either a fault or an intrusive contact with an andesite dike.

The limestone in area No. 2 of the deposit is predominantly black in color and dips steeply southward. The limestone beds appear to be truncated by chert at the top of the outcrop. Chert is also interbedded with the limestone in its lower and upper parts. A bed of limestone breccia as much as 1 foot or more in thickness occurs in the upper part of the limestone sequence and is identical with that exposed in the Haystack quarry, more than 1,500 feet to the north. A stratigraphic section of about 60 feet of limestone is exposed in the Marble quarry.

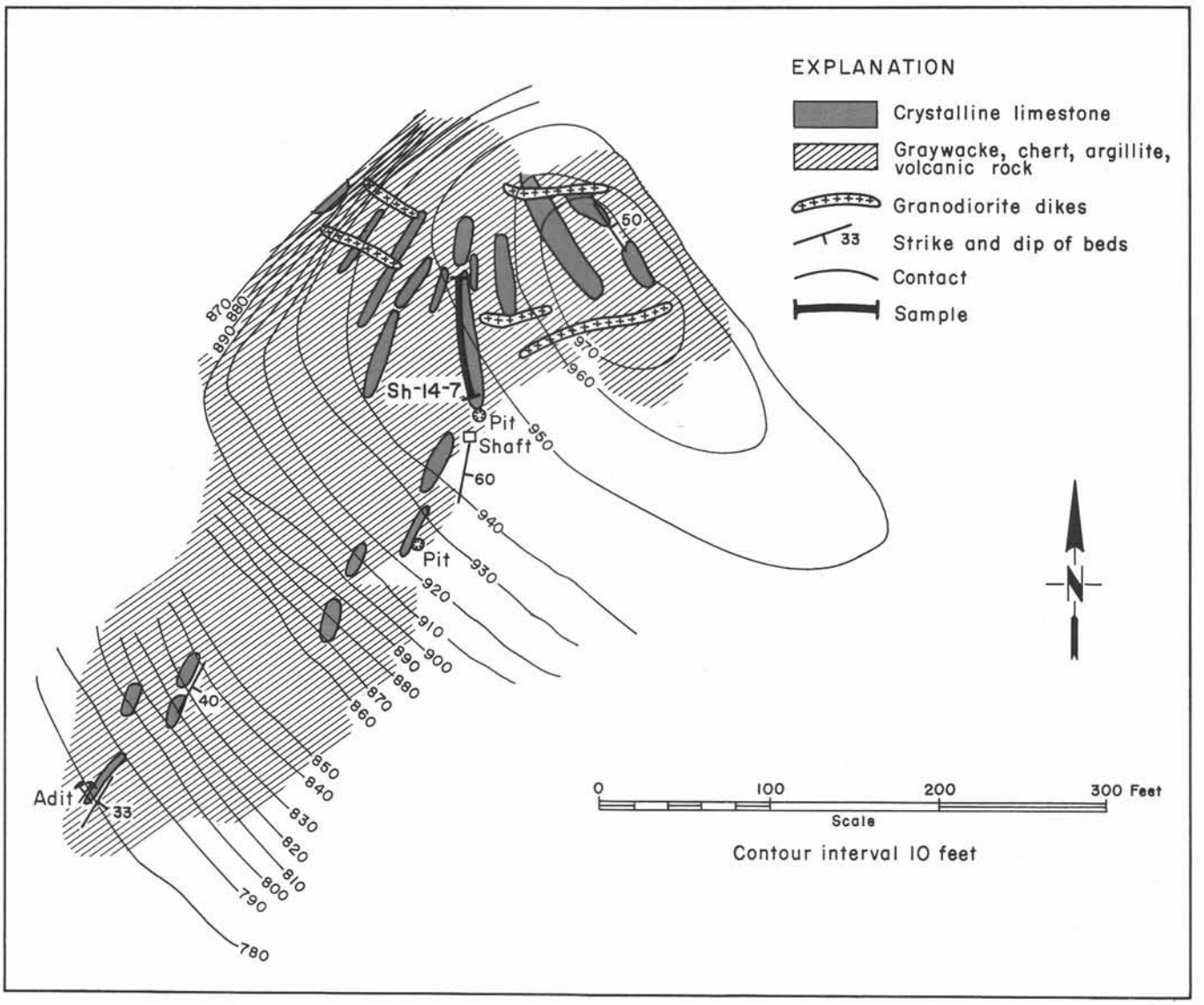


FIGURE 175.—Crystal Creek outcrop area. SE¼ sec. 16, T. 27 N., R. 9 E. Geology by W. R. Danner, E. A. Adams, and C. L. Smith. Compass and tape survey.

AREA NO. 3, CRYSTAL CREEK DEPOSIT

The Crystal Creek limestone outcrops are on the crest and southwest side of a prominent hill on the east side of the Crystal Creek valley. The south and east sides of the hill have relatively gentle slopes, but the north and west sides are precipitous. A thin mantle of glacial drift and soil and a dense growth of small trees and brush cover the outcrop area of the limestone. The outcrops of the Crystal Creek area consist mostly of long narrow beds of crystalline limestone as much as 20 feet thick and more than 100 feet long. Most of them are 10 feet or less in thickness. The southern and western beds strike northward and dip 30°-60° SE. The northern beds strike northwestward and dip from 50° NE. to vertical. Almost all of them are overlain or underlain by ribbon chert from a few inches to several feet in thickness. Argillite, graywacke, and conglomerate compose most of the surrounding rock. Several dikes of granodiorite cut the sequence in this area. Small solution cavities and crevices are present on most of the limestone outcrops.

Several additional small limestone outcrops to the southwest, near Crystal Creek, were not mapped.

Quality.—Most of the limestone of the Gold Bar deposits is siliceous. The abundance of chert makes it difficult to obtain high-grade limestone without careful sorting. Wollastonite ($CaSiO_3$) is abundant near intrusions in many parts of the Marble quarry and in the limestone of the Crystal Creek area.

Chemical analyses of Gold Bar limestone

Sample no.	Location	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
Analyses of samples collected for this report, Mark Adams, analyst										
Sh 14-1	Marble --	40	90.65	1.06	40.21	50.93	0.51	6.76	0.83	0.025
Sh 14-2	Marble --	30	94.39	1.23	41.75	53.03	0.59	3.02	0.84	0.031
Sh 14-3	Marble --	40	89.48	0.94	34.38	50.27	0.45	13.11	1.20	0.025
Sh 14-4	Marble --	10	93.77	0.66	40.88	52.68	0.32	5.09	0.60	0.030
Sh 14-5	Haystack -	40	91.51	1.63	41.04	51.41	0.78	5.04	1.22	0.035
Sh 14-6	Haystack -	40	92.93	1.17	41.14	52.21	0.56	4.74	0.75	0.027
Sh 14-7	Crystal --	70	95.46	0.41	41.78	53.63	0.20	3.49	0.44	0.018
Analysis from another source										
1/	Marble quarry --	width	97.1	0.8	42.0	54.4	0.4	2.5	0.6	

1/ Analysis courtesy of Great Northern Railway Co., 1941.

Chemical analysis of Gold Bar limestone, Haystack quarry 1/

Calcium carbonate	89.95	Manganese	0.059
Magnesium carbonate	0.38	Fluorine	0.008
Calcium carbonate equiv.	90.40	Phosphorus	0.019
Aluminum	0.31	Zinc	0.0055
Iron	0.31	Vanadium	0.0016
Potassium	0.035	Boron	0.0001
Sulfur	0.03	Copper	0.00034
Sodium	0.043	Molybdenum	0.00001
		Cobalt	< 0.0001

1/ Analysis by Agricultural Research Service, Soil and Water Conservation Research Division, U.S. Dept. of Agriculture, Beltsville, Maryland. Reference: Chichilo and Whittaker (1961, p. 141).

Ownership and development. — The property is owned by Leslie B. Miller, of Gold Bar, Wash., who lives just south of the highway below the deposits. It was first developed about 1940 by the Consumers Lime Company, which opened up the Marble quarry on its Marble No. 1 claim. The company used the rock for producing crushed agricultural limestone. A glory-hole method was used in quarrying. A few years later the Miller Lime Company bought the property and opened a small quarry on the outcrop to the north of the Marble quarry and two quarries on the Haystack deposit. The northern quarry of the Haystack is worked on two levels. A 12-foot adit, several pits, and a 40-foot vertical shaft were dug on the limestone outcrops of the Crystal Creek area some time prior to 1948, but there has been no quarrying there.

Most of the limestone obtained from this property has gone into the production of crushed agricultural limestone. A small amount has been used for flux stone, rock for fireplaces, for rock gardens, and for calcium carbide and the refining of sugar. The deposit is suitable for small selective operations. Additional occurrences of limestone may lie concealed under glacial drift and soil.

References. — Hodge (1938, p. 64-67), Northern Pacific Railway Co. (1941, unpublished notes, p. 14), Broughton (1942, p. 54), Mathews (1947, p. 43-44), Huntting (1950, p. 24), Danner (1957, p. 358-368, 406), Libbey (1957, p. 80), Valentine (1960, p. 55).

Proctor Creek Deposits

Location, size, and accessibility. — The Proctor Creek limestone deposits are in the NE¼ sec. 21, T. 27 N., R. 9 E., on the west side of Proctor Creek, a small tributary of the Skykomish River. Two areas of limestone outcrop are present. The southern area consists of three bodies of limestone, one containing about 50,000 tons, one about 10,000, and the third about 2,000 tons. The northern area contains seven outcrops, the combined tonnage of which is less than 20,000 tons.

The southern deposit is accessible by 2 miles of narrow and steep logging road that branches from U.S. Highway No. 2 at a point 2½ miles east of the town of Gold Bar and 61 miles by rail from Seattle. The northernmost outcrop is about 1,000 feet east of the logging road leading to the southern deposit. The deposits occur at altitudes of 830 to 1,260 feet above sea level in logged-off land covered with dense second-growth trees and brush.

Geology and description. — The Proctor Creek limestone deposits are similar to the Marble and Haystack outcrops of the Gold Bar deposits to the north, and occur in the same Jurassic-Cretaceous argillite-graywacke sequence.

The limestone of the Proctor Creek deposits is black to gray on fresh surfaces and weathers to a light gray. In places it has been recrystallized and is cut by white calcite veinlets. Much of it is oölitic in texture. Limestone breccia is common, and in area No. 1 some of the fragments are weathered to pink, red, or yellow on their outside surfaces, making the rock rather attractive in appearance. The fragments consist of dense-textured limestone and are angular to rounded in shape. They are imbedded in an oölitic matrix.

Chert beds and pods occur in almost all exposures and constitute a major impurity. Some of the chert beds are breccias. Small fragments of argillaceous or tuffaceous material are present in some of the limestone breccias and stand out in relief on weathered surfaces.

AREA NO. 1

The limestone of area No. 1 is on the east side of a 200-foot-high hill, where it is exposed in a series of cliff outcrops. The largest exposure lies along the west side of the Proctor Creek logging road, where it is underlain in part by a 5-inch-thick layer of chert and is in possible fault contact with contorted and slickensided argillite. It is exposed for about 225 feet north-south and has a maximum width of about 130 feet. It pinches out to the north and south. Three horizontal diamond drill holes were bored in the deposit in 1953 and indicated that andesite (probably a dike) borders the limestone on its west side. Although the cliff outcrop is very impressive and looks as if it would contain a large tonnage, the drill holes revealed that the deposit narrows with depth and contains only about half the tonnage (50,000 tons) one might estimate from surface exposures.

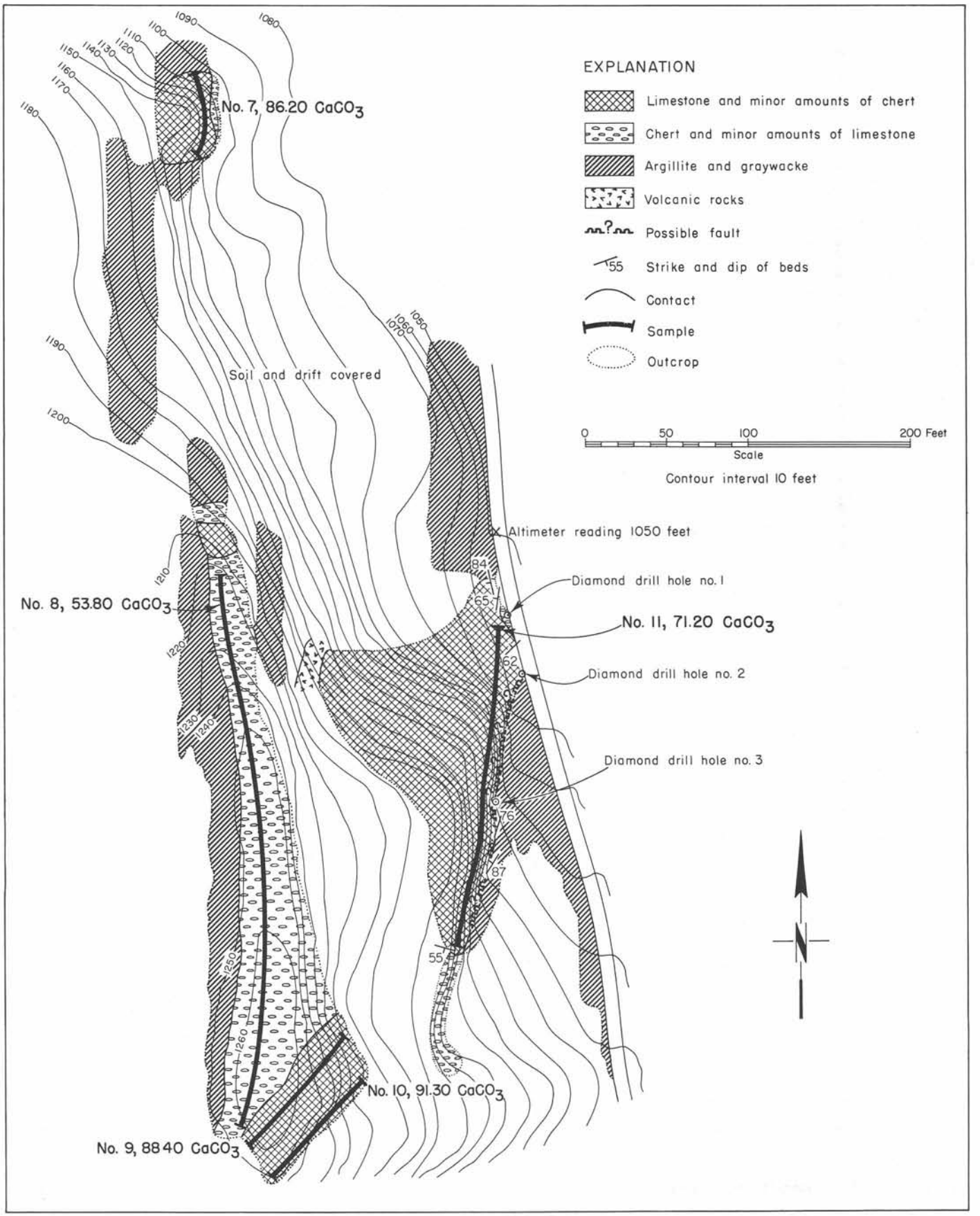


FIGURE 176.—Proctor Creek deposit, area No. 1. NE$\frac{1}{4}$ sec. 21, T. 27 N., R. 9 E. Geology by W. R. Danner and K. Riely. Compass and tape survey. Map courtesy of Ideal Cement Company.

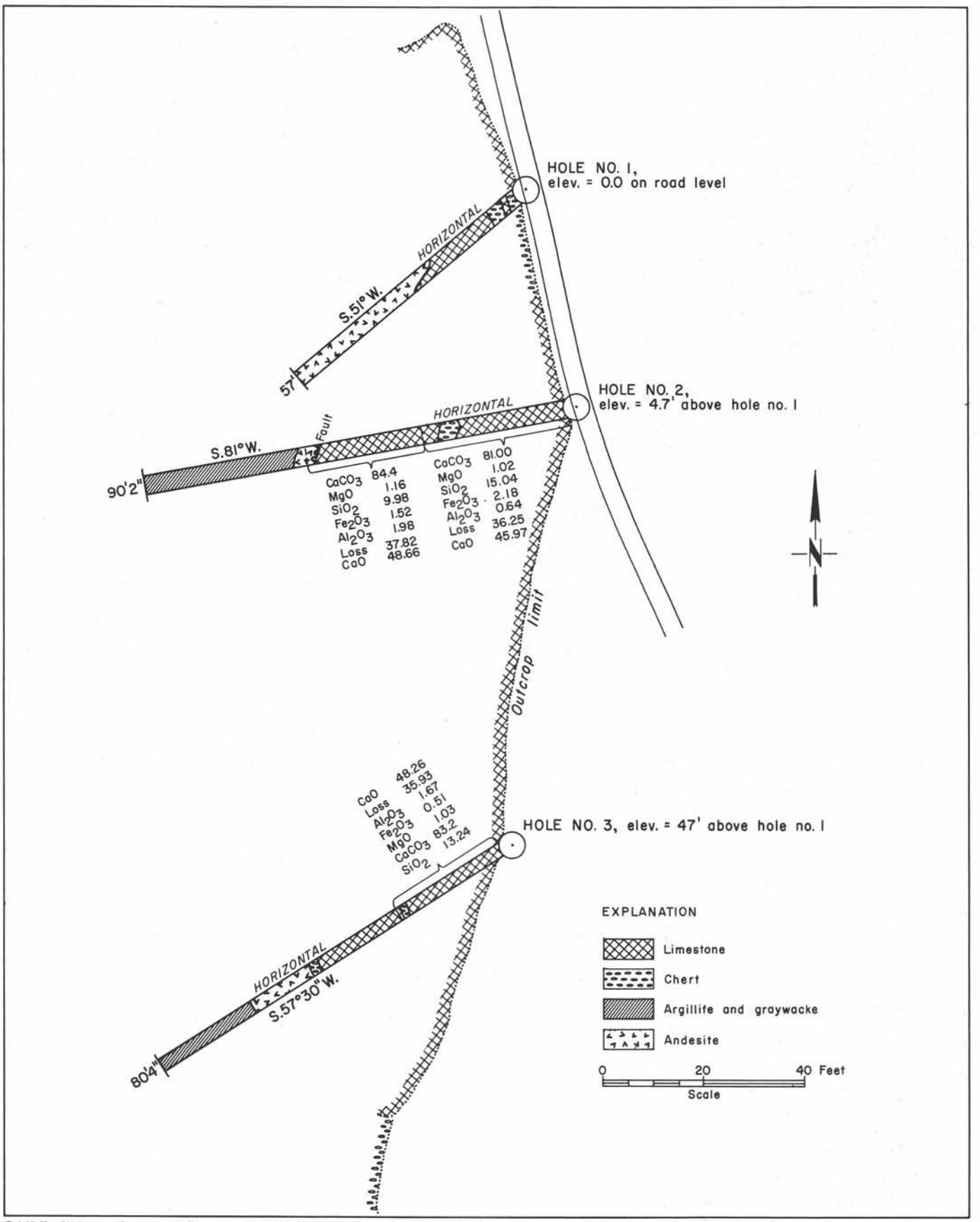


FIGURE 177. — Logs of diamond drill holes, Proctor Creek deposit, area No. 1. Geology by W. R. Danner. Courtesy of Ideal Cement Company.

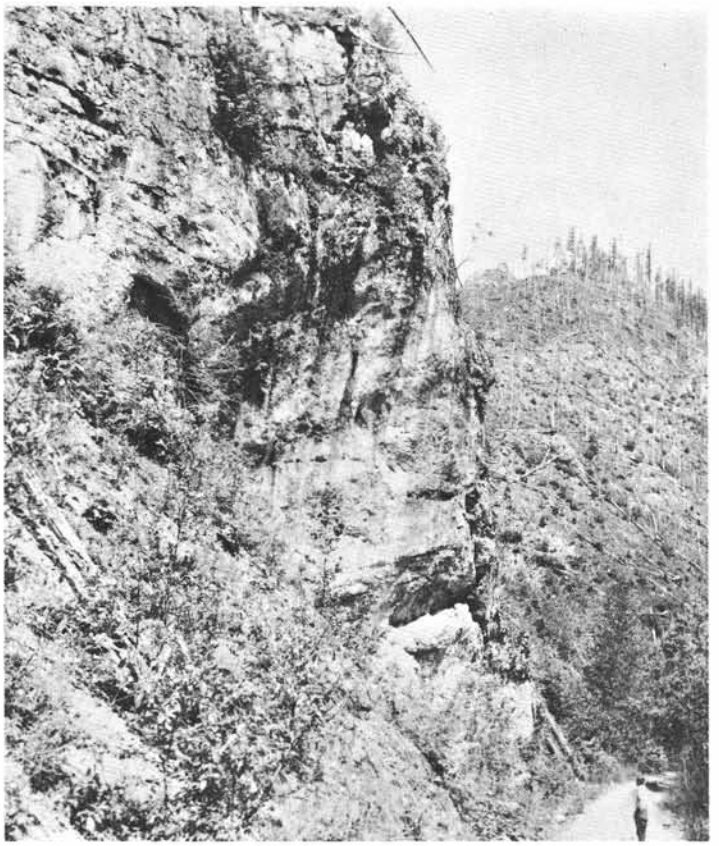


FIGURE 178.— Limestone cliff, Proctor Creek deposit, area No. 1. View looking north along logging road on west side of Proctor Creek, 1953.

About 80 feet to the north is another small cliff outcrop, about 35 feet wide, 100 feet long, and exposed for a vertical distance of about 60 feet. It contains small bodies of interbedded chert. North of it for a distance of 300 feet is a belt of chert containing minor amounts of limestone. About 350 feet north of the largest outcrop is a small cliff of limestone about 35 feet wide and 60 feet long that has 40 feet of vertical exposure. It also contains numerous small bodies of chert. The deposit is complexly folded and faulted, making it difficult to make any reliable estimate of the tonnage.

AREA NO. 2

Area No. 2 consists of seven exposures of limestone, mostly on the top and east side of a ridge forming the divide between Proctor Creek and a small western tributary. The limestone appears to form a series of lenticular beds striking northeast-southwest and dipping mostly at steep angles to the southeast. It is overlain in part by a bed of chert as much as 25 feet thick and is cut by andesite dikes. The limestone appears to be too broken up to comprise any major tonnage.

Several beds of limestone, mostly 10 feet or less in thickness, are exposed to the north, in the west side of the bottom of the canyon of Proctor Creek, just north of a junction with a small tributary entering from the west.

Quality.—Chert and argillaceous matter are common impurities in the Proctor Creek limestone deposits.

Chemical analyses of Proctor Creek limestone[1/]

Sample no.	Location	Sample length (ft.)	(in.)	$CaCO_3$	Loss on ignition	CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3	Remarks
Hole 3	Area 1 -----	29		73.50	30.85	43.30	1.42	22.32	0.87	1.41	
Hole 2	Area 1 -----	36		94.20	40.05	55.10	0.95	3.22	0.73	0.35	
Hole 3	Area 1 -----	25	6	83.2	35.93	48.26	1.03	13.24	0.51	1.67	Includes 9 in. chert.
Hole 3	Area 1 -----	26	6	56.9	27.87	35.08	13.18	26.59	0.87	7.65	Includes 9 in. chert and 7 ft. volcanics.
Hole 2	Area 1 -----	28	9	81.00	36.25	45.97	1.02	15.04	2.18	0.64	Includes 2 ft. 10 in. chert.
Hole 2	Area 1 -----	23	5	84.40	37.82	48.66	1.16	9.98	1.52	1.98	Includes 2 ft. volcanics.
No. 7	Area 1 -----	50		86.20							
No. 9	Area 1 -----	85		88.40							
No. 10	Area 1 -----	85		91.30							
No. 11	Area 1 -----	195		71.20							
No. 1	Area 2 -----	30		95.60							
No. 3	Area 2 -----	135		95.90							
No. 4	Area 2 -----	70		88.00							
No. 5	Area 2 -----	50		90.40							
No. 6	Area 2 -----	75		92.60							

1/ Unpublished analyses from private report.

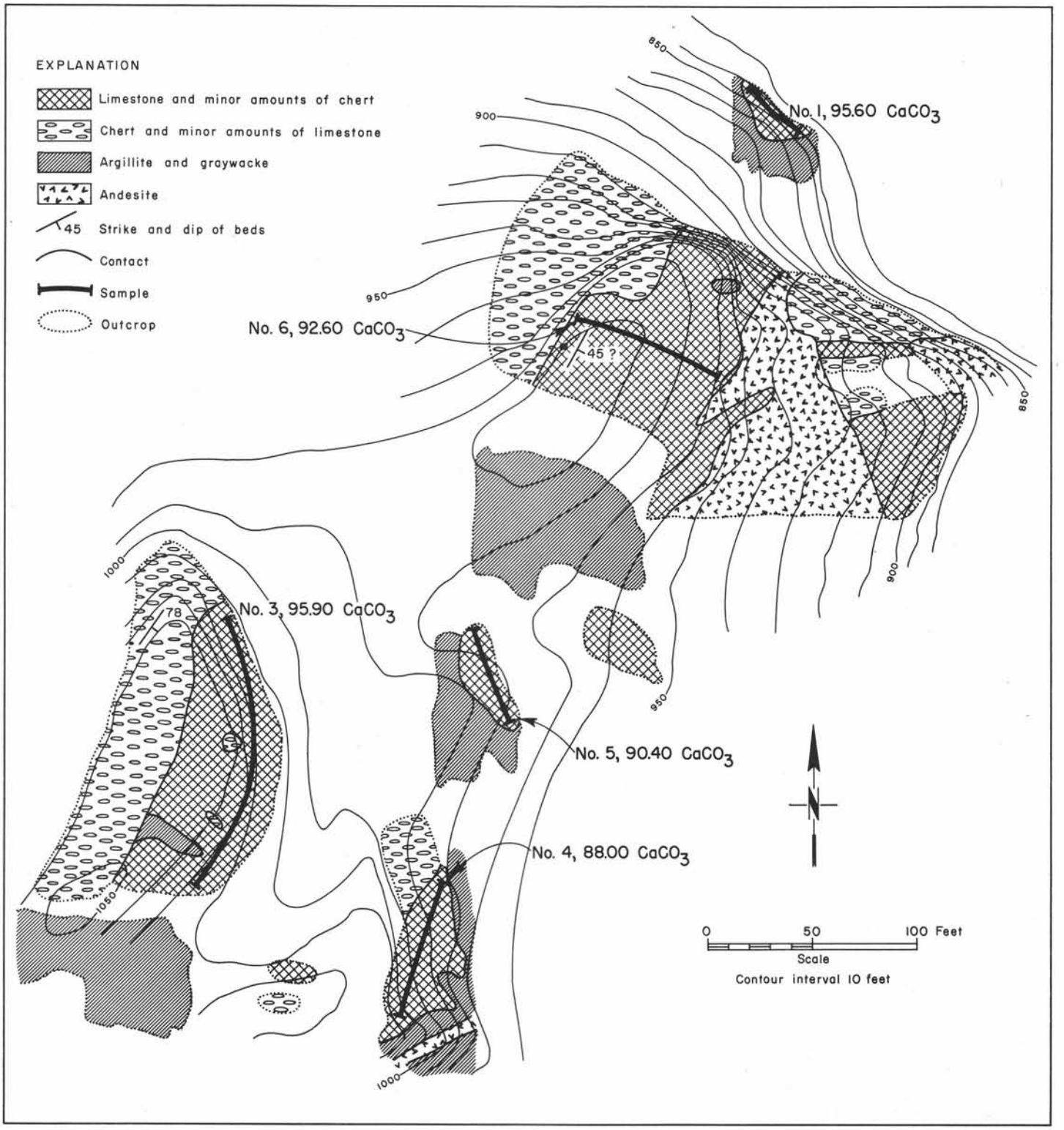


FIGURE 179.—Proctor Creek deposit, area No. 2. NE¼NE¼ sec. 21, T. 27 N., R. 9 E. Geology by W. R. Danner and K. Riely. Compass and tape survey. Courtesy of Ideal Cement Company.

Ownership and development. — The property is owned by the Northern Pacific Railway. There has been no development. The largest outcrop of area No. 1, on the Proctor Creek logging road, was diamond drilled in 1953. The deposits are too small to be of any great economic value, but they could supply a small operation for agricultural limestone and decorative stone.

Reference. — Danner (1957, p. 359-363).

Bonanza Queen Deposit

Location, size, and accessibility. — The Bonanza Queen limestone deposit is in the Bonanza Queen copper mine patented mineral claims in secs. 7, 8, 17, and 18, T. 30 N., R. 10 E., on Deer Creek about ½ mile north of Silverton, at an altitude of 2,400 feet. The deposit was not visited during this investigation. Walter L. Gonnason, geologist, reports (1959) that: "virtually 3 million tons of limestone has been blocked out by underground work and surface exploration."

The deposit is reached by a Forest Service road 1.3 miles east of Silverton that can be followed 2.5 miles up Deer Creek to a point approximately ½ mile east of the mine portal. An unused logging road and a short trail give access to the mine. The deposit is 26 miles east of Granite Falls, 45 miles from Everett, and 62.6 miles from Seattle by road.

Geology and description. — Gonnason gives the following description of the deposit:

> The work done on the property consists of a 1,000-foot tunnel on the 2,400-foot level, crosscutting the limestone property for 125 feet at the end of the tunnel. There is also a crosscut at the 1,000-foot station in the tunnel to the left, cutting about 80 feet of limestone, then a raise from the 2,400-foot level at the 1,000-foot station in the tunnel 300 feet to the 2,700-foot level, entirely in limestone. There is about 200 feet of drift on the 2,700-foot level in limestone, then a raise from the 2,700-foot level to the 3,000-foot level in limestone, then a drift on the 3,000-foot level northerly in a major shear zone (the old workings of the Bonanza Queen mine) to the surface in a steep mineralized canyon on the face of Long Mountain. This entire copper deposit is in a shear which cuts the limestone on a diagonal, so there is limestone on both sides of the shear, but my investigations have been on the southeasterly side of the shear. There is considerably more unexplored limestone to the northwest of the shear which I have not explored.

Beach (1962) made a study of the mine and described the country rock as belonging to the Canyon Creek "sedimentary series" (Permian), which contains basic volcanic rocks approximating basalt in composition. He states:

> Interbedded with the volcanics are relatively small lenses of limestone; one of the largest of these has served as host rock for the mineralizing solutions which precipitated the Bonanza Queen deposit. . . . the deposit is emplaced on the eastern edge of the marble lens. The entire lens is recrystallized due to heating, but in the central portion the alteration is conspicuously confined to 50 feet of its 125-foot width. Toward the edges of the lens (where it narrows), the skarn zone and the ore pods completely obliterate the marble. . . . On the lower level the marble is 125 feet wide and shows very sharp contacts with the basic hornfels country rock. Near the eastern edge of the marble are a series about 50 feet in width of zones of skarn rock with mixed marble. Each of these bands may be interpreted as a fracture zone which conducted ascending mineralizing solutions from the magma. . . . A large cavity occurs in the marble (middle level, 2,920 feet) about 40 feet west of the altered zone. This cavern is caused by solution and caving on the plane of a fault which dips approximately 70° to the west.

He describes the limestone as:

> . . . coarse-grained crystalline marble with a distinct black-and-white banding and a subtle gneissosity. The composition is relatively pure carbonate material with no obvious impurities. . . . 1 percent opaque minerals under microscope as disseminated grains; carbonate 98 percent, quartz 1 percent, sulfides 1 percent.

Limestone on the surface is limited to small lenses in a northwest-trending and offset silicified ore zone.

Quality. — Gonnason reports on the quality:

> Our analyses on this limestone average 97 percent calcium carbonate, with approximately 50 feet of width averaging over 98 percent calcium carbonate. Magnesium carbonate averages roughly 1.3 percent, but with the high-quality rock approximately 1 percent. The iron oxide averages 0.20 percent, with roughly 50 feet averaging 0.07 percent.

Ownership and development. — The property is owned (1962) by Byron L. Auker, 1650 Dry Creek Road, San Jose, Calif., and by Ralph A. Forbes, Arch Cape, Oreg. There has been no development of the limestone that has been intersected by underground workings of the Bonanza Queen copper mine. The limestone would have to be obtained by underground mining.

References. — Gonnason (1959, unpublished private report, 3 p.), Beach (1962, unpublished thesis, p. 16, 24-27, 82).

KING COUNTY

King County lies south of Snohomish County, is bordered by Puget Sound on the west, Pierce County on the south, and extends to the crest of the Cascade Mountains on the east. It is 50 to 60 miles in length east-west and about 30 to 48 miles in width. The western two-thirds of the county is lowland and foothills underlain by sedimentary clastic and volcanic rocks of Eocene, Oligocene, and Miocene age, covered in most places by glacial and interglacial deposits as much as 1,000 or more feet in thickness.

The eastern part of the county is rugged mountainous terrain underlain by igneous, sedimentary, and metamorphic rocks of Paleozoic, Mesozoic, and Cenozoic age. The greater part of the area is underlain by crystalline granitic rocks (mainly granodiorite, quartz diorite, and diorite) of Mesozoic and Cenozoic age.

Limestone occurs in two areas of the mountainous eastern part of the county, in metasedimentary rocks of Paleozoic age. One of these areas (Baring-Grotto) lies in the northern part of the county and extends about 6 miles south from the Snohomish County border. The limestones form crystalline lenses ranging in size from less than one ton to more than one million tons. Four of the largest and most easily accessible bodies have been quarried to supply a cement plant at Grotto. The quarries are now exhausted and abandoned, and none of the remaining, undeveloped limestone bodies appear to be of economic size or situated favorably enough to be developed in the mountainous terrain. About 16 miles due south of the Baring-Grotto area, just north and northwest of Snoqualmie Pass are two or more crystalline limestone bodies composing the second limestone area of King County. They crop out on Denny Mountain and Cave Ridge, and are interbedded in metasedimentary rocks and intruded by granitic rocks. Although they contain several million tons, their variable composition, relative inaccessibility, and high altitude in mountainous terrain make them uneconomic.

A few small pieces of limestone float have been found in river valleys draining the area between Grotto and Denny Mountain, but no limestone outcrops have been reported, and most of the area is underlain by granitic rocks.

Grotto Deposits

Location, size, and accessibility. — The Grotto limestone deposits form a north-south-trending belt in the W½ secs. 13, 24, and 25, T. 26 N., R. 10 E., between the south fork of the Skykomish River on the north and Money Creek on the south. This belt lies about 1½ miles southeast of the community of Baring and about 2 miles west of the village of Grotto.

The deposits consist of three relatively large limestone lenses that had a combined volume of over 2 million tons prior to quarrying, and more than 20 small pods and lenses ranging from exposures a few square feet in area up to bodies containing an estimated 200,000 tons.

All the limestone outcrops in the area were at one time or still are difficult of access. The Maloney quarry, during its operation, was approached by approximately 5 miles of gravel-surfaced road up Lowe Creek to an altitude of about 2,950 feet. From there it could be reached by 3,000 feet of tramline or by hiking up a narrow trail. The quarry was at an altitude of 4,300 feet on Maloney Mountain and was connected to the tram terminal by several hundred feet of truck road. The Marble quarries were accessible by about 4½ miles of steep and rough graveled road. These roads have not been maintained since quarrying ceased. Other outcrops can be reached only by following faint trails or by climbing the steep, rough, and densely forested slopes.

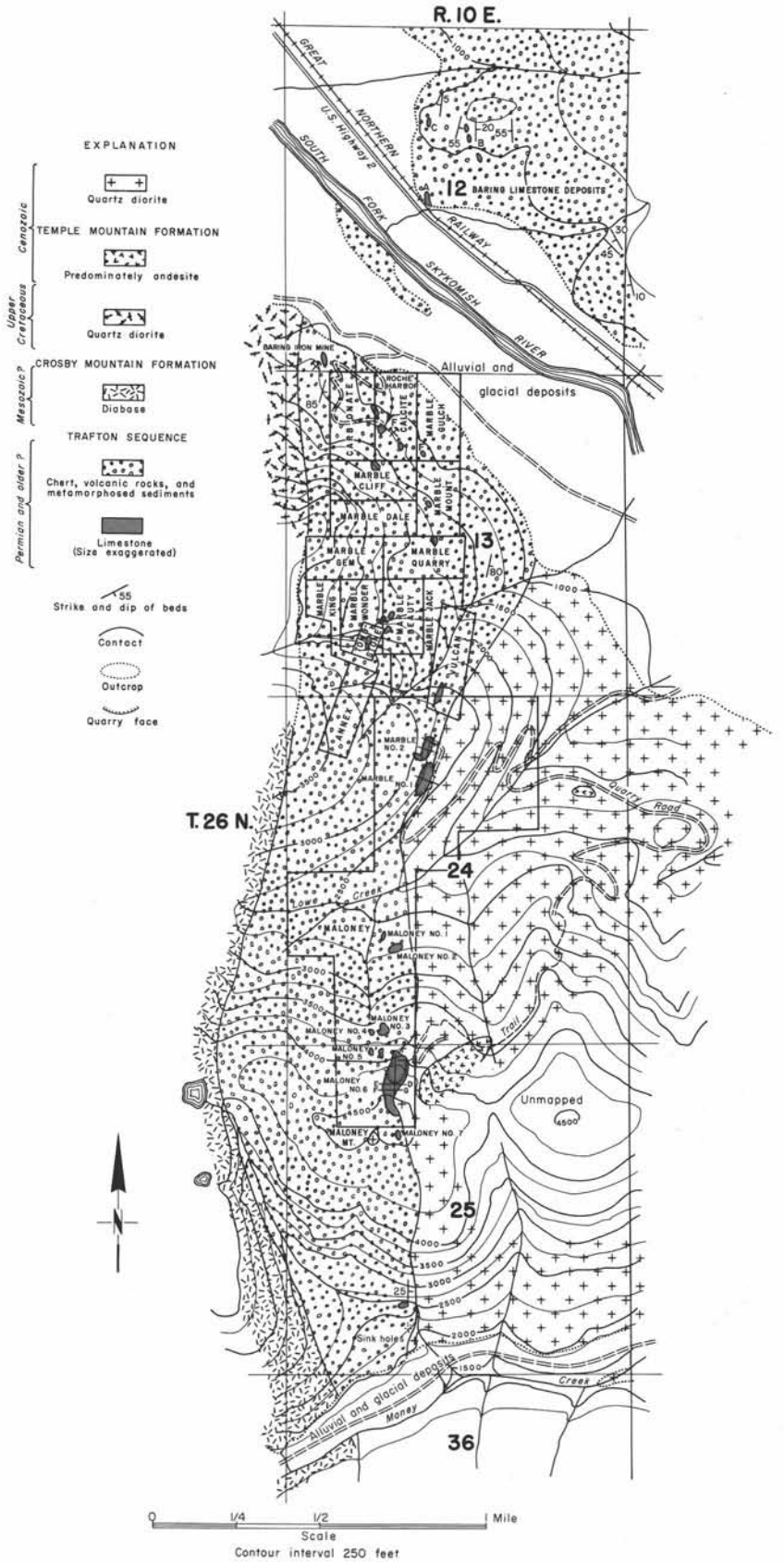


FIGURE 180.—Geologic map of limestone deposits of the Baring-Grotto area, King County. Secs. 12, 13, 24, and 25, T. 26 N., R. 10 E. Geology by W. R. Danner. Base map from U.S. Geological Survey Skykomish quadrangle.

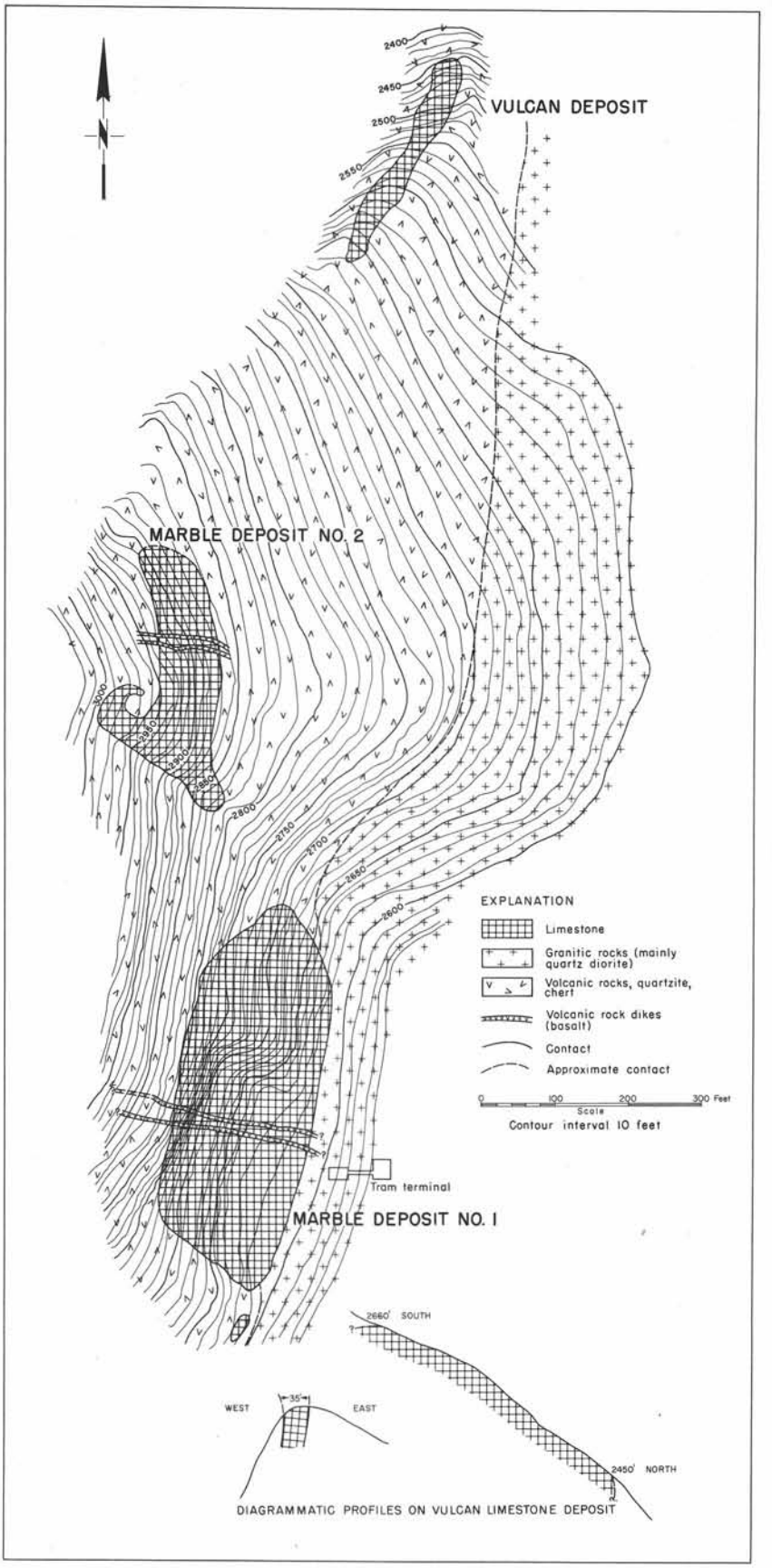


FIGURE 181.—Marble and Vulcan deposits, Grotto area. NW¼ sec. 24, T. 26 N., R. 10 E. Topography by J. L. McPherson, 1930. Geology by J. L. McPherson, 1930 and W. R. Danner, 1949. Map courtesy of Ideal Cement Company.

Relief in the deposit area is over 3,800 feet. The lower slopes have been logged, but the higher slopes are mostly still covered with virgin forests or patches of dense alder and devils club. The top of Maloney Mountain contains some alpine meadowland. Steep rock faces, cliffs, and narrow stream gorges are characteristic of the topography. Snow remains on the higher north slopes until late in July.

FIGURE 182.—Marble No. 1 deposit, Grotto area. Abandoned quarry. Marble No. 2 quarry lies over the shoulder of the hill to the right (north) of the quarry in this photograph. View looking northwest from lower terminus of Maloney quarry tramline, 1953. Only scraps of limestone remain on quarry face. Limestone is in contact with volcanic rocks to the west and diorite to the east.

the outcrop belt are intrusive contacts with quartz diorite. A lead-alpha age determination of this plutonic rock northwest of the limestone gave an age of 92 million years (Larsen and others, 1958, p. 43, 56), placing it in the Late Cretaceous. The diorite to the east is thought on geologic evidence to be of middle Cenozoic age, as it cuts lower Cenozoic volcanic rocks. Most of the western contact of the limestone-bearing sequence is with a diabase, but the exact nature of this contact is unknown.

The intrusion of the quartz diorite has recrystallized the limestone, and where it and the diorite are in contact, the limestone is composed of interlocking calcite crystals as much as an inch or more in diameter. Small pods of magnetite, including the variety lodestone; masses of crystalline brown garnet; and small amounts of pyrite and chalcopyrite occur along the contact and in adjacent sedimentary rocks. The limestone is cut by dikes of basalt, andesite, and diorite.

Geology and description.—The Grotto limestone deposits consist of a series of lenticular bodies of crystalline limestone interbedded with argillite, impure quartzite, ribbon chert, and altered volcanic rocks. The limestone-bearing sequence crops out in a north-south belt about 2 miles long and $\frac{1}{2}$ mile wide between the south fork of the Skykomish River on the north and Money Creek on the south. The rocks composing the outcrop belt strike approximately parallel with it. They are complexly folded, cut by numerous faults, and cut also by dikes of volcanic and plutonic rocks. The eastern and northwestern sides of

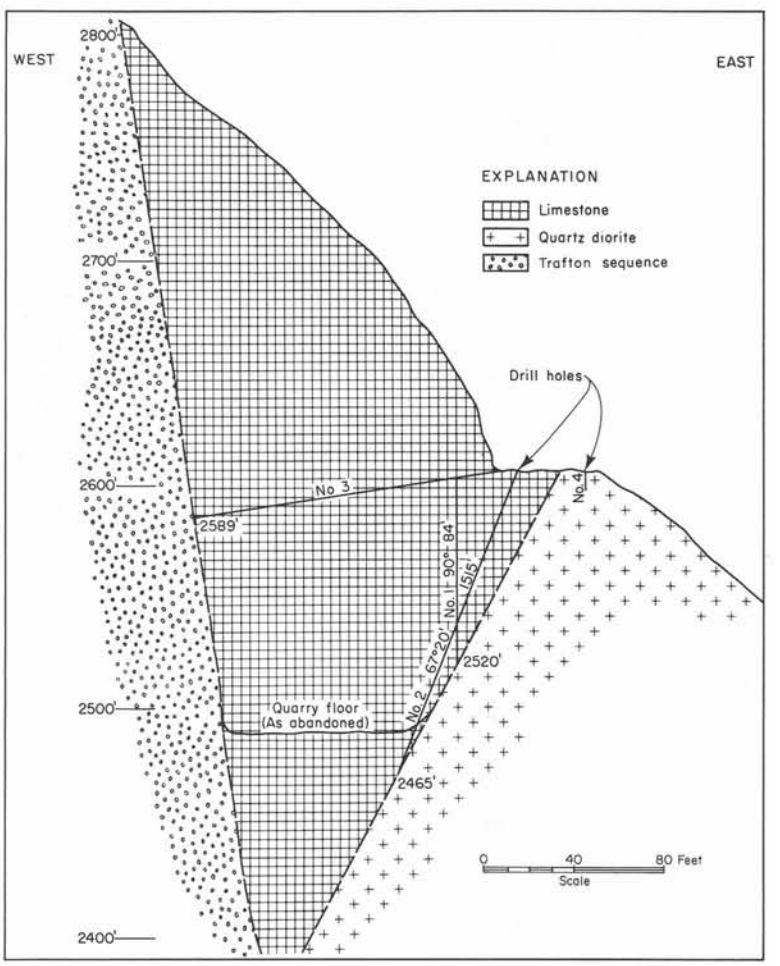


FIGURE 183.—East-west cross section of Marble No. 1 deposit, Grotto area. After 1930 survey by J. L. McPherson. All limestone above the quarry floor was quarried some time prior to 1945. Courtesy of Ideal Cement Company.

The limestone-bearing sequence was first described by Smith (1915, 1916), who collected Ordovician fossils from an outcrop near Lowe Creek. However, the writer has found Permian fusulinids and crinoid columnals of undetermined age preserved in the limestone bodies farther north. These rocks are tentatively assigned to the Trafton sequence, a widespread limestone-bearing Permian sequence cropping out in northwestern Washington.

Description of individual outcrops

MARBLE NO. 1 QUARRY

The first limestone outcrop to be quarried was the Marble No. 1, and the quarry site has been abandoned for several years. A lake 25 to 30 feet in depth occupies most of the quarry floor. The limestone body was about 450 feet long and 150 feet wide, and it was quarried vertically for about 200 feet on the steep mountainside. On its east contact it is intruded by diorite and contains a skarn zone consisting of massive garnet about 1 foot thick. The contact is almost vertical and strikes slightly east of north. The rock on the west side of the limestone is an altered basic volcanic rock that resembles a fine-grained black quartzite in appearance. Two prominent basalt dikes cut across the quarry in an east-west direction. Dikes are present elsewhere and range from mere stringers to bodies almost 5 feet in width. Reaction borders of grossularite and andradite garnets, tremolite, clinozoisite, wollastonite, and small specks of pyrite occur along the dikes (Knowles, 1938).

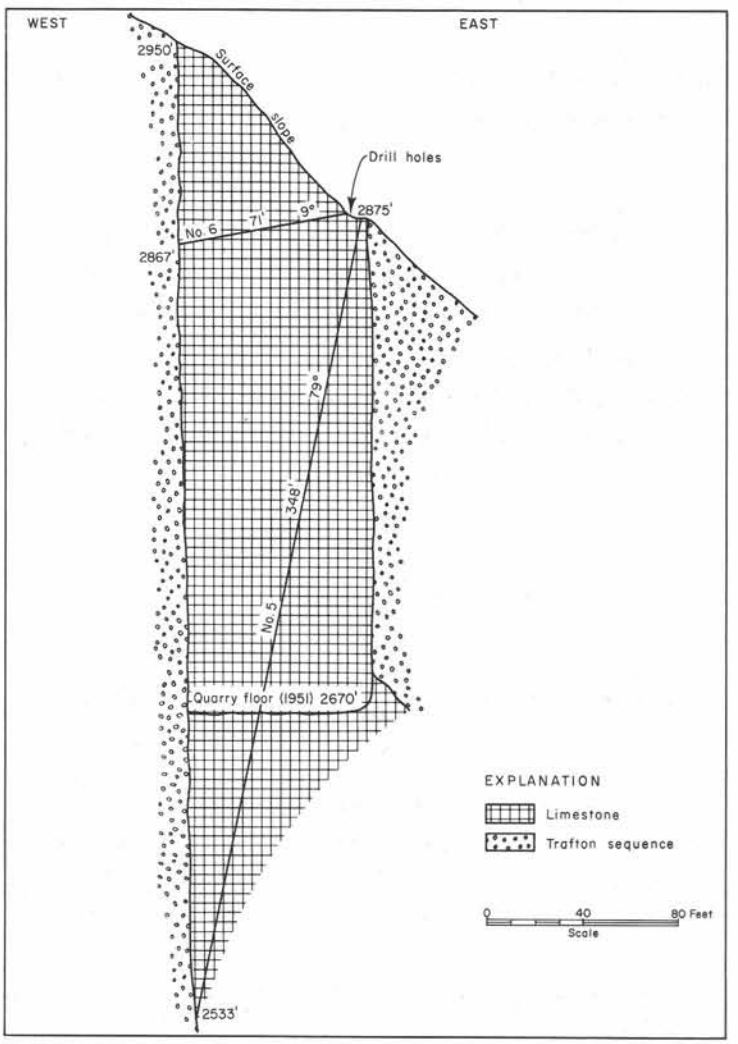


FIGURE 184.—East-west cross section, middle of Marble No. 2 deposit, Grotto area. After 1930 survey by J. L. McPherson. Courtesy of Ideal Cement Company.

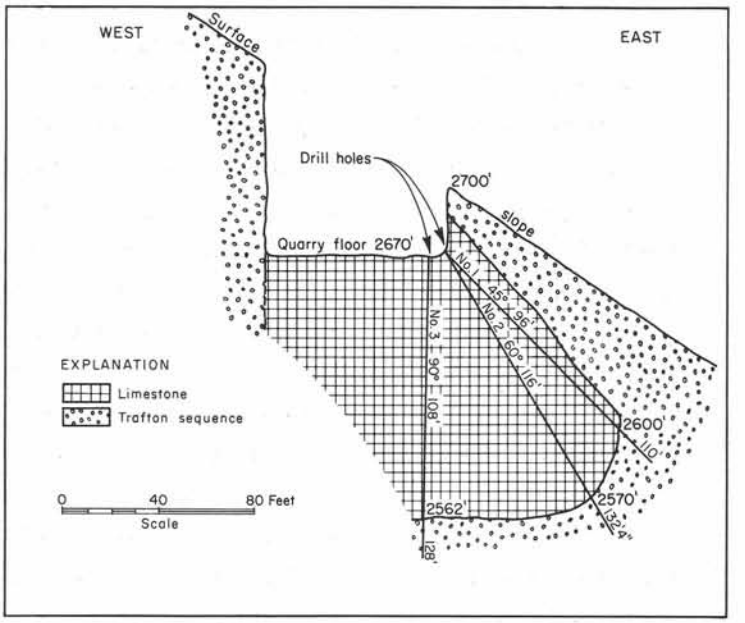


FIGURE 185.—East-west cross section of Marble No. 2 deposit, north end. 1951. Courtesy of Ideal Cement Company.

Almost all the limestone of this deposit has been removed, and at the north and south ends of the quarry only scraps of it remain, covered with as much as 10 feet or more of talus and slide material. Drilling in 1930 indicated that the limestone body became narrower with depth.

The limestone is bluish gray to light gray in color and fine to medium crystalline in texture. Faint outlines of large crinoid stems are visible where the recrystallization has not been too severe.

MARBLE NO. 2 QUARRY

The Marble No. 2 quarry is about 200 feet northwest of Marble No. 1. This quarry can be aptly described as a deep narrow trough. The west wall is nearly 300 feet high; the east wall is somewhat lower. The quarry is about 300 feet long and about 60 feet wide. The limestone body is nearly vertical and has a steep westerly dip near the top and a steep easterly dip near the bottom. The west wall consists of an altered basic volcanic rock, and the east wall is impure quartzite. As indicated by drilling done at the northeast end of the quarry in 1951, limestone extends eastward under the hillside for a maximum horizontal distance of 80 feet, about 70 feet below the quarry floor of that date. A vertical hole went out of limestone at 108 feet below the quarry floor. This drilling was done from approximately the same position on the quarry floor as the former drilling and was all in the same east-west vertical plane; therefore, it does not show how far to the north or south these measurements would hold true.

Small amounts of pyrite and chalcopyrite occur along the west contact of the limestone,and the oxidation of the iron in these minerals has colored the wall rock a rusty brown. This oxidation is pronounced along several minor shear zones. One fault of small displacement is exposed on the west wall of the quarry near the entrance.

The limestone is coarsely to finely crystalline in texture and white to bluish gray in color. Much of it is banded. Two small dikes about 6 inches wide extend east-west across the quarry in its central part. They dip southward, and the northern dike thins to the east and almost disappears in the east wall. Both dikes consist of a fine-grained greenish-black volcanic rock.

This quarry had to be abandoned when it became too dangerous to work, because of its narrow bottom and high vertical walls. The tonnage of limestone remaining in the quarry floor is small and uneconomic to obtain.

VULCAN CLAIM

The Vulcan limestone outcrop lies about 400 feet northeast of the Marble No. 2 quarry. It can be reached by following downslope the brink of the deep gully on the northwest side of the quarry entrance. The deposit consists of a narrow body of banded bluish-gray finely crystalline limestone that is exposed for about 300 feet north-south and has a maximum width of 40 feet. There is an altitude difference of 100 to 150 feet between the north and south ends of the outcrop. The limestone stands vertical and is bordered on each side by impure quartzite, which is probably formed of metamorphosed chert. The limestone is poorly exposed and is covered with virgin forest. It would be a difficult body to quarry, and because of its small size is probably uneconomic.

ANNEX CLAIM

The Annex claim contains small amounts of limestone float, but the writer did not find any limestone outcrops.

TOMBSTONE CLAIM

The Tombstone claim contains a pod of white crystalline limestone about 8 feet wide and nearly 100 feet long.

MALONEY NO. 1 DEPOSIT

The Maloney No. 1 deposit consists of a small limestone pod cropping out below Maloney No. 2, south of the Marble quarries on a steep hillside. The quantity of limestone is unknown. It was mapped in 1930 by J. L. McPherson as a lens-shaped body 150 feet long that has a maximum width of about 50 feet and lies between 2,740 and 2,820 feet in altitude.

MALONEY NO. 2 DEPOSIT

The Maloney No. 2 deposit is a limestone lens of about 20,000 tons lying between 2,830 and 2,920 feet in altitude on a steep hillside. Its length northeast-southwest is about 160 feet, and its maximum width is 70 feet. Contacts with bedrock are visible only on the south and east sides. The outcrop is below a talus accumulation on the hillside, and this material would tend to slide onto any quarry site. The limestone is cut by at least one dike of volcanic rock, about 9 inches wide. Chert and massive garnet occur as impurities within the limestone.

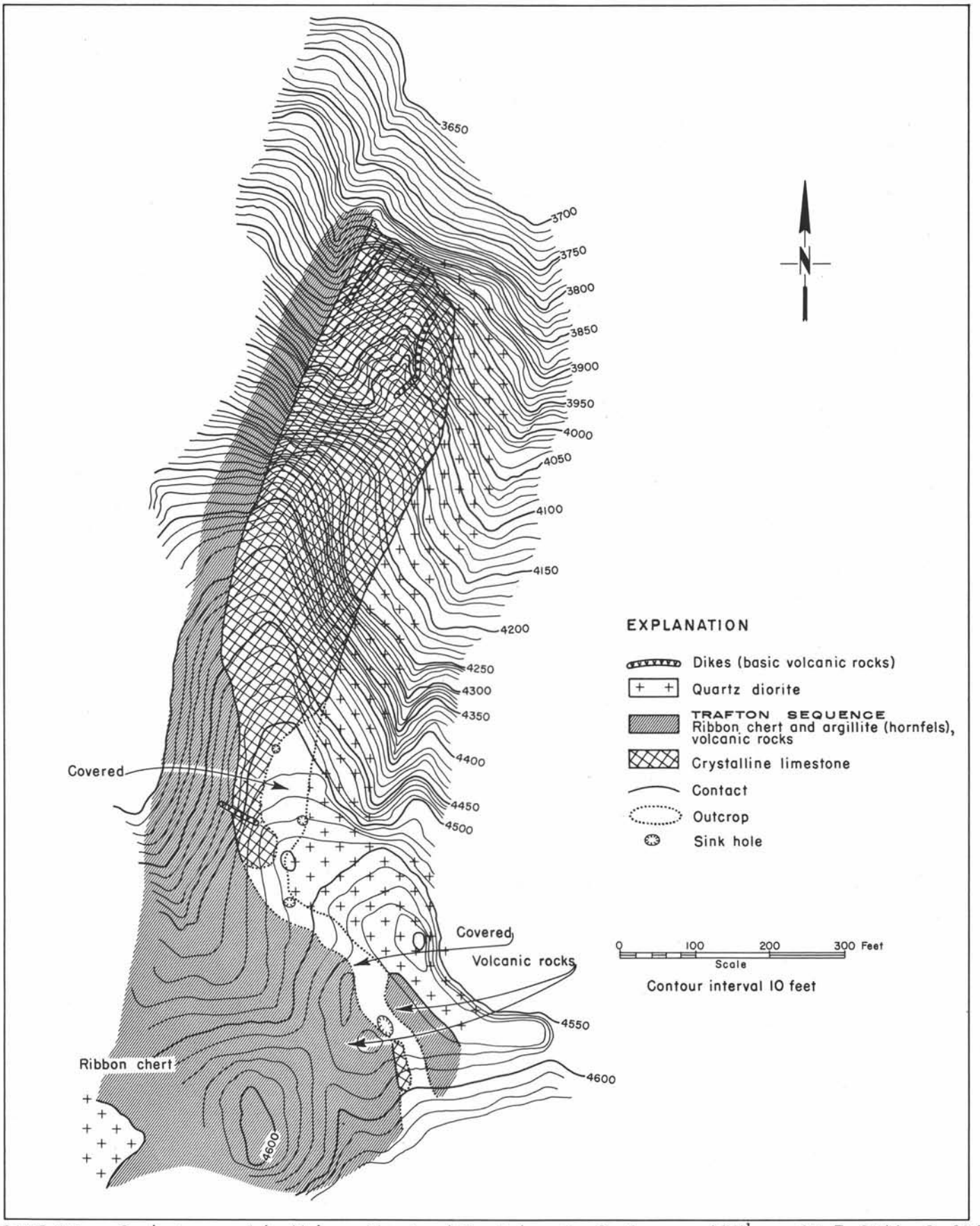


FIGURE 186.—Geologic map of the Maloney No. 6 and No. 7 deposits, Grotto area. NW¼ sec. 25, T. 26 N., R. 10 E. Topography and geology by J. L. McPherson, 1924-1930. Geology modified by W. R. Danner, 1949-1953. Courtesy of Ideal Cement Company.

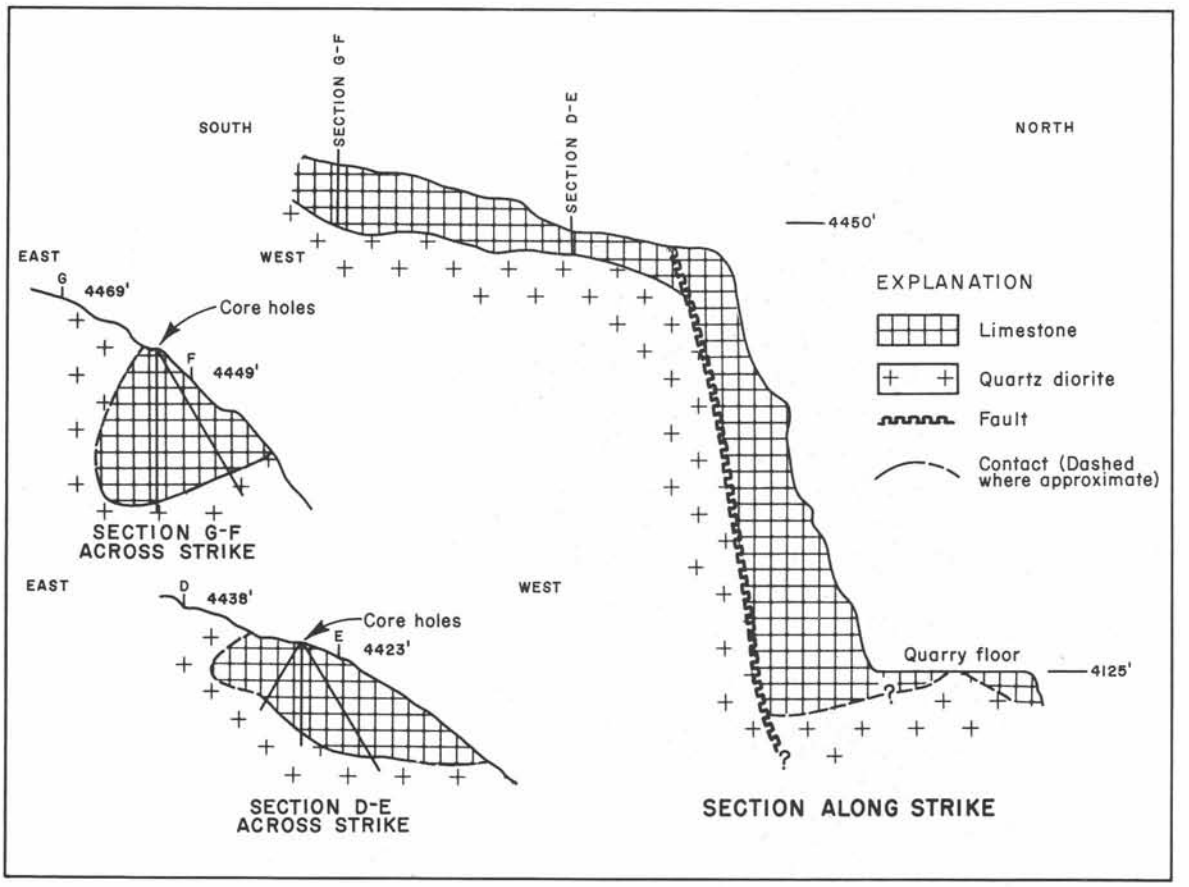


FIGURE 187.—Geologic cross sections indicated by drilling of the Maloney No. 6 deposit. By Carl N. Anderson, 1953. Courtesy of Ideal Cement Company.

MALONEY NO. 3 DEPOSIT

The Maloney No. 3 deposit is a small limestone lens exposed on a cliff face. It is estimated to contain about 50,000 tons but is in a poor location for quarrying.

MALONEY NO. 4 DEPOSIT

The Maloney No. 4 deposit is a small outcrop about 50 feet wide and 75 feet long at an altitude between 3,700 and 3,720 feet.

MALONEY NO. 5 DEPOSIT

The Maloney No. 5 outcrop, as mapped by McPherson, is about 125 feet wide and 200 feet long, lying between 3,790 and 3,900 feet in altitude.

MALONEY NO. 6 DEPOSIT

The Maloney No. 6 deposit is the largest of the Maloney group. It is about 600 feet long and 150 to 200 feet wide in outcrop. Private surveys of 1930 and 1949 indicated a volume of from 4 to 7 million tons on the basis of an extension with depth similar to that of the Marble quarries. The exposed vertical extent is about 500 feet.

The deposit was drilled in 1952, after about 500,000 tons of limestone had been quarried. It was determined from this drilling that the total volume of limestone would be somewhat less than 1 million tons and that the deposit had a depth of less than 50 feet, south along strike. The supposed extension with depth was occupied by an intrusion of quartz diorite. The

east contact of the deposit is with intrusive diorite, and the contact at high altitudes dips about 65° W. Lower down, the dip changes to about 30° E. The east contact contains a zone from a few inches to 3 feet in width composed of massive garnet and small pods of magnetite. The wall rock on the west side of the quarry is a hard brittle impure quartzite cut by several quartz diorite dikes. The contact dips about 85° E. When the limestone was blasted, large masses of this western wall rock would break loose and slide down onto the quarry floor, covering the limestone. The quarry thus became uneconomic and was abandoned.

At least three volcanic rock dikes cut the limestone, and as the quarry floor was advanced southward the limestone became narrower and one of these dikes on the east side of the deposit approximately doubled in width.

The limestone is light gray to bluish gray in color, and along the east side near the intrusive quartz diorite contact is coarsely crystalline in texture. It becomes finer grained to the west.

FIGURE 188.—Maloney quarry, Maloney deposit No. 6. View looking southwest, 1953. Wall rock on west, or right, side of quarry was sliding down onto the quarry floor in July 1953.

MALONEY NO. 7 DEPOSIT

Maloney No. 7 is a small outcrop in a gully on the south side of Maloney Mountain. The limestone body is 10 to 12 feet wide and 40 feet long. It is in contact with volcanic rocks on the west side, the contact dipping 60° W. Soil covers the east contact, but volcanic rocks crop out a few feet farther east. The limestone is coarsely crystalline in texture. A line of sinkholes lies between this outcrop and Maloney No. 6, to the north, so it is thought that the two outcrops may be connected under the soil cover. The outcrop area of Maloney No. 7 contains only a few hundred tons of limestone.

Quality.—The limestone of the Grotto deposits has been recrystallized, and in most outcrops is medium to coarsely crystalline in texture. Masses of chert or jasperoid and intrusive dikes form visible impurities. Where free of these materials, the limestone is mostly high in calcium.

Ownership and development.—The property is owned by Ideal Cement Company, Denver National Building, 821 17th Street, Denver, Colo. The deposits may have been discovered first by John Maloney, a prospector. Limestone was reported in the area by Kennery Byron and J. D. Rudderman in 1907. J. L. McPherson, Civil Engineer, surveyed the area of the deposits between 1925 and 1930. Descriptions of the regional geology were published in 1915 and 1916 by Warren S. Smith.

The Northwestern Portland Cement Company was incorporated on February 16, 1926, and bought the property for a reported price of $146,000. A cement plant was built in the Skykomish River valley, and the community of Grotto was established. The cement plant began operation in May 1928. The Marble quarries were operated first, and an aerial tram connected them to the plant, 9,000 feet to the east. The quarries are at an altitude of about 2,500 feet and were operated only during the summer months, enough limestone being stockpiled to enable the plant to run on the surplus during the winter.

About 1940 it was realized that the Marble quarries would soon become expensive and dangerous to operate and that they were also nearing exhaustion, so attention was turned to the Maloney No. 6 limestone body, situated to the southeast at an altitude of about 4,300 feet. Surveying of it began on July 17, 1945, and the first shot was set off at the Maloney quarry on August 19, 1948.

Chemical analyses of Grotto limestone and diorite

Sample	Location	Loss on ignition	$CaCO_3$	CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3	Na_2O	K_2O
1/ ----------	Unknown	42.15		55.00	1.63	0.18	0.20	0.24		
1/ ----------	-- do --	42.40		52.00	1.60	3.00	0.50			
1/ ----------	-- do --	43.07		54.32	1.73	0.02	0.37	0.05		
							R_2O_3			
White, finely crystalline 2/	-- do --	43.86	95.18	53.30	1.98	0.40	0.16			
Dark gray, finely crystalline 2/	-- do --	40.92	95.32	53.38	1.30	2.64	1.52			
							Fe_2O_3	Al_2O_3		
Diorite, east side Maloney No. 6 3/	-- do --	2.20		11.16	6.43	48.67	10.64	19.54	2.40	0.28

1/ Hodge (1938, p. 76).
2/ Shedd (1913, p. 235). A. A. Hammer, analyst.
3/ Ideal Cement Company.

The Marble quarries through 1946 produced 1,461,644 tons of limestone. When the Maloney quarry was abandoned in 1952 it had produced over 500,000 tons. The company then developed a quarry at Soda Springs, on the east side of the Cascade Mountains in Chelan County. In 1957 the Northwestern Portland Cement Company was purchased by the Ideal Cement Company.

The Grotto limestone deposits are now considered to be exhausted, and, except for a few small untouched bodies of limestone between the abandoned quarries, the area appears to have no future value for limestone production. The smaller bodies might be economical and produce a few thousand tons of limestone if reached by logging road, but the deposits themselves are not large enough to justify the construction of access roads or tram lines.

References.— Landes (1906, p. 380), Shedd (1913, p. 234-235), Smith (1915, p. 156-157; 1916, p. 559-582), McPherson (1930, unpublished private report), Glover (1936, p. 55), Hodge (1938, p. 69-70; p. 73-75), Knowles (1938), Northern Pacific Railway Co. (1941, unpublished notes, p. 13), Mathews (1947, p. 43), Larson and others (1958, p. 43,56).

Claims on Palmer Mountain

The limestone claims on Palmer Mountain are mostly on a northeast part of the mountain, in an area of extremely rugged topography containing many rock cliffs and deep canyons. The limestone bodies form a northerly extension of the Grotto deposits.

Description of individual deposits

BARING IRON MINE

The Baring iron mine deposit consists of a body of limestone about 10 feet wide, exposed vertically on a cliff face for nearly 100 feet. Extensions to the north and south are covered with soil and talus. The outcrop is near a contact between

intrusive quartz diorite and the limestone-bearing Paleozoic sedimentary and volcanic rock sequence. The limestone is white in color and coarsely crystalline in texture. Small veins of magnetite occur within the limestone near its western contact. About 50 feet to the southwest is an adit of the old Baring iron mine. An outcrop of magnetite 20 feet wide and 10 feet high is exposed at the adit entrance.

The deposit is southwest of and below the second western switchback of the logging road in the SW$\frac{1}{4}$ sec. 12, but is difficult to find.

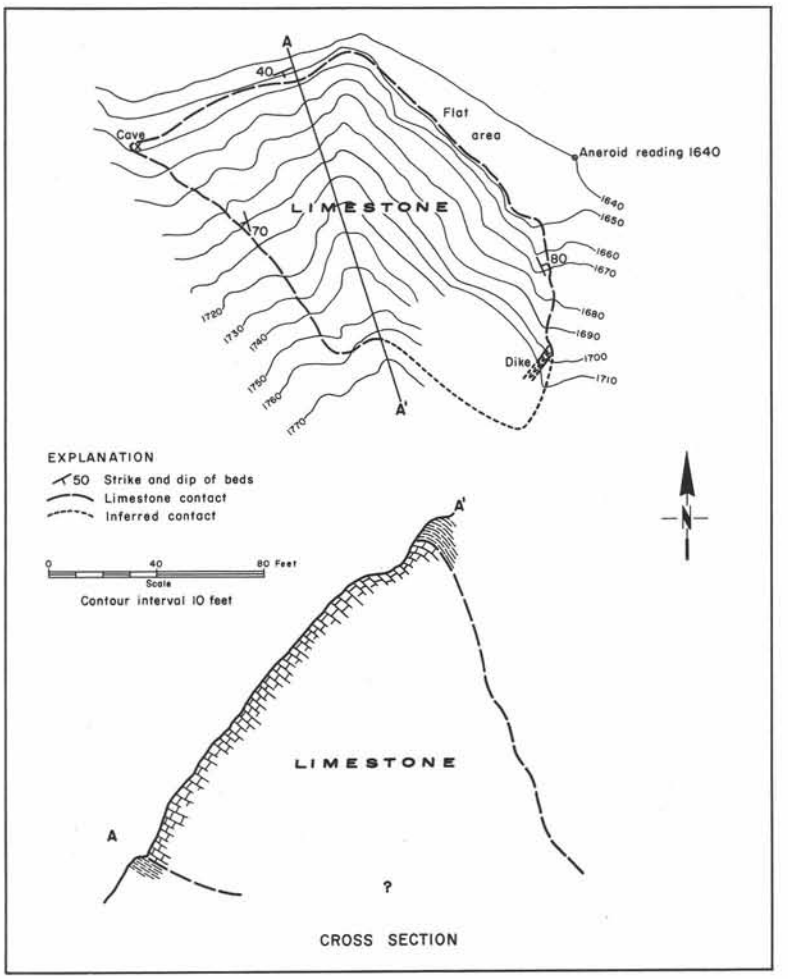


FIGURE 189.—Calcite placer claim, Roche Harbor deposit, on Palmer Mountain, Grotto area. NW$\frac{1}{4}$ sec. 13, T. 26 N., R. 10 E. Geology by W. R. Danner, 1953. Compass and tape survey. Map prepared before deposit was quarried.

CALCITE PLACER CLAIM (ROCHE HARBOR DEPOSIT)

The Calcite claim contained the only outcrop of limestone in the Palmer Mountain group of deposits that was suitable for quarrying. It was a lens of slightly more than 40,000 tons that was quarried in 1953 to supply the cement plant at Grotto. The limestone body was accessible by about 5 miles of road, the last $\frac{1}{2}$ mile of which was rough quarry access road.

The outcrop is on a northwesterly spur of the northeastern side of Palmer Mountain. The limestone strikes about N. 15° W. and dips steeply to the northeast. It ranges from black to dark bluish gray to white in color and is finely crystalline in texture. Poorly preserved small crinoid columnals were found in the limestone, but no fossils diagnostic of age were discovered. The limestone is overlain and underlain by metavolcanic rocks, chert, and cherty argillite. Before it was quarried the deposit contained some small solution cavities.

A second, smaller limestone lens is exposed on a cliff 500 to 600 feet to the east. It is 30 to 40 feet long and 10 feet wide. Limestone float on the steep hillside indicates other small limestone bodies in the vicinity.

CARBONATE PLACER CLAIM

Many tiny pods and lenses of limestone are exposed over the surface of this claim. The largest one examined is exposed for 50 feet vertically and is 35 feet wide. Drilling in 1954 showed that it has a depth of less than 20 feet back into the hillside. The limestone is similar to that of the Calcite placer claim (Roche Harbor deposit), 150 feet above and to the southeast. The limestone is badly fractured, and the deposit is estimated to contain between 2,000 and 3,000 tons.

MARBLE BEAUTY CLAIM

Four small outcrops of limestone are in a steep-sided gully on the Marble Beauty claim. The total volume of limestone is less than 500 tons. Two of the outcrops are on the north side of the gully, and two are on the south side. Those on the south side are not more than 8 feet wide. The outcrops on the north side are exposed at the base of an almost vertical rock

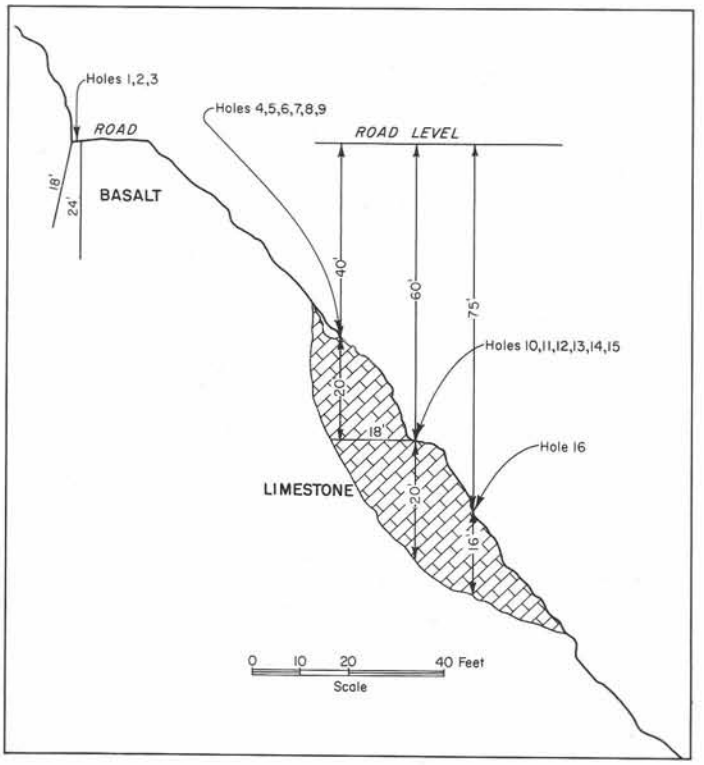


FIGURE 190.—Carbonate placer claim on Palmer Mountain. Cross section by J. Halloran as determined by drilling, 1954. Courtesy of Ideal Cement Company.

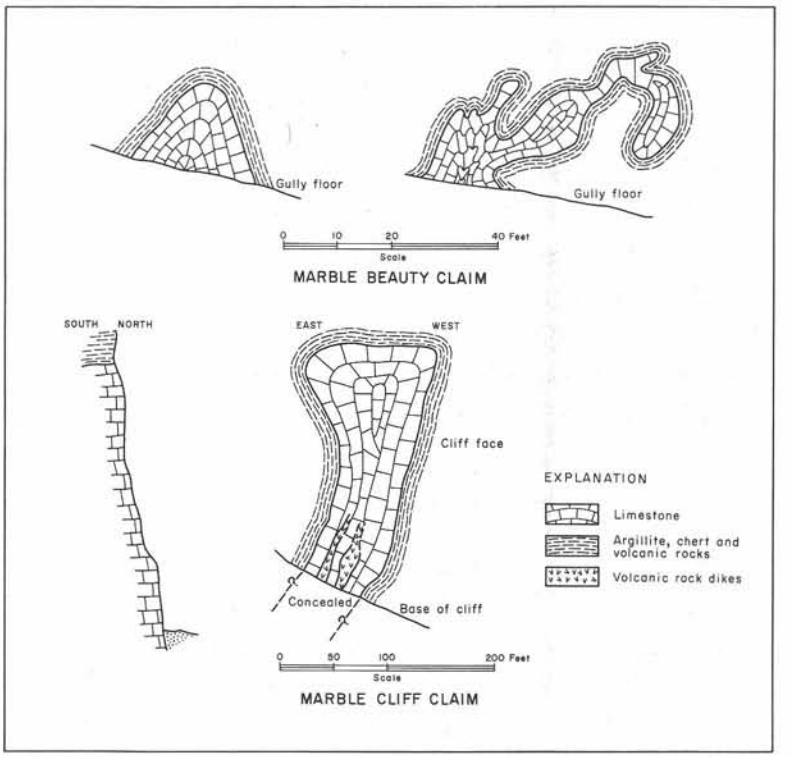


FIGURE 191.—Sketches of limestone outcrops on cliff faces, Marble Beauty and Marble Cliff claims, Palmer Mountain, Grotto area. W½ sec. 13, T. 26 N., R. 10 E. W. R. Danner. Courtesy of Ideal Cement Company.

face and consist of small folded limestone lenses, the largest of which is 20 feet wide at the base and extends vertically for about 20 feet. Old prospect pits have been sunk into the limestone outcrops.

MARBLE DALE CLAIM

On the Marble Dale claim no limestone outcrops are known to the writer. The area is composed of cliffs accessible only with great difficulty.

MARBLE CLIFF CLAIM

On the Marble Cliff claim is an outcrop of limestone that is flush with the face of a nearly vertical cliff. It is estimated to be not over 200 feet high, and its width is about 100 feet at the widest point. Its depth into the mountainside is unknown. The deposit is cut by at least two large dikes of volcanic rock near the base and is overlain by cherty argillite and volcanic rock. It is not large enough for underground mining and could not be quarried economically.

MARBLE GEM CLAIM

The Marble Gem claim extends over a relatively flat, soil-covered spur of Palmer Mountain. No outcrops or float specimens of limestone were found.

MARBLE GULCH CLAIM

Two small outcrops of limestone are on the Marble Gulch claim. One consists of an exposure of limestone about 5 feet high and 10 feet wide that is at the base of a cliff in a gully. The other is an exposure extending over about 100 square feet of the gully bottom a few feet below the first. The outcrops are too small to be of economic value. Limestone float in this gully below the outcrops contains poorly preserved Permian fusulinids.

MARBLE JACK CLAIM

The area of the Marble Jack claim consists of heavily forested cliffs. No limestone outcrops were found.

MARBLE KING CLAIM

On the Marble King claim there are no outcrops of limestone known to the writer. No limestone float was found.

MARBLE MOUNT CLAIM

Small limestone lenses are in a cliff area on the Marble Mount claim, but none of them are large enough to be of economic value. Limestone float is common. The claim is not easily accessible.

MARBLE QUARRY CLAIM

One small limestone lens flush on a cliff face near the top of a northeast spur on Palmer Mountain is included within the area of the Marble Quarry claim. It is poorly exposed and covers less than 100 square feet. Limestone float is present over the claim in small amounts.

MARBLE WONDER CLAIM

Over the area of the Marble Wonder claim no outcrops or limestone float were found by the writer.

Quality. — Because of the small size of most of the limestone bodies on the claims of the Palmer Mountain area, little study of their quality has been made. Some are high in calcium, but others are high in magnesia or contain silica in the form of chert and jasperoid.

Chemical analyses of Palmer Mountain limestone

(Analyses by Ideal Cement Company)

Location	Sample length (feet)	$CaCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3
Marble Cliff claim	50	94.54	42.40	52.14	3.64	1.18	0.36
Roche Harbor deposit --------	100	94.97	42.00	52.97	2.76	1.48	0.54
Carbonate placer claim ---	35	96.92	43.15	54.45	0.04	0.90	0.40
Carbonate placer claim ---	---	97.60	43.41	54.64	0.22	0.96	1/ 0.48
Carbonate placer claim ---	---	97.80	43.42	54.80	0.32	1.00	2/ 0.28

1/ $Fe_2O_3 = 0.13$, $Al_2O_3 = 0.35$.
2/ $Fe_2O_3 = 0.07$, $Al_2O_3 = 0.21$.

Ownership and development. — The 12 claims of this area are known collectively as the "Marble Placers," and were owned in 1925 by John McMillin, of the Roche Harbor Lime and Cement Company. At present (1963) only the Carbonate placer and Calcite placer claims are owned by the company. The Marble Gulch, Marble Cliff, Marble Dale, and Marble Mount claims are owned by the United States Government. The Marble Gem, Marble Quarry, Marble Wonder, Marble Beauty, Marble Jack, and Marble King claims are owned by King County.

The Baring iron mine was operated for a brief period many years ago, and the magnetite ore was taken to the Great Northern railroad at a point about where the Baring limestone deposit crops out. The land on which it is located is owned by R. Stanley Anderson, of 5313 Hohman Avenue, Hammond, Ind.

Much of the area contains rocks impregnated with pyrite and coated on the outside with iron oxides and hydroxides. Small prospect pits and adits are everywhere on the mountainside, along with the ruins of old log cabins connected by faint trails now largely overgrown by vegetation or destroyed during logging operations.

The Roche Harbor deposit of the Calcite placer claim was quarried in 1953 and produced about 40,000 tons of limestone, which was trucked to the cement plant at Grotto. Some of the limestone in this quarry has a finely crystalline, dark bluish gray matrix containing small white fossil crinoid columnals, and when this rock is polished it makes an attractive decorative stone.

In 1925 a brochure was circulated, estimating the claims on Palmer Mountain to contain limestone totaling 20 million tons; the "calcite and carbonate outcroppings occur 600 feet above the river, showing exposures estimated at 1,500 feet in height," according to this brochure. A detailed geologic study of the area by the former Northwestern Portland Cement Company indicated that, except for the Roche Harbor deposit, none of the limestone bodies is large enough to be economic under present conditions.

References.—McMillin (1925, advertising brochure), Danner (1950, unpublished private report).

Money Creek Deposits

Well-rounded fragments of black finely crystalline limestone as much as 10 inches in diameter occur in the bed of Money Creek from its tributary, Kimball Creek, up to Goat Basin. Similar-appearing limestone float occurs to the southwest, on the northeast side of Goat Basin. Galster (1956, p. 20) reports several small lenses of limestone south of Money Creek. Two small pods of crystalline limestone were found exposed in a stream bottom estimated to be a little east of the center of the SW$\frac{1}{4}$ sec. 25, T. 26 N., R. 10 E. These pods are interbedded in volcanic rocks and dip about 25° E. into the streambed. The upper pod is about 6 inches thick; the lower, which is only partly exposed, has a minimum thickness of 3 feet. The two bodies extend up dip to the west bank of the stream, where they thin and pinch out between layers of metamorphosed chert.

Baring (Skyko Camp) Deposits

Location, size, and accessibility.—Approximately 2 miles northwest of Grotto, the Baring limestone deposits are along the Great Northern Railway tracks and Bonneville-Grand Coulee-Chief Joseph electric transmission lines in the N$\frac{1}{2}$ and central part of sec. 12, T. 26 N., R. 10 E., north of the South Fork of the Skykomish River.

The deposits consist of three small beds of limestone: Deposit A, 50 feet thick and at least 75 feet in length, which has a minimum of 4,500 tons exposed; Deposit B, 10 feet thick, which crops out discontinuously for a length of 300 feet; and Deposit C, which is one small exposure of 24 cubic feet.

The outcrops are easily accessible and are from about 100 feet to 800 feet north of U.S. Highway 2. Deposit A is exposed in a railroad cut, and Deposits B and C are along a rough bulldozed track following the power transmission lines. In the outcrop area, rounded glacier-polished knobs of bedrock project through a thick cover of soil and glacial drift. Most of the area has been logged and is now covered with an exceptionally dense second growth of trees and brush.

Geology and description.—The Baring limestone deposits consist of small lenticular beds of crystalline limestone interbedded with ribbon chert and cherty argillite mostly metamorphosed to quartzite, and basic volcanic rocks now metamorphosed to schists. The sequence is correlated to the Permian Trafton sequence but may contain some rocks of older age. The Baring limestone deposits are a northern continuation along strike of the limestone of the Lowe Creek area (Grotto deposits) to the south.

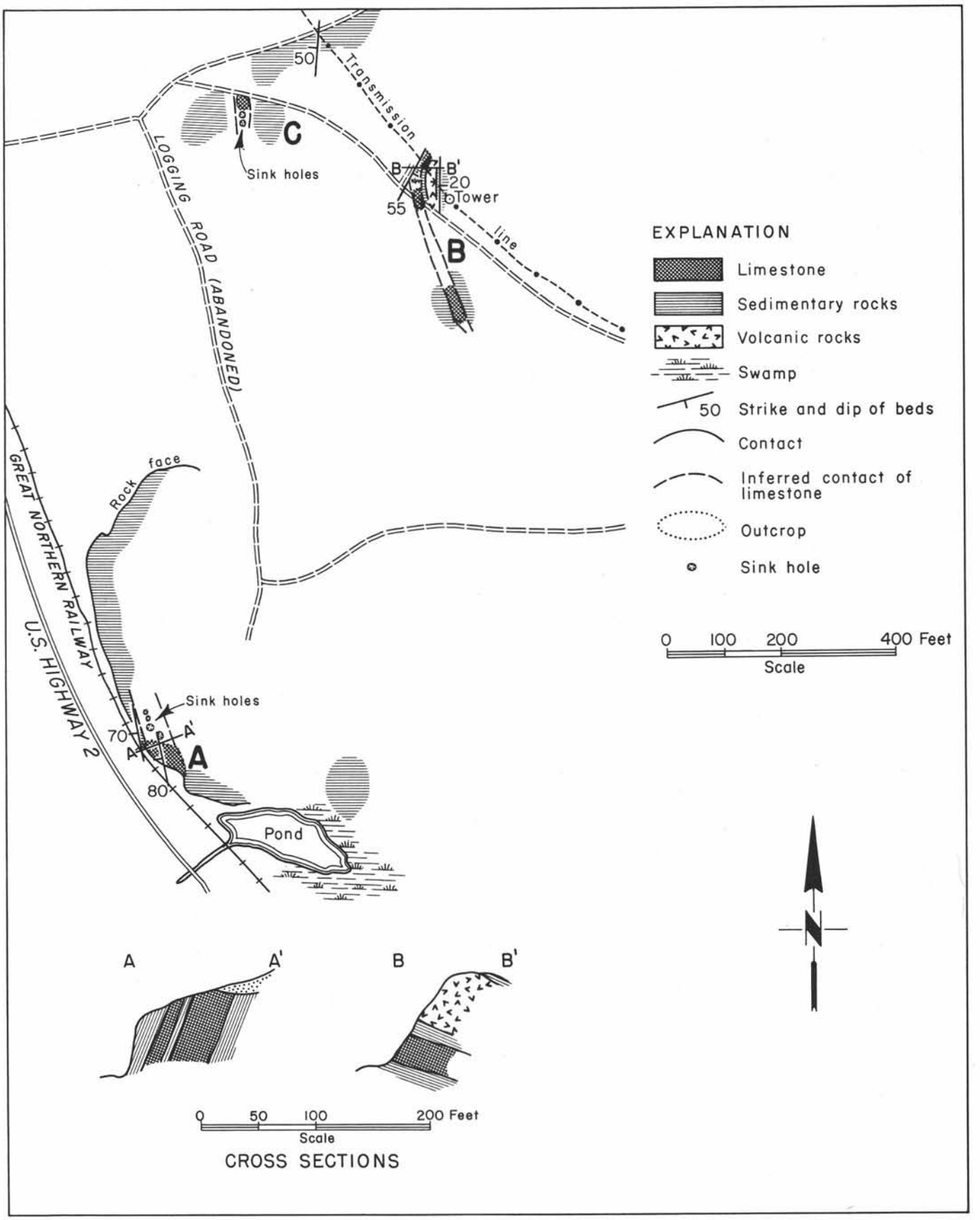


FIGURE 192.—Baring deposits. Sec. 12, T. 26 N., R. 10 E. Geology by W. R. Danner.

Deposit A is on the north side of a railroad cut just northeast of U.S. Highway 2 and about 100 feet northwest of a large pond. Limestone is exposed for about 65 feet along the tracks and vertically to a height of between 10 and 20 feet. The outcrop consists of a bed about 50 feet thick, striking N. 10° W. and dipping about 80° SW. Four small sinkholes were found over a distance of 75 feet along strike to the northwest. A bedrock face 400 feet to the north along strike does not expose any limestone. The limestone is bluish gray in color, banded, and medium to finely crystalline in texture. It contains small replacement masses of jasperoid. Along its western contact it is somewhat fractured and may be faulted. A layer of impure quartzite 2 feet thick is interbedded in the limestone 15 feet from the base.

Vegetation may conceal the limestone outcrop sufficiently to make finding the deposit difficult.

Present surface exposures above the railroad tracks and indications of the extension of limestone under soil and drift (sinkholes) suggest a minimum of 4,500 tons of limestone in the deposit. Some trenching has been done in the past to try to determine the possible extension of limestone along the strike under soil and drift, but no limestone was found. However, most of the trenching was done off the projected strike direction of the limestone outcrop.

Deposit B is about 1,000 feet northwest of Deposit A and an estimated 300 feet above it. The deposit is a bed of limestone 10 to 11 feet thick that is exposed at three places over a strike distance of 300 feet. The limestone is underlain by impure quartzite and overlain by metamorphosed ribbon chert and schistose volcanic rocks. A layer of argillite about 1½ feet thick is exposed in the northernmost outcrop about 5 feet from the base of the limestone bed and divides the limestone into two layers of almost equal thickness.

The northernmost outcrop lies on the slope of a steep west-facing rock scarp; the Bonneville power transmission lines extend almost directly overhead. The second outcrop is about 30 feet to the south and is poorly exposed in a roadbed. The third outcrop lies about 250 feet down the hillside to the southeast. It consists of thin-bedded, blue-gray to white, finely crystalline limestone that has shaly laminations. The limestone strikes north to northeastward and dips 20°-60° SW. It is reported that a cave at least "90 feet deep" extended down into the hillside at the north outcrop of Deposit B. A ladder was built down into the cave, and the bottom was said to be often filled with water. When the Bonneville powerline was constructed, the entrance to the cave was blocked and filled with debris.

The extension of the limestone to the north may be cut off by faulting or it may pinch out, as most limestone bodies in this area are lenticular.

Deposit C is a very small "outcrop" about 350 feet northwest of Deposit B. It looks like a limestone boulder embedded in soil and glacial drift on the south side of a bulldozed road, but it is believed to be an outcrop in place. Two small sinkholes are about 20 to 25 feet south of it. Impure quartzite crops out above and below the limestone.

All three of the Baring deposits may represent the same limestone bed, displaced along strike by northeast-southwest-trending faults or repeated by folding.

Quality.—The limestone of these deposits is of high-calcium type, similar to others in western Washington of Permian age.

Chemical analysis of Baring limestone

Sample	Location	Sample length	$CaCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3
1/	Deposit C	Composite	99.50	44.00	55.50	Trace	Trace	Trace

1/ Unpublished private report, Ideal Cement Company.

Ownership and development.—Deposit A, in the railroad cut, is owned by the Great Northern Railway. Deposits B and C are mostly along the Bonneville-Grand Coulee-Chief Joseph power transmission line right-of-way but partly on

property of Alex Cugini, 617 Burnett Street, Renton, Wash. The deposits have been prospected, but there has been no development, and they appear too small to be of any economic value.

References. — Hodge (1938, p. 75), Halliday (1963, p. 21-22).

Denny Mountain Deposit

Location, size, and accessibility. — The Denny Mountain limestone deposit is in the SE$\frac{1}{4}$ sec. 31, T. 23 N., R. 11 E., and the NE$\frac{1}{4}$ sec. 6 and NW$\frac{1}{4}$ sec. 5, T. 22 N., R. 11 E., on the southwest side of Denny Mountain at an altitude between 2,800 and 4,000 feet. The outcrop is about 2 miles northwest of Snoqualmie Pass and is estimated to contain about 6 million tons of limestone. The area is accessible by about 50 miles of road east from Seattle and by about 1$\frac{1}{2}$ miles of trail from the Denny Creek forest camp. The trail (Lake Melakwa trail) is a few hundred feet below the deposit, and the outcrop can be reached by climbing up the steep brushy slopes or by hiking a now faint trail that leads to an old quarry at the south end of

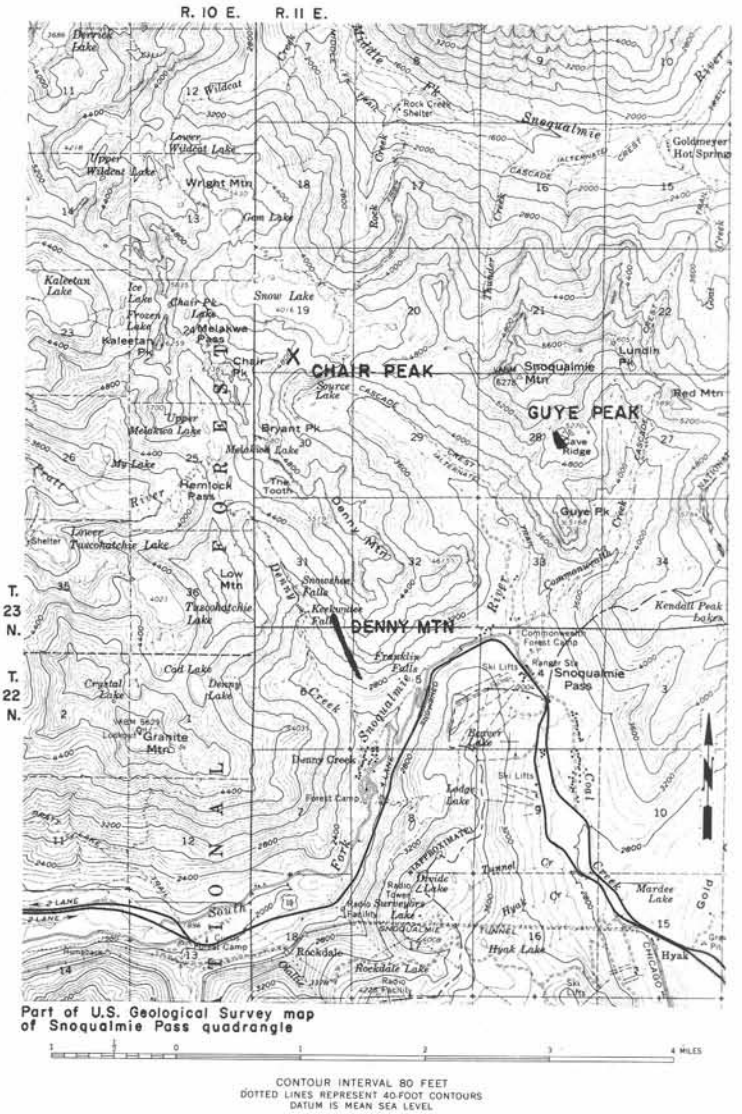


FIGURE 193. — Index map of limestone deposits near Snoqualmie Pass, King County.

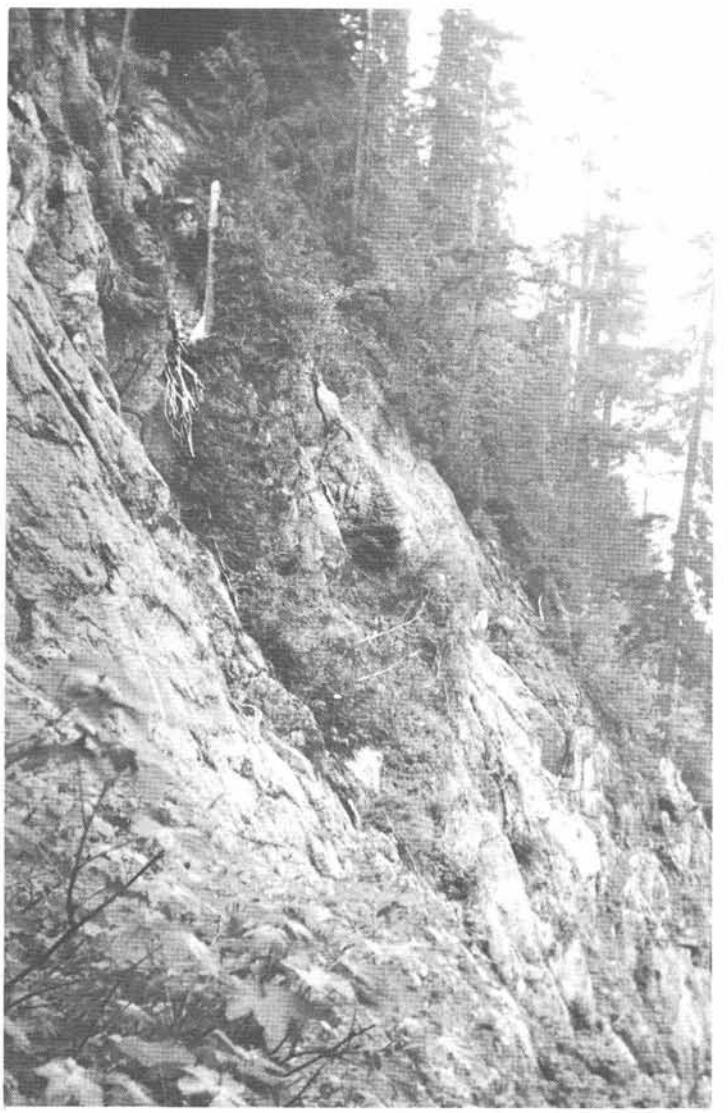


FIGURE 194. — Limestone cliff exposure, Denny Mountain deposit. View looking south.

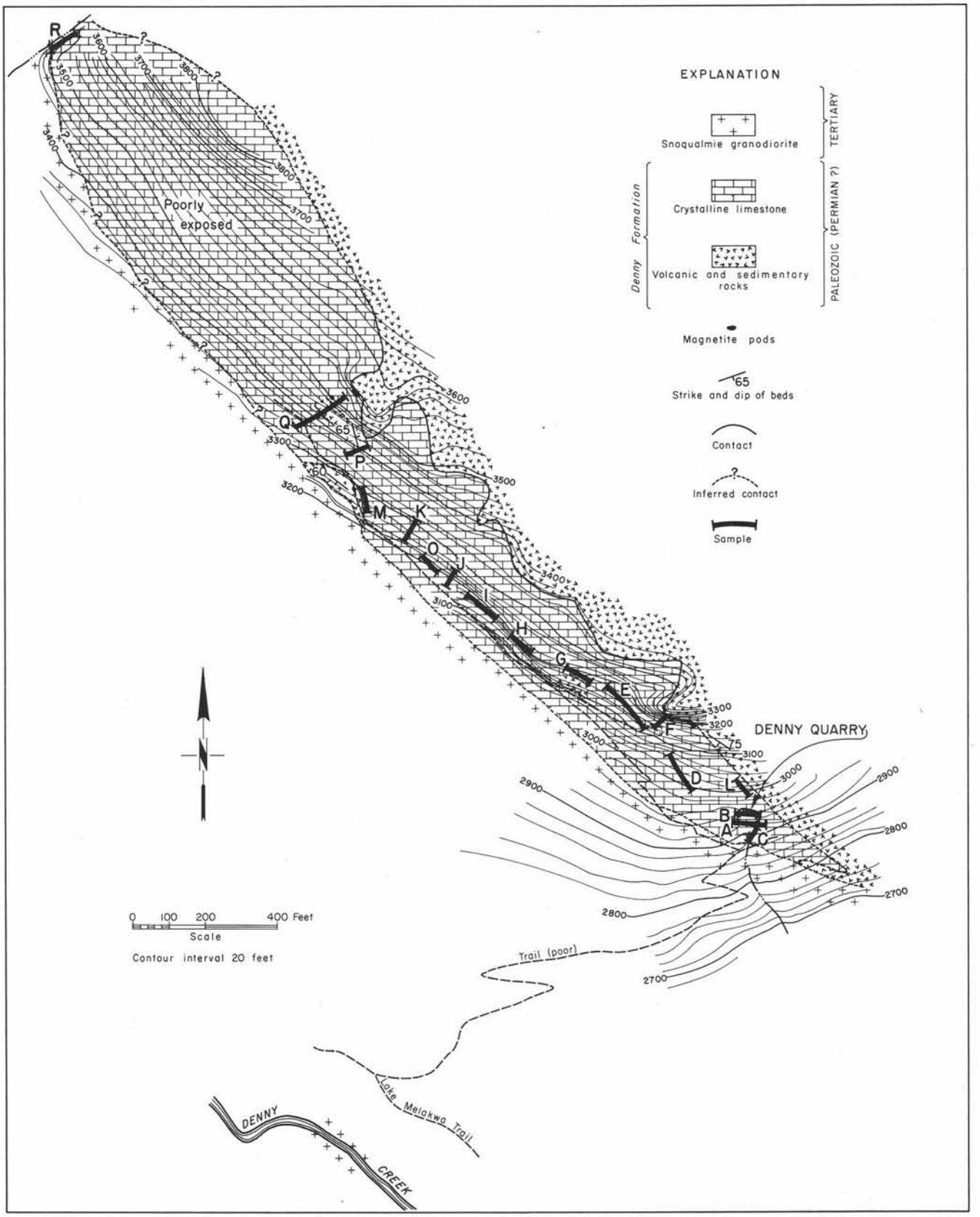


FIGURE 195.—Reconnaissance geologic map, Denny Mountain deposit. Elevation data from Pacific Coast Company surveys, 1926. Contouring and geology by W. R. Danner, 1948 and 1955.

the deposit. The steep slopes of Denny Mountain are in part composed of rock cliffs and in part are covered with virgin forest or thick brushy areas of vine maple, alder, and devils club. Travel over the deposit is by foot and is difficult. Much of the limestone is exposed in cliff faces. Two miles south of the deposit is the west entrance of the Chicago, Milwaukee, St. Paul and Pacific railroad's Snoqualmie Tunnel through the Cascade Mountains.

Geology and description. — The Denny Mountain deposit is a large lenticular body of crystalline limestone about 2,500 feet long and as much as 500 feet in width. Limestone is exposed vertically along strike for over 1,000 feet, and across the outcrop width it is exposed vertically for over 400 feet. It appears to dip steeply east into Denny Mountain in some places but steeply west in others. Above the limestone are cliffs composed mostly of greenish-black altered spilitic basalts and relatively unaltered basalts, and below it are similar volcanic rocks intruded by granodiorite. The granodiorite has intruded into part of the base of the limestone and formed a skarn containing coarsely crystalline and massive garnet, epidote, calcite, quartz, magnetite, hornblende, specular hematite, chalcopyrite, and pyrite. In some places the skarn is 10 feet or more in width, and it contains lenses of magnetite as much as 20 feet across. At least some of the unaltered basalts appear to intrude the limestone, and in at least two places large masses of basaltic rocks occur within it. Numerous dikes of andesitic and basaltic composition cut the limestone and range from a few inches to several feet in width. The limestone is medium to coarsely crystalline in texture and white to light bluish gray and dark bluish gray in color. Small stringers and irregular masses of pyrite and garnet occur throughout the limestone.

In the central part of the deposit, outcrops of the limestone form prominent cliffs that can be easily seen from the Snoqualmie Pass highway to the south. The cliff outcrops tend to exaggerate in appearance the size of the limestone body. Jointing is prominent, and most of the joint cracks dip gently to the east.

In 1927 an intensive study of the deposit was made by the Pacific Coast Company. At least 12 holes were drilled into the limestone and the cores analyzed. Unfortunately, the location of these holes is unknown, but those drilled horizontally went through limestone ranging in thickness from 10 feet to 140 feet. The logs of these holes are given below; the logs of two of the holes are unavailable.

Logs of Pacific Coast Company cores, Denny Mountain limestone

Hole no.	Angle of hole	Total limestone (ft)	(in)	Total "intrusive" (ft)	(in)	Length of hole (ft)	(in)	Core recovered (ft)	(ft)	Hole ended in:
1	Horizontal	10	9	22	3	33	0	24	2	20 feet of intrusive rock containing four limestone beds totaling 22 inches.
2	Down 50° from horizontal	78	3	26	7	105	0	50	9	9 feet of intrusive rock.
3	Horizontal	77	5	8	7	86	0	62	11	4 feet of intrusive rock.
4	Horizontal	19	0	11	0	30	0	10	0	10 feet of broken ground with crevices.
4½	Horizontal	63	2	7	10	71	0	39	6	5 feet of intrusive rock, followed by 8 inches of limestone, followed by 4 inches of intrusive rock.
5	Horizontal	147	7	9	5	157	0	100	11	4 feet of intrusive rock.

Logs of Pacific Coast Company cores, Denny Mountain limestone—Continued

Hole no.	Angle of hole	Total limestone (ft)	(in)	Total "intrusive" (ft)	(in)	Length of hole (ft)	(in)	Core recovered (ft)	(in)	Hole ended in:
6	Horizontal	84	5	7	7	92	0	70	4	2 feet of intrusive rock.
7	Horizontal	76	3	18	9	95	0	78	1	6½ feet of intrusive rock.
8	Horizontal	135	9	18	3	154	0	106	7	2 inches of intrusive rock.
9	Down 50° from horizontal	140	3	25	9	166	0	126	6	3 feet 3 inches of intrusive rock followed by 2 inches of limestone.

Hole no. 1

Horizontal

From (ft)	(in)	To (ft)	(in)	
0	0	0	8	Limestone
0	8	3	3	Intrusive rock
3	3	3	9	Limestone
3	9	5	0	Intrusive rock
5	0	13	0	Limestone
13	0	16	0	Intrusive rock
16	0	16	6	Limestone
16	6	16	9	Limestone and intrusive rock
16	9	22	7	Intrusive rock
22	7	22	11	Poor limestone
22	11	25	9	Intrusive rock
25	9	26	6	Limestone, poor
26	6	33	0	Intrusive rock

Hole no. 2

Down 50° Finished May 11, 1927

From (ft)	(in)	To (ft)	(in)	
0	0	45	10	Limestone
45	10	47	9	Intrusive rock
47	9	50	0	Limestone
50	0	50	5	Intrusive rock
50	5	50	8	Limestone
50	8	50	11	Intrusive rock
50	11	72	0	Limestone
72	0	72	4	Limestone and intrusive rock
72	4	74	0	Limestone

Hole no. 2—Continued

Down 50° Finished May 11, 1927

From (ft)	(in)	To (ft)	(in)	
74	0	89	0	Limestone and intrusive rock
89	0	96	0	Limestone
96	0	105	0	Intrusive rock

Hole no. 3

Horizontal Finished May 18, 1927

From (ft)	(in)	To (ft)	(in)	
0	0	1	3	Intrusive rock
1	3	66	6	Limestone
66	6	67	4	Intrusive rock
67	4	69	3	Limestone and intrusive rock
69	3	69	10	Intrusive rock
69	10	82	0	Limestone
82	0	86	0	Intrusive rock

Hole no. 4

Horizontal Finished May 20, 1927

0	0	17	0	Limestone
17	0	18	0	Crevice
18	0	20	0	Limestone
20	0	30	0	Broken ground with crevices

Hole no. 4½

Horizontal Finished May 27, 1927

From (ft)	From (in)	To (ft)	To (in)	
0	0	34	0	Limestone
34	0	35	0	Limestone and intrusive rock
35	0	36	6	Intrusive rock
36	6	65	0	Limestone
65	0	70	0	Intrusive rock
70	0	70	8	Limestone
70	8	71	0	Intrusive rock

Hole no. 5

Horizontal Finished May 24, 1927

From (ft)	From (in)	To (ft)	To (in)	
0	0	1	9	Limestone and intrusive rock
1	9	68	2	Limestone
68	2	69	0	Limestone and intrusive rock
69	0	79	0	Limestone
79	0	79	4	Intrusive
79	4	84	5	Limestone
84	5	84	9	Intrusive
84	9	115	0	Limestone
115	0	115	6	Intrusive rock
115	6	116	4	Limestone
116	4	117	3	Limestone, poor
117	3	135	0	Limestone
135	0	135	8	Intrusive rock
135	8	142	0	Limestone
142	0	142	4	Limestone, poor
142	4	153	0	Limestone
153	0	157	0	Intrusive rock

Hole no. 6

Horizontal Finished May 28, 1927

From (ft)	From (in)	To (ft)	To (in)	
0	0	2	0	Limestone
2	0	4	0	Limestone and intrusive rock
4	0	56	0	Limestone
56	0	57	0	Limestone and intrusive rock
57	0	64	3	Limestone
64	3	64	11	Intrusive rock
64	11	65	11	Limestone
65	11	66	7	Limestone and intrusive rock
66	7	71	10	Limestone

Hole no. 6—Continued

Horizontal Finished May 28, 1927

From (ft)	From (in)	To (ft)	To (in)	
71	10	72	4	Limestone and intrusive rock
72	4	77	0	Limestone
77	0	77	9	Intrusive rock
77	9	90	0	Limestone
90	0	92	0	Intrusive rock

Hole no. 7

Horizontal Finished May 31, 1927

From (ft)	From (in)	To (ft)	To (in)	
0	0	3	0	Limestone
3	0	4	0	Intrusive rock
4	0	20	6	Limestone
20	6	20	10	Intrusive rock
20	10	24	0	Limestone
24	0	24	4	Intrusive rock
24	4	32	11	Limestone
32	11	34	2	Intrusive rock
34	2	64	0	Limestone
64	0	69	4	Limestone and intrusive rock
69	4	77	0	Limestone
77	0	80	2	Intrusive rocks
80	2	84	9	Limestone
84	9	85	7	Intrusive rock
85	7	88	6	Limestone
88	6	95	0	Intrusive rock

Hole no. 8

Horizontal Finished June 5, 1927

From (ft)	From (in)	To (ft)	To (in)	
0	0	0	5	Limestone
0	5	1	8	Intrusive rock and limestone
1	8	2	8	Intrusive rock
2	8	3	2	Limestone
3	2	13	10	Limestone and intrusive rock
13	10	101	3	Limestone
101	3	101	7	Intrusive rock
101	7	113	8	Limestone
113	8	114	4	Intrusive rock
114	4	116	4	Limestone
116	4	118	0	Intrusive rock
118	0	137	10	Limestone
137	10	139	3	Intrusive rock
139	3	148	0	Limestone

Hole no. 8—Continued

Horizontal Finished June 5, 1927

From (ft)	From (in)	To (ft)	To (in)	
148	0	149	1	Intrusive rock
149	1	153	10	Limestone
153	10	154	0	Intrusive rock

Hole no. 9

Down hole at 50° Finished June 1927

From (ft)	From (in)	To (ft)	To (in)	
0	0	6	0	Intrusive rock
6	0	6	6	Limestone
6	6	10	0	Limestone and intrusive rock
10	0	67	8	Limestone
67	8	69	0	Intrusive rock
69	0	69	4	Limestone
69	4	70	0	Intrusive rock

Hole no. 9—Continued

Down hole at 50° Finished June 1927

From (ft)	From (in)	To (ft)	To (in)	
70	0	77	6	Limestone
77	6	78	4	Intrusive rock
78	4	107	2	Limestone
107	2	108	2	Intrusive rock
108	2	114	2	Limestone
114	2	114	8	Intrusive rock
114	8	116	8	Limestone and intrusive rock
116	8	141	6	Limestone
141	6	142	0	Intrusive rock
142	0	146	4	Limestone
146	4	147	0	Intrusive rock
147	0	153	4	Limestone
153	4	157	0	Intrusive rock
157	0	159	6	Limestone
159	6	160	2	Intrusive rock
160	2	160	6	Limestone
160	6	161	8	Intrusive rock
161	8	162	7	Limestone
162	7	165	10	Intrusive rock
165	10	166	0	Limestone

Smith and Calkins (1906, p. 7) described the limestone as part of the Miocene Guye Formation, but recognized that it might be of Paleozoic age. Foster (1955, p. 12) designated the limestone and associated rocks as belonging to the Sunset Formation of late Paleozoic age, but later changed the name to Denny Formation (Foster, 1957, p. 99; 1960, p. 111). The association of limestone with basalt, and in nearby outcrops with ribbon chert, suggests a correlation with the Trafton sequence of Permian age, which crops out 16 miles to the north.

Quality.—The Denny Mountain deposit was not visited or sampled during the present investigation. However, it was briefly studied by the writer in 1948 and 1955. Several chemical analyses are available from private sources and indicate a variable composition unsuitable for chemical uses and rather high in magnesia for use as cement rock.

Chemical analyses of Denny Mountain limestone[1/]

Sample	$CaCO_3$	MgO	Sample	$CaCO_3$	MgO	Fe_2O_3
A -----	86.3	1.7	J -----	77.4	8.0	
B -----	81.6	3.6	K -----	90.0	5.0	
C -----	84.3	4.06	L -----	78.4	6.85	
D -----	91.9	3.12	M -----	75.5	5.3	10.5
E -----	84.3	4.04	O -----	85.9	4.5	
F -----	89.4	1.40	P -----	84.2	1.5	
H -----	95.7	0.91	Q -----	95.7	1.4	
I -----	90.9	2.0	R -----	66.3		

1/ Unpublished private report.

Chemical analyses of Denny Mountain limestone

(Analyses by Pacific Coast Company, 1927)

Location	Sample length (feet)	$CaCO_3$	CaO	MgO	Insoluble	R_2O_3	Description of sample
Old quarry boulders	Composite of 12 sacks ------	85.88	48.12	4.21	1.68	3.16	Gray and white limestone.
Drill hole 2							
Surface	Single specimen from core -----	94.18	52.77	1.15	2.98	1.08	Pale gray, coarsely crystalline.
5 ft	------ do ------	93.07	52.15	0.61	2.98	2.34	Pale gray, coarsely crystalline.
10 ft	------ do ------	95.93	53.76	0.41	1.86	1.54	Pale gray, coarsely crystalline.
15 ft	------ do ------	86.68	48.56	4.21	4.34	2.82	Dark gray, crystalline.
16 ft	------ do ------	88.11	48.25	4.44	2.48	2.64	Dark gray, coarsely crystalline.
20 ft	------ do ------	95.94	53.76	0.68	1.46	1.46	White, crystalline
21 ft	------ do ------	96.59	54.12	0.52	1.00	1.30	White, coarsely crystalline.
25 ft	------ do ------	86.38	48.40	6.63	3.22	1.14	Dark gray, crystalline.
30 ft	------ do ------	83.54	46.81	6.32	1.88	3.04	White, crystalline.
31 ft	------ do ------	89.06	49.90	1.85	4.86	2.02	Dark gray and white mottled.
34 ft	------ do ------	60.07	33.66	19.19	3.38	2.80	Medium gray, crystalline.
35 ft	------ do ------	63.11	35.36	12.51	2.48	6.46	Dark gray, dense and crystalline.
40 ft	------ do ------	65.19	36.53	16.63	3.74	2.56	Pale buff, crystalline.
45 ft	------ do ------	63.50	35.58	5.73	18.80	9.48	Light gray, crystalline, pyritic.
49 ft	------ do ------	86.18	48.29	5.68	3.16	2.34	Pale green, white.
50 ft	------ do ------	51.33	28.76	0.95	1/ 31.56	25.46	Dark igneous rock.
55 ft	------ do ------	93.00	52.11	2.24	2.60	0.74	Light gray, crystalline.
59 ft	------ do ------	72.21	40.46	8.65	7.44	4.34	Pale green, coarsely crystalline.
60 ft	------ do ------	87.34	48.94	5.80	2.68	0.70	White, densely crystalline.
66 ft	------ do ------	98.45	50.12	2.53	1.24	0.48	White, crystalline.
72 ft	------ do ------	83.61	46.85	Trace	10.44	2.80	Pale green, coarsely crystalline.
75 ft	------ do ------	85.90	48.13	0.78	10.44	1.60	Pale green, coarsely crystalline.
79 ft	------ do ------	37.10	20.79	Trace	46.28	19.84	Medium gray, dense crystals.
85 ft	------ do ------	47.47	26.60	Trace	46.24	8.52	Medium gray, dense crystals.
89 ft	------ do ------	91.73	51.40	Trace	3.40	1.82	Medium gray, dense crystals.
96 ft	------ do ------	-----	23.62	0.80	1/ 42.54	30.52	Green igneous rock; brown intrusion.
106 ft	------ do ------	-----	24.69	0.88	1/ 43.86	29.28	Green igneous rock; brown intrusion.
Drill hole 3	0-10	85.13	47.70	0.83	5.54	6.08	Pale-green, white, and gray limestone.
------ Do ------	10-18	84.27	47.22	4.89	2.16	3.40	Gray limestone.
------ Do ------	18-25	80.56	45.03	1.94	10.68	5.64	White and gray limestone.
------ Do ------	25-31	80.36	45.03	2.24	12.72	3.54	White and gray limestone.
------ Do ------	31-33	63.34	35.49	0.54	27.52	9.72	Gray-green limestone.
------ Do ------	33-43	77.03	43.16	8.58	6.12	3.08	White limestone.
------ Do ------	43-50	71.71	40.18	6.56	8.56	7.36	White and some gray limestone.
------ Do ------	50-61	80.40	45.05	0.52	12.08	6.10	Gray limestone.
------ Do ------	61-71	79.76	44.69	0.32	12.08	7.10	Gray limestone.
------ Do ------	71-82	87.66	49.12	0.32	12.24	2.40	Gray and white limestone.
------ Do ------	82-86	18.17	10.18	0.14	68.22	15.64	Red-gray to green rock. This core was mixed with non-limestone from this core for composite rock analysis.
------ Do ------	82-86		28.62	1.37	1/ 41.50	2/	Same as above but analyzed by "fusion method." (Loss on ignition, 7.91).
------ Do ------	58		50.63	2.71	9.64	5.01	Total core of limestone in hole.
------ Do ------	5		18.17	0.14	68.22	15.84	Total core of rock in hole.

1/ SiO_2.
2/ Fe_2O_3=7.39, Al_2O_3=18.13.

Chemical analyses of Denny Mountain limestone—Continued

Location	Sample length (feet)	$CaCO_3$	CaO	MgO	Insoluble	R_2O_3	Description of sample
Drill hole 4½							
5 ft	Single specimen	92.89	52.05	1.35	3.00	1.36	White, crystalline.
15 ft	------ do -----	96.32	53.97	1.51	1.16	0.48	Dark gray, coarsely crystalline.
25 ft	------ do -----	68.17	38.20	11.67	13.06	5.98	Gray and white, coarsely crystalline.
35 ft	------ do -----	67.01	37.55	11.91	4.96	5.70	Pale gray, crystalline.
45 ft	------ do -----	83.29	46.67	1.08	8.08	5.90	Pale-gray limestone.
55 ft	------ do -----	89.23	50.00	0.85	7.54	2.18	Pale green, crystalline.
65 ft	------ do -----	90.32	50.61	1.53	2.88	3.92	Pale green, coarsely crystalline.
70 ft	------ do -----	86.41	48.42	1.32	3.28	6.46	Pale green, coarsely crystalline.
The core ends in dark-green rock at 71 feet.							
Drill hole 5							
Surface	Single specimen	82.48	46.19	0.42	15.80	0.82	Surface end of large core; light gray, coarsely crystalline.
5 ft	------ do -----	94.91	53.15	0.45	4.12	1.06	Large core; light gray, crystalline.
10 ft	------ do -----	97.82	54.78	0.92	1.46	0.48	White, crystalline.
20 ft	------ do -----	94.23	52.77	1.30	2.50	1.46	White, crystalline.
25 ft	------ do -----	94.02	52.65	0.97	1.90	1.64	Gray, crystalline.
30 ft	------ do -----	44.39	24.86	12.74	38.76	4.10	Dark gray, densely crystalline.
40 ft	------ do -----	65.37	36.61	16.42	2.12	0.90	White, densely crystalline.
50 ft	------ do -----	97.69	54.71	1.09	1.20	0.62	White, densely crystalline.
62 ft	------ do -----	95.73	53.61	0.25	3.52	1.16	Dark gray, coarsely crystalline.
75 ft	------ do -----	94.14	52.75	0.59	1.80	2.10	White, coarsely crystalline.
82 ft	------ do -----	94.67	53.13	0.64	2.52	1.72	Dark gray, coarsely crystalline.
95 ft	------ do -----	88.65	49.68	1.02	6.00	2.76	White, coarsely crystalline.
105 ft	------ do -----	77.62	43.49	0.43	17.80	5.40	Gray, coarsely crystalline.
115 ft	------ do -----	30.46	17.07	Trace	66.00	7.00	Dark green, coarsely crystalline.
125 ft	------ do -----	90.02	50.44	2.92	2.40	2.04	White, coarsely crystalline.
135 ft	------ do -----	30.73	17.23	Trace	66.72	12.54	Light green, dense and hard.
145 ft	------ do -----	84.00	47.07	Trace	16.12	0.52	White, greenish, coarsely crystalline.
155 ft	------ do -----	20.13	11.28	Trace	68.66	19.40	Dense green rock.
Drill hole 6							
5 ft	Single specimen	92.54	51.85	0.15	7.30	1.60	White, coarsely crystalline.
15 ft	------ do -----	81.24	45.52	7.10	1.60	2.84	Pale gray, crystalline.
25 ft	------ do -----	69.87	39.15	13.64	1.26	1.52	Gray, crystalline.
35 ft	------ do -----	89.84	50.34	0.61	4.04	4.64	White, coarsely crystalline.
45 ft	------ do -----	18.60	10.42	0.35	54.40	32.68	Dark gray, dense and hard.
55 ft	------ do -----	94.95	53.20	0.30	3.72	1.48	White, crystalline.
60 ft	------ do -----	94.36	52.87	0.52	3.40	1.40	Dark gray, crystalline.
65 ft	------ do -----	92.23	51.68	0.39	5.40	1.48	Pale green, coarsely crystalline.
75 ft	------ do -----	74.85	41.94	0.13	23.60	3.08	Gray, coarsely crystalline.
79 ft	------ do -----	92.70	51.94	Trace	6.84	0.56	Pale green, coarsely crystalline.
85 ft	------ do -----	90.77	50.86	0.81	4.38	2.68	Pale green, crystalline.
90 ft	------ do -----	85.06	47.66	0.33	10.76	2.78	Pale green, crystalline.
Drill hole 6							
------ Do ------	5-16	73.78	41.34	3.79	7.20	8.04	Pale-gray limestone.
------ Do ------	16-29	75.37	42.23	5.84	4.24	5.98	White with some gray limestone.
------ Do ------	29-42	81.15	45.47	0.93	8.90	6.84	Pale-gray limestone.
------ Do ------	42-56	79.65	44.63	0.27	11.22	6.32	Gray limestone with mixed brown rock.
------ Do ------	56-66	84.31	47.24	0.52	8.08	4.96	Gray limestone.
------ Do ------	66-79	83.36	46.71	0.55	6.30	6.74	Green and gray limestone; gray-green rock.
------ Do ------	79-90	85.58	47.95	1.18	4.98	5.34	Pale-green limestone.
------ Do ------	65 1/2	80.21	-----	1.92	7.33	6.37	Calculated composite, limestone only.
------ Do ------	4 1/3		20.73	0.30	[3] 39.96	[4]	Fusion method, rock only. (Loss on ignition, 2.28).
------ Do ------	4 1/3	16.08	-----	Trace	63.00	19.30	Calculated composite, rock only.

[3] SiO_2.

[4] Fe_2O_3=8.38, Al_2O_3=24.34.

Chemical analyses of Denny Mountain limestone—Continued

Location	Sample length (feet)	$CaCO_3$	CaO	MgO	Insoluble	R_2O_3	Description of sample
Drill hole 7							
Surface	Single specimen	90.16	50.52	0.17	9.34	1.58	Pale green, coarsely crystalline.
10 ft	------ do -----	94.57	52.99	Trace	4.52	1.08	White, coarsely crystalline.
20 ft	------ do -----	86.50	48.47	1.85	3.76	4.50	Pale gray, coarsely crystalline.
30 ft	------ do -----	69.03	38.68	12.24	0.66	3.26	White, crystalline.
40 ft	------ do -----	90.63	50.78	1.23	3.80	1.98	White, coarsely crystalline.
49 ft	------ do -----	80.17	44.92	7.15	2.56	2.98	Gray, white, crystalline.
61 ft	------ do -----	72.90	40.85	12.07	1.00	1.60	Pale gray, crystalline.
65 ft	------ do -----	41.21	23.09	0.19	61.66	5.02	Brown, gray, white, crystalline.
75 ft	------ do -----	88.56	49.62	0.39	9.04	1.86	Pale green, coarsely crystalline.
86 ft	------ do -----	94.23	52.80	Trace	4.76	1.12	White, coarsely crystalline.
Limestone grades to rock at about 89 feet; core ends at about 95 feet.							
Drill hole 8							
Surface	Single specimen	64.70	47.46	Trace	12.00	2.16	Pale green, coarsely crystalline.
10 ft	------ do -----	93.04	52.13	Trace	4.76	1.48	Pale green, coarsely crystalline.
20 ft	------ do -----	95.39	53.45	Trace	2.74	1.18	White, coarsely crystalline.
30 ft	------ do -----	74.96	42.00	8.66	1.56	1.18	Pale green, crystalline.
40 ft	------ do -----	94.45	52.92	Trace	5.84	1.06	White, coarsely crystalline.
51 ft	------ do -----	87.93	49.27	1.28	4.96	3.88	Gray, coarsely crystalline.
60 ft	------ do -----	96.93	54.31	0.23	1.00	1.48	White, coarsely crystalline.
70 ft	------ do -----	73.15	40.99	9.80	0.84	3.72	Pale gray, coarsely crystalline.
80 ft	------ do -----	83.81	46.85	5.29	1.04	3.40	Dark gray, coarsely crystalline.
90 ft	------ do -----	67.68	37.92	12.77	0.68	3.60	Pale gray, crystalline.
101 ft	------ do -----	88.09	49.36	3.89	4.22	2.06	Pale gray, coarsely crystalline.
110 ft	------ do -----	69.80	39.11	Trace	30.12	2.08	Pale gray, coarsely crystalline.
120 ft	------ do -----	94.71	53.07	Trace	2.14	2.24	Dark gray, crystalline.
130 ft	------ do -----	96.68	54.17	0.38	1.46	1.44	White, crystalline.
140 ft	------ do -----	87.83	49.21	Trace	11.78	1.72	Pale green, coarsely crystalline.
154 ft	------ do -----	92.19	51.66	0.62	4.00	1.92	Pale green, coarsely crystalline.
End of core 8 grades into dark-green rock; limestone only was sampled. There are numerous intrusions between 136 feet and 154 feet.							
Drill hole 9							
10 ft	Single specimen	93.30	52.28	Trace	4.22	1.94	Pale green, coarsely crystalline.
20 ft	------ do -----	86.56	48.50	4.34	3.28	3.76	Gray, coarsely crystalline.
30 ft	------ do -----	94.70	53.06	0.26	1.06	2.58	Pale gray, coarsely crystalline.
40 ft	------ do -----	92.36	51.75	2.77	1.62	1.44	White, coarsely crystalline.
50 ft	------ do -----	75.37	43.23	0.38	16.44	5.88	Pale green, coarsely crystalline.
60 ft	------ do -----	95.57	53.59	0.45	3.20	1.24	White, coarsely crystalline.
70 ft	------ do -----	92.38	51.76	Trace	8.82	1.48	White, coarsely crystalline.
80 ft	------ do -----	90.84	50.90	0.91	5.26	2.24	Dark gray, coarsely crystalline.
90 ft	------ do -----	92.20	51.66	0.96	1.94	2.64	Dark gray, crystalline.
100 ft	------ do -----	82.67	46.32	5.94	4.08	3.24	Dark gray, crystalline.
110 ft	------ do -----	89.98	50.42	0.37	4.06	4.10	Pale gray, coarsely crystalline.
120 ft	------ do -----	80.88	45.32	Trace	11.66	4.94	Pale gray, coarsely crystalline.
130 ft	------ do -----	84.70	47.46	1.30	8.46	4.48	Pale gray, coarsely crystalline.
140 ft	------ do -----	90.41	50.66	0.74	3.00	3.92	Pale gray, crystalline.
150 ft	------ do -----	87.88	49.24	0.35	5.46	4.42	White, coarsely crystalline.
160 ft	------ do -----	78.35	43.90	0.22	16.36	4.64	Green-gray, coarsely crystalline.
166 ft	------ do -----	61.88	34.66	0.74	8.82	17.32	Dark gray, crystalline.

Chemical analyses of Denny Mountain limestone—Continued

Location	Sample length (feet)	$CaCO_3$	CaO	MgO	Insoluble	R_2O_3	Description of sample
Drill hole 10							
------ Do------	0-6	23.38	13.10	Trace	60.80	16.94	Composite sample of all intrusive rock between the surface and 54 feet.
------ Do------	6-18	79.19	44.37	0.77	9.90	7.78	Gray and white limestone.
------ Do------	18-26	84.02	47.08	3.92	1.38	4.94	Pale-gray and white limestone.
------ Do------	26-36	74.23	41.59	3.61	4.50	7.18	Gray and white limestone.
------ Do------	36-43	84.27	47.22	2.14	2.52	6.08	White limestone.
------ Do------	43-54	81.96	45.92	0.83	6.86	7.56	White, green, and gray limestone.
------ Do------	54-64	85.49	47.90	0.55	10.78	3.14	Green and gray limestone.
------ Do------	64-78	88.31	49.48	Trace	10.66	2.32	Pale-green limestone.
------ Do------	78-92	87.86	49.23	0.14	9.50	3.10	Gray, white, and green limestone.
------ Do------	92-105	94.00	52.67	0.17	4.58	2.10	Gray and dark-gray limestone.
------ Do------	105-117	95.34	63.42	0.21	2.34	2.28	Dark-gray limestone.
------ Do------	117-129	93.07	52.15	0.17	3.56	2.80	Dark-gray limestone.
------ Do------	129-136	94.98	53.22	0.18	3.00	2.06	Dark-gray limestone.
------ Do------	136-142	96.21	53.91	0.24	2.52	1.82	Dark-gray limestone.
------ Do------	142-152	95.57	53.55	0.29	2.18	2.36	Dark-gray limestone.
------ Do------	152-164	91.18	51.08	0.15	3.06	3.38	Dark-gray limestone.
------ Do------	164-177	90.89	50.93	0.20	3.30	3.60	Dark-gray limestone.
------ Do------	177-183	91.88	51.48	0.37	3.30	3.10	Dark-gray limestone.
------ Do------	183-193	79.13	44.34	0.29	14.88	4.02	Gray, green, and white limestone.
------ Do------	193-201	93.21	52.23	0.27	3.04	2.42	Gray and white limestone.
------ Do------	201-208	86.04	48.21	0.43	9.38	3.02	Pale-gray limestone, green, gray rock.
------ Do------	0-92	23.38	13.10	Trace	60.80	16.94	Composite of non-limestone 10.75 feet.
------ Do------	183-208	21.38	11.98	Trace	66.24	17.06	Composite of non-limestone 2.75 feet.
------ Do------	Specimen, end of hole	14.33	8.03	Trace	70.40	19.28	Non-limestone 0.5 feet.
------ Do------	194	88.37	----	0.66	5.62	3.79	Calculated composite, limestone only.
------ Do------	13 1/2	22.97	----	Trace	61.91	16.96	Calculated composite, rock only.
------ Do------	207 1/2	84.12	----	0.62	9.28	4.65	Weighted average of all limestone and rock to end of limestone.
Drill hole 11							
------ Do------	0-11	90.61	50.77	3.26	1.76	2.56	Gray limestone; gray rock.
------ Do------	11-17	90.81	50.88	2.66	2.58	2.96	White limestone.
------ Do------	17-28	91.18	51.09	1.71	3.92	3.16	Gray and dark-gray limestone.
------ Do------	28-33	92.70	51.94	0.50	1.34	4.16	Dark-gray limestone.
------ Do------	33-41	90.27	50.58	1.89	5.74	2.44	Gray limestone; brown-gray rock.
------ Do------	41-51	88.11	49.37	1.25	6.18	3.96	Gray and white limestone.
------ Do------	51-61	81.56	45.70	1.87	9.80	6.14	Gray limestone.
------ Do------	61-66	60.50	33.90	0.35	26.08	10.16	Gray rock and limestone.
------ Do------	66-76	71.89	40.28	0.30	11.38	8.26	Gray limestone.
------ Do------	76-81	68.25	38.24	5.16	16.00	9.02	Gray limestone.
------ Do------	81-88	65.55	36.79	1.22	17.88	12.84	Gray and dark-gray limestone.
------ Do------	88-97	86.88	48.68	0.55	3.50	6.86	Dark-gray limestone.
------ Do------	97-111	80.01	44.83	1.59	11.56	6.80	Gray, gray-green, and white limestone.
------ Do------	111-124	72.51	40.63	1.43	17.52	7.76	Gray and dark-gray limestone.
------ Do------	124-126	23.17	12.93	0.55	55.24	23.66	Green-gray rock mixed with limestone.
------ Do------	0-66	7.75	4.34	4.34	78.28	11.82	12 feet of rock analyzed as a composite sample in this length of core.
------ Do------	76-124	24.29	13.61	0.56	57.34	20.06	Composite rock in this section of core.
------ Do------	108	80.88	-----	2.15	9.55	6.22	Calculated composition of all limestone in core.
------ Do------	15 1/4	11.27		3.53	73.80	13.58	Calculated composition of all rock in core.
------ Do------	82 2/3	72.27	-----	2.32	17.50	7.13	Weighted average of all limestone and rock in total recovered core.

Length of hole to end of limestone is 123 1/4 feet.

Ownership and development. — The Denny Mountain limestone deposit was surveyed in 1883 and 1884, and nine claims were patented, primarily for the bodies of magnetite associated with it. Claims known as the Denny Lode Iron Mine Nos. 38, 39, 40; Chief Lode Iron Mine No. 43; Climax Lode Nos. 44 and 45; and Cliff Lode Nos. 41 and 42 are owned by Richard E. Fuller, 3801 East Prospect Street, Seattle. In 1927 the deposit was investigated for limestone by the Pacific Coast Company, and during their exploration at least 12 holes were drilled and a few adits were sunk. Other investigations have been made in recent years, but all have indicated the deposit to be unsuitable in composition for most uses. At least one small quarry was developed near the south end of the deposit. Running water can be heard through a crevice in the wall of this quarry, indicating the presence of a cave. There are reports of a lost cave on Denny Mountain. In 1944 a deposit of quartz crystals at the upper north end of the deposit was investigated by the United States Geological Survey (Stoll and Norbisrath, 1945), but proved to be too small for development.

Snowfall is heavy in the area, and it is probable that quarrying of this deposit would be limited to about 5 months of the year. The steep slopes above the limestone would necessitate an underground operation, at least in part.

References. — Smith and Calkins (1906, p. 7), Shedd and others (1922, p. 86-90), Stoll and Norbisrath (1945, 2 p.), Foster (1955, p. 12-13; 1957, p. 99; 1960, p. 111), Danner (1957, p. 249-253), Halliday (1963, p. 18).

Guye Peak (Cave Ridge) Deposit

Location, size, and accessibility. — The Guye Peak limestone deposit is about 2 miles north of Snoqualmie Pass and U.S. Highway 10, at an altitude between 4,300 and 5,200 feet. It lies approximately 52 miles east of Seattle. The outcrops occur on the west side of a saddle (Cave Ridge) between Guye Peak and Snoqualmie Peak, in sec. 28, T. 23 N., R. 11 E. Several claims have been staked on the property, which can be reached by driving 1 mile on a logging road north from Snoqualmie Pass and then by hiking up the Snow Lake trail to the base of Cave Ridge and climbing up the steep slope of the ridge to the deposit. The deposit was not examined during this investigation.

Geology and description. — The general geologic relationships at the Guye Peak deposit are believed to be similar to those on Denny Mountain. A body of limestone has been intruded and recrystallized by granodiorite, and a skarn zone containing garnet and magnetite has been developed along the contact. Smith and Calkins (1906, p. 7) assigned the limestone to the supposed Miocene age Guye Formation, but Foster (1957, p. 99) included the limestone as part of his Denny Formation of late Paleozoic age.

Smith and Calkins (1906, p. 7) describe the limestone as, "one or two beds of limestone whose aggregate thickness is only a few feet." Foster (1955, p. 12-13) mentions, "Limestone . . . outcrops for several hundred feet on the west side of the Guye-Snoqualmie saddle." Foster (1957, p. 99) also mentions, ". . . . in this relatively flat saddle a small-scale karst-type topography has developed, and many sinkholes, some quite deep, were observed." William R. Halliday (oral communication, 1956) describes the deposit as alternating beds of crystalline limestone and schist that extend about $\frac{1}{4}$ mile at least and contain many sinkholes and karren. Halliday (1963, p. 22) describes several caves found in the deposit. James E. Hubbart (written communication, Feb. 1963), former owner, states that the limestone extends over 3,000 feet from east to west.

Quality. — The limestone is reported by Mr. Hubbart to be of high grade, some of it pure white, and he said it will take a very high polish. He also reported it to be "practically" free of phosphorus and iron.

Ownership and development. — The owner is Mr. Victor Borden, of Moclips, Wash. There has been no development. It is probable that in some parts of the deposit contamination by the granodiorite intrusion has developed a relatively high magnesium content similar to that of the limestone on Denny Mountain. The high altitude and distance from market make this deposit uneconomic under present conditions.

References. — Smith and Calkins (1906, p. 7, 13), Foster (1955, p. 15; 1957, p. 99; 1960, p. 111), Halliday (1963, p. 22-30).

Chair Peak Occurrence

Limestone float is found over an area about 4,400 to 4,800 feet in altitude south of Snow Lake on the east side of Chair Peak, in the south part of sec. 19, T. 23 N., R. 11 E., north of the Snow Lake trail. Limestone was not found in place, but it is probably associated with a sequence of ribbon chert cropping out in the area. The limestone is light gray in color and crystalline in texture.

KITTITAS COUNTY

Kittitas County lies east of King County and extends from the crest of the Cascade Mountains east to the Columbia River, a distance of 60 to 65 miles. Most of the county is underlain by volcanic and sedimentary rocks of Cenozoic age, none of which formed in a marine environment. Several areas in the mountainous western part of the county are underlain by metamorphic rocks believed to be of Paleozoic age. Small bodies of crystalline limestone occur in outcrops of these metamorphic rocks, but all are believed to be too small and remote to be of economic value. None of these occurrences were visited during the present investigation.

French Cabin Creek Deposit

A small area of impure limestone and calcareous shale crops out northwest of Cle Elum Lake and was referred "somewhat tentatively" to the Peshastin Formation by Smith and Calkins (1906). It was described as a thin-bedded and fine-grained gray limestone interbedded with calcareous shale and shaly sandstone. The calcareous rocks overlie Easton Schist, but are separated from it by a layer of metamorphosed rock. An unconformity exists, in which limestone and shale having a dip of 45° overlie the schist, which is vertical. Foster (1957) states,

> The marble from the ridge south of French Cabin Creek is a medium-grained, somewhat foliated rock of medium-gray color with brown bands marking the foliation. Microscopic examination reveals that it is composed mostly of large and small grains of somewhat sheared calcite, together with isolated grains of quartz and altered plagioclase.

The deposit is east of the head of French Cabin Creek, at an altitude of about 5,000 feet. The size is unknown.

References. — Smith and Calkins (1906, p. 2), Foster (1957, p. 15).

Boulder Creek Deposit

A narrow band of metamorphosed limestone is at the head of Boulder Creek, about 20 miles northwest of the town of Roslyn. It was assigned to the Peshastin Formation, of Carboniferous or older age, by Smith and Calkins (1906) and is reported by Hodge (1938) to be "an excellent deposit of lime rock of good grade, suitable for fluxing purposes."

References. — Smith and Calkins (1906, p. 2), Hodge (1938, p. 91).

Teanaway River Headwaters Area

Between the headwaters of the North and Middle Forks of the Teanaway River is an area of Peshastin Formation composed of black cherts, interbedded with slate and lenses of light-gray limestone. The lenses rarely measure more than a few yards in length. Russell (1900) reported them as small lens-shaped masses of white to dove-colored limestone.

G. H. Plummer, of the Northern Pacific Railway, reported the occurrence of a limestone deposit in sec. 3, T. 22 N., R. 15 E., 25 miles from the nearest railroad point. It was not considered to warrant further investigation because of limited size.

References. — Russell (1900, p. 103), Smith (1904, p. 3), Washington State Planning Council (1937, p. 26).

Taneum-Manastash Creek Area

In western Kittitas County there are small lenses of limestone in the Peshastin Formation in outcrops on mountain slopes 10 to 15 miles southeast of the town of Easton, on the Northern Pacific Railway; near the head of the North Fork of Taneum Creek; and on the South Fork of Manastash Creek. They are all reported as being too small and too far from transportation to be of economic value. Reports of recent geologic work in the area do not mention them.

Reference.—Hodge (1938, p. 91).

CHELAN COUNTY

Chelan County is north of Kittitas County and extends from the crest of the Cascade Mountains on the west to the Columbia River on the east. It is as much as 60 miles wide east-west and 85 miles long. Most of the bedrock of the county

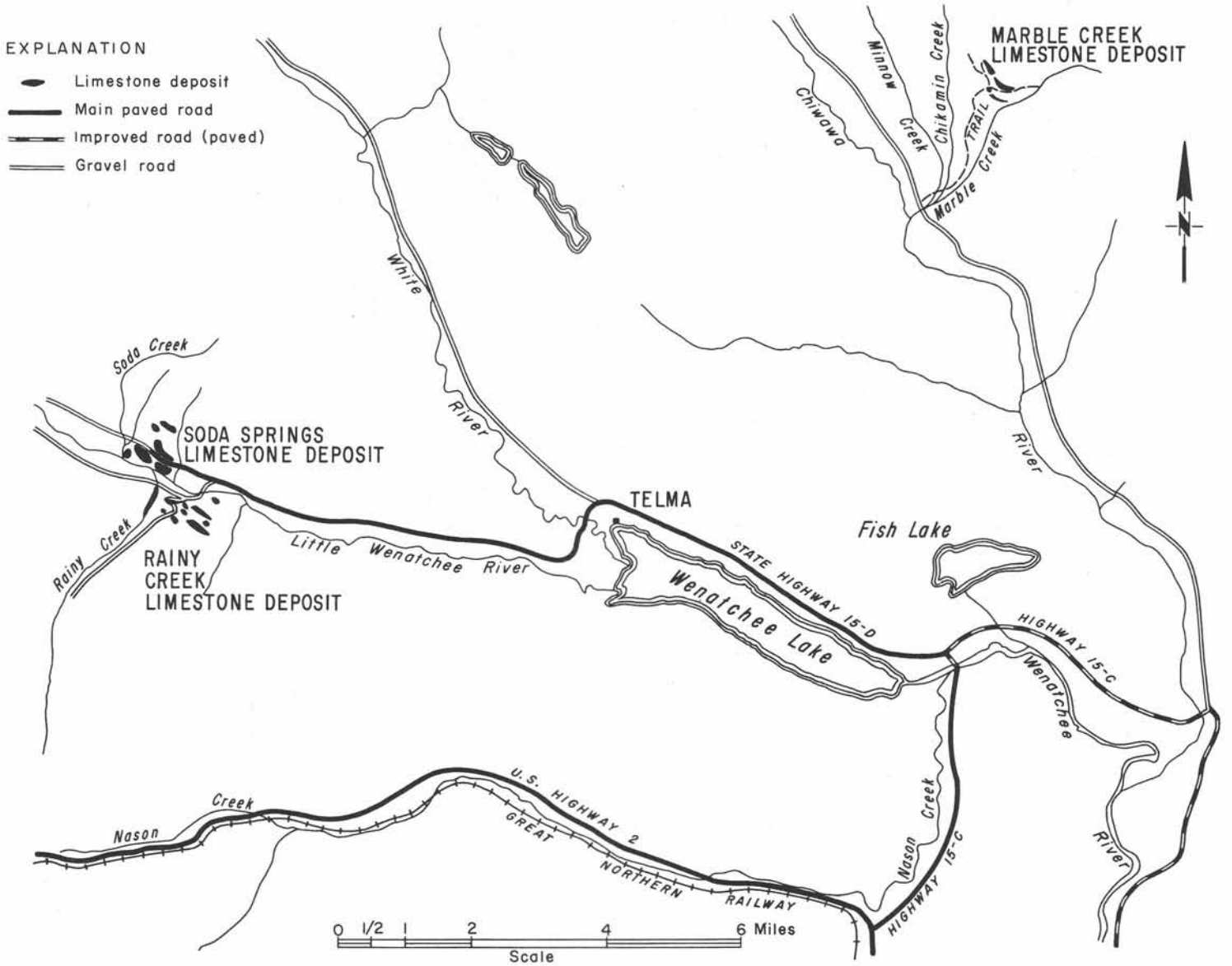


FIGURE 196.—Index map of limestone deposits of the Wenatchee Lake-Chiwawa River area.

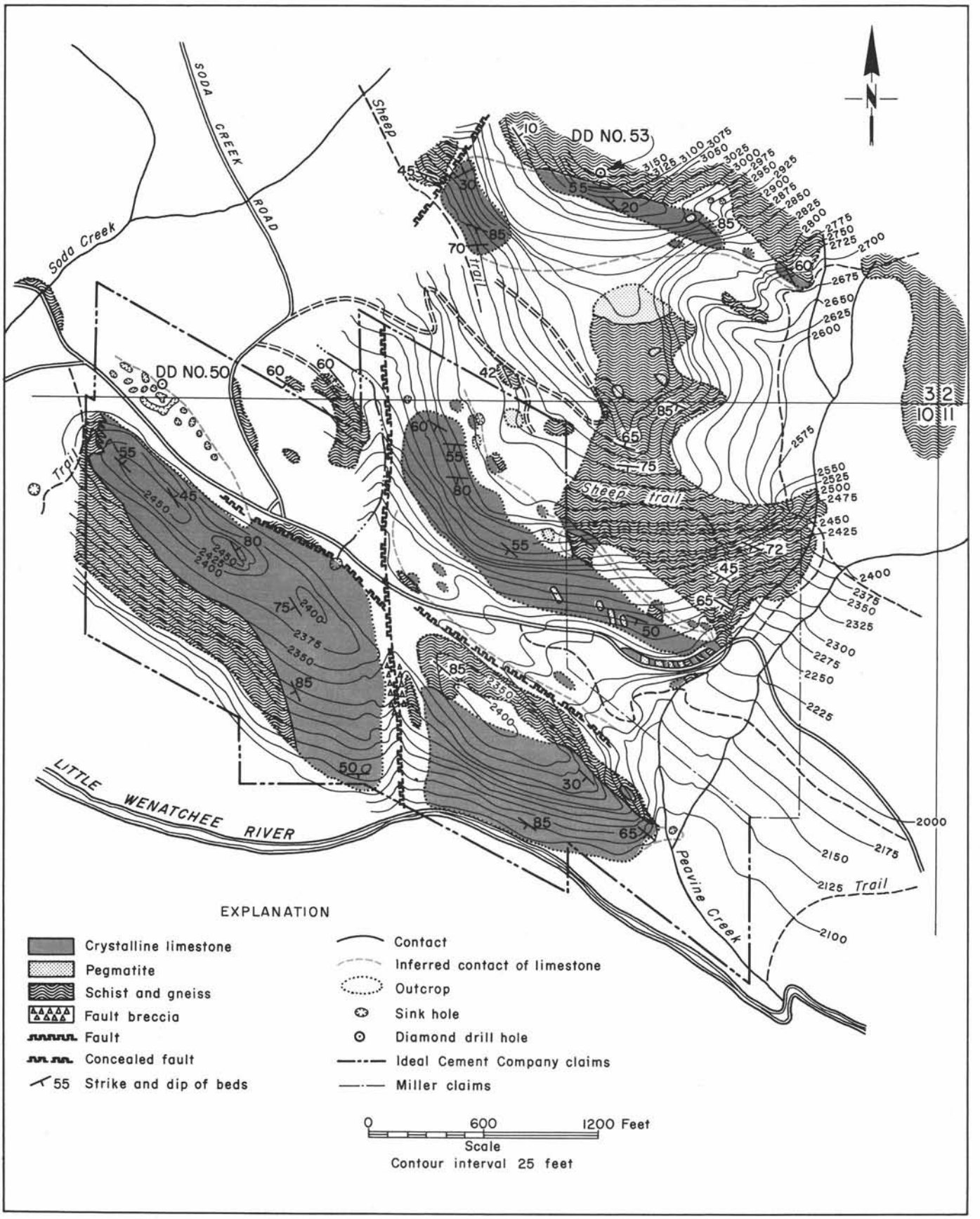


FIGURE 197.—Soda Springs deposit. T. 27 N., R. 15 E. Geology by W. R. Danner. Transit and compass and tape surveys by W. R. Danner, H. Pilz, L. Nothwang, R. Schwan, and W. Mark. Courtesy of Ideal Cement Company.

consists of metamorphic and igneous rocks thought to be of Paleozoic or Mesozoic age. A large wedge-shaped, down-dropped fault block filled with Late Cretaceous or early Cenozoic continental sandstones and conglomerates almost bisects the county. This fault block narrows to the north and widens to the south.

The metamorphic rocks exhibit a prominent northwest-southeast structural trend. They appear to represent a sequence of recrystallized marine sedimentary and volcanic rocks, but no fossils have been found within them. Crystalline limestones have been found in many places in these rocks, but most of the deposits are small and lenticular. Only those of the Soda Springs-Rainy Creek area west of Lake Wenatchee are large enough to be exploited on a moderate scale, but they have the disadvantage of being in a relatively remote mountainous area that is subject to heavy winter snowfall. The Soda Springs deposit was quarried until 1964 by the Ideal Cement Company to supply its cement plant at Grotto in King County. Several of the small limestone deposits near Lake Chelan and Wenatchee have been quarried in the past and used mostly as a source of lime for local consumption. Some of the smaller limestone bodies are white in color and might be used for decorative stone or terrazzo chips. No large high-quality limestone deposits are known to exist in the county.

Soda Springs Deposit

Location, size, and accessibility. — The Soda Springs limestone deposit is in the N½ sec. 10 and the SE¼ sec. 3, T. 27 N., R. 5 E., on the north side of the Little Wenatchee River in the Wenatchee National Forest, Chelan County. This deposit consists of five blocks of crystalline limestone cropping out between Soda Creek on the west and Peavine Creek on the east. The largest block, about 2,000 feet long and 300 to 900 feet wide, is being quarried at the present time (1964). Three of the other blocks range from 1,200 to 1,800 feet in length and are 50 to 450 feet wide. The fifth block is approximately 400 feet long and 50 to 100 feet wide. Most of the outcrops have about 100 feet or more of relief. All the outcrops are within an area of approximately 1 square mile.

The deposit is accessible by 8 miles of black-topped road from the resort area on the northwest side of Lake Wenatchee and by a total of 21 miles of paved road from the Great Northern Railway. Originally, the area was covered with virgin timber, but in recent years a part of it has been logged. The highest limestone outcrops are about 1,000 feet higher in altitude than the lowest outcrops.

Geology and description. — The Soda Springs limestone deposit consists of one or more beds of crystalline limestone broken by faulting and folding into five separate blocks. No continuation of the deposit to the west is known, but similar limestone is exposed in the Rainy Creek deposit to the southeast. The limestone is interbedded with a sequence of metamorphic rocks of undetermined geologic age. These rocks are complexly folded and faulted, but generally have a northwest-southeast structural trend. North of the limestone deposits the rocks are composed primarily of fine-grained granitic gneisses and minor amounts of talc, hornblende, actinolite, and garnet schist. The limestone is interbedded in a sequence of mica schists and mica gneisses that include staurolite schist, garnet schist, and garnet gneiss. Garnet-bearing rocks seem to be most abundant near the limestone, and in some places more than 25 percent of the rock consists of red garnets as much as 3/4 inch in diameter. However, the garnets are not well crystallized and are opaque, so are of no value as gem material.

FIGURE 198. — Area of Soda Springs deposit. View looking northwest from the Rainy Creek deposit. Quarry of the Ideal Cement Company in foreground, in valley of the Little Wenatchee River. June 1957.

Small dikes and intrusions of several different types of igneous rock cut the metamorphic rocks. The most abundant dike rock is a quartz-muscovite-feldspar pegmatite. It occurs in both the limestone and the surrounding rocks as bodies as much as 100 feet or more in width. Muscovite crystals up to $1\frac{1}{4}$ inches in diameter are present, but most of the pegmatite minerals are smaller than this. One beryl crystal approximately 1 inch long and 3/4 inch thick was found in a pegmatite outcrop along the Lake Creek logging road, south of the Little Wenatchee River. It is opaque and of a pale yellow-green color. Only the larger pegmatite masses appear to show any contact effect on the limestone. Diopside crystals occur along the contact with limestone on the Burns claim, along the Peavine Creek trail.

Fine-grained quartz-feldspar dikes occur in a few places, and northwest of the Soda Springs area there are a few basic dikes composed of unidentified minerals but containing scattered grains of chromite. Nonfoliated medium-grained quartz diorite cuts the metamorphic rocks to the south, in the headwaters of Rainy Creek and on Nason Ridge.

The limestone is medium to coarsely crystalline in texture and light gray to white in color. It contains thin irregular interbeds of schist and quartzite. Hornblende schist appears to be most abundant within the limestone, and some of it contains a high percentage of pyrite. Tiny crystals of pyrite and flakes of various micas and graphite are common in much of the limestone. Traces of molybdenite and chalcopyrite have been found in the limestone on the Miller claims; however, the deposit as a whole cannot be considered to be highly mineralized, and it is definitely a disappointment to mineral collectors.

The two largest limestone blocks form a prominent ridge bordering the north side of the Little Wenatchee River. Originally, there was a low saddle in about the middle of this ridge, where the crusher and other buildings are now located. This saddle marked the trace of a north-south fault. Good exposures of fault breccia could be observed when the crusher site was being excavated.

The limestone block to the west of this fault is now being quarried. It is about 2,000 feet long and ranges in width from 300 to 900 feet. At its eastern end the limestone dips southward, but toward the west the dip steepens to vertical and then changes to a northerly direction. The outcrop narrows in width toward the west, and the limestone is believed to pinch out in schist where the ridge becomes lower and finally disappears as a topographic feature at the border of the forest camp. The northern limit of this block is marked by a prominent scarp, and quarrying has revealed a fault at its base. However, numerous sinkholes are north of the projected trace of this fault to the west, indicating additional limestone buried under glacial drift. Before quarrying was started, a large sinkhole with a small stream draining into it was at the northeastern corner of this block; part of this sinkhole is still visible on the quarry floor. Other large depressions occur at the west end of the deposit.

The second block, forming the eastern part of the ridge, is about 1,200 feet long and averages about 450 feet in width. It consists of a large thin slab of limestone dipping steeply southward down to the river. It thins out to the west because of erosion and disappears to the east under alluvium. It may extend under the Little Wenatchee River and its alluvial deposits, to reappear in two small outcrops 3,000 feet and 5,400 feet, respectively, to the southeast. The steep exposures of limestone, largely barren of vegetation, on the south slope of this ridge are spectacular and may easily lead to the belief that the entire hill is a mass of limestone. However, this hillside is a dip slope, and drilling has shown the limestone to range in thickness from 50 feet or less near the top to about 100 feet halfway down. Pegmatite dikes cut the limestone in several places.

The third block lies north of the highway and forms a prominent northwest-trending, south-facing cliff. Limestone is exposed over a length of about 1,800 feet and a width of 600 to 700 feet. Much of the width of the deposit is concealed by glacial drift. The limestone dips steeply to the south, roughly parallel to the cliff face. The same fault that cuts the limestone ridge to the south cuts off this deposit along its western border. Another fault borders the block along its south side, in the small valley in which the highway is located. The limestone appears to thin toward the east and disappears under the drift and alluvium in the valley of Peavine Creek. Although small pegmatite dikes are common in all the limestone outcrops, they do not constitute an important impurity except in this block. Large pegmatite dikes are fairly numerous, particularly at the eastern end on the Miller claims.

The fourth block lies about 1,800 feet north of the highway and forms a steep hillside and cliff area. It is not well exposed except on the steepest slopes. Along its northern edge it contains numerous interbedded schist layers. The western

part of the block appears to be on the nose of an anticlinal fold, but the sparse outcrops to the east do not support this hypothesis, as they have only steep north dips. This block is about 1,800 feet long, but varies in width from 400 feet on the west to 50 feet or less on the east. It is cut off to the northwest by a fault and appears to pinch out to the east. Along its north side the block dips steeply north under schist and gneiss. On its south side it disappears under soil and drift, but between the last limestone exposure of this block and the first outcrop of the block to the south are numerous knobs of schist and gneiss cut by irregularly shaped bodies of pegmatite.

The fifth and smallest of the limestone exposures occurs along the north side of the Little Wenatchee River, where it forms a cliff nearly 100 feet high. It ranges from 50 to 100 feet in width and is exposed parallel to the river for a distance of approximately 400 feet. A few small pegmatite dikes cut the deposit. Its structure is unknown, but it appears to be a fault block. It is within the boundary of the Soda Springs forest camp and is on lands reserved for camping; therefore, it is not open to staking or exploitation.

It might be emphasized here that the area of the Soda Springs limestone claims contains more and larger bedrock outcrops that the adjacent areas. The area containing limestone seems to be more resistant to erosion than the areas composed only of schist and gneiss. Where the limestone appears to pinch out, the ridges that usually mark its outcrop also disappear. Limestone in this area tends to form ridges and cliffs. Noteworthy also is the fact that the drift-filled depressions between the ridges appear to be mostly fault controlled.

Quality.—The quality of the limestone in the Soda Springs deposit is quite variable. Much of it is a high-calcium type, and when mixed with the schist and quartzite impurities, it makes an excellent cement rock.

Chemical analyses of Soda Springs limestone

(Analyses by Ideal Cement Company, Melvin Matheny, analyst)

Sample	Location	Sample length (feet)	$CaCO_3$	Loss on ignition	CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3	Na_2O	K_2O
Hole 1	East side, Ace Away claim	150									
Box 1	----------	-------	89.3	39.79	49.99	0.42	7.72	Trace	1.16	0.04	0.04
Box 2	----------	-------	67.7	28.10	37.88	0.72	26.40	2.22	3.52	0.26	0.18
Box 3	----------	-------	98.5	43.28	55.12	Trace	0.54	Trace	0.16	0.00	0.00
Box 4	----------	-------	96.2	42.76	53.93	Trace	2.70	0.00	0.05	0.00	0.00
Box 5	----------	-------	96.0	42.62	53.74	Trace	3.08	Trace	0.16	0.00	0.00
Hole 6	Soda Springs 1	150									
Box 1	----------	-------	97.2	41.90	54.40	0.54	3.42	0.07	---	0.06	0.02
Box 2	----------	-------	83.6	36.02	46.87	1.25	12.46	1.32	---	0.18	0.04
Box 3	----------	-------	97.2	42.71	54.40	0.86	2.06	0.18	---	0.05	0.01
Box 4	----------	-------	97.75	42.93	54.74	1.12	1.36	0.15	---	0.06	0.01
No. 2	SW. corner, Betty 5	Hand specimen	95.20	41.30	53.98	0.70	2.86	0.41	0.63	0.07	0.05
No. 4	NE. part of Peavine 3	Hand specimen	97.40	43.08	54.88	0.80	0.62	0.40	0.10	0.12	0.04
No. 1	NW. part of Peavine 3	Hand specimen	96.30	41.87	53.70	1.20	1.80	0.74	0.46	0.13	0.08
No. 3	Betty 1, north	Hand specimen	97.60	43.74	53.70	0.80	0.46	0.49	0.09	0.54	0.11
No. 2	Betty 1, south	Hand specimen	97.10	43.29	53.70	0.80	0.46	0.49	0.09	0.44	0.11

Ownership and development.—The Soda Springs limestone deposit is owned by the Ideal Cement Company, Denver National Building, 821 - 17th Street, Denver, Colo. It is believed to have been first staked in the spring of 1930, but the claims were later dropped because of their distance from a market. The property was staked by different persons again in 1952, and purchased from them by the Northwestern Portland Cement Company, of Seattle. The latter company developed the Soda Springs quarry in the spring of 1953, and the quarry continually produced limestone for cement manufacture

Chemical analyses of Soda Springs diamond drill cores

(Courtesy of Ideal Cement Company)

Sample	Depth (ft)	Loss on ignition	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	Total
Hole 53, Betty claim	10-15	4.86	10.29	4.13	52.24	15.04	7.60	94.17
------- Do -------	15-41½	12.44	24.17	2.45	42.76	9.82	4.39	96.03
------- Do -------	41½-44	6.29	17.52	1.58	54.39	13.89	3.88	97.55
------- Do -------	44-68	21.82	34.56	1.85	30.40	6.54	2.90	98.07
------- Do -------	68-78	38.62	45.35	0.62	11.71	2.33	0.47	99.10
------- Do -------	78-93	27.73	38.85	1.05	24.49	4.21	1.86	98.19
------- Do -------	93-128	2.87	10.05	3.58	49.19	18.44	11.93	96.06

FIGURE 199.—Soda Springs quarry of the Ideal Cement Company. View looking west, July 1956. Stockpile in right foreground.

until 1964. The company and all its properties were purchased by the Ideal Cement Company in 1957. More than 1 million tons of limestone has been quarried. Rock is trucked from the quarry 21 miles to Nason Creek, a station on the Great Northern Railway, and then shipped 35 miles to the plant at Grotto. The quarry was shut down in 1964.

In 1952 the original property included 12 claims. Later, as a result of geologic exploration, 4 additional claims were staked. When the property was patented, some of the original claims were dropped. Some of the southern claims lying adjacent to the Little Wenatchee River were not included in the patent, as they are on lands held in reserve by the United States Government as a reservoir site for a proposed dam a short distance downstream. However, it is unlikely that this dam will be built, due to the great width of the valley and the presence of a landslide area adjacent to the proposed site. The most southwesterly outcrop is on lands of the Wenatchee National Forest and is included in the withdrawn lands of the Soda Springs campground.

References.—Washington State Planning Council (1937, p. 26), Libbey (1957, p. 81), Valentine (1960, p. 56).

Lucky Line Claims (Miller Soda Springs)

Location, size, and accessibility.—The Lucky Line claims are in the NE¼ sec. 10, T. 27 N., R. 15 E., on the north side of the Little Wenatchee River in the Wenatchee National Forest. The limestone deposit is mostly on the north side of the forest highway and west of Peavine Creek. The property is adjacent to and is an extension of one of the blocks of crystalline limestone of the Soda Springs deposit of the Ideal Cement Company. Surface outcrops of limestone are exposed over an area about 900 feet long and 300 feet wide. The deposit is accessible by 8 miles of black-topped road from the resort area on the northwest side of Lake Wenatchee and by a total of 21 miles of paved road from the Great Northern Railway. The area is covered in various parts with dense second-growth trees and brush, with virgin timber, and with small, partly grass-covered bedrock outcrops.

Geology and description. — Limestone exposed on the Lucky Line claims is on the southeast extension along strike of a band of crystalline limestone striking northwest-southeast and dipping about 50° SW. On the western border of the property the limestone has an exposed width of at least 300 feet, but it may be much wider under cover. To the north, the limestone is underlain by gneiss and schist, and to the south it is covered by glacial drift, soil, and talus. Scattered outcrops to the southeast indicate approximately the same width of limestone, but outcrops stop on the west side of Peavine Creek, and for a distance of over 3,600 feet southeast along strike no bedrock is exposed. This area is overlain by glacial deposits (a prominent lateral moraine) and by talus and landslide debris.

From 30 to 90 feet north of the main outcrop is a small bed of limestone 5 to 10 feet thick that is overlain and underlain by schist and gneiss.

Pegmatite dikes composed of quartz and feldspar cut the limestone in several places and are as much as 10 feet or more in thickness. They appear to be more abundant in the limestone of this property than elsewhere in the area, and they increase in number eastward.

Four beds of garnet-bearing gneiss and schist are interbedded with the limestone at its eastern outcrop terminus and may indicate that the limestone thins and pinches out in that direction.

The limestone is medium to coarsely crystalline in texture and gray to white in color. It contains minute amounts of pyrite and graphite, and near some of the pegmatite dikes small crystalline masses of chalcopyrite and molybdenite occur.

Quality. — The composition of the limestone is variable; both high- and low-calcium rocks are present.

Chemical analysis of Lucky Line limestone

(Mark Adams, analyst)

Sample no.	Location	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
Cn 2-1	Along highway	100	90.30	1.23	39.98	50.73	0.59	7.09	1.43	0.055

Ownership and development. — Two claims, Lucky Line No. 1 and Lucky Line No. 2, were staked in 1952 by Leslie B. Miller, Miller Lime Company, Gold Bar, Wash. There has been no commercial development. The western part of the property contains limestone of a quality similar to that of the adjacent Soda Springs deposit and could be quarried most economically as a continuation of the development of that deposit. The eastern part of the property has too many schist layers and pegmatite dikes to produce good-quality limestone, except by careful sorting.

Rainy Creek Deposits

Location, size, and accessibility. — The Rainy Creek limestone deposits are in the SE¼ sec. 10, SW¼ sec. 11, NW¼ sec. 14, and NE¼ sec. 15, T. 27 N., R. 15 E., on the south side of the Little Wenatchee River. Limestone outcrops have been traced discontinuously for a distance of about 5,700 feet east of the canyon of Rainy Creek. The deposits are estimated to contain a minimum of 5,000,000 tons of limestone.

They are accessible by 21 miles of road from the Great Northern Railway at Nason Creek. Twenty miles of this is paved road, and 1 mile is gravel-surfaced logging road. Of the latter, ½ mile is the Labyrinth Mountain logging road and ½ mile is the Rainy Creek logging road.

Part of the area is logged-off land, and part is covered with virgin forest. Large patches of devils club occur in moist areas on the mountainsides, and an extremely dense second growth of trees and brush covers the southwestern part of the deposit, above Rainy Creek. There is more than 1,500 feet of relief between limestone outcrops in the canyon of Rainy

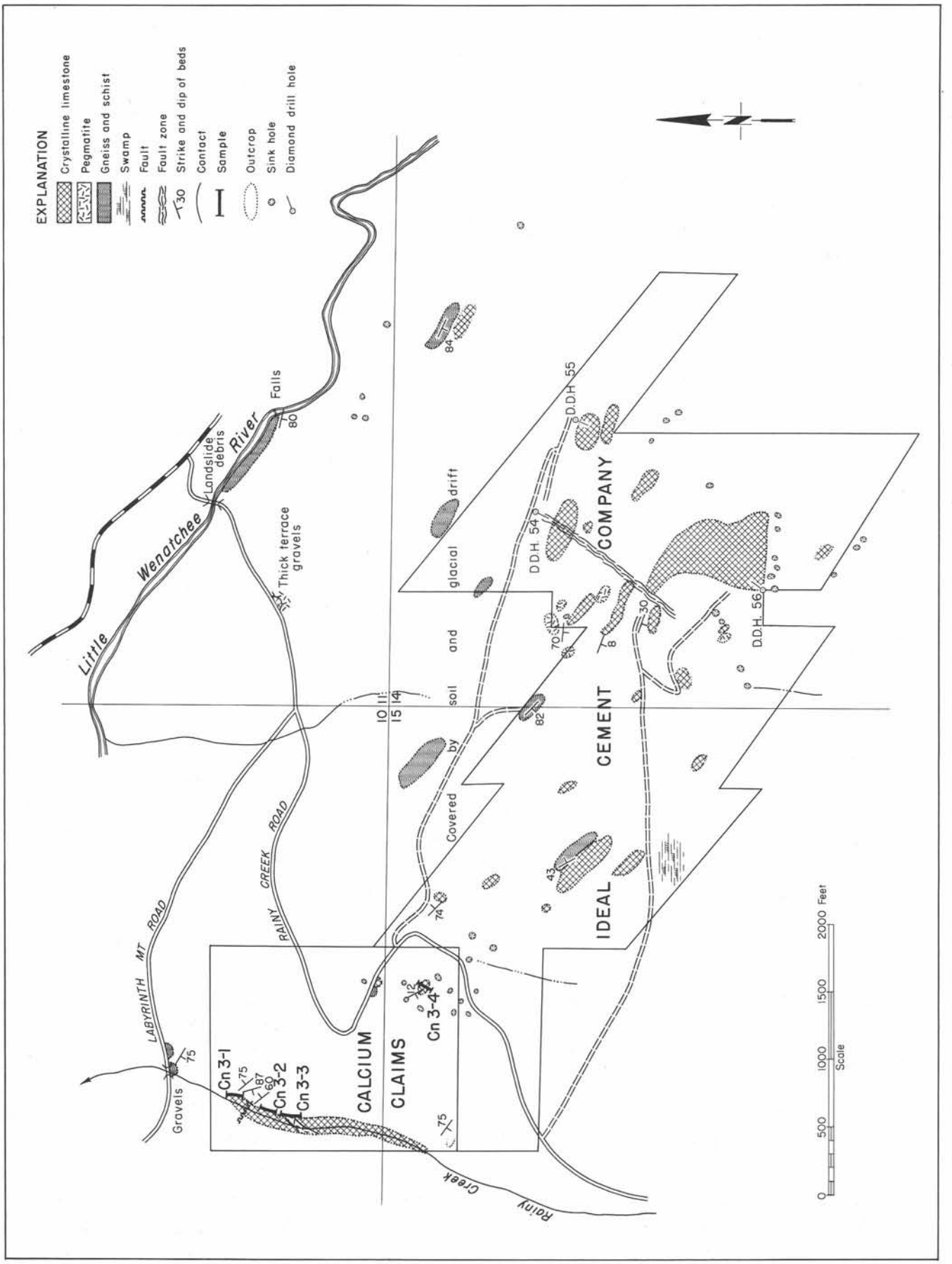


FIGURE 200.—Rainy Creek deposits. T. 27 N., R. 15 E. Reconnaissance geologic map. Geology by W. R. Danner, modified in the southeast part by B. R. Wilk. Courtesy of Ideal Cement Company.

Creek and those on the mountainside to the southeast. Altitudes on the deposits range from 2,000 to 3,500 feet above sea level.

Geology and description. — Much of the area is overlain by a cover of soil, glacial drift, or alluvial terrace sands and gravels. This cover may reach a thickness of 50 feet or more near the Little Wenatchee River.

The limestone is medium to coarsely crystalline in texture and white to gray in color. It contains minute crystals of pyrite, graphite, and white and green muscovite similar to those in the Soda Springs deposit to the northwest. Locally, graphite crystals make up as much as 3 percent of the rock. The graphite-rich bands in the limestone, when freshly broken, emit a strong odor of hydrogen sulfide or ethyl mercaptan.

Schists and gneisses, some of which are garnetiferous, are interbedded with and overlie and underlie the limestone. Pegmatite dikes composed of quartz, feldspar, and muscovite cut the sequence in many places. These dikes generally do not show any contact effect. However, at one contact with the limestone there is a body of white massive quartz containing crystals of epidote as much as $2\frac{1}{2}$ inches in length and $\frac{1}{2}$ inch in diameter.

The best exposures of the limestone are in the canyon walls along the lower part of Rainy Creek, about 600 feet south of the Labyrinth Mountain road bridge over the creek. Crystalline limestone cut by pegmatite dikes and in places interbedded with schist is exposed along the canyon walls for at least 1,500 feet to the south, and vertically in cliffs from 20 to 50 feet high. Bedding is not readily identifiable in this limestone, but a few steeply dipping and strongly contorted layers of impurities may be relics of it. One pegmatite dike is exposed for a width of 100 feet on the west wall of the canyon and for a lesser distance on the east wall. Glacial drift covers the limestone to a depth of 8 to 10 feet along the canyon rim. Numerous small solution cavities are present in the limestone exposed in the canyon walls.

Southeastward from Rainy Creek, outcrops of bedrock are relatively rare for almost 6,000 feet. The few that do occur consist mostly of limestone containing interbeds of schist and gneiss and intrusive pegmatite dikes. Between the outcrops are many sinkholes believed to be produced by the subsidence of overlying glacial sediments into cavities formed by ground-water solution in the underlying limestone. Some of the sinkholes are 25 or more feet deep and as much as 50 feet in diameter. In at least two places, small streams flowing down the mountainside disappear into the bottom of sinkholes.

The width of the limestone-schist-gneiss outcrop area east of Rainy Creek ranges from 1,000 to 1,800 feet, but how much of this is underlain by limestone is unknown. The largest limestone outcrop is a north-facing cliff averaging about 50 feet in height and extending for approximately 1,700 feet in a northwest-southeast direction. It exposes limestone for a width of about 150 feet along its outcrop. A relatively flat area to the south, back of the rim of this cliff, contains numerous sinkholes.

To the northeast of the main outcrop area and just south of the Little Wenatchee River is another area of sinkholes, but only two outcrops of limestone were seen. One is only a few feet in area and is exposed in a roadcut about 900 feet southwest of the bridge over the river. It appears to be surrounded by pegmatite and overlain by a thick deposit of terrace sands and gravels.

The second outcrop, 2,200 feet to the southeast, is about 300 feet long and 75 to 100 feet wide. Immediately north of it is an outcrop of garnet gneiss with foliation dipping 84° N.

Proper evaluation of the Rainy Creek deposit area can be made only by stripping and drilling, but the deposit appears to be one of the largest known occurrences of limestone in Chelan County.

There may be additional outcrops of limestone to the southeast along strike, but so far as is known, none have been reported. To the northwest, the limestone disappears under thick alluvial terrace gravels on the west side of Rainy Creek and does not reappear in the next bedrock outcrops along strike. A search of both sides of the Little Wenatchee Valley upriver from the Soda Springs and adjacent Rainy Creek deposits did not reveal any additional limestone.

Quality. — The composition of the limestone is highly variable, but small sections are of a quality satisfactory for cement rock, and locally one is high in calcium.

Chemical analyses of Rainy Creek limestone

(Mark Adams, analyst)

Sample no.	Location	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5	Na_2O (ppm)	K_2O (ppm)	TiO_2 (ppm)	S (ppm)
Cn 3-1	Rainy Creek Canyon, north end --------	150	96.28	1.44	42.78	54.09	0.69	2.92	0.73	0.039	195	620	100	816
Cn 3-2	Rainy Creek Canyon	150	91.88	2.47	41.69	51.62	0.85	4.62	1.12	0.025				
Cn 3-3	Rainy Creek Canyon	100	97.56	0.98	43.75	54.81	0.47	0.68	0.36	0.064				
Cn 3-4	Southeast corner, Calcium claims ---	10	95.92	1.40	42.65	53.89	0.67	2.16	0.61	0.007				

Chemical analyses of Rainy Creek diamond drill cores

(Courtesy of Ideal Cement Company)

Depth (feet)	Loss on ignition	CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3	Total
Hole No. 54							
42.5 - 50	23.00	32.42	1.49	30.37	2.26	8.78	98.32
50 - 61	11.96	19.72	1.36	46.98	2.89	14.37	97.28
61 - 110	2.98	10.28	3.56	54.62	7.63	18.47	97.54
110 - 128	19.24	21.22	2.31	32.01	3.58	20.70	99.06
128 - 149	7.04	35.91	2.37	34.21	7.41	12.41	99.35
149 - 152	21.70	35.97	2.84	24.70	4.76	9.69	99.66
152 - 163	36.55	46.77	1.47	9.06	1.74	3.12	98.71
163 - 218	3.01	6.79	3.05	62.27	5.08	15.85	96.05
Hole No. 55							
0 - 44.5	34.66	44.56	0.82	15.86	1.37	2.54	99.81
44.5 - 51	28.84	40.93	2.00	20.92	2.60	5.44	100.73
51 - 60.5	36.77	46.29	1.29	11.90	0.82	2.33	99.40
60.5 - 91.8	15.15	27.36	2.05	39.91	3.71	12.02	100.20
91.8 - 142.5	31.47	40.56	0.63	21.94	1.06	3.41	99.07
142.5 - 174	33.11	43.02	0.94	17.18	1.85	3.34	99.44
174 - 177.5	17.83	28.05	2.24	35.15	5.25	9.26	97.78
177.5 - 198	27.62	45.27	0.95	19.24	1.72	4.19	98.99
198 - 199.7	35.48	45.27	0.69	16.89	0.70	1.36	100.39
199.7 - 205	17.63	27.82	1.80	40.43	3.42	8.61	99.71
Hole No. 56							
25 - 32	14.77	22.52	1.92	43.79	1.16	13.04	97.20
32 - 79	42.92	53.96	0.50	1.54	0.10	0.62	99.64
79 - 116	35.56	45.50	0.38	15.61	0.16	2.43	99.64
116 - 131.2	0.57	1.59	0.32	69.72	0.72	22.16	95.08
131.2 - 138	41.55	52.72	0.75	3.69	0.29	1.19	100.19
138 - 151.3	13.83	24.89	1.98	40.10	3.88	12.27	96.95
151.3 - 166	35.69	46.26	0.90	13.11	1.05	2.60	99.61

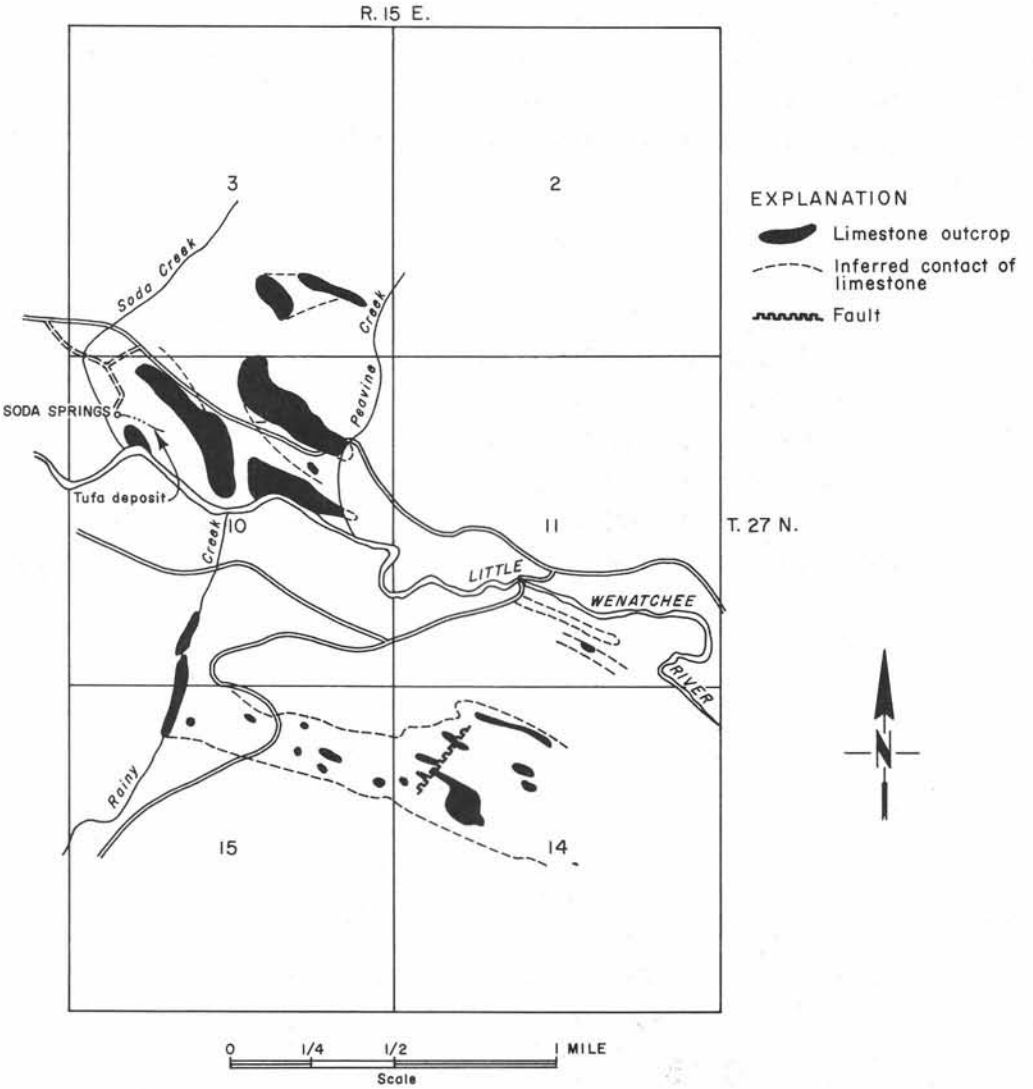


FIGURE 201.— Limestone deposits in the Soda Springs-Rainy Creek area. T. 27 N., R. 15 E.

Ownership and development.—Claims have been staked on the limestone in this area since about 1940, but many of them were apparently abandoned and later restaked by other parties. In November 1952 Robert D. Dysart, of Seattle, filed the U.R.L. claim along Rainy Creek, and on the same date Walter E. Thomas filed three claims adjacent to each other south of the U.R.L. and named them the Hazel No. 1, Hazel No. 2, and School Boy No. 1. The development of the Soda Springs deposit, to the north, brought about renewed staking activity. In 1954 three claims (Calcium No. 1, No. 2, and No. 3) were staked along the canyon of Rainy Creek by Paul D. Donaldson and W. C. McGinnis. In 1958 these claims were owned by Paul D. Donaldson, Estelle Lowry, and Carl A. Olson. Late in 1956 four claims were filed on outcrops to the southeast of Rainy Creek by the Rainy Creek Mining and Development Company, Inc., of Seattle. The present status of these claims is unknown. Twenty claims to the south and east of Rainy Creek were staked in 1957 by the Northwestern Portland Cement Company, now a division of the Ideal Cement Company, Denver National Building, 821 - 17th Street, Denver, Colo. These companies have constructed roads and trails on the property and have done some exploratory diamond drilling.

There has been no commercial development of this deposit. Its distance (21 miles) from rail transportation detracts from its economic value. Also, it might have to be shut down for several weeks in winter because of heavy snowfall in the

area. However, its size would enable it to be worked on a fairly large scale, and its quality is suitable for the production of portland cement. Under present economic conditions, probably its best use is as a reserve for the Ideal Cement Company, to be developed when the Soda Springs deposit, to the north, is exhausted.

References.—Northern Pacific Railway Company (1941, unpublished notes, p. 13), Huntting (1943, p. 53), Valentine (1960, p. 56).

Dry Creek Deposit

Location, size, and accessibility.—The Dry Creek limestone deposit extends from the NW$\frac{1}{4}$ to the SE$\frac{1}{4}$ of sec. 23, T. 6 N., R. 18 E., on the western slope of the Entiat Mountains and within the boundaries of the Wenatchee National Forest. It consists of a series of small lenses of limestone aligned in a northwest-southeast direction over a distance of at least 5,000 feet. The largest body exposes about 40,000 tons of limestone.

The deposit can be reached by driving 9 miles on State Highway 15C north of the town of Leavenworth to the Great Northern Railway tunnel; from there a dirt road is followed east about 3$\frac{1}{4}$ miles to the Dry Creek road and then north to the Sugarloaf Lookout trail, a total distance of about 5 miles. An access road for the southern part of the deposit was started

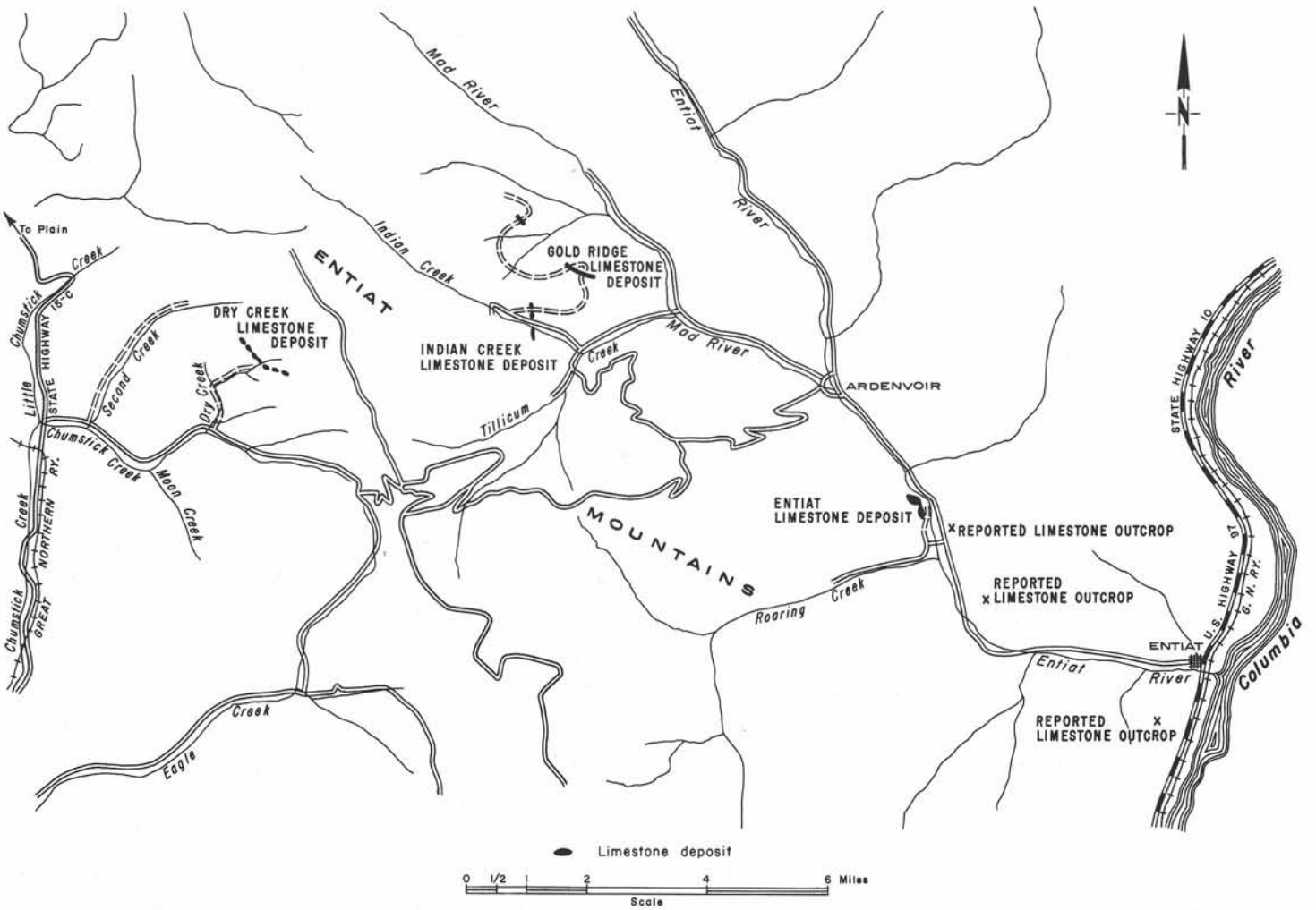


FIGURE 202.—Index map of limestone deposits of the Entiat Mountains area. Base map from U.S. Geological Survey Chelan and Chiwaukum quadrangles. Road locations approximate only.

from the Sugarloaf Lookout trail in 1953; it extended southward for about 4,000 feet, climbing approximately 780 feet in this distance. In 1960 this road and the last 1½ miles of the Dry Creek road appeared to be passable only for four-wheel-drive vehicles. The deposit can also be reached by driving 1 mile east from the highway and then traveling northeast up Second Creek about 5 miles, the last 2 miles of which is steep and rough and is suitable only for four-wheel-drive vehicles.

The topography consists of steep-sided hills covered with pine forest and grass. Limestone outcrops extend from 2,900 to 3,480 feet in altitude.

Geology and description. — The Dry Creek limestone deposit consists of several poorly exposed small lenticular bodies of fine to coarsely crystalline limestone exposed over a northwest-southeast strike distance of at least 5,000 feet. The enclosing rock rarely forms outcrops and is mostly soft and easily weathered biotite mica schist. The limestone-bearing sequence is part of the Swakane Gneiss. Its geologic age is unknown, but is considered to be pre-Ordovician by Waters (1932). The northwest extension of the limestone is cut off by a fault that strikes approximately N. 35° E. in the Dry Creek area. West of the fault lies the Chiwawa River valley, underlain by sandstone, conglomerate, and shale of the early Tertiary or Late Cretaceous Swauk Formation. The fault is in the valley just west of the limestone deposit and cuts across the Swakane Gneiss a few hundred feet northwest of the last mapped limestone outcrop.

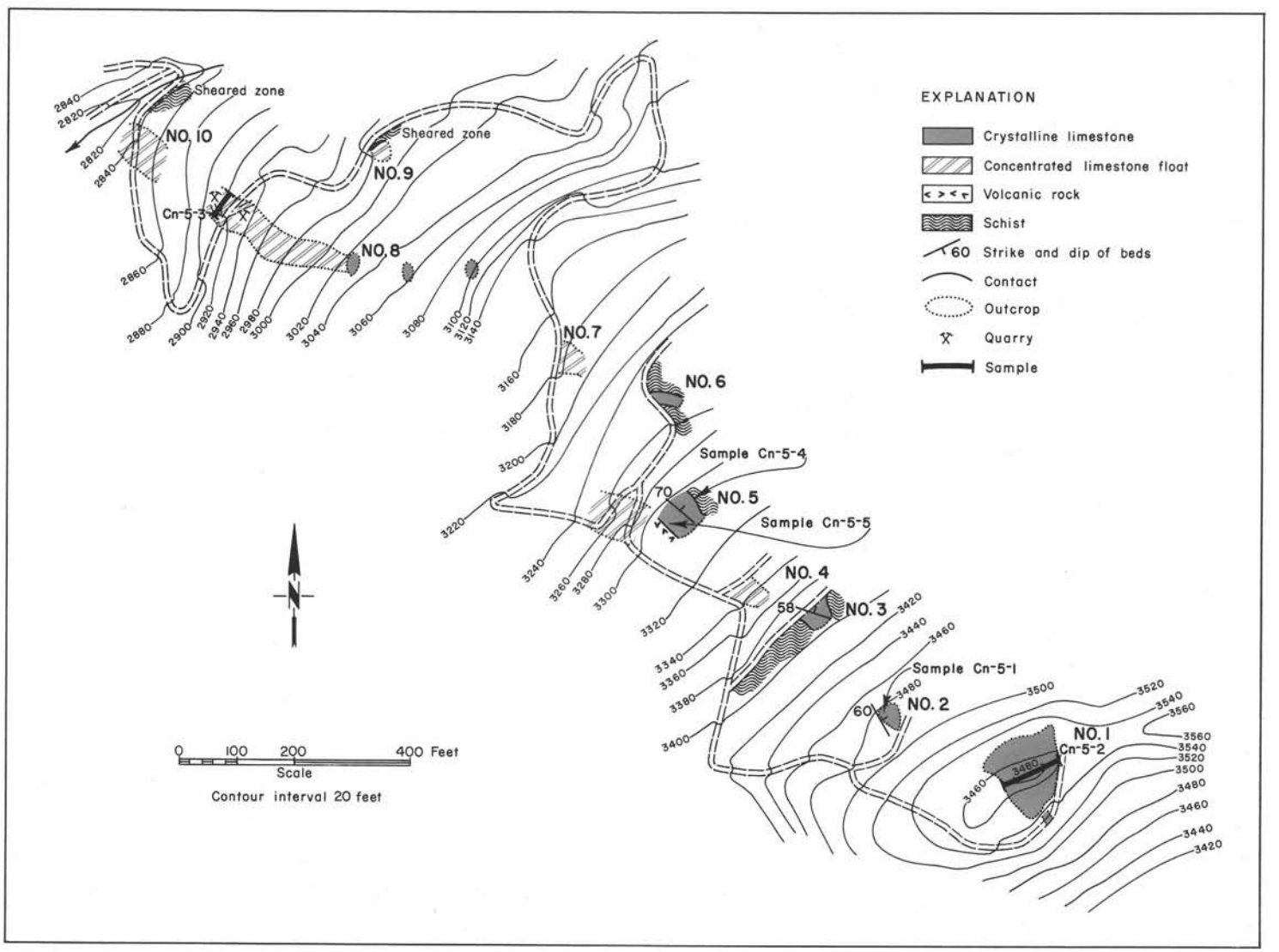


FIGURE 203. — Dry Creek deposit, south part. Sec. 23, T. 26 N., R. 18 E. Geology by W. R. Danner and E. A. Adams. Compass and tape survey.

Most of the limestone is white to light gray in color and finely to coarsely crystalline in texture. However, some parts of it are composed of thin-bedded, finely crystalline white, gray, buff, and black layers that are highly contorted and show numerous small folds and faults on the outcrop surface. The limestone appears to be mostly free of visible impurities, but small segregations of quartz and feldspar are present. A dike of volcanic rock cuts the limestone in one outcrop.

Description of individual outcrops in south part of area

The south part of the Dry Creek deposit consists of at least five outcrops of limestone on the upper part of a northwest-facing ridge slope, and several areas of limestone boulders downslope that have been formed either by talus coming from above or by breakdown of an underlying limestone body. The limestone in most outcrops and float fragments is thin bedded; highly contorted; blue, gray, and creamy white in color; and contains small siliceous inclusions. White, medium to coarsely crystalline limestone and black, thin-bedded, finely crystalline graphitic and siliceous limestone are also present. The limestone in some of the outcrops is highly sheared. In most of the outcrops the limestone appears to dip steeply to the northeast.

Outcrop 1 is the largest exposure of limestone in the deposit and forms a local high area on an east-west-trending ridge. It is 175 feet long northwest-southeast and about 60 feet wide at its south end. It consists of white to blue-gray crystalline limestone. A cut has been made along the south and east sides.

Outcrop 2 lies about 180 feet northwest and downslope from outcrop 1. It is about 30 feet wide and 40 feet long and forms a small knob on the steep hillside. It consists mostly of thin-bedded crystalline limestone that is crumpled and folded. There is a drill hole at the southeast end of the outcrop.

Outcrop 3 is exposed mainly in a cut, where it has a width of almost 41 feet. The limestone is white in color, crystalline in texture, and is interbedded with schist and highly sheared. It strikes about N. 85° W. and dips 58° NE. A section in the cut is as follows:

	ft
Top of section	
Soil cover	
Limestone	2
Sheared limestone and schist	2 to 3
Limestone	1½
Sheared schist	1
Limestone	4
Broken limestone	2+
Sheared schist	1 to 2
Limestone with shear zone	2 to 3
Fractured schist	1
Fractured limestone and schist	2
Fractured limestone	2
Soil with schist and limestone fragments	2
Covered.	

Outcrop 4 consists of an area of loose blocks of limestone so concentrated that they might be part of an outcrop that has been broken up. It might also consist of limestone float from outcrop No. 3, above it.

Outcrop 5 is limestone exposed in a cut for a width of about 70 feet. At the west end of the cut the limestone is intruded by a dike of fine-grained volcanic rock. The outcrop consists mostly of white crystalline limestone containing some black thin-bedded layers. The limestone strikes about N. 55° W. and dips 70° NE. An accumulation of limestone talus lies below this outcrop in a bend of the road. A drill hole was seen in the east end of the outcrop.

Outcrop 6 is white crystalline limestone exposed for almost 45 feet in a roadcut.

Outcrop 7 is a small concentration of limestone blocks in a roadcut.

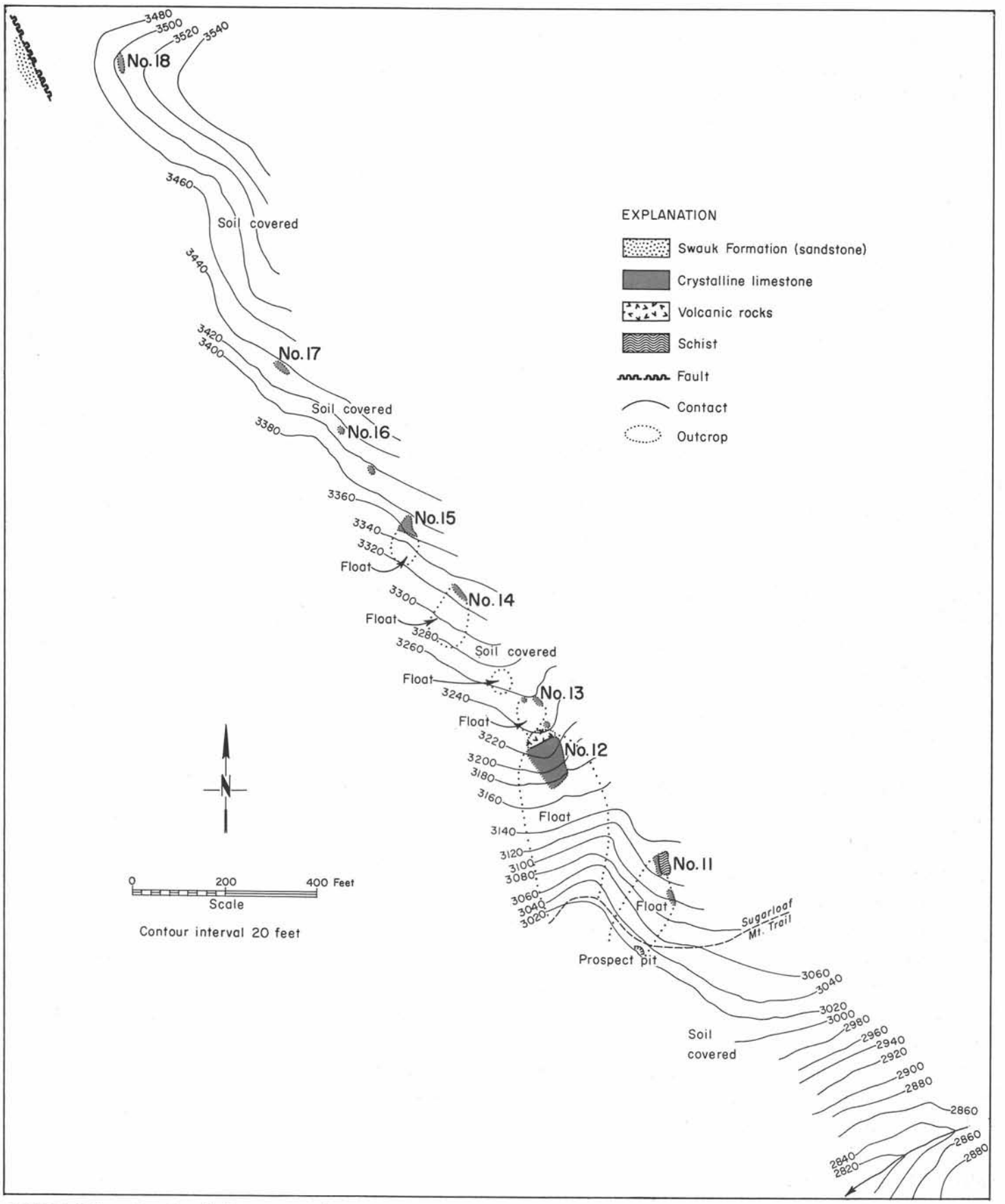


FIGURE 204.—Dry Creek deposit, north part. Sec. 23, T. 26 N., R. 18 E. Geology by W. R. Danner and K. Coryell. Compass and tape survey. Map courtesy of Ideal Cement Company.

Outcrop 8 is an area of numerous cuts or prospect pits in large boulders or masses of broken limestone fragments on the hillside. The occurrences appear to occupy a narrow band about 20 to 40 feet wide. At the road, small quarries have been made above and below in a mass of limestone boulders, which may represent either talus or a broken-up outcrop.

Outcrop 9 consists of a 5- to 6-foot layer of limestone boulders overlying a highly sheared zone of greenish-gray phyllite.

Outcrop 10 is an area of limestone float along a road, probably derived from the movement downslope of limestone from outcrop area 8.

Description of individual outcrops in north part of area

Limestone exposures in the northern part of the deposit are aligned at approximately N. 40° W. and consist of small knobs surrounded by soil and talus. Most of these exposures have areas of limestone float downslope from them that may conceal extensions of the limestone. Also, it is possible that where there is no visible solid limestone exposure, some of the areas of limestone float actually represent broken outcrops.

At least eight distinct outcrops are in the northern 3,000 feet of the deposit and are described briefly as follows:

Outcrop 11 is about 33 feet long and less than 5 feet wide. It crops out on a hillside and is in contact with mica schist on the northeast; its contacts on all other sides are covered with soil. About 60 feet to the south is a limestone outcrop occupying a roughly triangular area 18 feet long and 6 feet wide, flush with the ground surface. It is surrounded on all sides by soil. About 50 feet to the southwest are two small knobs of limestone from 1 to 3 feet in diameter, surrounded by soil. They could be partly buried float. About 65 feet farther to the southwest a prospect pit has exposed a chunk of limestone surrounded by soil. It appears to be float. Small pieces of limestone are common in the soil on the hillside northeast above this pit up to the outcrop.

Outcrop 12 is about 100 feet long north-south and 50 feet wide. A large area of float lies down the hillside to the south, and it is possible that some of the larger supposed float specimens of limestone are outcrops. Limestone stands up in a knob about 20 feet high at the southeast edge of this outcrop. The northwestern edge of the outcrop area is bordered by dark basic volcanic rock, probably a dike.

Outcrop 13 consists of three small exposures surrounded by limestone float. The largest is about 26 feet long and 5 feet wide. The contact on all sides is with soil. About 50 feet to the north is a small area of soil containing small limestone fragments but no visible outcrop.

Outcrop 14 is about 50 feet long and 5 feet wide and is in contact with soil on all sides. The outcrop is flush with the hillside, and an area of limestone float extends southwest down the slope below it.

Outcrop 15 is the second largest outcrop area in the north part of the deposit. Small limestone knobs stick up through the soil over a triangular area with maximum dimensions of 40 and 50 feet. Limestone is exposed vertically for more than 20 feet. Below it, southwestward down the hillside, is an area of limestone float.

Outcrop 16 consists of two small limestone exposures about 110 feet apart. The southern one is 5 feet long and 1 foot wide, and the northern one is 3 feet long and 2 feet wide. Soil surrounds them, and there is no visible limestone float in the immediate vicinity of the outcrop.

Outcrop 17 is about 30 feet long and 5 to 10 feet wide. All contacts are with soil, and there is very little limestone float in the vicinity. Between this outcrop and the next outcrop to the north is an area covered with a thick growth of grass and brush beneath which some limestone possibly may be concealed.

Outcrop 18 is the last outcrop known in the northern part of the Dry Creek deposit. It consists of white crystalline limestone about 5 feet wide and approximately 44 feet long exposed in the grass at the base of two large pine trees. No bedrock was found in contact with the limestone, but several outcrops of schist were seen up on the side of the ridge to the east.

Westward down the ridge, about 200 feet below the limestone, is an outcrop of Swauk Sandstone.

Quality.—The composition is quite variable, and some parts of the limestone are high in magnesia.

Chemical analyses of Dry Creek limestone

(Mark Adams, analyst)

Sample no.	Location	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
Cn 5-1		Composite	83.26	1.73	37.29	46.78	0.83	13.01	1.21	0.068
Cn 5-2		100	95.72	2.46	43.14	53.78	1.18	1.13	0.23	0.021
Cn 5-3		40	88.86	5.72	41.61	49.36	2.74	4.70	0.86	0.037
Cn 5-4	Black limestone	Single specimen	87.05	1.21	38.90	48.91	0.58	9.51	1.51	0.035
Cn 5-5	White limestone	Single specimen	95.60	0.27	43.20	53.71	1.13	0.80	0.24	0.010

Ownership and development.—The claims are owned by Patrick Hallett, et al., of Leavenworth, Wash. Many years ago, limestone from this deposit was burned in an old kiln that was below and west of outcrop area 1, in the south part of the deposit. Claims Dry Creek No. 1 and No. 2 and Lime Hill No. 1 and No. 2 were staked on the property in the spring of 1953 by Patrick Hallett. Claims Black No. 1 and No. 2 were located in July 1955 by John Henderickson.

Several small cuts have been made, quarry sites prepared, holes drilled, and 4,000 feet of road has been constructed on the property in the past few years, but there has been no known recent production. The small size and scattered nature of the outcrops and the variable composition of the limestone make it an uneconomic deposit for most uses under present conditions. When cut and polished, some of the banded limestone is attractive decorative stone. Several miles of the road leading to the deposit is passable only during dry weather, and some of this road crosses private property and requires permission from the land owners for use.

References.—Waters (1932), Washington State Planning Council (1937, p. 26).

Marble Creek Deposit (Paradise Claims)

Location, size, and accessibility.—The Marble Creek limestone deposit is mostly in the SE¼ of unsurveyed sec. 10, T. 28 N., R. 17 E., but is believed to extend into the SE¼ sec. 11, the NE¼ sec. 15, and the NW¼ sec. 14. Part of the deposit is on the north side of the valley of Marble Creek and part on the west side of a northwest-trending ridge to the north. It consists of two relatively large outcrops and several small ones. The largest exposure is about 440 feet long and 50 feet wide; with a depth of 100 feet it would contain an estimated 150,000 tons of limestone. Other exposures contain a lesser tonnage, but exploration might show a continuation between outcrops that would increase the tonnage considerably.

The trail to the Marble Creek deposit begins at a point about 27 miles by road up the Chiwawa River valley from the town of Leavenworth. Ten miles of this road is gravel- or dirt-surfaced logging road, and the rest is black-topped State Highway 15C. Approximately 3 miles of trail, climbing 1,500 feet, leads to the deposit. The area is covered with relatively open stands of virgin pine forest and scattered areas of thick brush, grass, and barren rock slopes and cliffs.

Geology and description.—The limestone of the Marble Creek deposit occurs as beds and lenses in a sequence consisting mostly of mica schist. Locally, large but poorly developed garnets have been formed in the schist. Just east of the schist-limestone sequence are exposures of gneiss and granitic rocks. Dikes of granodiorite and diorite cut the schist.

Most of the limestone is very finely crystalline or sugary in texture. It is usually white. Some of it shows thin banding, in part highly contorted by flowage. Segregations of siliceous material that resemble fossils and range from tiny spots to shell-like masses 1½ inches across were found in the limestone. None of these objects could be definitely identified to be of organic origin. Some parts of the limestone are finely banded, and other parts look porphyritic and have clear gray

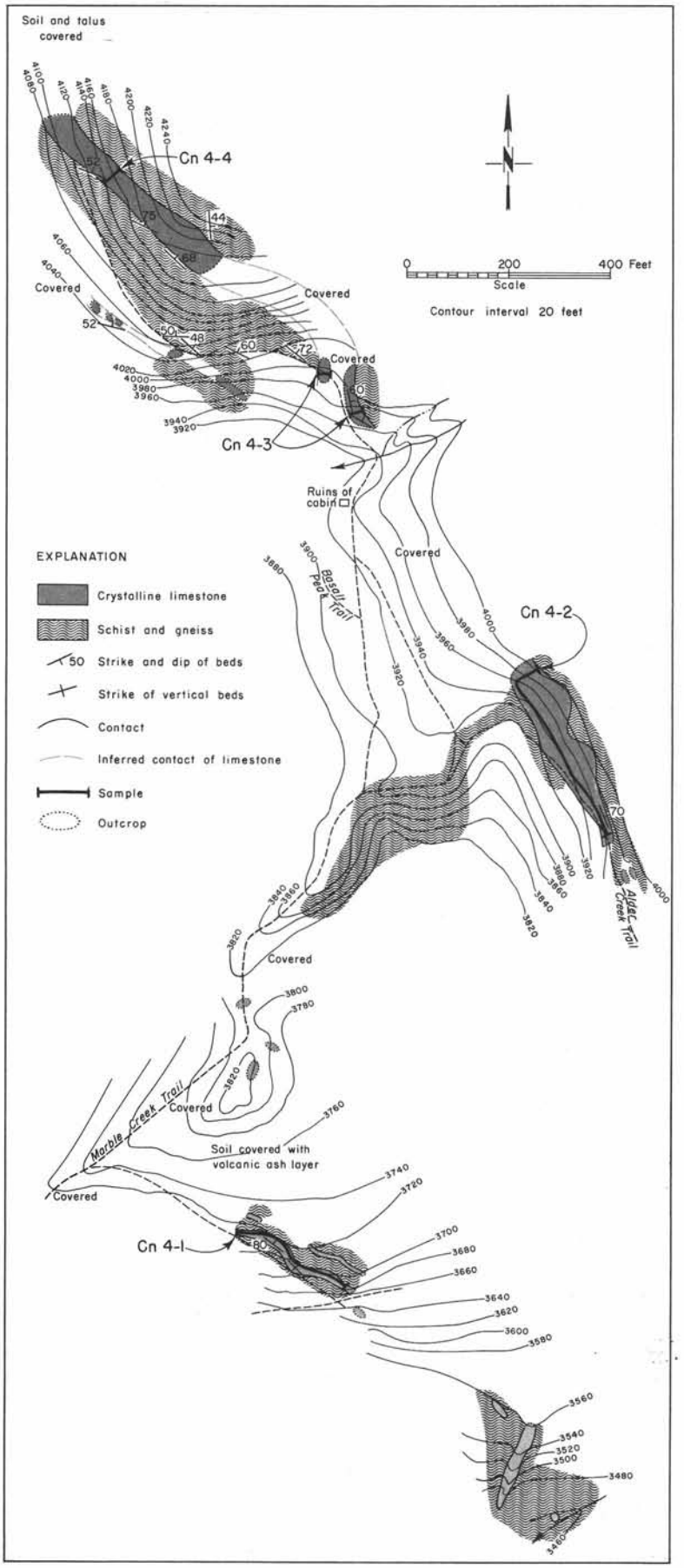


FIGURE 205.—Marble Creek deposit, Paradise claims. SE¼ sec. 10, SE¼ sec. 11, NE¼ sec. 15, and NW¼ sec. 14, T. 28 N., R. 17 E. Geology by W. R. Danner and E. A. Adams. Compass and tape survey.

calcite crystals uniformly distributed in a finer grained white calcite matrix. Jointing is prominent, a pattern formed at approximately right angles to the bedding being the most common. Locally, thin layers of quartz mica schist are interbedded with the limestone. The limestone is cut by a few dikes of volcanic rock and granitic material, but most of it is free of intrusions.

Most of the limestone outcrops are on steep rocky slopes, and it is possible that covered areas on more gently sloping hillsides between outcrops contain extensions of the limestone beds. The covering material is composed of soil, talus, and at least one thin layer of volcanic ash containing pumice "pellets" as much as 1½ inches in diameter.

The southernmost limestone outcrops are mostly small and consist of thin-bedded and often highly contorted bands of crystalline limestone. One outcrop, traceable for almost 300 feet, averages about 8 feet in thickness and is overlain by 20 to 30 feet of schist, in turn overlain by another limestone bed about 3 feet thick.

In the east-central part of the deposit is a large outcrop exposed on a steep hillside above the trail. It can be traced for about 400 feet, but ends rather abruptly to the north and may be cut off by faulting. It appears to thin and pinch out to the south. The limestone dips about 70° NE. into the hillside at its east end, but dips vertically to steeply southward at its west end. Its outcrop has a maximum width of about 100 feet, but the bed itself is less than 50 feet thick. Much of this outcrop consists of beautiful white, finely crystalline rock that when polished is a nice decorative stone.

The northern area of the deposit contains two crystalline limestone beds. The lower of these is about 10 feet thick and can be traced by discontinuous outcrops for about 400 feet along strike. The upper bed lies about 70 feet higher on the hillside and is separated from the lower limestone by schist. It is between 40 and 50 feet thick. The upper limestone can be traced by almost continuous outcrops for about 450 feet and probably connects under soil cover to other outcrops 400 feet to the south. However, this supposed southern extension ends abruptly a few hundred feet farther south. At its northern end it disappears under soil cover and talus and may pinch out.

The two limestone beds strike N. 48°-68° W. and dip 44°-75° NE.

Most of the volcanic and granitic dikes are in the northern outcrop area.

A small amount of limestone float northeast of the northern outcrop indicates that additional limestone outcrops may exist in that area farther up the hillside.

Quality.—Most of the limestone is high in calcium.

Chemical analyses of Marble Creek limestone

(Mark Adams, analyst)

Sample no.	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5	Na_2O (ppm)	K_2O (ppm)	TiO_2 (ppm)	S (ppm)
Cn 4-1	280	96.92	1.71	42.76	54.45	0.82	1.52	0.53	0.125	175	610	60	55
Cn 4-2	450	86.36	1.43	42.92	54.08	0.70	1.43	0.24	0.048				
Cn 4-3	40	98.32	1.77	43.26	55.24	0.85	0.35	0.37	0.080				
Cn 4-4	50	95.10	1.63	43.16	53.43	0.78	1.97	0.21	0.074				

Ownership and development.—The Marble Creek limestone deposit was staked as six claims in 1948 by Fred Shelton, Route 2, Box 218, Vail, Oreg., and by W. W. Thomson, Star Route, Leavenworth, Wash. There has been no major development work. A logging road may be constructed near the deposit in the future, which would make the limestone more accessible. The steep north dip into the mountainside would make quarrying difficult and would limit the amount of limestone recoverable. Its white color would make this limestone usable as a decorative stone and for terrazzo chips and roofing granules. Its quality makes it suitable for other uses, but, before any major development is started, the deposit should be investigated thoroughly by diamond drilling and stripping to determine the quantity of rock available.

References.—Huntting (1943, p. 53), Valentine (1960, p. 56).

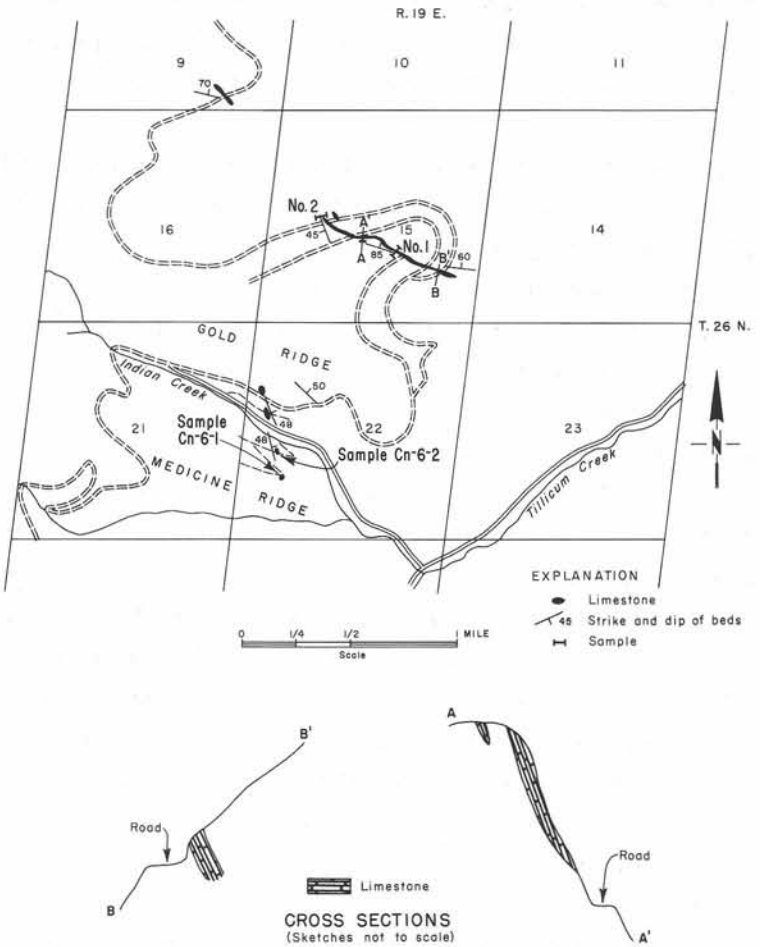


FIGURE 206.—Gold Ridge and Indian Creek deposits. Secs. 9, 15, 21, and 22, T. 26 N., R. 19 E. Base map by U.S. Forest Service.

Indian Creek Deposit

Location, size, and accessibility.—The Indian Creek limestone deposit is in the W½ sec. 22, T. 26 N., R. 19 E., on the north and south slopes of Indian Creek valley about a mile northwest of its junction with Tillicum Creek valley. The deposit consists of a band of crystalline limestone and interbedded schist ranging from 2 to 12 feet in thickness and traceable by discontinuous outcrops a distance of approximately 2,500 feet. The deposit is accessible by 10 miles of oiled road from the town of Entiat to Ardenvoir and from there by 6 miles of good logging road. Outcrops can be reached by hiking up old abandoned logging roads on both sides of Indian Creek. The land has been logged, and there are open wooded and brushy areas, grassy slopes, and rock bluffs. The deposit lies between 3,000 and 4,000 feet in altitude.

Geology and description.—The Indian Creek limestone consists of an impure band of crystalline limestone interbedded in a sequence of hornblende, mica, garnet, actinolite, and talc schists; the band is cut by quartz-feldspar pegmatites and massive quartz veins. The most southerly outcrop visited is a small exposure in a roadcut at the end of a switchback on an old logging road. It consists of an outcrop of pure white crystalline limestone about 2 feet wide and 1½ feet high and is surrounded by intrusive pegmatite partly covered with soil. No other limestone outcrops were visible for a distance of several hundred feet up the mountainside. A second outcrop, exposed to the north on a lower switchback, comprised the following section:

	Ft
Top of section	
Limestone with schist interbeds	2 to 5
Schist	3 to 6
Crystalline limestone and schist	1½ to 3
Mica schist	½ to 2
Crystalline limestone	2
Covered	
Bottom of section	

The strike is about N. 15° W., and the dip is 47°-48° NE.

On the north side of Indian River an abandoned logging road cut exposes a section as follows:

	Ft
Top of section	
Crystalline limestone and schist	1
Schist	1
Crystalline limestone and schist	1
Schist	4
Crystalline limestone and schist	2
Hornblende gneiss	
Bottom of section	

Another exposure, higher up the mountainside to the north on the Gold Ridge road, contains 6 to 8 feet of highly contorted, thin-bedded crystalline limestone. It is cut by a 6-inch-thick basalt dike.

Limestone of this deposit is white, gray, and blue gray in color and finely to coarsely crystalline in texture. Most of it contains small interbedded layers of mica schist.

The limestone-bearing sequence as a whole strikes northwestward and dips 40°-50° NE. It extends beyond the limits of the mapped area.

Quality.—Visible impurities in the limestone are in the form of interbedded mica schist layers, and it would be difficult to find a large mass of pure limestone. In small areas where the limestone is free of visible impurities it is high in calcium.

Chemical analyses of Indian Creek limestone

Sample no.	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5	Na_2O	K_2O
1/ Cn 6-1	2	97.72	0.83	43.16	54.90	0.40	0.52	0.28	0.084		
1/ Cn 6-2	12	70.52	0.79	31.01	39.62	0.38	27.27	1.27	0.035		
2/	Float boulders	72.40		32.25	40.50	3.60	21.24	3/ 2.02		0.12	0.12

1/ Samples collected for this report, Mark Adams, analyst.
2/ Private analysis.
3/ Fe_2O_3= 0.65, Al_2O_3= 1.37.

Ownership and development.—The deposit is on lands of the Wenatchee National Forest, and there has been no development. Where weathered, the limestone with its schist layers develops a banded surface etched in relief that might make it attractive for rock gardens. If cut and polished, it might make an attractive decorative stone; however, it is too thin and contains too many impurities for other physical or chemical uses.

Gold Ridge Deposit

Location, size, and accessibility.—The Gold Ridge limestone deposit is in the south-central part of sec. 15 and the SE¼ sec. 9, T. 26 N., R. 19 E., on the north side of Gold Ridge at an estimated altitude of 3,500 to 4,200 feet. The largest outcrop is of a bed of limestone almost 2,500 feet long, ranging from about 25 to 50 feet in thickness, and exposed

vertically for about 500 feet. The deposit is accessible by 18 miles of road from the town of Entiat; 10 miles of this is oiled road from Entiat to Ardenvoir, and the rest is 2½ miles of logging road up Mad River, 2½ miles up Tillicum Creek, and about 3 to 3½ miles up the Indian Creek-Gold Ridge road, climbing about 1,500 feet. The area is covered in part with timber and in part with dense brush, grass, and barren rock outcrops.

Geology and description. — Limestone outcrops examined are on two ridges about ½ mile apart. Limestone may also crop out in the deep canyon between the two ridges, but this area was not visited. In sec. 15 the deposit consists of one or more bands of thin-bedded white crystalline limestone. The limestone is fine to medium grained and contains a few thin quartz and mica schist layers. It is exposed across the top of a ridge and in logging road cuts on the north and south sides of this ridge. Horizontally, it is exposed for a distance of almost 2,500 feet, and vertically, for about 500 feet. Its usual strike is about N. 70°-80°W., and it dips steeply to the northeast at 60°-85°. Locally, it strikes more toward the north and may dip vertically or steeply to the southwest. It is strongly jointed and breaks easily into flat slabs along northward-dipping joint planes. Nowhere did the outcrop appear to be much more than 50 feet thick, and mostly it is about 25 feet thick. It tends to thicken and thin along strike. In many of the roadcuts two limestone beds are present, one only a few inches thick and the other several feet thick, separated by 3 to 10 feet of mica schist. Phyllite, mica schist, and chlorite schist make up most of the country rock and contain small lenticular bodies of crystalline limestone.

On the north side of the ridge the limestone crops out as a thin slab almost parallel to the hillside slope. To the southwest it dips into the south-facing slope. Smaller lenses of limestone lie parallel to the main body along the strike. One dike of basalt cuts the limestone approximately at a right angle to its strike.

In sec. 9 the limestone is exposed in a logging road cut and in scattered outcrops up the hillside. In the cut the limestone is about 25 feet wide but contains interbedded layers of schist.

Between the outcrops in sec. 15 and sec. 9 lies a steep-walled canyon more than 1,500 feet deep. No limestone outcrops could be seen in the canyon walls, but if the deposit is at all continuous, limestone should be present there.

Quality. — The limestone on the crest of the ridge appears to be of the best quality and contains the fewest visible impurities.

Chemical analyses of Gold Ridge limestone[1/]

Sample no.	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3	Na_2O	K_2O
1	50	97.00	2.50	42.92	50.30	1.20	0.09	0.16	4.96	0.22	0.05
2	25	76.40	4.18	33.65	42.80	2.00	15.61	1.63	3.83	0.15	0.17
3	Composite (high grade)			40.83	54.49	1.06	1.66	0.24	0.81	Alkali 0.99	
4	Composite (low grade)			8.87	12.66	1.51	49.62	3.39	16.81	6.12	

1/ Private analysis.

Ownership and development. — Six claims staked on the property are owned by Harris M. Thomason, of Ardenvoir, and others. In 1945, development work consisted of one small excavation along a logging road, where slabs of limestone were removed for use in rock gardens. The limestone is suitable for decorative stone, roofing granules, and other uses requiring pure-white stone. The deposit would be difficult to quarry because of its narrowness and steep descent along strike on both sides of the ridge. That part exposed on the more gently sloping ridgetop appears to be the best for quarrying, as it is thicker and of better quality than that on the lower slopes to the north and south.

Reference. — Valentine (1960, p. 56).

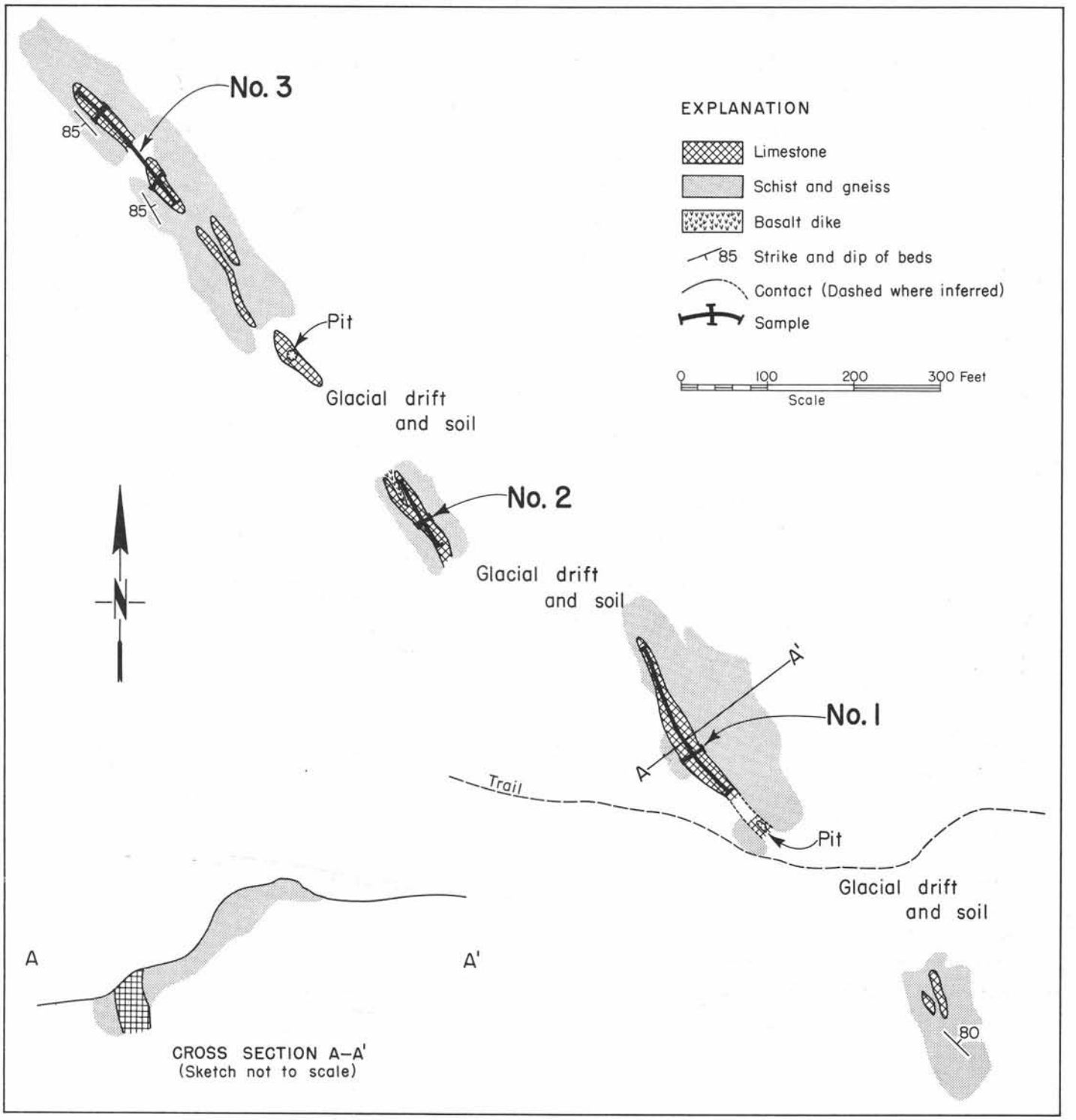


FIGURE 207.—Manson (Wapato Lake) deposit. Sec. 15, T. 28 N., R. 21 E. Geology by W. R. Danner. Compass and tape survey by W. R. Danner and John Adams. Map courtesy of Ideal Cement Company.

Manson (Wapato Lake) Deposit

Location, size, and accessibility.—The Manson limestone deposit is in sec. 15, T. 28 N., R. 21 E., up the Joe Creek valley north of Wapato Lake. The deposit consists of a series of limestone lenses extending along strike for a distance of about 1,450 feet. The width of the deposit is usually less than 20 feet, but in a few places it is 50 feet or more. The limestone is accessible by about 11 miles of black-topped road from the town of Chelan. It is reached by turning north off the Chelan-Manson highway onto the Wapato Lake road and then driving up the Joe Creek road to the Overbay Farms. Less than ¼ mile of old wagon road leads across a farm to the vicinity of the outcrops.

Geology and description.—Limestone occurs as a series of lenticular outcrops striking about N. 45° W. along a gently southward-sloping hillside. The outcrops were mapped along the strike for a distance of 1,450 feet, but were not found to extend beyond this distance on the property. The maximum width is 50 feet, but usually the width is less than 20 feet. The limestone is laminated to massive in appearance, white to gray in color, and finely to medium crystalline. Flow banding around fragments of schist is common, and the limestone is interbedded with mica schist and gneiss and is cut by quartz veins and dikes of basalt. The sequence strikes northwest-southeast and dips steeply to the northeast. Numerous small inclusions of schist are present, and in some exposures there are two thin crystalline limestone beds separated by as much as 30 feet of schist. In a few places the limestone appears to be split into two beds by intrusive sills of volcanic rock. Mostly, the limestone dips steeply to the northeast, but in some places its attitude is vertical or, more rarely, steeply dipping to the south. It pinches and swells vertically and horizontally.

Quality.—The limestone of this deposit is not of good quality, being relatively high in silica, alumina, and iron.

Chemical analyses of Manson limestone[1/]

Location	Sample length	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3	Na_2O	K_2O
Central part of deposit --	Composite	85.00		37.03	49.50	0.66	8.31	1.46	2.66	0.32	0.06
East end ----	Composite	85.90		37.39	49.80	1.30	7.49	1.96	1.68	0.33	0.05
West end ----	Composite	74.30		33.47	41.50	1.17	15.37	1.06	4.42	2.72	0.19

1/ Private analysis.

Ownership and development.—The deposit is owned by Ralph Overby, of Manson, Wash. There has been no major development. At one time the limestone was quarried to a small extent to burn for lime to be used in building a local schoolhouse. The deposit has no economic value except as a small-scale operation that might provide decorative stone and material for rock gardens. Because of its white color it might also be suitable for roofing granules or terrazzo chips.

References.—Northern Pacific Railway Company (1941, unpublished notes, p. 13), Valentine (1960, p. 56).

Entiat Deposit

Location, size, and accessibility.—The Entiat limestone deposit is in the NE¼ sec. 4, T. 25 N., R. 20 E., and extends a short distance into the NW¼ sec. 3, T. 25 N., R. 20 E., and sec. 33, T. 26 N., R. 20 E. It is just south of the Entiat River, at altitudes of 1,000 to 1,460 feet. Outcrops are exposed for a distance of about 1,900 feet northwest-southeast and have an exposed width of from 63 to 480 feet. However, the true thickness of the limestone is between 50 and 160 feet, and as much as 40 feet of this may be composed of interbedded layers of schist and gneiss.

The deposit can be reached by driving about 6 miles on black-topped road northwest from the town of Entiat, then about ½ mile on black-topped road and 0.3 mile on dirt road, crossing the Entiat River at the bridge north of Roaring Creek,

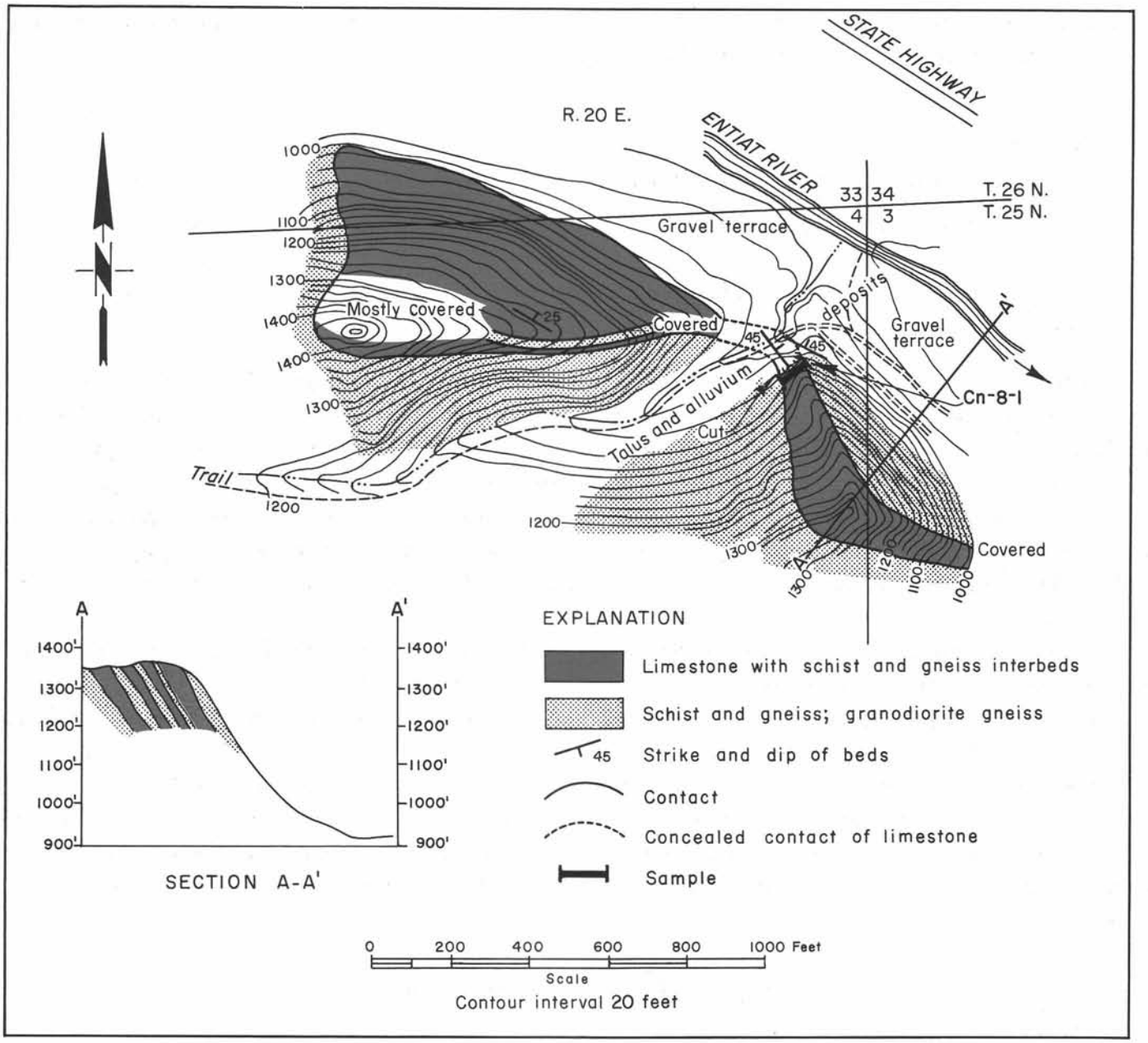


FIGURE 208.—Entiat deposit. Sec. 4, T. 25 N., R. 20 E. Geology by E. T. Hodge, 1938, modified by W. R. Danner and E. A. Adams.

and proceeding north beyond the fish hatchery. The terrain is mostly rocky, steep, grass-covered hillside with areas of pine trees on the slopes and dense brush in the valleys.

Geology and description.—The deposit is composed of a sequence of interbedded crystalline limestone, schist, and gneiss striking N. 45°-75° W. and dipping 25°-60° NE. The exposure of this sequence forms a slablike outcrop on the southwest side of the Entiat River; the limestone strikes approximately parallel to the river and dips toward it beneath a gravel terrace. A narrow stream gully separates the outcrop into two ridges; it divides the deposit into a northwest part and a southeast part. At first glance there appears to be a large amount of limestone, as it is exposed vertically for over 400 feet above the gravel terrace at the river. However, the limestone sequence dips approximately parallel to the slope, so that it is simply a thin slab on the noses of two ridges.

The limestone thickens and thins along strike and down dip. It contains thin laminae of muscovite mica, lenticular quartz and schist inclusions from a fraction of an inch to a foot or more in diameter, and interbedded layers of hornblende gneiss. A section exposed near the northwest end of the southeast ridge contains the following:

	Ft
Top of section	
Limestone, white and greenish-gray, well-laminated	10 to 15
Hornblende gneiss with flow structures	3 to 5
Limestone, white to gray-green	2½ to 3
Gneiss	3
Limestone, white, with thin schist layers	10 to 15
Limestone with hornblende schist layers	10
Bottom of section	

Along its south side, 20 feet above its base, the southeast hill contains a bed of gneiss from 30 to 40 feet thick, and to the north it contains numerous interbeds of schist and gneiss. It has a greater proportion of schist and gneiss impurities than the northwest outcrop has. The schist and gneiss beds appear to be lenticular, and they pinch and swell throughout the limestone. It is possible that some of the schist and gneiss layers represent metamorphosed dikes of igneous rock.

Most of the Entiat limestone is thin bedded and breaks off in slabs or, where laminated, into thin plates. It is white to greenish gray in color, and most of it is finely crystalline and has a dense porcelaneous texture. In a few places it is medium crystalline. No organic structures are visible, and if there were any fossils originally present, they have been obliterated by recrystallization and flowage.

The limestone has a joint system approximately at right angles to the bedding. Gneissic biotite hornblende granodiorite underlies the limestone. The granodiorite is cut by basalt dikes, but none of these were seen to cut the limestone.

Limestone outcrops trend off the ridge to the north, and their extension, if any, is under the gravel terrace bordering the Entiat River. Similarly, they disappear under gravel to the south.

No outcrops were found to the northwest along strike in sec. 33. This area is underlain by gneissic granodiorite. However, the outcrops at Gold Ridge, 5 miles to the northwest, are roughly aligned along the same strike direction. Small outcrops of similar-appearing limestone are reported to occur to the southeast over a distance of 6 miles in secs. 3 and 11, T. 25 N., R. 20 E., and in the NE¼ sec. 30, T. 25 N., R. 21 E. The latter outcrop is about 35 feet thick; it strikes N. 60° E. and dips 20° NE.

Description of diamond drill core hole no. 2

From (ft)	From (in)	To (ft)	To (in)	
0	0	2	7	Schist and gneiss.
2	7	5	7	Limestone, white, coarsely crystalline.
5	7	10	4	Schist and gneiss.
10	4	13	4	Limestone, white, coarsely crystalline, with thin schist layers.
13	4	23	0	Limestone, white to gray-green, dense, and calcareous schist.
23	0	23	9	Schist.
23	9	24	0	Limestone, white.
24	0	29	2	Mica schist.
29	2	39	0	Limestone, green-gray to white, dense.
39	0	42	0	Mica schist.
42	0	51	3	Limestone, white and green-gray, dense, with thin schist layers.
51	3	56	0	Limestone, white, in alternating thin bands, and schist.
56	0	59	0	Limestone, white, dense.
59	0	60	6	Mica schist.

Description of diamond drill core hole no. 2—Continued

From (ft)	From (in)	To (ft)	To (in)	
60	6	64	0	Limestone, white.
64	0	65	0	Schist.
65	0	66	6	Limestone, white.
66	6	72	0	Gneiss and mica schist.
72	0	82	6	Limestone, white, crystalline.
82	6	84	6	Limestone, white, and schist.
84	6	100	10	Limestone, white, crystalline.
100	10	105	3	Mica schist.
105	3	107	0	Limestone, white, coarsely crystalline.

Length of core examined: 107 ft. Total limestone: 78 ft 4 in.

Description of diamond drill core hole no. 3

From (ft)	From (in)	To (ft)	To (in)	
0	0	11	7	Limestone, white to green-gray, banded.
11	7	16	0	Biotite chlorite schist.
16	0	16	7	Limestone, schistose, white to green.
16	7	18	0	Schist.
18	0	38	0	Limestone, white, thin schist interbeds.
38	0	39	3	Gneiss.
39	3	44	0	Schist.
44	0	45	0	Limestone, white.
45	0	50	0	Schist.
50	0	53	0	Limestone, white.
53	0	74	6	Limestone, white, sugary textured, with thin gray layers and interbedded schist layers.
74	6	78	6	Mica schist.
78	6	79	0	Mica schist.
79	0	110	0	Limestone, white, dense to coarsely crystalline, with gray layers and thin schist beds.
110	0	110	6	Gneiss.
110	6	111	6	Limestone.
111	6	127	0	Biotite schist.
127	0	129	0	Limestone, white.
129	0	131	0	Schist.
131	0	141	0	Amphibolite schist with calcareous layers.
141	0	141	6	Limestone, white, sugary textured.
141	6	150	0	Schist, calcareous.
150	0	152	0	Limestone, white.
152	0	152	10	Schist.

Length of core examined: 152 ft 10 in. Total limestone: 94 ft 2 in.

Quality.—The purity of the Entiat deposit varies greatly from layer to layer along strike, and the numerous inclusions of schist and gneiss would make obtaining a pure material extremely difficult.

Chemical analyses of Entiat limestone

(Mark Adams, analyst)

Sample no.	Location	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
Cn 8-1		60	79.45	2.02	34.89	44.64	0.97	17.00	2.57	0.074
Cn 8-2	White limestone	Single specimen	97.18	1.50	42.95	54.60	0.72	0.56	0.44	0.094
Cn 8-3	Green limestone	Single specimen	80.76	2.13	35.32	45.39	1.02	13.84	3.69	0.073

Chemical analyses of Entiat River limestone 1/

Sample no.	Location	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3	P_2O_5
U.S.E.D. 231B	Across quarry face --------	88.60		38.67	49.64	0.64	6.74	1.38	2.55	
	Unknown ----	95.03			53.25	0.77	2.20	1.48		0.185
	---- do -----	91.60			51.33	0.83	6.14	1.30		0.265
	---- do -----	98.48			55.18	0.69	1.14	0.41		0.247
	---- do- ----	97.62			54.70	0.89	1.42	0.88		0.279
	---- do -----	98.44			55.16	1.11	0.60	0.21		0.155
	---- do -----	98.12			54.98	0.36	2.37	0.21		0.298

1/ Hodge (1938, p. 85).

Chemical analyses of Entiat diamond drill cores

(Courtesy of Ideal Cement Company)

Location	From		To		Core recovered		$CaCO_3$	CaO	MgO	Insol.	Remarks
	(ft)	(in)	(ft)	(in)	(ft)	(in)					
Hole 2 1/ -----	0	0	29	2	27	5	53.00	36.12	2.48	34.60	
----- Do -----	29	2	71	3	37	5	68.00	41.62	2.85	25.40	
----- Do -----	71	3	128	8	47	0	79.00	38.75	3.21	18.57	
Hole 3 2/ -----	0	0	8	11	8	5	79.20	44.79	1.96	13.40	Limestone.
----- Do -----	8	11	18	7	9	0	17.40	12.49	4.56	66.91	Schist.
----- Do -----	18	7	22	6	2	11	73.50	43.31	1.68	18.50	Limestone.
----- Do -----	22	6	39	0	16	0	80.20	46.08	1.46	15.21	Limestone.
----- Do -----	39	0	50	3	10	1	10.20	8.77	2.96	71.83	Schist.
----- Do -----	50	3	75	6	24	5	93.00	43.60	3.67	5.44	Limestone.
----- Do -----	75	6	80	0	4	6	6.80	5.60	2.68	85.15	Schist.
----- Do -----	80	0	111	10	30	7	88.80	46.63	5.60	10.72	Limestone.
----- Do -----	111	10	152	10	39	4	22.00	16.05	5.15	71.69	Schist.

1/ July 1953, vertical angle 30°, bearing S. 30° W.

2/ June 1953, vertical angle 30°, bearing S. 30° W.

Ownership and development.—At one time a small quarry was started on the deposit by the Superior Lime and Mining Company. In 1953 four claims on the property were held by J. J. Keegan, of Wenatchee. These have been transferred to the Lovitt Mining Company, Inc., of Wenatchee, the present (1963) owner. No major development has taken place. Estimates of the quantity of limestone range from 1 million to 3 or 4 million tons, but because of the variable amount of impurities it is difficult to tell which amount would constitute usable limestone. The limestone is too impure to be of value for cement or chemical requirements, but probably could be used for decorative stone, roofing granules, terrazzo chips, and other similar uses.

References.—Hodge (1938, p. 80-87), Huntting (1943, p. 52), Valentine (1960, p. 56).

Storme (Wenatchee, Starnose, Staples) Deposit

Location, size, and accessibility.—The Storme limestone deposit is in the N½ and SW¼ sec. 10, T. 23 N., R. 20 E., about ¼ mile west of the Columbia River about 3 miles north of the mouth of the Wenatchee River. It consists of small lenticular bodies of crystalline limestone in schist and gneiss. The deposit is accessible by a paved highway (U.S. 10) 5 miles north from the city of Wenatchee, and is in a rocky gully at altitudes of 1,250 to 1,360 feet. It was not examined during this investigation.

Geology and description.—Hodge (1938, p. 88) describes the deposit as limestone in metamorphosed sediments dipping 60° W. and striking N. 55° E. The various bodies appear to be lenticular in shape and pinch out to the north and south, and in between they can be seen to pinch and swell in many places. Schist lenses as much as 1½ feet thick and 8 feet long were observed within the limestone. The limestone is white to gray in color and finely to coarsely crystalline in texture.

Quality.—The Storme deposit consists of high-calcium limestone.

Chemical analysis of Storme limestone

Sample	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3
1/	98.68	None	43.98	55.26	None	0.38	0.21

1/ Shedd (1913, p. 171), A. A. Hammer, analyst.

Ownership and development.—In 1938 the deposit was owned by the Chelan Company. In the deposit's early period of quarrying, a kiln with a capacity of about 60 barrels of lime per day was operated during part of the year. Three small quarries were developed. Hodge (p. 91) states,

> These beds are of minor economic importance because of the small tonnage available, large amount of overburden, and numerous small intrusions of schist which would necessitate hand sorting. An early unsuccessful attempt was made to work the deposit. . . . The limestone could probably be utilized on a small scale to furnish lime rock for local consumption, to be worked intermittently when the operators are not otherwise gainfully employed.

References.—Shedd (1913, p. 171), Hodge (1938, p. 88-91), Huntting (1943, p. 53).

Lake Chelan Area

Several small exposures of crystalline limestone, all situated within sec. 29, along the shore of Lake Chelan, are described together as the "Section 29 deposits."

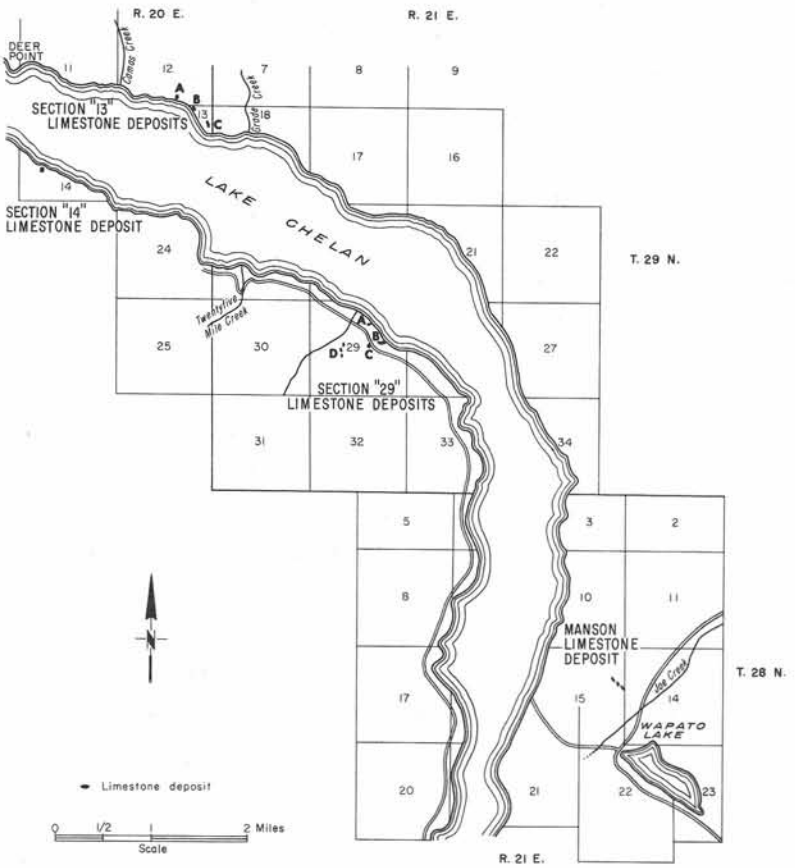


FIGURE 209.—Index map showing limestone deposits of the Lake Chelan area.

Section 29 Deposits

Location, size, and accessibility.—The Section 29 limestone outcrops are in the NE$\frac{1}{4}$, SW$\frac{1}{4}$, and SE$\frac{1}{4}$ sec. 29., T. 29 N., R. 21 E., along the south shore of Lake Chelan and on the mountainside to the southwest. The deposits range in altitude from 1,079 feet to 2,000 feet and consist of several small outcrops of highly folded crystalline limestone containing not more than a few hundred tons each. They are accessible by paved highway about 19$\frac{1}{2}$ miles west of the town of Chelan. Limestone outcrops occur on the lakeshore from 150 to 250 feet below the highway, in roadcuts, and on the hillside above the road over a strike distance of about $\frac{1}{2}$ mile.

Geology and description.—Exposure A consists of an outcrop along the shore of Lake Chelan about 150 to 200 feet below the highway. It is composed of white crystalline limestone containing flakes of muscovite mica and interbedded layers of chert and schist. The limestone is interbedded with schist and is cut by several dikes of black basalt and gray-colored dikes of undetermined composition. The bedding of the limestone is highly contorted, and the texture is finely to coarsely crystalline. Limestone is exposed continuously for about 45 feet along the shore of Lake Chelan and discontinuously for about 25 feet to the south. A small cut has been made in an outcrop about 20 feet above the shore.

About 1,000 feet southeast of exposure A is another exposure of crystalline limestone on the shore of Lake Chelan. It is white and has a finely crystalline, sugary texture. An old quarry contains the following stratigraphic section:

	Ft
Top of section	
Soil and glacial drift	
Dike rock, porphyritic, gray	2$\frac{1}{2}$
Limestone, white, crystalline	2$\frac{1}{2}$ to 3
Rock dike, granitic	1
Limestone	5
Dike rock, porphyritic	2
Limestone	1$\frac{1}{2}$
Dike	3
Limestone	3
Schist	$\frac{1}{2}$
Limestone	2
Schist	2
Limestone intruded by dikes	6
Bottom of section	

The quarry face is about 35 feet high and extends for more than 25 feet along the lake shore.

About 85 feet to the west, across a covered interval, is a second small quarry. It is largely filled with blocks of dike rocks. Its floor is about 6 feet above lake level and is 25 feet wide along the shore. It extends 20 to 25 feet south into

the steep hillside to a vertical face that is 10 to 15 feet high. A bed of crystalline limestone 6 feet wide is exposed at the base of the south face, the rest of the quarry walls either being covered with soil or exposing dike rocks. A small pile of limestone spalls 2 or 3 tons in volume is at the east end of the quarry.

About 10 feet to the west is a third small quarry, 10 feet above the lake and extending for 20 feet along the shore and 25 feet southward back into the hillside. Its south face is vertical and 20 feet high. The quarry is almost filled with soil and talus debris from the hillside above, but shows a few feet of limestone underlying gray dikes. The limestone in the quarry appears to strike northeast-southwest and dips steeply to the southeast. Several small solution cavities a few inches wide extend back into the hillside.

About 200 to 250 feet south, above the lake shore, limestone is exposed in a cut along the highway. It extends 25 feet east-west, but the exposure is not continuous. The limestone appears to be cut by, and also mostly enclosed in, a dike complex composed of basalt, andesite, and rhyolite. The limestone is white in color, finely crystalline in texture, strikes N. 45° E., and dips 55° SE.

Three small lenses of white, sugary to medium-grained crystalline limestone are exposed on the south side of a gully extending through the south-central part of sec. 29, at an estimated altitude of 2,000 feet. The limestone strikes northwest-southeast and dips to the northeast. The highest of these three bodies is exposed for a length of 80 feet and has a width of 3 to 4 feet. Below it is a similar bed about 100 feet long and 5 feet wide. Below this and offset north of it about 100 feet is a limestone lens 40 feet long and 10 to 15 feet wide.

Limestone float is abundant in the area, and there may be additional outcrops.

Quality.—The limestone is variable in composition.

Chemical analyses of Lake Chelan Section 29 limestone

(Mark Adams, analyst)

Sample no.	Location	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
Cn 7-1	Spall pile --	31	93.05	3.59	42.22	52.28	1.72	2.75	0.53	0.030
Cn 7-2		Composite	94.12	1.86	41.91	52.88	0.89	3.40	0.59	0.011

Ownership and development.—The owners of the various outcrops are unknown. Part of the shore of Lake Chelan where the limestone occurs is divided into lots for summer homes. Limestone from this area is reported to have been burned for lime prior to 1914. Three small quarries were developed along the lake shore, but probably only a few hundred tons of limestone was obtained. The limestone is cut by so many interbedded schist layers that hand sorting would be required in order to provide a high-quality stone. The deposits are too small to be of any economic value under present conditions, and the lakeshore outcrops are considered to be exhausted.

References.—Shedd (1913, p. 172), Huntting (1943, p. 53), Valentine (1960, p. 56).

Section 13 Deposits

(Adapted from field notes of G. W. Thorsen)

Location, size, and accessibility.—Several small outcrops of limestone are on the north side of Lake Chelan, northwest of Twentyfive Mile Creek and between Camas Creek and Grade Creek. They are known as the Section 13 deposits and are in the NE¼ sec. 13 and the SE¼ sec. 12, T. 29 N., R. 20 E. The deposits consist of several small lenticular beds of crystalline limestone about 22 miles from the town of Chelan. They are accessible by boat.

Geology and description. — Outcrop A is a small prospect pit in white and light-gray crystalline limestone containing irregular bands of siliceous impurities and lenses of brown garnet. The limestone is exposed over a width of about 20 feet and a length of 10 feet along strike.

Outcrop B is about 1,250 feet east of outcrop A. It consists of a bed of crystalline white and light-gray limestone that appears to be more pure than that in deposit A. The rock trends N. 10°-30° W. and dips approximately 50° E. The outcrop is 10 to 15 feet wide at the water's edge, but pinches out about 200 feet to the north. It is interbedded with gneiss.

Outcrop C, known as the Dutch Harbor deposit, is a belt of limestone lenses and outcrops about 1,200 feet east of outcrop B. The belt is not more than 100 feet wide; it extends about 300 feet up the hillside and narrows to 8 feet in width at the highest exposure. It contains lenses of foreign rock as much as 16 inches in thickness. The limestone is medium to coarsely crystalline in texture and lightly banded. Smaller lenses of crystalline limestone are exposed in metamorphic rocks to the west, and are reported to occur at several places along the shore of the lake from the mouth of Grade Creek west to Deer Point. Most of them are less than 10 feet long and only a few feet wide.

Quality. — An old chemical analysis indicates calcium limestone, but the composition of the deposit is probably quite variable.

Chemical analysis of Lake Chelan Section 13 limestone

Sample	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
1/	95.14	----	43.26	53.28	0.65	2.40	Trace	----

1/ Shedd (1913, p. 174), A. A. Hammer, analyst.

Ownership and development. — Outcrop A is owned by Ross Williams; outcrop B, by Albert Brenson, Manson, Wash.; outcrop C, by Carl B. Wolferton. Outcrop A contains a small prospect pit, and outcrop C contains two small quarries. Sometime prior to 1914, limestone from outcrop C was burned to lime in a wood-burning kiln that is now covered with water. When the lake level was raised in 1921, a few tons of coarse limestone with fragments as much as 2 feet in diameter was stockpiled near the main pit.

References. — Shedd (1913, p. 173-174), Huntting (1943, p. 53), Thorsen (1960, unpublished field notes), Valentine (1960, p. 56).

Section 14 (Bud's Lime Quarry)

(Adapted from field notes of G. W. Thorsen)

Location, size, and accessibility. — The Section 14 limestone deposit is in the S½ sec. 14, T. 29 N., R. 20 E., a little over 200 feet south of the lakeshore at a bearing of S. 39° W. from the mouth of Camas Creek on the north shore of Lake Chelan. It is a small deposit exposed for a width of less than 150 feet and a length of less than 225 feet. It is about 20 miles from the town of Chelan, and is accessible by boat.

Geology and description. — Limestone faces as much as 10 feet high are exposed in cuts for 120 feet along an abandoned trail. The total stratigraphic thickness of the limestone is unknown, but is more than 30 feet. The limestone is light gray in color and medium crystalline in texture. It is interbedded with lenses of iron oxide-stained metamorphosed sedimentary rock as much as 1 foot thick and quartz lenses as much as 3 inches thick. The sequence strikes N. 50° W. and dips 65°-70° SW.

Quality. — Unknown.

Ownership and development.—The deposit is on National Forest land. Some limestone was burned to lime in a kiln built here prior to 1914.

References.—Shedd (1913, p. 172), Huntting (1943, p. 53), Thorsen (1960, unpublished field notes), Valentine (1960, p. 56).

Holden Area

Limestone has been reported to occur on the south slope of Martin Peak, 2 miles northeast of Holden, as a 10- to 40-foot bed extending for several thousand feet. A similar occurrence is reported on the north and east slopes of Buckskin Mountain, south of Holden. It has been traced for several miles. Both of these locations are in high mountainous country and are relatively inaccessible. A thin pinching and swelling layer of crystalline limestone occurs in hornblende schist on the west side of Carne Mountain, about 8 miles south of Holden.

References.—Crowder (1959, p. 836), Valentine (1960, p. 56).

OLYMPIC PENINSULA

The shores of the Olympic Peninsula have been prospected for limestone in the hope of finding deposits close to water transportation. Unfortunately, most of the bedrock of the coastal areas of the peninsula is of Cenozoic age and contains only small deposits, which range in composition from calcareous shales and sandstones to impure argillaceous limestone. Most of the occurrences are lenticular or concretionary bodies in sedimentary rocks, but a few are a result of precipitation during the deposition of submarine pillow lavas.

The mountainous interior of the peninsula is composed largely of graywackes, slates, conglomerates, and lithic and feldspathic sandstones, and does not contain any limestone except for small lenses associated with a few interbedded volcanic flows.

A great sequence of Metchosin basalts, including flows, pillow lavas, fragmental volcanic rocks, and interbedded sedimentary rocks, fringes the peninsula on the north, east, and south. This sequence contains numerous deposits of red- to maroon-colored argillaceous limestone, some of which are of appreciable size but too impure and inaccessible to be of economic value. Small bodies of blue and green limestone also occur.

West Coast of the Olympic Peninsula Deposits

At several places on the Pacific Ocean coast, rocks believed to be of Oligocene age (Huntting and others, 1961) contain numerous small lenses or concretions of argillaceous limestone. These occur most commonly in thick, massive to well-bedded shale units that in many places are highly sheared and fractured and form prominent landslide areas. In the vicinity of Alava Point, north of Cape Alava, the limestone occurs in primary concretions as much as 2 feet or more in diameter that are dark gray on fresh surfaces and weather to a blue gray. Many of these concretions contain fucoidal markings of unknown origin. Some of the limestone emits a bituminous odor when freshly broken. Irregular-shaped masses of brown impure calcareous rock occur in dark-gray shales in beach exposures between Cape Alava and Wedding Rock.

South of LaPush, at various places along the beach, shale sequences similar to those north of Cape Alava also contain numerous bodies of argillaceous limestone. Some of these bodies contain poorly preserved plant fragments and fossil shells. When freshly broken, the limestone emits a strong bituminous odor. Most of the bodies are irregularly elliptical in outline. Layers of dark-brown needlelike crystalline calcite form some of the bodies of limestone, which may be of fresh- or brackish-water origin.

Bogachiel State Park Occurrence

East of the bridge of U.S. Highway 101 over the Bogachiel River at Bogachiel State Park, the river has cut into a slide area composed of shale and sandstone containing gray to greenish-gray concretionary masses of argillaceous limestone. These range from a few inches to 2 feet in diameter. They are dense textured and have a porcelaneous surface. They contain small foraminifers visible only in thin section.

Hoh River Occurrence

A hard dark fine-grained medium-bedded sandstone sequence exposed in sec. 35, T. 27 N., R. 11 W., along the Hoh River, is reported (Lupton, 1914, p. 71) to contain "here and there near the top thin lenses of limestone."

Reference. — Lupton (1914, p. 71).

LIMESTONES OF THE METCHOSIN FORMATION

Limestone is widely distributed throughout the volcanic rocks of the Metchosin Formation. It appears to be of two types. The more common variety forms lenses and irregular bodies interbedded with pillow lavas and small sequences of argillite associated with the volcanic rocks. Most of it is maroon in color, but some is bluish gray. The maroon-colored limestone commonly weathers to brown, the coloring matter being ferric oxide and perhaps a little manganese. The texture is mostly fine grained or dense and commonly porcelaneous. In thin section this limestone usually shows the tests of several types of foraminifers and is seen to be more argillaceous and impure than the blue limestone. The maroon limestone formed as a sediment in association with the volcanic rocks and received a major contribution from calcareous-shelled organisms. Park (1942, p. 440) states that the red color of the limestones is due to finely divided hematite. Most of the impure limestone contains from 1 to 5 percent of manganese oxide (MnO), which probably is combined in the main with silica but possibly in part with carbonic oxide.

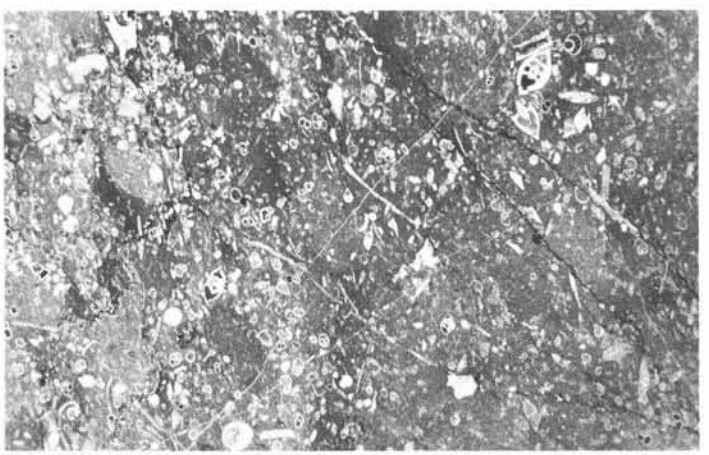


FIGURE 210. — Foraminiferal limestone of the Metchosin Formation. Photomicrograph of blue-gray limestone from an outcrop along the trail between Marmot and Buckhorn Passes, Jefferson County, Olympic National Forest. X $7\frac{1}{2}$.

FIGURE 211. — Orbitoid foraminiferal limestone near base of the Metchosin Formation. Photomicrograph of limestone from outcrops along the trail between Marmot and Buckhorn Passes, Jefferson County, Olympic National Forest. X 5.

The second type of limestone usually forms only small bodies irregular in shape and intimately intermixed with the pillow lavas where they have vesicular areas and also within the interior of some of the pillows. This limestone is usually light gray, bluish gray, buff, or greenish gray in color and finely crystalline in texture. It precipitates rapidly during the volcanic eruptions and receives its calcium carbonate mainly from the reaction of the hot gases with the surrounding sea water. Kania (1929) has investigated this method of limestone formation in detail.

Fossils are relatively rare in the Metchosin sequence except for foraminifers. In the lower part of the formation the Foraminifera include such genera as Globigerina, Globorotalia, and one or more species of orbitoids. They indicate an early Eocene age for the lower part of the Metchosin. The upper part of the Metchosin is richly fossiliferous and contains fossils indicating a middle to late Eocene age.

The maroon- or red-colored limestones are of particular interest to geologists, as associated with them are most of the manganese deposits found in the Metchosin Formation. The volcanic rocks and associated sedimentary beds of the Metchosin form a horseshoe-shaped outcrop belt around the northern, eastern, and southern Olympic Mountains. The structure of the outcrop belt is complex, and locally individual beds are standing at 90° or are overturned. In general, however, the sequence dips steeply away from the mountains on all sides.

The limestone beds range in thickness from that of a knife edge to 300 feet or more, but most of them are less than 25 feet thick.

Quality. — Manganese is a minor constituent of the limestone. Eight chip samples of limestone taken at the Rose Astrid manganese property averaged 7.6 percent manganese oxide. At the Crescent mine the highest manganese oxide content in 10 samples of the limestone was 0.96 percent (Park, 1942, p. 438-439). The calcium carbonate content averages about 60 percent in the few samples that have been analyzed.

Partial analyses of red limestones and argillites in the Olympic Mountains

	1	2	3	4	5	6	7	8
Insoluble in HNO_3	32.07	42.33	61.70	57.63	21.09	26.05	27.73	-----
CaO	35.30	28.28	13.24	19.38	36.94	36.78	36.18	31.70
MgO	0.56	1.48	3.00	1.90	0.82	0.76	1.04	3.03
MnO	0.90	1.11	0.96	0.23	0.39	0.99	2.82	8.52
FeO	0.42	0.90	1.25	0.92	3.05	1.79	0.34	-----
CO_2 calculated	29.11	25.02	15.02	18.00	32.01	31.40	31.50	24.42
SiO_2								11.53
Al_2O_3								6.18
Fe_2O_3								7.95
TiO_2								0.60
P_2O_5								0.40
Acid insoluble contains: MnO	0.28	0.02	0.14	Trace	Trace	0.08	2.13	
Fe_2O_3								10.65

Localities: [Samples from localities 1 through 7 are reported by Park (1946, p. 312).]

1. Elevation 1,500 ft. Trail to Apex prospect from Lake Cushman. Analyst, R.E. Stevens.
2. Elevation 1,950 ft. Elkhorn prospect, Dosewallips River. Analyst, R. E. Stevens.
3. Elevation 1,900 ft. Northeast wall, Crescent mine open cut. Analyst, R. E. Stevens.
4. Blue Mountain fire lookout. Analyst, R. E. Stevens.
5. Elevation 1,250 ft. Lake Crescent, ½ mile north of Thompson Point. Analyst, R. E. Stevens.
6. Roadcut, 1.2 miles south of Slab Creek guard station. Analyst, R. E. Stevens.
7. Elevation 4,250 ft. East layer of limestone on north Copper Mountain. Analyst, R. E. Stevens.
8. Lake Crescent, Wash. Analyst, J. G. Fairchild. Quoted by J. T. Pardee, U.S.G.S. Bull. 795-A, p. 7, 1927.

Ownership and development. — Almost all of the limestone bodies in the Metchosin Formation are within the boundaries of the Olympic National Forest. A few are in the Olympic National Park. Their small size, poor quality, and general inaccessibility make them of little economic value. However, Park (1942, p. 438) suggests that large bodies containing about 5 percent manganese oxide might "conceivably" be mined as low-grade manganese ore, but he considers this very unlikely. It is reported that the Metchosin Formation limestones can be used for making rock wool.

Description of deposits. — Limestone occurs in the Metchosin Formation in Grays Harbor, Clallam, Jefferson, and Mason Counties. Four deposits were examined during this study. Others are mentioned briefly from published descriptions and from previous studies by the writer.

Grays Harbor County

Humptulips River Deposit

Two beds of tan and gray dense-textured limestone, each about 2 feet thick, are exposed on the East Fork of the Humptulips River in the north part of sec. 4, T. 20 N., R. 9 W. The beds occur in a siltstone-claystone sequence and are separated by 4 feet of interbedded shale and siltstone. The sequence strikes N. 85° W. and dips 45° NE. Upstream from the limestone-bearing rocks the river cuts a gorge through basalt. Between the basalt and limestone the sedimentary rocks contain limestone concretions. The deposit can be reached by hiking through dense second-growth trees and brush from a private road of Rayonier Incorporated, about 1 mile to the east.

Humptulips East Fork Deposit No. 1

Location, size, and accessibility. — The Humptulips East Fork No. 1 limestone deposit is in the north-central part of sec. 4, T. 20 N., R. 9 W., and is also described as being in the N½NW¼ sec. 4. Limestone crops out on both sides of the Humptulips River East Fork. It forms a rounded hill 50 feet high, 100 feet long, and 50 feet wide on the north side of the river, and a bed 110 feet thick across the river to the southeast. The deposit can be reached by driving about 7 miles on a good logging road, starting from U.S. Highway 101 south of the village of Humptulips, then by hiking about 2½ miles along an abandoned logging road to the vicinity of the deposit.

Geology and description. — The area could not be visited during the 1960 field season due to hazardous fire conditions. The deposit was discovered by Sheldon L. Glover (oral communication, 1956), of the Washington Division of Mines and Geology. It is difficult to find and has not been investigated in detail. The limestone on the north side of the river is reported to be somewhat porous in texture, and that on the south side dense in texture.

Quality. — Reported to be siliceous.

Chemical analysis of Humptulips limestone

Sample no.	Location	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3
1/	Unknown -------	82.70					11.10	1.80	1.30

1/ Hodge (1938, p. 18).

Ownership and development. — The deposit was owned in 1938 by Phil S. Locke, of Aberdeen, and H. S. Shorey. It is now owned by Rayonier Incorporated, of Hoquiam. There has been no development.

Reference. — Hodge (1938, p. 19-21).

Quinault Area

On the north side of the divide between Skunk and Cook Creeks in the SW¼SW¼ sec. 20, T. 22 N., R. 9 W., red calcareous argillite and dark-red limestone are reported to occur in association with manganese minerals.

Reference.—Green (1945, p. 43).

Stevens Creek Deposit

Red argillaceous limestone is reported to crop out in the NW¼ sec. 31 and the SW¼ sec. 30, T. 22 N., R. 9 W.

Reference.—Magill (1960, p. 73-74).

Schofield Creek Deposit

(From field notes of W. A. G. Bennett and Weldon W. Rau)

The Schofield Creek limestone deposit is in the NW¼ sec. 13, T. 23 N., R. 7 W., on the Grisdale road near the junction of Schofield Creek and the Wynoochee River. The deposit is at an altitude of about 1,350 feet in the Olympic National Forest and is about 11½ miles by road north of Grisdale. It consists of a red argillaceous limestone bed that has an exposed thickness of 25 to 30 feet and that was traced for about 200 feet. It is best exposed in the bed of Schofield Creek. The limestone appears to be highly argillaceous and contains veins of calcite. In some places lighter colored carbonate is interbedded with graywacke and phyllite.

Chemical analysis of Schofield Creek limestone

(Mark Adams, analyst)

Sample no.	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
GH-2	15.46	3.86	7.22	8.69	1.85	69.93	12.59	0.300

Reference.—Bennett and Rau (1960, unpublished field notes).

Copper Creek Deposit

The Copper Creek limestone deposit is in the NW¼ sec. 12 and the NE¼ sec. 11, T. 23 N., R. 7 W., in the Olympic National Forest. It is along a logging road on the east side of the east branch of the Wynoochee River valley at an estimated altitude of 2,450 feet. It is on logged land, reached by about 13 miles of logging road north from Grisdale.

Outcrops have been traced along strike for approximately 500 feet, and may extend farther. The width is estimated to be about 100 feet. The limestone is red and argillaceous and usually has a manganese stain on weathered surfaces. At the northern end the outcrop appears to be faulted to the north by a northeast-trending fault exposed in a small gully. Graywacke borders the limestone to the north, west, and east.

The outcrop is covered to the east and south by soil, so the true thickness and extent to the south is undetermined. It contains many veinlets of calcite. Bedding in the limestone is indistinct, but it appears to strike N. 30° W. and dip 70° N.

Reference.—Bennett and Rau (1960, unpublished field notes).

Hoquiam Deposit

A limestone deposit in sec. 1, T. 17 N., R. 10 W., near Hoquiam, was reported by Wood and Russell of the Northern Pacific Railway in 1895 as not good for cement and too low grade for lime. An analysis of Dec. 2, 1905 shows: lime, 82.69 percent; silica, 11.1 percent; iron, 1.8 percent; alumina, 1.3 percent; and manganese, a trace.

Reference.—Washington State Planning Council (1937, p. 26).

Clallam County

Many lenses of red argillaceous limestone have been found associated with manganese deposits in the northern Olympic Mountains in Clallam County, and limestone appears to be more abundant there than in other parts of the Metchosin outcrop area.

Helen Mine

The Helen mine limestone deposit is in the N½ sec. 30, T. 30 N., R. 10 W. It consists of red limestone enclosed in basalt. In the lower pit, at an altitude of 1,900 feet, a limestone bed ranging in width from 10 to 30 feet is exposed for a strike length of 150 feet. The north wall of the limestone is in fault contact with basalt. The upper pit, at an altitude of about 2,500 feet, exposes a 30-foot thickness of red argillaceous limestone that strikes east and dips vertically. The limestone bed is bordered by basalt on both sides.

Reference.—Magill (1960, p. 35).

Lake Pleasant Area

At the Bill prospect at the headwaters of Ellis Creek, in the SW¼ sec. 25, T. 31 N., R. 13 W., at an altitude of approximately 1,300 feet, red argillaceous limestone is exposed in contact with basalt. The occurrence is accessible by 3½ miles of trail from the end of the road at Bear Creek. In this vicinity, red argillaceous limestone is also reported in the SE¼ sec. 25 and the NE¼ sec. 36, T. 31 N., R. 13 W., and in the NW¼ sec. 31, T. 31 N., R. 12 W.

Reference.—Magill (1960, p. 6-9).

State Lease

Red limestone containing concentrations of iron oxide crops out in the NW¼SE¼ sec. 16, T. 30 N., R. 12 W. It is overlain with sandy shale. The main limestone belt is 35 feet thick, strikes N. 80° E., and dips 20°-30° N. on the surface, the dip increasing to 45° with depth.

References.—Green (1945, p. 26), Magill (1960, p. 12).

Victory Lode (Bear Creek) Deposit

The Victory Lode is in the NW¼SW¼ sec. 24, T. 30 N., R. 12 W. It consists of a large body of limestone above and 300 feet west of the Victory Lode manganese deposit.

Reference.—Green (1945, p. 27).

Clallam Deposits No. 1, No. 2, and No. 3

Limestone wall rock encloses manganese minerals in the NW¼NW¼ sec. 28, T. 30 N., R. 11 W.

References.—Green (1945, p. 27), Magill (1960, p. 16-18).

Blue Eyes Claims

Manganese deposits in red limestone are reported in the N½SW¼ sec. 24, T. 30 N., R. 11 W.

Reference.—Green (1945, p. 27-29).

Ed B Group Claims

Red limestone grades into limonite that has an exposed width of 15 feet in the SE$\frac{1}{4}$ sec. 24, T. 30 N., R. 11 W., at an altitude of 1,545 feet.

References.—Green (1945, p. 29), Magill (1960, p. 26-27).

June Group Deposit

Red limestone crops out on the north side of a manganese ore body in the SE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 19, T. 30 N., R. 10 W., at an altitude of 1,265 feet.

Reference.—Green (1945, p. 29).

Sunshine Deposit

Red limestone and argillite are exposed approximately 75 feet south of the manganese ore body in the NW$\frac{1}{4}$NW$\frac{1}{4}$ sec. 23, T. 30 N., R. 10 W., at an altitude of 2,340 feet.

Reference.—Green (1945, p. 30).

Crescent Mine

The Crescent mine limestone deposit is about 1 mile west of Lake Crescent, near the line between secs. 23 and 24, T. 30 N., R. 10 W. The Crescent manganese ore deposit is enclosed in badly crushed and sheared red limestone, which in turn is enclosed in sheared basalt. The limestone is partly replaced by hausmannite, which shows the nodular texture of the limestone. Three ore bodies have been found, all in red limestone.

References.—Pardee (1927, p. 17), Green (1945, p. 30-31).

Thomson Group Deposit

A zone of tuff and limestone occurs at an altitude of 3,400 feet in sec. 27, T. 30 N., R. 8 W.

References.—Park (1942, p. 447), Magill (1960, p. 53).

Skookum Claims and Hurricane Claim

On the west side of the south branch of Little River within the Olympic National Park, in secs. 18 and 19, T. 29 N., R. 6 W., is a highly altered basalt containing pods or lenses of red limestone. The limestone is associated with manganese ore bodies. At the Hurricane claim an inclined shaft follows a manganiferous red limestone bed down dip a distance of 154 feet. The deposits are at an altitude of about 3,900 feet.

References.—Park (1942, p. 448-449), Green (1945, p. 33), Magill (1960, p. 49).

Hurricane Ridge-Mount Angeles Trail Deposits

Red limestone occurs along the trail from Hurricane Ridge to Mount Angeles, and along the Greywolf River to the east are several thin beds of red or gray dense to crystalline-textured limestone interbedded with basalt. These bodies are only a few feet thick at most.

Bertha Deposit

The Bertha property lies just below the crest on the north slope of Aurora Ridge about 1$\frac{1}{2}$ miles west of Lizard Head Peak, or 4 miles south of the east end of Crescent Lake. Red limestone bodies are exposed for several miles to the west.

Reference.—Magill (1960, p. 51-52).

Dungeness-Forks Area

Lenses of argillaceous limestone occur along the Dungeness River east of the Dungeness Forks campground.

Jefferson County

Argillaceous limestone occurs in the Metchosin Formation outcrops in the eastern part of Jefferson County.

Tubal Cain Deposit

Lenses of manganese minerals occur in red limestone on the northwest side of Iron Mountain, in sec. 7, T. 27 N., R. 3 W., in the Olympic National Forest. Limestone crops out on the surface just east of the crest of a ridge about 6,900 feet in altitude. An adit about 2,000 feet long, driven at an altitude of 4,400 feet, penetrated the limestone, but no ore was found. This adit cuts 75 feet of red limestone in a bed 114 feet from the face. The limestone fragments in the mine dump are reddish brown, are cut by calcite veinlets, and contain poorly preserved foraminifers. Small pods and lenses of bluish limestone rich in foraminifers crop out in volcanic rocks to the southwest, along the trail from the mine to Buckhorn Pass and along the trail from Buckhorn Pass to Marmot Pass. Red limestone float containing Globigerina is common along the trail up the Big Quilcene River between Shelter Rock and Camp Mystery. A lens of red limestone occurs on the top of the ridge to the south between the Big Quilcene River and Tunnel Creek.

References.—Park (1942, p. 450), Green (1945, p. 35), Magill (1960, p. 58-59).

Tunnel Creek Deposit

Lenses of red limestone heavily stained with black manganese oxide crop out at the head of Tunnel Creek, directly east of Mount Constance. They are small and are found between pillows of basalt. The altitude is approximately 5,500 feet.

Elkhorn Deposit

Near Miners Creek in secs. 13 and 24, T. 26 N., R. 4 W., there are three distinct red limestone beds interbedded with basalt. The limestone beds trend approximately north-south and stand almost vertical, although locally they show marked variation from this attitude. The limestone contains manganese-bearing bodies. Other limestone lenses crop out on the ridge from 1,250 to 5,700 feet in altitude. Some blue, white, or pink limestone bodies a few inches thick occur in pillow basalts and between flows. The greatest width observed was 25 feet.

References.—Park (1942, p. 451-452), Green (1945, p. 35), Magill (1960, p. 56-57).

Pulali Point Deposit

In about the center of sec. 18, T. 26 N., R. 1 W., on the shore of the east side of the peninsula making up Pulali Point, is an exposure of shales and sandstones interbedded in basalt. The sedimentary rocks contain numerous concretionary masses and nodular bodies of gray argillaceous limestone that are concentrated on the beach and give the false impression of a large limestone deposit. Fossil gastropods and pelecypods are common in the sandy beds, and at least one bed of impure glauconitic calcarenite contains oyster shells and orbitoid foraminifers. Calcareous concretions contain crabs, fossil wood, and pelecypods; nodular argillaceous limestone contains algae. The fossils include Turritella uvasana and indicate a middle to late Eocene age for the sequence.

Quality.—

Chemical analyses of Pulali Point argillaceous limestone

(Mark Adams, analyst)

Sample no.	Sample length	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3	P_2O_5
1/	Composite	74.35		32.67	41.66	0.44	13.86	2.02	5.74	
								R_2O_3		
2/ J1-1	Composite	72.37	1.75	32.74	40.66	0.84	16.46	8.87		0.020

1/ Unpublished private analysis.
2/ Sample collected for this report, Mark Adams, analyst.

Mason County

Argillaceous limestone occurs in the Metchosin Formation in Mason County, in the southeastern part of the Olympic Peninsula.

Triple Trip Deposit

The Triple Trip limestone deposit is in secs. 4 and 9, T. 23 N., R. 5 W., about ¼ mile up Copper Creek from its confluence with the Skokomish River. Red limestone is reported to occur with the manganese minerals at this locality.

References.—Park (1942, p. 455), Green (1945, p. 39), Magill (1960, p. 62).

Apex Mine

The Apex mine is at an altitude of 2,400 feet, about ½ mile up Copper Creek from the Triple Trip. Red limestone is reported to occur in nearly vertical beds with greenstone. At least two beds of limestone between 20 and 30 feet wide are known.

References.—Park (1942, p. 456), Green (1945, p. 40), Magill (1960, p. 60-61).

Bosnia Claim

The Bosnia claim is in sec. 10, T. 23 N., R. 6 W., on Steel Creek, a tributary of the South Fork of the Skokomish River on the south slope of Wonder Mountain. A manganese body 8 to 10 feet wide, at least 200 feet long, and 100 feet in vertical extent is enclosed by red limestone.

References.—Pardee (1921, p. 241), Park (1942, p. 456-457), Magill (1960, p. 64).

Black and White Mine

The Black and White mine is on the west slope of Mount Gladys, at an altitude of about 4,300 feet. Red limestone crops out a short distance to the northeast.

Reference.—Magill (1960, p. 64).

Four Stream Deposit

An outcrop of gray massive limestone is situated where Four Stream enters the Skokomish River. The contact is 78 feet from the bridge over Four Stream and at right angles to it. The outcrop of limestone is 175 feet long from its beginning near the bridge to where it ends down the river.

Reference.—Dinsmore (1953, p. 34).

Red Reef Pool Deposit

Approximately 1,320 feet up the Skokomish River from the bridge at Staircase Resort is an area called the Red Reef Pool, which is an outcrop of red calcareous argillite. The outcrop is about 55 feet wide, strikes N. 40°-67° E., and dips 75°-70° E. There are a few lenses of gray limestone and green argillite in the outcrop. The largest limestone body is 18 inches long and 6 inches thick. The lower contact of the limy sediment is with basalt; the upper contact is concealed.

Reference.—Dinsmore (1953, p. 37).

Staircase Deposit

A body of well-bedded gray limestone crops out in sec. 4, T. 23 N., R. 5 W., along the south side of the Skokomish River near the Staircase Resort, east of the gaging station and across the river from the National Park Service campground. The limestone consists of beds 2 to 6 inches thick. Where weathered, it is red colored and heavily stained with manganese. Above and below the bedded limestone is a more massive red calcareous shale. The entire sequence is exposed for 100 to 120 feet along the river. Basalt lies below and above the calcareous sedimentary rocks. The strike of the sequence varies from N. 40° E. to N. 68° E., and the dip ranges from 65° SE. to 50° NW. In thin section the limestone is seen to contain abundant remains of Globigerina. These appear as tiny white specks on the weathered surface of the limestone. Another bed of red limestone, about 20 to 30 feet thick, lies east of the first and is separated from it by pillow basalt. This bed can be traced for at least 200 feet south along strike.

Along the trail, where people have walked on the limestone it has taken on a bright metallic polish because of its manganese content. The bedded limestone appears to have been deposited in a rhythmic manner, with its less resistant and more resistant beds alternating. The sequence is somewhat contorted.

Quality.—

Chemical analyses of Staircase limestone

(Mark Adams, analyst)

Sample no.	Location	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
M 1-1	East bed ---------	100	60.98	3.15	24.63	34.26	1.51	25.17	13.34	0.049
M 1-2	West bed --------	30	59.48	3.03	23.89	33.42	1.45	26.84	13.84	0.118

LIMESTONE IN THE INTERIOR OF THE OLYMPIC MOUNTAINS

Lenses of red, green, blue, and gray limestone crop out in sequences of basalt interbedded in the Soleduck Formation of the interior of the Olympic Mountains. Most of these bodies are small and range from a few inches to a few feet in thickness. Some of the limestone bodies are a result of sedimentation accompanying the deposition of the basalt flows on the sea floor, whereas others are a result of chemical precipitation during the volcanic eruptions. The latter are usually finely crystal-

line limestones and are blue and from white to green in color. The former are usually red or blue gray, dense textured, and argillaceous, and they contain foraminifers. The basalt sequence making up Mount Deception and Mount Claywood contains many small limestone bodies; lesser amounts of limestone occur on Sentinel Peak and Diamond Mountain. In some places the limestone is partially replaced by manganese minerals. On Mount Claywood, limestone beds total more than 50 feet in thickness; red limestone makes up about 30 feet of the total, and thin-bedded greenish-gray limestone about 20 feet of it. Few beds in the section are thicker than 10 feet.

Quality.—

Chemical analyses of limestone in the interior of the Olympic Mountains[1/]

Location	$CaCO_3$	Loss on ignition	CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3
Mount Deception, green limestone	87.80	36.28	49.20		7.52	2.01	3.99
Tubal Cain mine, red limestone		20.04	25.11	2.17	31.06	10.94	8.46
Greywolf Valley, red limestone		15.06	19.88	2.20	41.96	6.26	11.06
Miners Creek, Dosewallips, white limestone	79.54	34.40	44.57	1.47	11.94	2.21	3.49

1/ Unpublished private analyses.

References.—Green (1945, p. 35-37), Danner (1948, p. 43-46).

SOUTHWESTERN WASHINGTON

The southwestern part of the State of Washington is underlain by thick sequences of Cenozoic sedimentary and volcanic rocks that were deposited mostly in a marine environment to the west and brackish water and continental environments to the east. Except for a few small, thin lenticular bodies of argillaceous limestone and numerous calcareous concretions, the sedimentary rocks consist of sandstone, shale, and conglomerate containing a high proportion of volcanic debris. Only one limestone body, on Bear River in Pacific County, has been quarried, and it is not being worked at the present time (1963). A few tons of limestone for agricultural use could perhaps be obtained from a small deposit near Menlo, in Pacific County. Other than these, none of the limestone occurrences in the southwestern part of the State appear to be of any economic value, and it is unlikely that any of large size or good quality will be found in this area in the future.

Lewis County

Lewis County is about in the center of southwestern Washington and has a hilly and mountainous terrain developed on Cenozoic sedimentary and volcanic rocks. A dense cover of first- and second-growth trees conceals much of the bedrock. There are two reports of limestone deposits in the county. One of these deposits was briefly examined during this investigation. The location reported for the other is so vague that it is unlikely that the occurrence could be found, and actually this rumored deposit may be the same as the one that was visited.

Newaukum Occurrence

Limestone is reported to crop out in sec. 27, T. 14 N., R. 2 E., along the Newaukum River in Lewis County. The original source publication gives no specific location. Valentine (1949, p. 50) shows it as being in sec. 27, T. 12 N., but a revision of this publication (Valentine, 1960, p. 56) places it in T. 14 N. Culver (1919, p. 18) states,

> The sedimentaries include conglomerates, sandstones, shales, and dolomitic limestones. . . . The limestones were found in but two localities and have a very limited areal extent. . . . lenses of limestone are interbedded with the graywacke-conglomerate series.

He described the limestone-bearing sequence as belonging to the Newaukum Series of pre-Puget Group age, which would presumably make it pre-Eocene. No recent geologic work has been published for this area. Culver's only information on location is a brief description of the Cinnabar area geology (1919, p. 103), in which he states, "It is not known how much of the district is occupied by the Newaukum formation, which here shows some quartzite and carbonate phases not found elsewhere."

References.—Culver (1919, p. 18, 23, 103), Valentine (1949, p. 50), Valentine (1960, p. 56).

Mineral Creek Deposit
(From notes by Wayne S. Moen, 1962)

The Mineral Creek limestone deposit is in north-central Lewis County, about 3 miles east of the town of Mineral. The deposit crops out on the North Fork of Mineral Creek in the SE¼ sec. 12, T. 14 N., R. 6 E. It can be reached by driving east from Mineral 2.4 miles on Airport Road to an abandoned logging road, and by following this road 3.7 miles up Mineral Creek to the vicinity of the deposit.

The limestone is on State-owned land, on which E. J. Cowan, of Tacoma, holds a mineral lease on 200 acres, which includes the SE¼ and the NE¼SW¼ sec. 12.

The limestone, as exposed in the bed and along the banks of Mineral Creek, consists of white to light-brown, medium- to coarse-grained calcite veins. The veins, which range from 2 to 12 inches in width, have an average strike of N. 60° E., dip 70° N., and occur as fissure fillings in brecciated andesite of Eocene age.

The calcite veins are exposed for a width of about 200 feet along Mineral Creek; across this width the veins make up about one-third of the rock mass. Away from the creekbed along strike they are obscured by dense vegetation and overburden. Trenching or stripping of the overburden would be required in order to determine the extent of the deposit.

Quality.—

Chemical analysis of Mineral Creek limestone

Sample no.	$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3	Al_2O_3
1/	90.00	1.00	5.10	2.42	0.50

1/ Analysis by Bennett's Chemical Laboratory, Tacoma, courtesy of E. J. Cowan.

References.—Valentine (1960, p. 56), Moen (1962, unpublished field notes).

Thurston County

Limestone boulders are reported to occur in the bed of Perry Creek, about 5 miles west of the city of Olympia. The source of the limestone has been sought but never found. The creek is less than 5 miles in length and is paralleled in part by U.S. Highway 101.

Pacific County

Pacific County is a small county at the southwestern tip of Washington. It is north of the Columbia River and is bordered on the west by the Pacific Ocean and Willapa Bay. The county is underlain by volcanic and sedimentary rocks, mostly Eocene, Oligocene, and Miocene in age; a large proportion of them were deposited in a marine environment. These rocks have been deformed by folding and faulting during the late Tertiary, and they crop out in hilly country that is usually covered with a dense growth of trees and shrubs. Oligocene rocks contain two limestone deposits and many argillaceous limestone concretions. One of the limestone bodies, the Bear River deposit, is believed to be a reef or organic bank. This is the only limestone deposit in southwestern Washington that has been exploited. It is possible that similar limestone bodies will be found in the county in the future, but their probable small size and argillaceous composition would limit their use, and they would be most suitable for agricultural stone.

Bear River Deposit

Location, size, and accessibility. — The Bear River limestone deposit is in the SE¼SE¼ sec. 20, T. 10 N., R. 10 W., on a bend of the Bear River 2¼ miles northeast of the Columbia River. In 1911 E. O. Quinn, in a private report, estimated that the deposit contained 72,950 tons of limestone. It appears to have been somewhat larger than that, but at present (1963) less than 100,000 tons remain in the quarry above the level of Bear River. The deposit can be reached by 3½ miles of gravel-surfaced logging road, starting from the west side of the Megler-Ilwaco highway bridge over the Chinook River. The last 3/4 mile of the road is quarry access road and is narrow and rough. The Bear River is 20 to 25 feet wide and 3 to 4 feet deep at the deposit when the tide is in on the nearby coast. The area consists of low rounded hills having a maximum relief of about 400 feet. The hills are covered with dense vegetation, and the lowlands between are swampy.

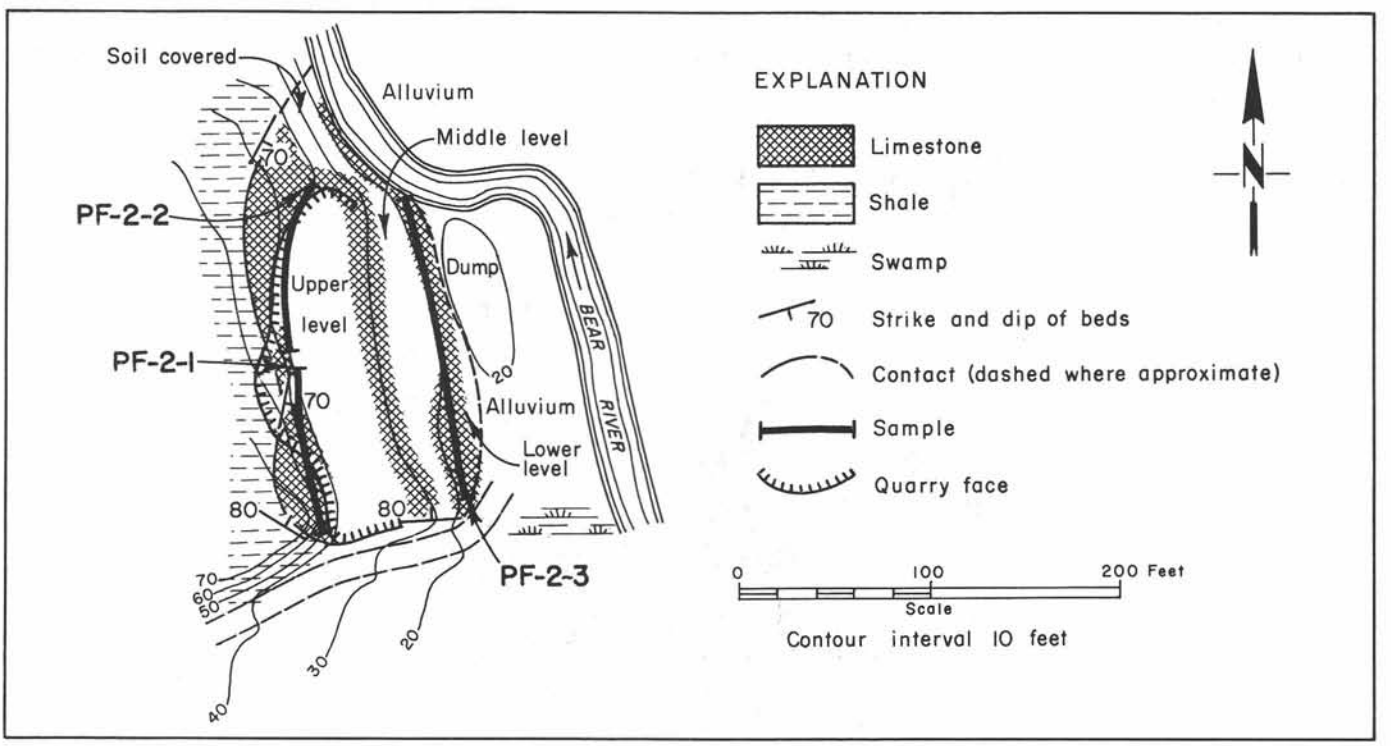


FIGURE 212. — Bear River deposit. SE¼SE¼ sec. 20, T. 10 N., R. 10 W. Geology by W. R. Danner and E. A. Adams. Compass and tape survey.

FIGURE 213.—Bear River limestone quarry. View looking northwest, 1954. Contact of limestone with shale is visible on the left side of the quarry.

Geology and description.—The deposit consists of a lenticular body of limestone striking northwest-southeast and dipping steeply (80°) to the northeast along its southwest side. The dip becomes more gentle to the east across the strike. The exposed length of the limestone is about 225 feet, and its maximum width is about 125 feet. Possible extension of the outcrop toward the east is covered with quarry dump and alluvium. The greatest vertical exposure is about 50 feet. The limestone contact on the west is with shale, and on the east it is concealed by the Bear River. Some movement has occurred along the limestone-shale contact, but it is not thought to be a fault of large displacement.

The limestone is made up in part of dense vuggy algal material and in part of a coquina of pelecypod shells, and appears to be a reef or bank. It is bluish gray to gray on fresh surfaces, and it weathers to a light-brown or buff color. The limestone tends to crumble upon long exposure to the air and contains a high proportion of argillaceous material. Many vugs in the limestone are filled with iron-stained argillaceous material, and a few are lined with a drusy layer of calcite crystals.

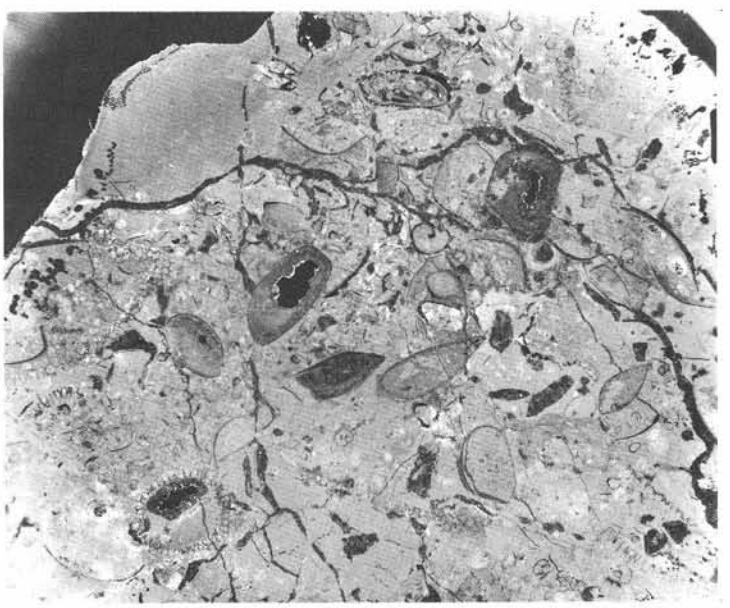


FIGURE 214.—Fossiliferous limestone of the Bear River deposit. Acetate peel, negative print. Pelecypods, gastropods, and algae in a dense calcite matrix. Many of the pelecypod shells are vuggy. X 3/4.

The commonest fossils are dasycladacean algae and a species of the small pelecypod Volsella. The latter, weathered out from the limestone, are abundant around the dumps and the older faces of the quarry. A large species of Solen and a few gastropods and ostracods were the only other fossils seen. Rarely, some parts of the fossil shells are silicified. The limestone is thought to be of Oligocene age and is enclosed in shales.

Hodge (1938) measured the following section in the deposit:

	Ft
Limestone, gray, "marbleized"	20
Limestone, fossiliferous, buff-colored	3
Clay, fossiliferous	½
Limestone, buff-colored, and clay seams	3
Limestone, crystalline	6
Clay, fossiliferous	2
Limestone, crystalline	100
Total	134½

Quality.—Most of the limestone is argillaceous and has a high silica content.

Chemical analyses of Bear River limestone

Sample no.	Location	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3	P	Na_2O	K_2O	SO_3
1/	Unknown --------					50.44		2.80	0.66					
1/	------ Do -------					61.14		12.66						
1/	------ Do -------		97.37	0.34	2/ 0.41			1.67	0.47					
1/	------ Do -------				42.21	53.52	0.30	2.24	0.68	0.76				
									R_2O_3					
3/	------ Do -------				47.5	51.2	1.35	6.62			0.028			
4/	------ Do -------		91.50		47.57	51.04	0.90	4.40	1.14					
4/	------ Do -------		89.39		41.54	50.06	0.73	6.36	1.38					
4/	------ Do -------		95.75		43.17	53.62	Trace	2.30	0.94					
									Fe_2O_3	Al_2O_3				
5/	"Astoria" (McIntosh) shale overburden -	12			7.40	0.67	1.93	60.26	8.48	19.08		0.46	1.90	Trace
5/	Limestone face ----	10			36.65	45.66	0.97	10.33	2.12	3.36		0.25	0.60	0.36
5/	Limestone face ----	10			40.09	49.08	0.80	5.53	0.99	2.19		0.12	0.51	0.23
5/	Limestone face ----	10			38.76	47.87	0.76	7.03	1.21	2.34		0.12	0.67	0.79
5/	Limestone face ----	10			37.17	46.91	1.01	8.83	2.09	2.85		0.50	0.35	0.50
5/	1/8-inch stockpile-				37.08	44.60	0.93	9.76	2.52	4.69		0.15	0.50	0.20

1/ Hodge (1938, p. 18).
2/ Organic matter.
3/ Source unknown.
4/ Analyses by E. W. Layell, 1928.
5/ Analyses by Ideal Cement Company.

Ownership and development.—The deposit was first described in 1916, but very little information is available concerning the early history of its development. In 1938 it was owned by the Willapa Pulp and Paper Mills Company; from 1945 through 1953 by Mr. A. J. Young, Roseburg, Oreg.; in 1954 by the Estacada Sand and Gravel Company, of Vancouver, Wash.; and in 1959 by the Columbia River Lime Company. From 1945 through 1948 it was operated by the Shell Rock Products Company, Oregon City, Oreg., and in 1952 and 1953 by the Columbia River Lime Company.

Chemical analyses of Bear River limestone

(Mark Adams, analyst)

Sample no.	Location	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
Pf 2-1	Upper level, south end -------	90	88.96	1.75	40.42	49.98	0.84	5.70	2.84	0.053
Pf 2-2	Upper level, north end -------	90	89.10	2.65	40.86	50.06	1.27	5.11	2.50	0.049
Pf 2-3	Lower level, north-south on face ----	160	94.37	1.81	42.05	52.46	0.87	2.89	1.51	0.038

Limestone removed from the Bear River quarry

(Data incomplete)

Year	Production (cu yd)
1945	454
1946	100
1947	1,024
1948	240
1952	3,527
1953	14,167
Total	19,512

Total past production is estimated to have been about 50,000 tons.

Hodge (1938) reports,

> In the past the stone was crushed and used for fertilizer. The material was floated out at high tide on small barges. Reports indicate that some stone was burned for lime, but no record of such operation could be traced.

The quarry has two levels, and limestone was trucked 3½ miles from the quarry to a crushing plant on the Megler-Ilwaco highway, where the road to the deposit joins that highway (U.S. 101) and Airport Road at the mouth of the Chinook River. In 1960 the crushing plant appeared to be abandoned, the deposit was not being operated and the quarry was partly overgrown with alder trees.

References.—Glover (1936, p. 55), Hodge (1938, p. 22-24), Northern Pacific Railway (1941, unpublished notes, p. 13).

Menlo (Lawson Ranch) Deposit

Location, size, and accessibility.—The Menlo limestone deposit is in the SW¼NW¼ sec. 24, T. 13 N., R. 8 W., along the Willapa River adjacent to the Chehalis-Raymond highway 1.9 miles southeast of the community of Menlo. The deposit consists of an outcrop of limestone about 25 feet long northwest-southeast, about 10 feet wide, and exposed vertically for about 7 feet. Farther along the river are 20 or more small lenticular beds of limestone, usually not more than 2 or 3 feet in thickness. The deposit is easily accessible by a paved highway 11 miles from the town of Raymond. It is on the river bank and is covered with grass and dense brush.

Geology and description. — The principal outcrop consists of two knoblike masses of limestone exposed on the bank of an old oxbow of the Willapa River about 50 to 60 feet east of the Stanley Niemcziek farmhouse. Soil and gravel overlie the limestone and cover its possible extension to the northwest. The limestone is a dense-textured micritic lithographic type containing many small solution cavities and vugs. It is light tan to cream colored on weathered surfaces, bluish gray on fresh surfaces, and contains poorly preserved and partially silicified gastropods and pelecypods. In some places the limestone is deeply weathered and has developed a pisolitic structure.

Small lenticular bodies of similar-appearing but more argillaceous limestone interbedded with shale crop out along the banks and in the bed of the Willapa River for over 2,000 feet to the south and west.

The sequence strikes about N. 50°-60° W. and dips 20°-35° NE. At one place along the river 17 lenticular layers of limestone were noted. The distance between outcrops averages about 20 feet. The limestone in the principal outcrop is bluish gray in color, dense textured, and contains small vugs. Irregular masses of chert and imperfectly silicified shells are common. The lenticular limestone bodies are light gray and appear to be more argillaceous than the larger masses of the main part of the deposit. The shales between the limestone beds contain spherical and cylindrical calcareous concretions, many of which contain fossil gastropods, pelecypods, fish teeth, and wood. The limestone is Oligocene in age.

Quality. — The limestone is argillaceous and partially silicified.

Chemical analyses of Menlo limestone

Sample no.	Location	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3	P_2O_5
1/	Unknown -------		81.71	1.96	36.52	45.91	0.94	9.69	1.75	5.07	
2/	Outcrop on oxbow	Composite	93.36	2.48		52.45	1.19	9.00	1.14	2.67	
2/	Outcrop, Willapa River	Composite	97.68	2.98		54.88	1.43	9.42	1.71	2.40	
									R_2O_3		
3/ Pf 1-1	Outcrop, Willapa River ---------	Composite	82.61	2.52	37.69	46.41	1.21	9.50	4.54		0.168
3/ Pf 1-2	Outcrop on oxbow	Composite	81.11	1.90	37.24	45.57	0.91	10.56	4.74		0.062

1/ Hodge (1938, p. 18).
2/ Northwest Laboratories.
3/ Samples collected for this report, Mark Adams, analyst.

Ownership and development. — The deposit is owned by Stanley Niemcziek, Route 1, Raymond, Wash., who lives on the property. The deposit is too small to be of any real economic value but could be developed, on a limited scale, for local use as a source of agricultural limestone. However, the chert would cause difficulties in crushing. Samples tested contained from 12 to 26 percent insoluble material.

References. — Glover (1936, p. 55), Hodge (1938, p. 24-25), Northern Pacific Railway (1941, unpublished notes, p. 13).

Other Limestone Reported in Pacific County

Limestone deposits have been reported at Megler and Cape Disappointment in Pacific County (Hodge, 1938, p. 25), but, as indicated by Hodge, nobody he contacted in the vicinity of Cape Disappointment knew of any limestone in that area, and there are no reports in the published geologic literature that indicate the presence of limestone. A brief examination of the area by the writer in 1955 failed to disclose any limestone.

Similarly, nothing is known about a reported deposit near Megler, but it is possible that calcareous shales and calcareous concretions along the Columbia River in this vicinity have given rise to the reports of limestone. Weaver (1916, p. 209) states that east of Knappton, on the north shore of the Columbia River, "Some of the shale bands are thinly bedded and occasionally calcareous . . . . small nodules occur in shale beds. These are decidedly calcareous and normally contain at their center a small fossil or pebble."

References.—Weaver (1916, p. 209), Hodge (1938, p. 25).

TUFA DEPOSITS

Tufa is a variety of calcium carbonate ($CaCO_3$) deposited in fresh water. It is a spongy, chalky rock that forms surficial deposits about springs and seeps, in streambeds, and sometimes along the shores of lakes. The carbonate is deposited on rocks, logs, and on the leaves and stems of growing vegetation; it commonly bears the imprint of these objects. Deposits of tufa are usually called travertine, but this name should be restricted to the more dense, banded deposits, which are common in limestone caverns and which form flowstone, dripstone, stalactites, and stalagmites, but which may also coat rock outcrops on the surface or be deposited in cracks and crevices. The term "tufa" comes from the Latin tophus and was used by Virgil and Pliny (Emig, 1917, p. 10) for porous spring deposits. The term "calcareous sinter" should be restricted to forms of calcium carbonate deposited from warm or hot waters.

Small coatings of tufa and travertine were seen in the vicinity of many limestone outcrops in western Washington, but only a few are large enough to merit description. In most of the deposits the tufa is associated with springs or streams issuing from limestone-containing bedrock sequences, and the tufa originated as a result of the solution of limestone by ground water. Tufa deposits occur where these streams have steep gradients or falls, and the precipitation of the tufa can be attributed to greater evaporation at these places.

A few tufa deposits occur in areas where limestone is not known to occur in the exposed bedrock. The source then may be limestone-bearing sequences that have no surface exposure, or the lime may have originated as a result of the alteration and decomposition of other materials, such as calcium-rich volcanic rocks.

Algae and mosses also are able to induce the precipitation of calcium carbonate in the form of tufa, but their contribution to the formation of deposits in western Washington has not been investigated. Shells of small fresh-water gastropods are common in some of the deposits.

All the tufa deposits of western Washington are small in size and of Recent origin. Several of them are still in the process of formation. Three deposits have been quarried and the tufa used for agricultural stone, chicken grit, flux, and for burning into lime. Much of the tufa might find a market as ornamental stone in rock gardens, both for its pleasing appearance and as a slow contributor of lime to the soil.

SAN JUAN COUNTY

Orcas Island

Orcas Knob Tufa Deposit

Seepages of water on the cliffs and steep slopes composing the west side of Orcas Knob have in a few places deposited small areas of tufa and travertine. One deposit about 75 feet above and 350 feet north of the northern Soderberg limestone quarry contains layers of creamy white tufa and travertine coating bedrock. The deposit ranges in thickness from a fraction of an inch to over 1 foot and covers an area of less than 10 square feet.

WHATCOM COUNTY

Church Mountain Tufa Deposit

Location, size, and accessibility. — The Church Mountain tufa deposit is in the central part of sec. 33, T. 40 N., R. 7 E., on the north side of the Nooksack River valley about 1,200 feet north of the Mount Baker highway from the bridge over Coal Creek. The locality is about 2.6 miles east of the village of Glacier.

The tufa consists of a Recent creekbed deposit about 840 feet long and averaging less than 10 feet in width. Exposures of pure material are generally less than 2 feet thick.

The area can be reached by hiking north through the woods from the Coal Creek bridge on the Mount Baker highway to where the small tufa-depositing stream empties onto a flat area. The tufa outcrops can then be traced from an altitude of 1,300 feet up to an altitude of 1,750 feet by climbing up the streambed. The area is heavily wooded.

Geology and description. — The deposit consists of brownish-yellow to buff-colored calcareous tufa. Much of the tufa is in soft and crumbly irregular masses, but in a few places it forms hard layers. All of it is porous. The tufa is being deposited at present in the streambed and is coating rocks and branches. Well-preserved leaf imprints occur in some of the denser, harder layers. The thickest deposition seems to have taken place where the slope is steepest and where small waterfalls have developed. No tufa is being deposited where the stream flows over the gently sloping surface of the valley floor.

Relatively pure masses of the tufa are exposed in the streambed and bank; they seldom exceed 2 feet in thickness. Tufa mixed with gravel and sand was found in one exposure up to a thickness of 5 feet. The outcrops in the narrow stream canyon are generally less than 10 feet wide, but in some places their width is as much as 20 feet.

The stream precipitating the tufa issues as a spring from a jumbled mass of volcanic rock talus

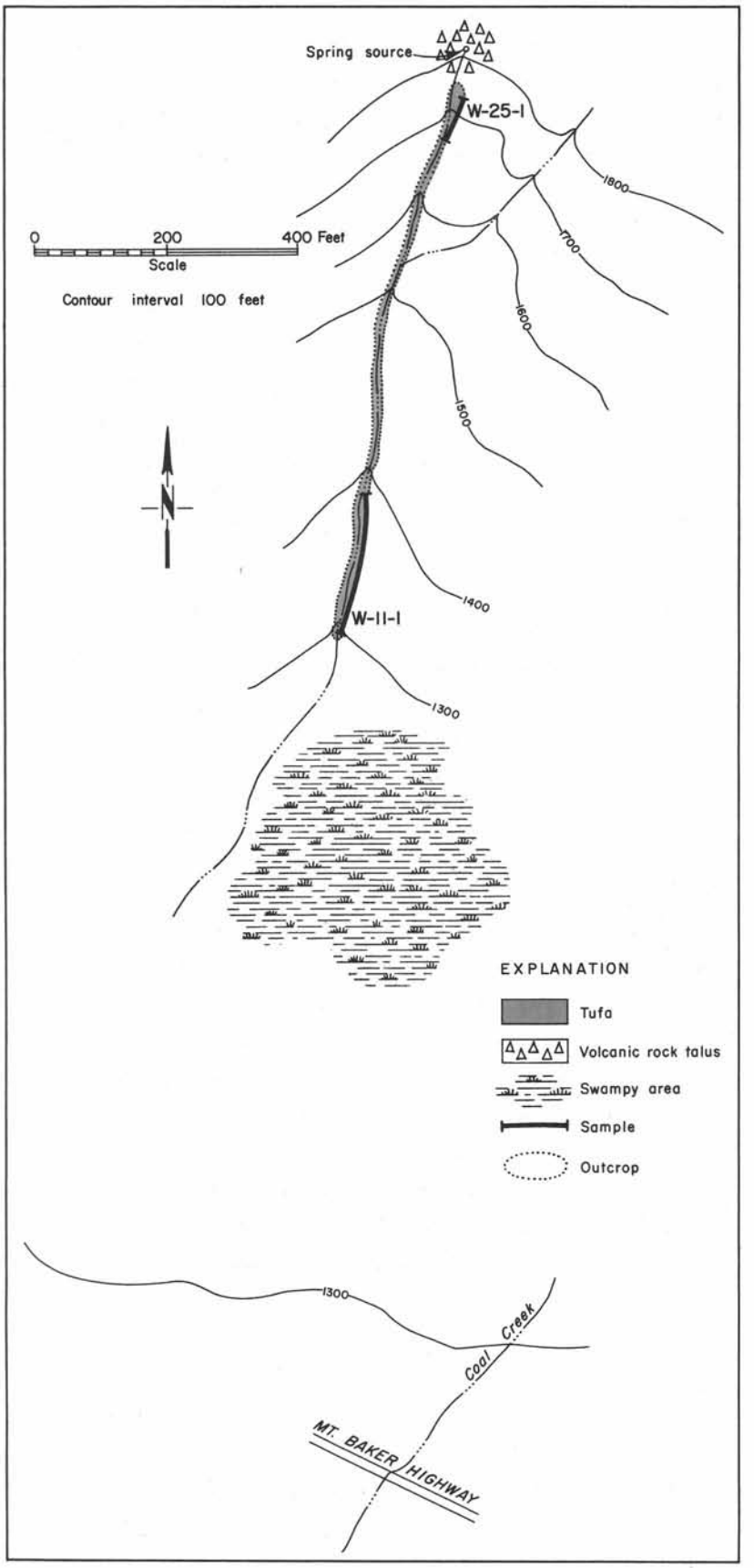


FIGURE 215. — Church Mountain tufa deposit. Central part of sec. 33, T. 40 N., R. 7 E. Geology by W. R. Danner, C. F. McKillop, and A. M. Rivisto. Compass and tape survey.

at an altitude of about 1,800 feet on the west end of the south side of the Church Mountain ridge. An easterly fork of this same stream has a source higher on Church Mountain, but it is not precipitating tufa. Upstream, however, it does contain a few specimens of float of a harder type of tufa, which comes from an unknown deposit above on the mountainside. Small limestone bodies in the Paleozoic bedrock higher on Church Mountain may be the source of the calcium carbonate forming this tufa deposit.

Quality.—The tufa is of good quality where not mixed with soil.

Chemical analyses of Church Mountain tufa

(Mark Adams, analyst)

Sample no.	Location	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
W 11-1	Lower ----------	220	94.25	0.689	43.33	52.95	0.33	1.97	1.17	0.010
W 25-1	Upper ----------	70	97.20	0.209	44.25	54.61	0.10	0.29	0.21	0.006

Ownership and development.—Claims on the tufa deposit have been staked by Robert Breining, Sumas, Wash. The area is part of the Mount Baker National Forest. There has been no development other than the removal of hand specimens of the tufa. The occurrence is too small for any large-scale operation and would have to be worked mostly by hand to obtain pure material. It might be used as a source of ornamental stone for rock gardens or be crushed for agricultural lime.

Silver Lake No. 2 Tufa Deposit

Location, size, and accessibility.—The Silver Lake No. 2 tufa deposit is on a steep hillside below the crest of a ridge that forms the north side of a canyon in the NW¼SW¼ sec. 7, T. 40 N., R. 6 E. The tufa lies just below limestone outcrops of the Silver Lake No. 2 limestone deposit and north of the Silver Lake No. 1 limestone deposit. The size of the deposit is unknown, but the tufa is believed to be restricted to a few feet on either side of a small spring-fed stream. Its thickness is less than 6 inches. It can be reached by hiking up the steep hillside west of the "Day" farmhouse, now owned by Oliver Ferry, who lives on the next farm to the north. The stream flows south on the north side of the canyon.

Geology and description.—A small spring issues from the ground on the hillside below the south part of the Silver Lake No. 2 limestone deposit. As it flows down the hillside it deposits thin layers of soft argillaceous tufa and small, hard, porous lumps of pure tufa. The material is creamy white in color and is accumulating in sands and gravels in the streambed and in black organic soils alongside the stream.

Quality.—The tufa is intermixed with soil and other impurities and would be difficult to obtain in pure form.

Chemical analyses of Silver Lake No. 2 tufa

(Mark Adams, analyst)

Sample no.	Location	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
W 10-1	Soft calcareous mud ---------	Composite	64.76	1.02	35.70	36.38	0.49	21.15	5.56	0.017
W 10-2	Pure lumps from stream bed ---	Composite	86.00	0.83	41.04	48.32	0.40	8.04	1.94	0.018

Ownership and development.—The owner of the property is unknown. There has been no development, and the tufa deposit is too small and impure to be of any economic value.

Reference.—Valentine (1960, p. 59).

SKAGIT COUNTY

Strong Tufa Deposit

Location, size, and accessibility.—The Strong tufa deposit is in the NE¼NE¼ sec. 9, T. 35 N., R. 8 E., northwest of the town of Concrete. The extent of the occurrence is unknown, but tufa is exposed in a trench 55 feet long, 20 feet wide, and 10 feet deep. It can be reached by following old State Highway 17A for 0.6 mile west from its junction with the Baker Lake road to a dirt road going north, and by following this dirt road ¼ mile to the deposit.

Geology and description.—The tufa was uncovered by a fire many years ago. It is on a gently sloping hillside and consists of layers of soft porous crumbly tufa and hard porous tufa that total at least 6 feet in thickness. The only exposure is in a prospect trench. Tufa has been reported to underlie at least 40 acres, but no exposures of it were seen in other prospect pits in the area. The deposit is overlain by a mixture of gravel and sand that is from 2 to 4 feet thick and contains pebbles as much as 4 inches or more in diameter.

The tufa is mostly lithified and breaks into rough chunks. However, some layers are soft and claylike. In most places the tufa is relatively pure and contains only a few pebbles and an occasional lens of carbonaceous matter. A few cavities present appear to be casts of logs. Small fresh-water gastropod shells are embedded in the tufa, but they are not abundant. Botryoidal and fibrous forms of tufa are common here.

The origin of this deposit is unknown, but the tufa could have developed from a spring issuing from thick gravel deposits up the hillside to the north, or it might have been deposited along the shore of a temporary lake.

Chemical analyses of Strong tufa

(Mark Adams, analyst)

Sample no.	Location	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
St 1-1	West face of cut -------	55	96.26	1.52	43.98	54.09	0.73	1.15	0.32	0.035
St 1-3	East side cut -	Hand specimen, powder form	93.57	0.627	43.07	52.57	0.30	2.97	0.73	0.044

Ownership and development.—The deposit is owned by D. R. Strong, whose home is along the road from the highway to the deposit. It was operated at one time (1959) by J. E. George, Box 546, Issaquah, Wash., but drying, which was required before the tufa could be crushed for agricultural stone, proved to be difficult.

Reference.—Valentine (1960, p. 59).

Alverson Tufa Deposit

Location, size, and description.—The Alverson tufa deposit is reported to be 350 feet west of the Strontium mine, in sec. 2, T. 33 N., R. 2 E., on the south shore of Fidalgo Island. Its locality is just southwest of the town of La Conner. It has been described as a small spring deposit at tide level, too small for economic operation. It was not visited during this investigation.

Reference.—Valentine (1960, p. 59).

SNOHOMISH COUNTY

Reece Ridge Way Tufa Deposit

Location, size, and accessibility. — The Reece Ridge Way tufa deposit is north of Dan Creek on the southwest side of Prairie Mountain in the NE$\frac{1}{4}$ sec. 16, T. 32 N., R. 10 E., at an altitude of about 2,000 feet above sea level. It is a small deposit, reached by traveling 2 miles on a trail east from the Reece farmhouse and by going due south downslope to a small stream.

Geology and description. — A minor tufa deposit is in the process of forming in a deep stream gully, where a spring emerges on the north bank. Less than $\frac{1}{2}$ ton of the rock was found in place.

Quality. — Unknown.

Ownership and development. — The tufa is on lands of the Mount Baker National Forest. There has been no development, and the deposit is probably too small to be of any economic value.

Reference. — Guard (1943, unpublished field notes).

Blackoak Creek (Whitechuck, Dan Creek) Tufa Deposit

Location, size, and accessibility. — The Blackoak Creek tufa deposit is in the SW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 1 and the SE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 2, T. 31 N., R. 10 E., near the base of the west slope of a steep mountainside bordering the Dan Creek-Blackoak Creek Valley. The deposit lies just north of the junction of the Dan Creek and Blackoak Creek logging roads. It covers slightly less than 3 acres to an estimated average thickness of 6 feet. It is accessible by about 3$\frac{1}{2}$ miles of good gravel-surfaced logging road (Dan Creek road) from its junction with the Sauk River road, which is 7 miles south of the Sauk River bridge at Darrington. The Dan Creek road borders the west side of the deposit.

Geology and description. — The tufa forms a blanket-like mass lying on the hillside slope. It is roughly rectangular in shape, extending northeast-southwest for about 550 feet, and is about 300 feet wide at its widest point. Its thickness ranges from a few inches to 15 feet, the maximum thickness being at the lower end, bordering the road. The tufa appears to have been deposited as a terrace by springs issuing from the hillside. At the present time (1962), a spring-fed stream borders the deposit on both the north and south sides. To the west, on the valley floor, is a swampy area marking the head of Blackoak Creek. Tufa may underlie part of this swamp. Farther west, serpentine is exposed in a knob containing a small quarry.

The tufa appears to be mostly free from gravel and other impurities except where contaminated by surface soil and vegetation. However, it is reported that parts of the tufa deposit were overlain by gravel and clay, which had to be removed before quarrying was commenced. The area of the deposit has been logged, and in part is being overgrown by dense brush.

The tufa is cream to light brown in color, crumbly, and has a porous, layered structure. Some parts are botryoidal and fibrous. A few small high-spired and planospired gastropod shells are embedded in the tufa. Hodge (1938, p. 68) reports well-preserved leaf impressions, and Popoff (1949c, p. 3) and Hodge (1938, p. 68) report tufa being formed when they examined the deposit, but no indications of such deposition were seen during the time of the present investigation.

The hillside above the deposit is steep to gently sloping, and where logged is covered with dense brush and second-growth trees. Several hundred feet above the limestone are a few outcrops of calc-silicate rock of the type associated with several of the fault zones in western Washington. About $\frac{1}{4}$ mile up the slope is limestone float from the Conn Creek No. 1 limestone deposit.

Quality. — Popoff (1949c, p. 4) gives the specific gravity of the tufa as less than 2.25 and the moisture content as about 7 percent.

Ownership and development. — The deposit is owned by Louie Kratz, of Arlington, Wash. It was operated formerly as the Whitechuck Lime Company, and in recent years it has been operated by J. E. George, Box 546, Issaquah, Wash. The property was staked in 1935 as the Three Stars placer claim by Messrs. Gustafson, Wheeler, and Blacker. It is now known as

Chemical analyses of Blackoak Creek tufa

Sample no.	Location	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3		P_2O_5	S
1/ Sh 1-1	Roadcut -----	6 vertical	96.04	1.88	44.12	53.96	1.15	0.29	0.24		0.008	
									Fe_2O_3	Al_2O_3		
2/ S1		5 vertical			44.4	54.4	0.9	0.1	0.2	0.2	3/ 0.016	0.119
2/ S2		22 horizontal			44.5	54.1	1.9	0.1	0.04	0.0	0.003	0.099

1/ Sample collected for this report, Mark Adams, analyst). 2/ Popoff (1949c, fig. 1). 3/ Phosphorus.

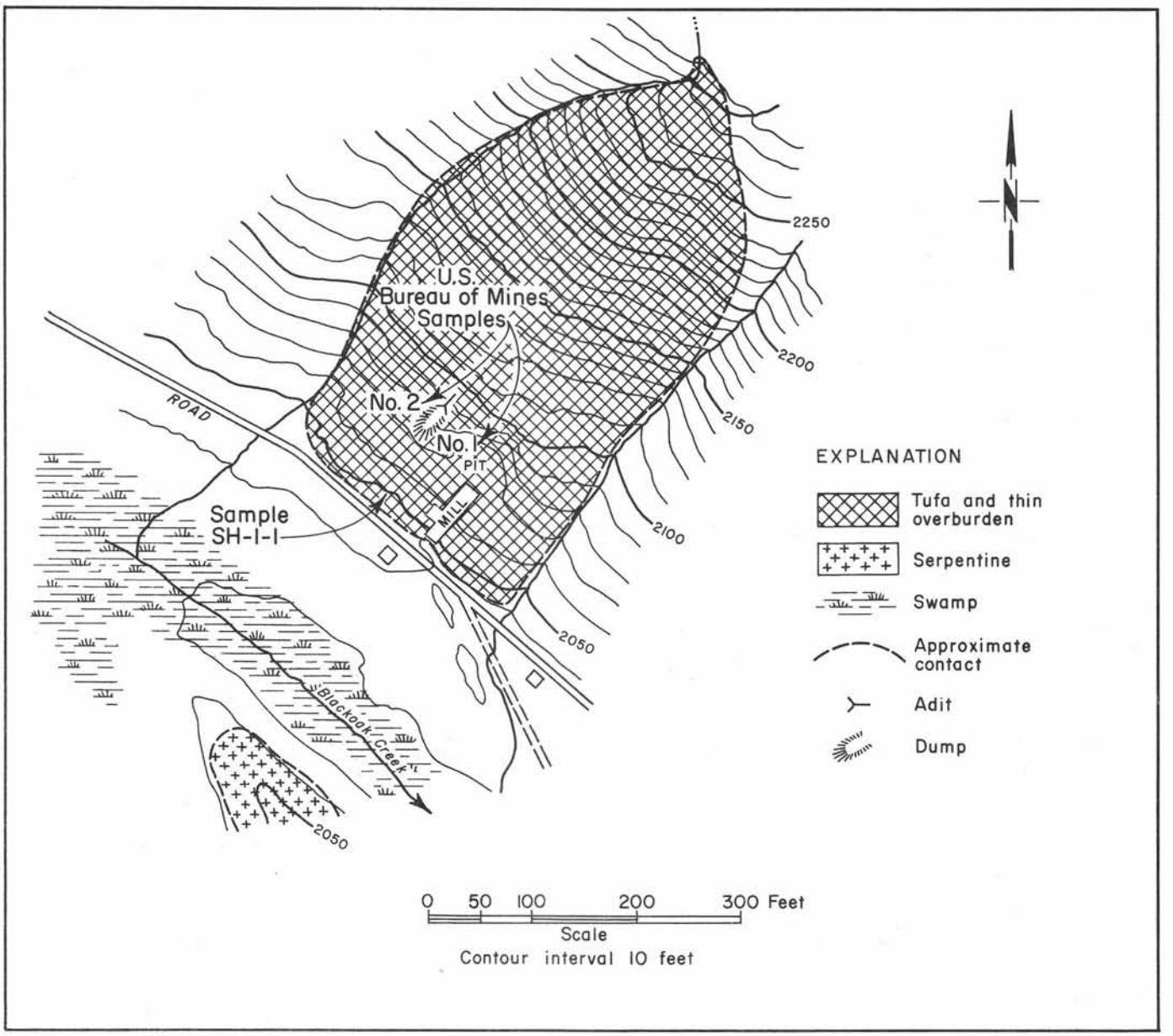


FIGURE 216.—Blackoak Creek tufa deposit. SW¼SW¼ sec. 1 and SE¼SE¼ sec. 2, T. 31 N., R. 10 E. Geology by C. C. Popoff, 1949. Map reprinted with slight modification from U.S. Bureau of Mines Report of Investigations No. 4565.

the Whitechuck placer claim (unpatented). About 1,200 tons of tufa was mined and sold for agricultural purposes in 1940-41, and a small mill was constructed on the property. In the summer of 1960 the deposit was not being worked.

During 1963 further development work was done on the property and a pilot mill was set up on a rail spur adjoining the town of Darrington. The mine and mill were in operation on a small scale. Late in 1963 the operation was "farmed out" to Rock & Sand, Inc., of Seattle. That company in turn revamped the mill to a 200 to 300 ton per day operation during 1964.

Several bulldozed pits are present on the deposit, and an adit 17 feet long was reported by Popoff in 1949 but was not visible in 1960.

References. — Hodge (1938, p. 67), Broughton (1942, p. 54), Guard (1943, unpublished field notes), Popoff (1949c, p. 1-4).

Paddock Tufa Deposit

Location, size, and description. — The Paddock tufa deposit is in the NE$\frac{1}{4}$ sec. 16, T. 32 N., R. 10 E. It is reported to contain less than $\frac{1}{2}$ ton of tufa. The deposit was not visited during this investigation.

Reference. — Valentine (1960, p. 59).

PIERCE COUNTY

McMillin Tufa Deposit

Location, size, and accessibility. — The McMillin tufa deposit is in the S$\frac{1}{2}$ sec. 7, T. 19 N., R. 5 E., about 3 miles north of the town of Orting and about 3/4 mile east of the village of McMillin. The deposit is on a steep bluff on the east side of the Puyallup River. Outcrops of tufa and interbedded gravel are spread over an area of approximately 500,000 square feet and range in thickness from a few inches to 40 feet. The deposit is easily accessible by about 3/4 mile of good graveled road from the village of McMillin. The area is covered in part with dense second-growth trees and brush.

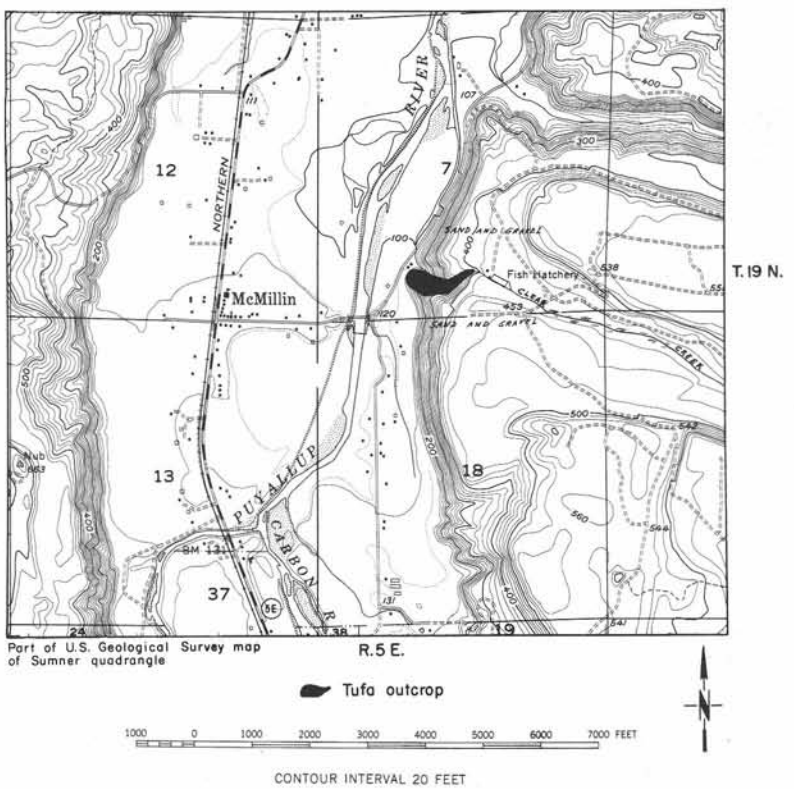


FIGURE 217. — McMillin tufa deposit. S$\frac{1}{2}$ sec. 7, T. 19 N., R. 5 E. Geology by W. R. Danner.

Geology and description. — No bedrock is exposed in the vicinity. All exposures consist of sediments of Pleistocene or Recent age. The Puyallup River is entrenched about 500 feet below the general land surface, and alluvial silts have been deposited on the valley floor.

This tufa deposit appears to be the only one of its kind in this part of western Washington. On the northern side of a small ridge trending in an east-west direction, tufa crops out from the top of the bluff down to the Puyallup River. The crest of the ridge forms the southern boundary of the deposit, and a swift-flowing creek south of the northern outcrop limit indicates approximately the northern boundary. To the west the tufa is exposed to the base of the bluff. The eastern boundary is concealed by vegetation. Beds of sand and gravel are exposed to the north and south.

The deposit has an exposed thickness of at least 40 feet on the west side. About 900 feet to the east it is about 1 foot thick and is underlain by sand and gravel. The southernmost exposure is about 15

inches thick and is underlain by at least 20 feet of gravel and sand, the upper layers of which are cemented with tufa. On the north side of the creek are exposures of tufa from 1 to 2 feet or more in thickness underlain by sand, gravel, and clay. The tufa is overlain by about 1 foot of soil.

Cuts as much as 10 feet in depth have been made into the tufa in the central part of the deposit. Layers of gravel and sand underlie it at varying depths beneath the surface. One cut contains dark carbonaceous clay underlying tufa. At the southern end of the deposit, tufa and underlying gravel dip about 20° SW. Exposures up the streambed to the east have approximately the same attitude.

From 1 to 3 feet of soft crumbly weathered tufa is exposed over most of the deposit. It contains a few blocks of hard tufa and travertine. The soft material may be the "fines" of previous operations spread over the surface (Hodge, 1938, p. 77). The hard lumps of tufa and travertine are as much as 2½ feet long and 2 feet thick. Some of the lumps are composed of long tubular clusters of aragonite, and others are botryoidal in shape. Small gastropod shells are cemented in the material. A few blocks of tufa were found consisting of an interlocking mass of tiny hollow tubes, probably formed by precipitation around water plants. Most of the larger tubes are casts of stems and branches. No definite blanket beds of hard tufa were found. Gravel cemented by tufa is common throughout the deposit. Usually, the more strongly cemented material contains a few pebbles in a tufa matrix. Loosely cemented gravels are composed mostly of pebbles or cobbles and little tufa. Some cobbles are as much as 7 inches in diameter.

The small stream flowing across the deposit near the north end appears to lose a large amount of its volume by seepage into the tufa. It is probable that this stream built the tufa deposit on a gravel delta at the base of the bluff above the Puyallup River.

Quality.—Very little is known about the quality of the tufa. The shipped product bore the following analysis on the outside of its containers:

$CaCO_3$	MgO	SiO_2	FeO
93.95	0.45	2.40	0.50

Ownership and development.—The deposit is owned by L. C. Beck, of Seattle. A private home is now on the site of the abandoned quarry. Originally, the property was part of a Northern Pacific Railway land grant. It was first staked for the mining of tufa in April 1878 by Joseph Mullender and William H. Cronk. Later the Tacoma Lime Company was formed, and in April 1884 John S. McMillin purchased a one-fourth interest and became manager of the company. In December 1884, three mineral placer claims of 20 acres each, the Lime, Dandy Lime, and Jennie, were located on the property. In 1887 McMillin formed the Tacoma and Roche Harbor Lime Comapny, and in 1889 the town of McMillin was platted. Two kilns were in operation. McMillin later sold out his interest, and the property changed hands several times from 1915 to 1919. During part of this time J. B. Agnes operated the quarry for fertilizer rock. The last quarrying was done during the period 1932 to 1943. In 1938 the deposit was owned by the Valley Lime and Power Company, of Seattle (G. C. Winn, owner). The main pit was 250 feet long and 25 to 30 feet deep, and the material being worked was from waste of previous quarrying operations, mostly fines, with blasting powder cans found buried in it. A plant was situated on the property with a capacity to grind 8 tons of raw lime in 10 hours. Limestone from the deposit was used for agricultural lime, chicken grit, and as a stock feed additive. Some was shipped to the Atlas Iron Foundry, in Tacoma, and to the Tacoma smelter.

The deposit is considered to be exhausted, and the tufa that remains has no commercial value because of the interbedded gravel layers. A few blocks of the harder variety could be used for ornamental stone and rock gardens.

References.—Patty and Glover (1921, p. 140), Glover (1936, p. 55), Hodge (1938, p. 76-78), Mathews (1947, p. 108), McDonald (1957, p. 2).

Mount Rainier National Park Mineral Springs Tufa Deposits

At Longmire, in Mount Rainier National Park, several mineral springs are surrounded by deposits of platy and crusty calcareous sinter. Much of it is stained an orange color from iron in the spring waters. Small amounts of banded travertine are also present. The springs give off a considerable amount of carbon dioxide.

These deposits are of no commercial value, but they are good examples of the formation of calcareous deposits by springs and thus form a "living" geologic exhibit well suited to preservation in a national park.

The hot springs at Ohanapecosh in the southeastern corner of the park also contain small deposits of tufa.

OLYMPIC PENINSULA

Dosewallips Tufa Occurrence

Tufa is reported to occur in the SE¼ sec. 7, T. 26 N., R. 4 W., and to be exposed for 85 feet along a trail and 70 feet up the hillside. This locality is on unsurveyed land of the Olympic National Park.

Reference.—Valentine (1960, p. 59).

West Creek Tufa Deposit

About 3 miles up West Creek from its junction with the Dosewallips River, in sec. 24, T. 27 N., R. 5 W., a small stream that crosses the trail leading to Anderson Pass is actively depositing a white chalky tufa on rocks, logs, and moss. The maximum thickness seen was about 5 inches. The deposit is in mountainous country of the Olympic National Park and is too small and thin to be of commercial value.

Quality.—

Chemical analysis of West Creek tufa

Sample no.	Sample length (feet)	$CaCO_3$	Loss on ignition	CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3
1/	Composite	88.75	43.91	49.73	0.25	3.74	0.30	1.14

1/ Unpublished private analysis.

Olympic Hot Springs Tufa Occurrence

Specimens of hard brown tufa have been found in the vicinity of Olympic Hot Springs and east toward the Elwha River, in the northern part of the Olympic National Park. All specimens known to the writer were obtained from float, and no deposits have been reported in place. It is probable that the tufa has been deposited by springs issuing from faults in the northern Olympic Mountains. Tufa might also be found in the vicinity of Sol Duc Hot Springs.

CHELAN COUNTY

Soda Springs Tufa Deposit

Location, size, and accessibility.—The Soda Springs tufa deposit is in the NW¼ sec. 10, T. 27 N., R. 15 E., on the north side of the Little Wenatchee River in the Soda Springs campground of the Wenatchee National Forest. Tufa occurs in outcrops along a small stream for a distance of at least 500 feet and has a width ranging from a few feet to over 40 feet.

The exposed thickness is at least 2 feet. The deposit is accessible by about 8 miles of black-topped road and ½ mile of graveled road from the resort area on the northwest side of Lake Wenatchee. Virgin timber and dense brush cover the area.

Geology and description.—A small carbon dioxide-producing spring issues from the base of a ridge at the west end of the Soda Springs limestone deposit. The Soda Springs campground derived its name from this feature. The small stream issuing from the spring is depositing a reddish-brown iron oxide material in its bed and banks near its source. Farther downstream a porous tufa is being deposited on logs and a soft, mushy tufa-rich mud is being formed in the streambed. About 500 feet downstream, outcrops of tufa are exposed in the banks of the stream and consist of hard porous tufa layers as much as 3 inches in thickness. About 5 inches below the surface of the ground the hard tufa layers are interbedded with layers of soft porous and powdery calcareous material that in some places contains bands of black carbonaceous matter. The hard tufa is dark gray brown in color and commonly contains the imprints of leaves and stems.

The extent of the tufa is unknown, but the deposit appears to be small.

Quality.—

Chemical analysis of Soda Springs tufa

(Mark Adams, analyst)

Sample no.	Location	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
Cn 1-1	Soda Springs stream bank --	Composite	96.28	0.94	44.47	54.09	0.45	0.43	0.33	0.020

Ownership and development.—The tufa is on withdrawn lands of the Soda Springs campground of the Wenatchee National Forest and thus is not open to staking or mining. The deposit is not well enough exposed to determine its size, but it is probably not over a few feet in thickness and is too small to be of any commercial value.

References.—Glover (1936, p. 70), Valentine (1960, p. 66).

DEPOSITS OF DISCARDED SHELLS

OYSTER SHELLS

Small piles of discarded oyster shells are found at several places in western Washington, but at present none are believed large enough to constitute an economic source of calcium carbonate. However, they are used locally for road surfacing. Oyster-shell deposits were not investigated for this report, but a few localities are listed below.

Pacific County.—Small piles of discarded oyster shells lie at several places along the shores of Willapa Bay in western Pacific County.

Jefferson County.—Shell deposits have accumulated where oysters are harvested at several places along the shores of Hood Canal. The town of Quilcene, in eastern Jefferson County, is the center of the local industry.

Skagit County.—Oysters are harvested along the shores of Samish Bay, in northwestern Skagit County, and Padilla Bay, southeast of the city of Anacortes. The oyster industry was started in 1921 in Samish Bay. Piles of oyster shells lie at several places fringing these bays.

Thurston and Mason Counties.—Oysters are harvested in the inlets from the vicinity of Olympia, in Thurston County, north to Shelton, in Mason County, and beyond. The shells have been used locally for road surfacing.

After harvesting, most of the oyster shells are returned to the oyster beds, so that the oyster larvae may have something to attach to. This is a highly recommended procedure and is being followed by the oyster growers at the present time, so it appears that there would not be a continuing supply of discarded shells.

FIGURE 218.—Clam shells. Indian midden north of English Camp, San Juan Island.

CLAM SHELLS

Clams are abundant in parts of western Washington, but accumulations of clam shells are small. Many Indian shell heaps are known, the largest of which may be as much as 10 feet in height and 100 feet or more in length. A modern accumulation of clam shells is reported at Washington Harbor, on the northern Olympic Peninsula. An Indian midden of clam shells north of English Camp, San Juan Island, is shown in Figure 218.

APPENDIX A

CHEMICAL ANALYSES OF WESTERN WASHINGTON LIMESTONES

Sample no.	Location Sec. T. R.	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5	Na_2O (ppm)	K_2O (ppm)	TiO_2 (ppm)	S (ppm)
CHELAN COUNTY														
Cn 1-1	10 27 15E	*	96.28	0.94	44.47	54.09	0.45	0.43	0.33	0.020				
Cn 2-1	10 27 15E	100	90.30	1.23	39.98	50.73	0.59	7.09	1.43	0.055				
Cn 3-1	10 27 15E	150	96.28	1.44	42.78	54.09	0.69	2.92	0.73	0.039	195	620	100	816
Cn 3-2	10 27 15E	150	91.88	2.47	41.69	51.62	0.85	4.62	1.12	0.025				
Cn 3-3	10 27 15E	100	97.56	0.98	43.75	54.81	0.47	0.68	0.36	0.064				
Cn 3-4	15 27 15E	10	95.92	1.40	42.65	53.89	0.67	2.16	0.61	0.007				
Cn 4-1	10 28 17E	280	96.92	1.71	42.76	54.45	0.82	1.52	0.53	0.125				
Cn 4-2	10 28 17E	450	86.36	1.43	42.92	54.08	0.70	1.43	0.24	0.048	175	610	60	55
Cn 4-3	10 28 17E	40	98.32	1.77	43.26	55.24	0.85	0.35	0.37	0.080				
Cn 4-4	10 28 17E	50	95.10	1.63	43.16	53.43	0.78	1.97	0.21	0.074				
Cn 5-1	23 26 18E	*	83.26	1.73	37.29	46.78	0.83	13.01	1.21	0.068				
Cn 5-2	23 26 18E	100	95.72	2.46	43.14	53.78	1.18	1.13	0.23	0.021				
Cn 5-3	23 26 18E	40	88.86	5.72	41.61	49.36	2.74	4.70	0.86	0.037				
Cn 5-4	23 26 18E	**	87.05	1.21	38.90	48.91	0.58	9.51	1.51	0.035				
Cn 5-5	23 26 18E	**	95.60	0.27	43.20	53.71	1.13	0.80	0.24	0.010				
Cn 6-1	21 26 19E	2	97.72	0.83	43.16	54.90	0.40	0.52	0.28	0.084				
Cn 6-2	21 26 19E	12	70.52	0.79	31.01	39.62	0.38	27.27	1.27	0.035				
Cn 7-1	29 29 21E	31	93.05	3.59	42.22	52.28	1.72	2.75	0.53	0.030				
Cn 7-2	29 29 21E	*	94.12	1.86	41.91	52.88	0.89	3.40	0.59	0.011				
Cn 8-1	4 25 20E	60	79.45	2.02	34.89	44.64	0.97	17.00	2.57	0.074				
Cn 8-2	4 25 20E	**	97.18	1.50	42.95	54.60	0.72	0.56	0.44	0.094				
Cn 8-3	4 25 20E	**	80.76	2.13	35.32	45.39	1.02	13.84	3.69	0.073				
GRAYS HARBOR COUNTY														
GH 1	12 23 7W		72.90	2.59	32.61	40.82	1.23	13.04	10.21	0.116				
GH 2	13 23 7W		15.46	3.86	7.22	8.69	1.85	69.93	12.59	0.300				
JEFFERSON COUNTY														
J 1-1	18 26 1W	*	72.37	1.75	32.74	40.66	0.84	16.46	8.87	0.020				
MASON COUNTY														
M 1-1	4 23 5W	100	60.98	3.15	24.63	34.26	1.51	25.17	13.34	0.049				
M 1-2	4 23 5W	30	59.48	3.03	23.89	33.42	1.45	26.84	13.84	0.118				
PACIFIC COUNTY														
Pf 1-1	23 13 8W	*	82.61	2.52	37.69	46.41	1.21	9.50	4.54	0.168				
Pf 1-2	24 13 8W	*	81.11	1.90	37.24	45.57	0.91	10.56	4.74	0.062				
Pf 2-1	20 10 10W	90	88.96	1.75	40.42	49.98	0.84	5.70	2.84	0.053				
Pf 2-2	20 10 10W	90	89.10	2.65	40.86	50.06	1.27	5.11	2.50	0.049				
Pf 2-3	20 10 10W	160	94.37	1.81	42.05	52.46	0.87	2.89	1.51	0.038				
SAN JUAN COUNTY														
SJ 1-1	34 36 3W	50	86.25	9.17	44.16	50.48	4.39	0.40	0.43	0.010				
SJ 2-1	29 36 3W	15	50.83	9.17	23.01	28.57	0.62	44.74	2.18	0.040				
SJ 4-1	19 35 3W	6	97.56	0.71	43.00	54.87	0.34	0.61	0.96	0.100				
SJ 4-2	30 35 3W	65	96.01	1.38	43.32	53.94	0.66	0.80	0.71	0.080				
SJ 5-1	13 35 4W	*	97.81	0.58	43.61	54.95	0.28	0.27	0.40	0.070				

* Composite
** Single specimen

CHEMICAL ANALYSES OF WESTERN WASHINGTON LIMESTONES—Continued

Sample no.	Location Sec. T. R.	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5	Na_2O (ppm)	K_2O (ppm)	TiO_2 (ppm)	S (ppm)
						SAN JUAN COUNTY—Continued								
SJ 5-2	13 35 4W	30	95.83	1.98	42.92	53.84	0.95	0.77	1.27	0.150				
SJ 6-1	11 35 4W	40	83.14	13.16	43.11	46.71	6.30	1.75	1.87	0.220				
SJ 7-1	24 35 4W	160	90.26	7.06	43.41	50.71	3.38	1.59	0.90	0.100	} 260	560	325	180
SJ 7-2	24 35 4W	160	85.51	7.29	41.68	48.04	3.49	5.17	1.11	0.030				
SJ 7-3	23 35 4W	120	93.46	4.34	43.56	52.51	2.08	0.93	0.50	0.030				
SJ 7-4	23 35 4W	160	84.17	12.60	43.98	47.29	6.03	1.20	0.70	0.170	} 270	530	-30	60
SJ 7-5	23 35 4W	280	85.44	11.12	42.63	47.58	5.79	3.63	0.61	0.088				
SJ 7-6	23 35 4W	200	94.48	2.96	43.19	53.08	1.42	1.15	0.91	0.045				
SJ 8-1	15 37 2W	30	94.96	0.67	42.48	53.35	0.32	3.60	0.56	0.044				
SJ 9-1	20 37 2W	350	82.41	0.81	36.68	46.30	0.39	15.95	0.78	0.023				
SJ 10-1	14 37 2W	35	82.57	13.58	42.59	46.39	6.50	1.99	2.53	0.455				
SJ 11-1	15 37 2W	70	97.63	0.27	43.30	54.85	0.13	1.10	0.50	0.041				
SJ 13-1	15 37 2W	40	85.42	0.35	37.36	47.99	0.17	13.34	1.05	0.012				
SJ 14-1	15 37 2W	70	91.26	0.50	40.97	51.27	0.24	6.84	0.60	0.013				
SJ 15-1	15 37 2W	75	95.08	0.69	42.23	53.42	0.33	3.03	0.56	0.003				
SJ 16-1	15 37 2W	40	76.48	0.37	34.09	42.97	0.18	22.22	0.60	0.044				
SJ 17-1	14 37 2W	250	53.40	0.56	23.74	30.00	0.27	45.07	1.08	0.032				
SJ 18-1	20 36 3W	100	93.68	1.16	41.83	52.45	0.55	3.63	0.10	0.018				
SJ 19-1	20 37 2W	120	91.92	0.52	40.60	51.64	0.25	5.89	0.82	0.011				
SJ 20-1	14 37 2W		89.93	1.20	40.19	50.35	0.57	6.78	1.78	0.004				
SJ 21-1	20 37 2W	40	97.06	0.29	42.64	54.53	0.14	1.84	0.31	0.001				
SJ 22-1	20 37 2W	22	96.47	0.46	41.90	54.20	0.22	2.36	0.28	0.006				
SJ 23-1	20 37 2W	235	96.63	0.33	41.36	54.29	0.16	4.31	1.05	0.018				
SJ 24-1	22 37 2W	70	96.81	0.85	43.17	54.39	0.41	1.38	0.82	0.112				
SJ 25-1	22 37 2W	21	97.95	0.73	43.23	55.03	0.35	0.69	0.35	0.150	270	610	-30	70
SJ 26-1	22 37 2W	90	86.54	2.75	39.30	48.62	1.31	7.86	2.37	0.290				
SJ 27-1	23 37 2W	30	87.71	0.43	39.18	49.28	0.21	9.99	1.16	0.054				
SJ 27-2	23 37 2W	10	92.18	2.82	42.12	51.79	1.35	3.33	0.90	0.010				
SJ 27-3	23 37 2W	40	92.77	0.73	40.65	52.12	0.35	4.81	1.33	0.062				
SJ 27-4	23 37 2W	15	97.06	0.60	42.94	54.53	0.29	1.40	0.36	0.028				
SJ 28-1	22 37 2W	10	84.55	0.60	37.29	47.50	0.29	13.33	0.93	0.100				
SJ 28-2	22 37 2W	*	84.87	0.58	37.62	47.68	0.28	13.31	0.74	0.078				
SJ 29-1	2 36 2W	70	96.17	0.56	42.05	54.03	0.27	2.44	0.60	0.172				
SJ 29-2	2 36 2W	70	97.56	0.52	42.69	54.81	0.25	0.61	0.49	0.218				
SJ 29-3	2 36 2W	40	98.02	0.19	42.62	55.07	0.09	0.93	0.17	0.175				
SJ 29-4	2 36 2W	*	97.99	0.63	43.02	55.05	0.30	0.85	0.25	0.092				
SJ 29-5	2 36 2W	60	98.54	0.33	43.10	55.36	0.16	0.48	0.21	0.105				
SJ 30-1	23 37 2W	30	95.19	0.98	42.27	53.48	0.47	2.69	0.80	0.120				
SJ 30-2	23 37 2W	35	93.80	3.40	43.12	52.70	1.63	1.61	0.73	0.055				
SJ 30-3	23 37 2W	17	96.61	0.64	43.10	54.28	0.31	1.20	0.65	0.024				
SJ 31-1	22 37 2W	*	96.83	0.62	42.22	54.40	0.30	1.48	0.92	0.210				
SJ 32-1	3 36 2W	50	98.07	0.83	42.86	55.10	0.40	0.84	0.42	0.240				
SJ 32-2	3 36 2W	55	98.11	0.73	43.34	55.12	0.35	0.86	0.33	0.100				
SJ 32-3	3 36 2W	90	96.88	0.91	42.89	54.43	0.44	1.34	0.70	0.160				
SJ 32-4	3 36 2W	*	98.68	0.69	43.73	55.44	0.33	0.27	0.16	0.107				
SJ 32-5	3 36 2W	*	94.37	4.68	43.41	53.02	2.24	0.50	0.65	0.170				
SJ 32-6	3 36 2W	38	97.38	0.56	42.75	54.71	0.27	1.62	0.49	0.192				
SJ 32-7	3 36 2W	20	97.57	0.41	43.01	54.83	0.20	1.18	0.75	0.130				
SJ 33-1	11 36 3W	14	97.52	0.89	43.46	54.79	0.43	0.71	0.45	0.037				
SJ 33-2	11 36 3W	20	89.60	0.31	39.54	50.34	0.15	9.12	0.72	0.011				
SJ 34-1	25 36 3W	400	99.00	0.39	43.19	55.62	0.19	0.38	0.19	0.001				
SJ 34-2	25 36 3W	500	98.97	0.54	43.80	55.60	0.26	0.22	0.09	0.037				
SJ 35-1	19 36 2W	75	99.43	0.21	43.79	55.86	0.10	0.23	0.14	0.029				
SJ 36-1	9 36 2W	60	98.48	0.35	41.92	55.33	0.17	4.20	0.42	0.046				
SJ 36-2	9 36 2W	130	98.54	0.33	43.03	55.36	0.16	0.40	0.32	0.044				

* Composite

CHEMICAL ANALYSES OF WESTERN WASHINGTON LIMESTONES—Continued

Sample no.	Location Sec. T. R.	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5	Na_2O (ppm)	K_2O (ppm)	TiO_2 (ppm)	S (ppm)
						SAN JUAN COUNTY—Continued								
SJ 36-3	9 36 2W	50	98.61	0.35	43.42	55.40	0.17	0.41	0.56	0.205				
SJ 36-4	9 36 2W	60	99.00	0.23	43.68	55.62	0.11	0.38	0.14	0.032				
SJ 36-5	9 36 2W	80	99.07	0.27	43.59	55.66	0.13	0.15	0.15	0.051				
SJ 37-1	31 37 2W	80	98.64	0.229	42.80	55.42	0.11	0.70	0.38	0.009				
SJ 37-2	31 37 2W	100	98.00	0.33	43.45	55.06	0.16	0.63	0.32	0.009				
SJ 38-1	30 37 2W	*	97.72	0.459	43.10	54.90	0.22	1.22	0.14	0.030				
SJ 38-2	31 37 2W	60	95.63	0.188	42.02	53.73	0.09	2.74	0.69	0.012				
SJ 39-1	29 37 2W	50	97.38	0.56	42.65	54.71	0.27	0.90	0.72	0.158				
SJ 39-2	29 37 2W	23	97.68	0.459	43.61	54.88	0.22	0.69	0.45	0.108				
SJ 39-3	29 37 2W	30	97.56	0.31	42.97	54.81	0.15	0.80	0.33	0.068				
SJ 40-1	30 37 2W	55	96.76	0.41	42.52	54.36	0.20	1.51	0.77	0.009				
SJ 40-2	30 37 2W	150	98.39	0.20	43.01	55.28	0.10	0.48	0.27	0.006				
SJ 41-1	29 36 3W	50	98.84	0.25	43.43	55.53	0.12	0.72	0.19	0.080				
SJ 42-1	29 36 3W	10	98.79	0.25	42.96	55.50	0.12	0.86	0.25	0.128				
SJ 42-2	29 36 3W	5	97.13	0.31	42.86	54.57	0.15	1.27	0.58	0.051				
SJ 42-3	29 36 3W	*	93.75	0.40	40.95	52.67	0.19	5.38	0.41	0.045				
SJ 43-1	18 36 3W	55	96.22	1.00	42.85	54.06	0.48	1.71	0.95	0.113				
SJ 43-2	18 36 3W	130	95.46	1.23	42.63	53.63	0.59	2.35	1.13	0.200				
SJ 44-1	34 36 3W	40	95.96	0.60	42.47	53.87	0.29	3.02	0.49	0.036				
SJ 44-2	34 36 3W	20	97.45	0.23	42.61	54.75	0.11	1.52	0.15	0.048				
SJ 45-1	34 36 4W	150	83.67	14.56	43.98	47.01	6.97	1.76	0.29	0.132				
SJ 48-1	13 36 2W	*	93.50	0.33	41.38	52.53	0.16	0.90	0.74	0.027				
SJ 50-1	14 36 4W	38	65.5	1.23	30.24	36.80	0.59	28.29	3.64	0.059				
SJ 50-2	13 36 4W	4½	76.45	0.62	34.17	42.95	0.30	19.29	2.85	0.052				
SJ 51-1	23 36 4W	25	98.43	0.35	43.56	55.31	0.17	0.28	0.17	0.039				
SJ 51-2	23 36 4W	25	98.18	0.50	43.20	55.16	0.24	0.22	0.19	0.036				
SJ 51-3	23 36 4W	30	98.64	0.46	43.67	55.42	0.22	0.31	0.14	0.018				
SJ 51-4	23 36 4W	20	98.56	0.65	43.68	55.37	0.31	0.13	0.35	0.032				
SJ 52-1	23 36 4W	10	98.75	0.42	43.53	55.48	0.20	0.50	0.22	0.023				
SJ 52-2	23 36 4W	*	98.92	0.21	43.58	55.59	0.10	0.32	0.17	0.024				
SJ 53-1	23 36 4W	50	98.04	0.54	43.52	55.08	0.26	0.65	0.27	0.021				
SJ 54-1	19 36 3W	20	54.70	0.98	24.58	30.73	0.47	41.75	2.57	0.082				
SJ 55-1	15 36 4W	20	96.77	0.46	42.68	54.37	0.22	1.80	0.51	0.096				
SJ 56-1	15 36 4W	35	98.47	0.43	43.46	55.32	0.21	0.84	0.17	0.010				
SJ 56-2	15 36 4W	80	97.18	0.25	42.98	54.60	0.12	1.31	0.46	0.018				
SJ 56-3	15 36 4W	*	95.85	0.55	42.49	53.85	0.17	2.65	0.39	0.100				
SJ 57-1	21 36 4W	100	97.73	0.50	43.25	54.91	0.24	0.72	0.33	0.138				
SJ 58-1	15 36 4W	100	97.54	0.43	41.65	52.87	0.21	4.25	0.48	0.058				
SJ 58-2	15 36 4W	75	86.36	0.46	42.79	54.14	0.23	2.03	0.38	0.072				
SJ 59-1	22 36 4W	100	98.27	0.33	43.53	55.21	0.16	0.22	0.20	0.144				
SJ 59-2	22 36 4W	100	82.75	0.35	36.48	46.60	0.17	15.57	0.79	0.096				
SJ 60-1	15 36 4W	90	96.76	0.64	42.77	54.36	0.31	1.69	0.43	0.041				
SJ 60-2	15 36 4W	40	93.84	0.46	41.81	53.23	0.22	3.74	0.41	0.163				
SJ 60-3	15 36 4W	*	95.78	0.92	42.57	53.81	0.44	1.97	0.93	0.127				
SJ 61-1	18 36 3W	100	54.55	0.50	24.39	30.65	0.24	43.06	1.59	0.040				
SJ 61-3	18 36 3W	50	96.12	1.15	42.92	54.00	0.55	1.44	1.01	0.205				
SJ 62-1	23 36 4W	320	97.75	0.60	43.28	54.92	0.29	1.11	0.33	0.032				
SJ 63-1	29 36 3W	225	97.27	0.48	42.86	54.65	0.23	1.35	0.43	0.048	} 100	560	250	470
SJ 63-2	29 36 3W	125	85.52	0.90	38.26	48.05	0.43	11.87	1.13	0.033				
SJ 64-1	25 36 4W	35	96.86	0.83	42.96	54.42	0.39	1.13	0.79	0.015				
SJ 64-2	25 36 4W	63	96.43	0.71	42.94	54.19	0.34	1.51	0.90	0.030				
SJ 65-1	25 36 4W	75	96.45	0.56	41.53	54.19	0.27	2.65	1.00	0.160				
SJ 65-2	25 36 4W	90	96.00	0.54	42.45	53.93	0.26	1.91	1.04	0.071				
SJ 65-3	25 36 4W	100	95.35	0.52	42.01	53.57	0.25	3.03	0.95	0.070				
SJ 66-1	24 35 4W	*	96.12	1.06	43.12	54.00	0.51	1.16	0.61	0.014				

* Composite

CHEMICAL ANALYSES OF WESTERN WASHINGTON LIMESTONES—Continued

Sample no.	Location Sec. T. R.	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5	Na_2O (ppm)	K_2O (ppm)	TiO_2 (ppm)	S (ppm)
						SAN JUAN COUNTY—Continued								
SJ 67-1	25 37 2W	185	97.79	0.209	42.93	54.94	0.10	0.84	0.41	0.180				
SJ 67-2	25 37 2W	200	95.17	1.08	42.45	53.47	0.52	2.54	0.50	0.120	330	565	1,250	143
SJ 67-3	25 37 2W	20	25.09	1.60	11.33	14.10	0.77	68.03	4.51	0.205				
SJ 68-1	25 37 2W	50	86.11	2.17	39.16	48.38	1.04	9.36	1.41	0.092				
SJ 68-2	25 37 2W	*	97.01	0.41	42.50	54.50	0.20	1.77	0.58	0.130				
SJ 69-1	8 36 1W	*	78.83	16.84	42.58	44.29	8.06	4.14	1.21	0.027				
SJ 70-1	5 36 1W	100	93.43	0.37	40.97	52.49	0.18	4.72	0.96	0.236				
SJ 71-1	8 36 1W	180	97.41	0.64	43.30	54.73	0.31	0.86	0.32	0.012				
SJ 71-2	8 36 1W	110	98.00	0.689	43.41	55.06	0.33	0.41	0.30	0.018				
SJ 71-3	8 36 1W	15	98.13	0.418	42.90	55.13	0.20	1.19	0.50	0.039				
SJ 71-4	8 36 1W	*	97.49	0.79	43.24	54.77	0.38	0.87	0.26	0.015				
SJ 72-1	5 36 1W	90	90.95	0.75	40.63	51.10	0.36	5.99	1.53	0.033				
SJ 72-2	5 36 1W	150	81.54	0.66	36.74	45.81	0.32	14.32	1.97	0.034				
SJ 72-3	5 36 1W	200	82.78	3.82	38.30	46.51	1.83	11.35	2.02	0.032				
SJ 73-1	17 36 2W	30	97.52	0.29	42.93	54.79	0.14	1.28	0.39	0.008				
SJ 74-1	18 36 2W	50	90.06	4.20	42.02	50.60	2.36	4.30	0.67	0.013				
SJ 75-1	17 37 1W	*	80.63	0.73	35.94	45.30	0.35	16.94	1.13	0.039				
SJ 76-1	17 37 1W	20	76.87	1.42	34.53	43.19	0.68	20.10	1.43	0.021				
SJ 76-2	17 37 1W	85	75.98	3.51	35.15	42.69	1.68	18.84	1.34	0.020	160	420	260	240
SJ 76-3	17 37 1W	65	53.04	0.56	23.75	29.80	0.27	44.12	1.89	0.027				
SJ 76-4	17 37 1W	40	48.14	3.00	30.57	27.05	1.44	29.48	1.46	0.014				
SJ 77-1	16 37 1W	325	80.54	0.48	36.32	45.25	0.23	15.80	2.00	0.032	300	490	810	256
SJ 77-2	16 37 1W	100	89.21	0.43	40.33	50.12	0.21	7.41	1.91	0.019				
SJ 77-3	16 37 1W	**	88.34	0.56	39.68	49.63	0.27	9.14	1.17	0.015				
SJ 77-4	16 37 1W	**	49.98	0.43	23.07	28.08	0.21	45.45	3.00	0.054				
SJ 78-1	17 37 1W	20	94.39	0.33	41.91	53.03	0.16	3.29	1.02	0.014				
SJ 79-1	19 37 1W	225	93.78	1.96	41.70	52.69	0.94	2.85	1.38	0.020				
SJ 79-2	19 37 1W	225	97.63	0.35	42.71	54.85	0.17	1.59	0.28	0.011				
SJ 79-3	19 37 1W	200	92.73	1.35	41.15	52.10	0.65	4.39	1.53	0.180				
SJ 79-4	19 37 1W	90	97.15	0.75	43.02	54.58	0.36	1.37	0.45	0.006				
SJ 79-5	19 37 1W	*	94.44	0.89	41.87	53.06	0.43	3.23	0.91	0.007				
SJ 79-6	19 37 1W	35	95.31	1.90	42.61	53.55	0.91	1.79	1.07	0.011				
SJ 80-1	19 37 1W	80	66.78	0.71	29.95	37.52	0.34	30.10	1.92	0.028				
SJ 80-2	19 37 1W	150	76.77	1.50	34.86	43.13	0.72	19.05	2.05	0.023				
SJ 81-1	30 37 1W	*	97.72	0.39	43.15	54.90	0.19	0.81	0.50	0.130				
SJ 82-1	29 36 2W	*	98.18	0.418	43.45	55.16	0.20	0.43	0.13	0.008				
SJ 82-2	29 36 2W	*	98.45	0.52	43.24	55.31	0.25	0.18	0.61	0.063				
SJ 83-1	29 36 2W	*	97.06	0.20	42.55	54.53	0.10	1.99	0.46	0.064				
SJ 84-1	30 36 2W	100	95.17	0.58	41.83	53.47	0.28	3.37	0.52	0.032				
SJ 85-1	30 36 2W	30	97.54	0.43	42.82	54.80	0.21	1.22	0.30	0.068				
SJ 85-2	30 36 2W	*	98.45	0.04	43.33	55.31	0.02	0.34	0.61	0.193				
SJ 86-1	31 37 1E	*	98.20	0.16	43.05	55.17	0.08	1.19	0.37	0.004				
SJ 87-1	23 37 1W	25	94.69	0.25	42.05	53.20	0.12	3.41	0.93	0.009				
SJ 88-1	30 37 1W	120	92.20	0.31	40.47	51.80	0.15	6.30	0.64	0.066				
SJ 89-1	30 37 1W	70	95.90	0.60	42.19	53.88	0.29	2.06	0.74	0.043				
SJ 90-1	27 37 4W	*	49.70	9.22	23.29	27.92	4.42	29.16	5.17	0.316				
SJ 91-1	32 36 2W	*	96.44	0.45	41.42	54.18	0.22	3.77	0.97	0.013				
SJ 92-1	29 37 1W	80	43.09	17.97	28.26	24.21	8.60	32.87	6.51	0.265				
						SKAGIT COUNTY								
St 1-1	9 35 8E	55	96.26	1.52	43.98	54.09	0.73	1.15	0.32	0.035				
St 1-3	9 35 8E	**	93.57	0.627	43.07	52.57	0.30	2.97	0.73	0.044				
St 2-1	30 36 9E	20	92.91	3.84	42.57	52.20	1.84	2.61	0.94	0.019	165	450	250	375
St 2-2	30 36 9E	120	93.12	3.86	42.49	52.32	1.85	2.63	0.95	0.018				
St 3-1	5 35 9E	90	92.56	0.31	40.97	52.00	0.15	6.55	0.42	0.007				

* Composite
** Single specimen

CHEMICAL ANALYSES OF WESTERN WASHINGTON LIMESTONES—Continued

Sample no.	Location Sec. T. R.	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5	Na_2O (ppm)	K_2O (ppm)	TiO_2 (ppm)	S (ppm)
						SKAGIT COUNTY—Continued								
St 4-1	4 35 9E	*	94.10	0.44	41.50	52.87	0.21	4.66	0.88	0.007				
St 5-1	5 35 9E	150	97.36	0.397	42.98	54.70	0.19	1.30	0.40	0.005				
St 6-1	5 35 9E	120	95.49	0.02	42.11	53.65	0.01	3.82	0.29	0.007				
St 8-1	23 35 10E	350	96.44	0.29	41.69	54.18	0.14	4.22	0.65	0.005				
St 8-2	23 35 10E	750	96.04	0.37	42.31	53.96	0.18	2.80	0.39	0.005				
St 9-1	26 35 10E	100	97.65	0.29	42.76	54.86	0.14	1.59	0.39	0.001				
St 9-2	26 35 10E	*	94.99	0.37	41.85	53.36	0.18	3.18	0.82	0.008				
St 10-1	23 35 10E	350	95.51	0.56	42.48	53.66	0.27	2.74	0.73	0.003				
St 11-1	20 35 10E	50	66.98	0.96	29.82	37.63	0.46	31.07	1.29	0.066				
St 11-2	20 35 10E	25	82.69	0.87	37.47	46.46	0.42	13.35	1.85	0.073				
St 11-3	20 35 10E	25	89.30	0.94	39.91	50.17	0.45	8.39	0.86	0.056				
St 11-4	20 35 10E	15	87.94	0.56	39.51	49.41	0.27	9.43	0.87	0.055				
St 11-5	20 35 10E	60	85.13	1.00	37.94	47.83	0.48	11.90	1.77	0.065				
St 11-6	20 35 10E	100	87.55	0.92	38.95	49.19	0.44	10.04	1.35	0.090				
St 11-7	19 35 10E	94	83.96	5.18	39.48	47.17	2.48	8.91	2.01	0.106				
St 11-8	19 35 10E	174	83.10	0.87	37.23	46.69	0.42	13.37	1.90	0.057				
St 11-9	19 35 10E	**	98.13	0.188	43.41	55.13	0.09	0.55	0.42	0.003				
St 12-1	21 35 10E	30	89.24	0.56	39.60	50.14	0.48	8.78	0.90	0.090				
St 12-2	21 35 10E	40	62.35	6.33	30.23	35.03	3.03	30.71	1.53	0.021				
St 12-3	21 35 10E	80	68.19	1.19	25.74	38.31	0.57	38.34	3.17	0.102				
St 12-4	21 35 10E	*	60.19	1.02	27.22	33.82	0.49	36.43	1.55	0.049				
St 13-1	3 35 12E	50	89.28	9.86	43.91	50.16	4.72	1.06	0.31	0.064	125	380	150	125
St 13-2	3 35 12E	50	88.82	10.11	43.41	49.90	4.84	1.25	0.96	0.200				
St 14-1	8 35 9E	*	97.18	0.12	41.91	54.60	0.06	2.83	0.32	0.008				
St 14-2	8 35 9E	100	89.60	0.75	38.99	50.34	0.36	9.03	0.92	0.007				
St 15-1	4 35 9E	60	96.97	0.64	42.23	54.48	0.31	2.63	0.19	0.003				
St 15-2	4 35 9E	300	97.93	0.29	42.53	55.02	0.14	1.96	0.33	0.008	150	490	100	350
St 15-3	4 35 9E	400	98.73	0.33	42.75	55.47	0.16	0.89	0.20	0.008				
St 16-1	4 35 9E	460	96.06	0.39	40.97	53.97	0.19	3.35	0.98	0.013				
St 16-2	4 35 9E	170	98.02	0.48	41.93	55.07	0.23	2.01	0.31	0.005				
St 16-3	5 35 9E	105	96.36	0.50	41.60	54.14	0.24	2.99	0.72	0.010				
St 16-4	5 35 9E	*	96.97	0.188	42.30	55.00	0.17	1.93	0.30	0.006				
St 17-1	15 35 9E	50	96.97	0.188	42.10	54.48	0.09	2.28	0.79	0.018				
St 17-2	15 35 9E	50	97.52	0.188	42.08	54.79	0.09	2.04	0.48	0.006				
St 17-3	16 35 9E	100	98.25	0.125	42.53	55.20	0.06	1.59	0.22	0.004				
St 17-4	9 35 9E	60	91.49	1.40	40.22	51.40	0.67	6.86	0.62	0.008				
St 17-5	9 35 9E	150	59.16	2.69	28.15	33.24	1.29	32.92	4.62	0.018				
St 18-1	16 35 9E	50	97.59	0.27	42.15	54.83	0.13	2.27	0.30	0.003				
St 18-2	16 35 9E	250	90.81	2.69	39.74	51.02	0.48	7.56	1.16	0.008				
St 18-3	16 35 9E	150	71.39	1.15	31.30	40.11	0.55	25.05	3.44	0.015				
St 18-4	16 35 9E	300	89.56	0.89	38.75	50.32	0.43	9.04	1.27	0.005				
St 18-5	16 35 9E	25	92.82	0.52	40.16	52.15	0.25	6.29	0.99	0.005				
St 19-1	5 36 8E	250	96.12	0.54	43.21	54.00	0.26	1.47	0.43	0.013				
St 22-1	7 36 8E	290	78.26	1.98	35.86	43.97	0.95	17.65	1.26	0.054				
St 22-2	1 36 7E	*	74.27	1.19	32.69	41.73	0.57	23.22	2.24	0.060	185	490	250	325
St 22-3	7 36 8E	*	95.58	0.39	42.20	53.70	0.19	2.72	0.37	0.010				
St 23-1	32 35 9E	32	77.78	7.23	37.86	43.70	3.46	12.64	2.11	0.045				
St 23-2	32 35 9E	30	75.59	0.75	33.76	42.47	0.36	21.74	1.62	0.017				
St 23-3	32 35 9E	45	78.26	1.90	34.30	41.72	0.91	18.31	4.74	0.038				
St 24-1	32 35 9E	52	94.12	0.73	41.87	52.88	0.35	3.69	0.74	0.007				
St 24-2	32 35 9E	500	98.91	0.81	42.83	55.57	0.39	1.08	0.36	0.017	175	490	180	195
St 24-3	32 35 9E	400	97.71	0.48	42.24	54.89	0.23	2.36	0.29	0.021				
St 24-4	32 35 9E	250	87.22	1.81	38.68	49.00	0.87	10.64	0.73	0.018				
St 24-5	32 35 9E	300	90.97	1.40	39.78	51.11	0.67	8.03	0.60	0.010				
St 25-1	30 34 10E	100	14.94	1.88	7.45	8.39	0.90	75.58	7.03	0.175				
St 25-2	30 34 10E	100	26.53	1.33	13.33	14.91	0.64	63.89	6.41	0.200				

* Composite
** Single specimen

CHEMICAL ANALYSES OF WESTERN WASHINGTON LIMESTONES—Continued

Sample no.	Location Sec. T. R.	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5	Na_2O (ppm)	K_2O (ppm)	TiO_2 (ppm)	S (ppm)
						SNOHOMISH COUNTY								
Sh 1-1	2 31 10E	6	96.04	1.83	44.12	53.96	1.15	0.29	0.24	0.008				
Sh 2-1	24 32 11E	75	74.88	3.15	34.52	42.07	1.51	20.53	1.73	0.027				
Sh 3-1	18 31 11E	13	64.89	1.96	30.17	36.46	0.94	28.68	3.36	0.041				
Sh 3-2	18 31 11E	20	92.84	1.00	41.44	52.16	0.48	4.03	1.46	0.024				
Sh 3-3	18 31 11E	60	92.32	0.73	40.90	51.87	0.35	5.20	1.39	0.022				
Sh 4-1	24 32 8E	100	95.12	3.15	42.87	53.44	1.51	1.40	0.48	0.004				
Sh 4-2	24 32 8E	*	95.97	0.71	42.29	53.92	0.34	2.70	0.36	0.005				
Sh 4-3	24 32 8E	40	92.70	5.43	42.78	52.08	2.60	1.71	0.39	0.004				
Sh 4-4	24 32 8E	**	97.91	0.75	42.58	55.01	0.36	1.36	0.40	0.005				
Sh 4-5	24 32 8E	**	97.95	0.81	42.51	55.03	0.39	1.43	0.52	0.006				
Sh 5-1	25 32 8E	35	87.95	11.95	43.29	48.85	5.72	1.75	0.50	0.004				
Sh 5-2	25 32 8E	35	88.94	10.74	43.17	49.97	5.14	1.11	0.49	0.006				
Sh 9-1	1 31 10E	220	54.06	37.70	42.17	30.26	18.04	2.80	6.51	0.003				
Sh 10-1	1 31 10E	75	94.46	0.54	42.32	53.07	0.26	2.60	0.81	0.026				
Sh 10-2	1 31 10E	100	93.27	0.69	41.76	52.40	0.33	3.96	1.12	0.034				
Sh 10-3	1 31 10E	160	94.87	0.54	42.62	53.30	0.26	2.50	0.88	0.009				
Sh 11-1	36 32 10E	75	90.47	1.19	40.51	50.83	0.57	6.50	0.76	0.025				
Sh 11-2	36 32 10E	100	78.12	0.62	34.79	43.89	0.30	19.08	1.57	0.030				
Sh 11-3	36 32 10E	100	75.88	0.73	33.75	42.63	0.35	20.99	1.83	0.049				
Sh 11-4	35 32 10E		33.09	4.14	16.50	18.53	1.97	54.97	7.42	0.100				
Sh 11-5	35 32 10E		38.40	2.42	18.46	21.50	1.15	50.56	8.11	0.096				
Sh 11-6	35 32 10E		28.90	2.71	14.92	16.18	1.29	60.65	6.81	0.068	310	625	800	915
Sh 12-1	5 31 7E	40	96.52	0.919	43.19	54.23	0.44	1.11	0.29	0.017				
Sh 12-2	5 31 7E	40	94.96	2.069	42.88	53.35	0.99	1.51	0.68	0.006				
Sh 12-3	5 31 7E	60	92.79	4.78	43.13	52.13	2.29	1.21	0.27	0.022				
Sh 12-4	5 31 7E	**	97.45	1.02	43.41	54.75	0.49	0.67	0.27	0.005				
Sh 12-5	5 31 7E	**	77.32	20.27	44.82	43.44	9.70	0.78	0.97	0.009				
Sh 13-1	33 30 7E		8.29	48.85	30.51	4.64	23.22	34.24	7.33	0.006				
Sh 14-1	16 27 9E	40	90.65	1.06	40.21	50.93	0.51	6.76	0.83	0.025				
Sh 14-2	16 27 9E	30	94.39	1.23	41.75	53.03	0.59	3.02	0.84	0.031				
Sh 14-3	16 27 9E	40	89.48	0.94	34.38	50.27	0.45	13.11	1.20	0.025				
Sh 14-4	16 27 9E	10	93.77	0.66	40.88	52.68	0.32	5.09	0.60	0.030				
Sh 14-5	16 27 9E	40	91.51	1.63	41.04	51.41	0.78	5.04	1.22	0.035				
Sh 14-6	16 27 9E	40	92.93	1.17	41.14	52.21	0.56	4.74	0.75	0.027				
Sh 14-7	16 27 9E	70	95.46	0.41	41.78	53.63	0.20	3.49	0.44	0.018				
						WHATCOM COUNTY								
W 1-1	7 40 6E	280	81.06	6.81	39.72	45.54	3.26	10.22	0.89	0.024	290	530	130	530
W 1-2	7 40 6E	320	97.52	1.67	43.62	54.79	0.80	0.50	0.18	0.030				
W 2-1	17 40 6E	60	95.47	0.66	42.43	53.64	0.32	3.02	0.51	0.010				
W 3-1	7 40 6E	*	87.25	1.65	38.98	49.02	0.79	7.92	2.16	0.076				
W 4-1	19 40 6E	120	95.92	0.64	42.57	53.89	0.31	2.43	0.55	0.010	250	550	65	840
W 5-1	22 40 6E	180	99.02	0.33	42.97	55.63	0.16	0.67	0.32	0.200				
W 5-2	22 40 6E	120	99.16	0.20	43.12	55.71	0.10	0.37	0.26	0.248				
W 5-3	22 40 6E	100	98.48	0.39	43.37	55.33	0.19	0.09	0.09	0.150				
W 5-4	22 40 6E	100	98.54	0.39	43.10	55.36	0.19	0.40	0.37	0.209				
W 6-1	12 40 5E	130	92.98	2.40	42.26	52.24	1.15	3.68	0.68	0.022				
W 6-2	12 40 5E	120	89.17	0.66	39.74	50.10	0.32	8.75	0.85	0.024				
W 6-3	12 40 5E	170	88.60	1.08	39.84	49.78	0.52	7.45	2.44	0.023	235	540	250	220
W 6-4	12 40 5E	140	79.06	1.14	35.61	44.42	0.55	18.65	0.72	0.035				
W 6-5	12 40 5E	120	94.71	1.69	42.72	53.21	0.81	2.57	0.83	0.030				
W 7-1	4 40 6E	1,000	80.13	16.21	44.33	45.02	7.76	2.05	1.02	0.026	250	500	70	245
W 7-2	4 40 6E	500	86.36	0.83	38.34	48.52	0.40	11.01	1.63	0.018				
W 7-3	4 40 6E	400	60.43	2.25	27.72	33.95	1.08	34.58	2.62	0.047	220	440	700	1,770
W 7-4	4 40 6E	300	84.67	11.91	43.74	47.57	5.70	2.72	0.57	0.019	225	500	95	110
W 7-5	4 40 6E	200	93.61	0.71	41.66	52.59	0.34	4.51	0.91	0.010				
W 7-6	4 40 6E	*	96.63	0.58	42.84	54.29	0.28	1.90	0.60	0.018				

* Composite
** Single specimen

CHEMICAL ANALYSES OF WESTERN WASHINGTON LIMESTONES—Continued

Sample no.	Location Sec. T. R.	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5	Na_2O (ppm)	K_2O (ppm)	TiO_2 (ppm)	S (ppm)
						WHATCOM COUNTY—Continued								
W 7-7	4 40 6E	200	83.96	0.418	37.25	47.17	0.20	14.74	0.47	0.012				
W 8-1	23 40 5E	120	89.28	0.64	39.84	50.16	0.31	8.52	1.08	0.011				
W 9-1	7 40 6E	150	89.14	0.96	40.70	50.08	0.46	7.70	1.48	0.050	} 225	560	315	150
W 9-2	7 40 6E	60	88.60	1.14	39.97	49.78	0.55	8.16	1.66	0.049				
W 10-1	7 40 6E	*	64.76	1.02	35.70	36.38	0.49	21.15	5.56	0.017				
W 10-2	7 40 6E	*	86.00	0.83	41.04	48.32	0.40	8.04	1.94	0.018				
W 11-1	33 40 7E	220	94.25	0.689	43.33	52.95	0.33	1.97	1.17	0.010				
W 12-1	32 40 7E	20	95.60	0.46	42.69	53.71	0.22	2.43	0.71	0.056				
W 12-2	32 40 7E	385	96.15	0.52	42.77	54.02	0.25	2.25	0.75	0.009				
W 13-1	32 40 7E	12	96.33	0.52	42.85	54.12	0.25	1.72	0.94	0.009				
W 15-1	7 40 6E	230	85.16	2.15	40.12	49.53	1.03	7.81	1.30	0.045				
W 15-2	7 40 5E	150	90.08	1.21	40.12	50.61	0.58	5.82	2.23	0.029				
W 16-1	28 40 5E	130	93.89	0.58	41.90	52.75	0.28	3.81	0.96	0.004				
W 16-2	28 40 5E	80	86.20	0.75	38.54	48.43	0.36	11.25	0.97	0.009				
W 16-3	28 40 5E	140	96.45	0.37	42.70	54.19	0.18	2.16	0.64	0.010				
W 16-4	28 40 5E	170	92.34	0.64	41.13	51.88	0.31	5.50	0.93	0.004				
W 16-5	28 40 5E	275	84.63	0.96	37.80	47.55	0.46	11.87	2.00	0.023				
W 16-6	28 40 5E	225	87.55	0.98	39.04	49.19	0.47	9.43	1.43	0.026				
W 16-7	28 40 5E	*	96.04	0.54	42.67	53.96	0.26	2.43	0.47	0.010				
W 16-8	28 40 5E	240	95.49	0.37	42.59	53.65	0.18	2.70	0.76	0.012				
W 16-9	28 40 5E	250	94.60	0.96	42.32	53.15	0.46	2.76	0.84	0.008				
W 16-10	28 40 5E	130	96.20	0.48	42.73	54.05	0.23	2.06	0.62	0.007				
W 16-11	21 40 5E	110	90.74	0.20	40.25	50.98	0.10	7.33	1.05	0.010				
W 16-12	28 40 5E	100	91.54	0.37	40.68	51.43	0.18	6.25	1.22	0.006	210	565	200	73
W 16-13	28 40 5E	*	89.67	0.29	39.84	50.38	0.14	8.84	0.71	0.008				
W 16-14	28 40 5E	*	95.67	0.94	42.32	53.75	0.45	2.28	0.71	0.004				
W 17-1	21 40 5E	80	50.16	43.57	43.89	28.18	20.85	6.67	0.54	0.018				
W 17-2	21 40 5E	30	53.86	28.75	38.47	30.26	13.76	17.04	0.99	0.020				
W 18-1	21 40 5E	*	90.30	0.96	40.44	50.73	0.46	7.16	0.90	0.008	175	560	250	740
W 18-2	21 40 5E	60	89.39	1.29	40.20	50.22	0.62	6.91	1.72	0.009				
W 18-3	21 40 5E	270	58.15	2.19	26.12	32.67	0.15	33.61	7.45	0.072				
W 18-4	21 40 5E	140	95.28	0.48	41.92	53.53	0.23	2.61	1.46	0.008				
W 18-5	21 40 5E	*	95.92	0.43	42.69	53.89	0.21	2.41	0.71	0.005				
W 18-6	21 40 5E	*	92.89	2.73	43.60	52.19	1.31	2.27	0.94	0.007				
W 18-7	21 40 5E	*	96.95	0.37	43.10	54.47	0.18	1.48	0.52	0.090				
W 18-8	21 40 5E	*	98.38	0.41	43.45	55.27	0.20	0.26	0.16	0.004				
W 18-9	21 40 5E	*	94.92	0.29	42.21	53.33	0.14	3.15	1.03	0.007				
W 19-1	9 40 5E	150	90.40	0.92	40.43	50.79	0.44	6.95	1.09	0.031				
W 19-2	9 40 5E	70	92.47	1.15	41.32	51.95	0.55	5.05	0.82	0.021				
W 20-1	5 40 6E	**	78.90	1.44	35.70	44.33	0.69	15.72	2.65	0.066				
W 20-2	5 40 6E	200	52.01	3.63	24.52	29.50	1.74	37.38	6.62	0.013				
W 21-1	5 40 6E	40	88.64	0.39	39.34	49.80	0.19	9.61	0.79	0.014				
W 22-1	34 41 5E	*	74.83	1.40	33.47	42.04	0.67	21.23	2.11	0.076				
W 23-1	17 40 6E	150	91.42	0.25	40.83	51.36	0.12	6.49	0.82	0.016				
W 24-1	14 40 5E	110	88.53	1.609	39.65	49.74	0.77	8.74	0.97	0.024				
W 24-2	14 40 5E	320	72.99	2.50	33.60	41.01	1.20	20.96	2.91	0.034				
W 24-3	14 40 5E	200	81.43	2.25	36.90	45.75	1.08	14.90	0.86	0.026				
W 24-4	14 40 5E	300	77.46	2.15	35.56	43.52	1.03	17.27	2.30	0.049				
W 24-5	14 40 5E	*	90.40	6.10	43.22	50.79	2.92	2.56	0.38	0.020				
W 25-1	33 40 7E	70	97.20	0.209	44.25	54.61	0.10	0.29	0.21	0.006				
W 26-1	34 38 9E		95.31	0.92	42.33	54.11	0.44	1.42	1.12	0.244				
W 27-1	32 37 8E	40	99.30	0.50	42.91	55.79	0.24	0.61	0.25	0.013				
W 28-1	32 37 8E	100	97.59	0.39	43.53	54.83	0.19	0.35	0.30	0.020				
W 28-2	32 37 8E	230	97.33	0.39	43.06	54.68	0.19	0.88	0.60	0.019				
W 28-3	32 37 8E	200	97.72	0.31	43.48	54.90	0.15	0.41	0.34	0.025				

* Composite
** Single specimen

CHEMICAL ANALYSES OF WESTERN WASHINGTON LIMESTONES—Continued

Sample no.	Location Sec. T. R.	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5	Na_2O (ppm)	K_2O (ppm)	TiO_2 (ppm)	S (ppm)
WHATCOM COUNTY—Continued														
W 28-4	32 37 8E	*	61.85	2.00	27.90	34.75	0.96	28.89	6.48	0.068				
W 29-1	33 37 8E	*	89.72	0.62	40.26	50.41	0.30	7.34	0.97	0.026				
W 29-2	33 37 8E	*	93.32	0.37	41.71	52.43	0.18	4.10	0.75	0.022				
W 29-3	33 37 8E	110	94.92	0.459	42.09	53.33	0.22	3.30	0.67	0.022	155	490	170	460
W 29-4	33 37 8E	*	94.66	0.37	42.40	53.18	0.18	2.72	0.43	0.014				
W 29-5	33 37 8E	50	90.65	2.19	41.01	50.93	1.05	5.27	1.35	0.021				

* Composite

APPENDIX B

SPECTROCHEMICAL ANALYSES OF WESTERN WASHINGTON LIMESTONES

CHELAN COUNTY

Oxide \ Field No.	Cn 1-1	Cn 2-1	Cn 3-1	Cn 3-2	Cn 3-3	Cn 3-4	Cn 4-1	Cn 4-2	Cn 4-3	Cn 4-4	Cn 5-1
Na_2O	.17	.18	---	.09	---	---	---	.11	---	---	.61
Al_2O_3	.13	.72	.28	.50	.093	.10	.093	.17	.028	.037	1.95
K_2O	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.0044	.031	.0072	.0092	.002	---	.0048	.012	.006	.004	.03
V_2O_5	---	---	---	---	---	---	---	---	---	---	---
Cr_2O_3	---	---	---	---	.00099	---	.0005	.0005	.00058	.00064	.00064
MnO	.07	.042	.05	.045	.02	.019	.10	.029	.037	.055	.048
Fe_2O_3	.17	.60	.32	.57	.10	1.46	.26	.19	.17	.10	.37
CoO	---	---	---	---	---	---	---	---	---	---	---
NiO	.0017	.001	---	.001	.0026	.001	---	---	---	---	.001
CuO	.00082	.0022	.0019	.0025	.00082	.0015	.0011	.00082	.0022	.00093	.0014
SrO	.059	.021	.029	.041	.021	.11	.02	.015	.01	.011	.031
ZrO_2	---	---	---	---	---	---	---	---	---	---	---
Ag_2O	---	---	---	---	---	---	---	---	---	---	---
BaO	.29	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---

Oxide \ Field No.	Cn 5-2	Cn 5-3	Cn 5-4	Cn 5-5	Cn 6-1	Cn 6-2	Cn 7-1	Cn 7-2	Cn 8-1	Cn 8-2	Cn 8-3
Na_2O	---	.22	.58	---	---	.29	.064	.15	1.23	---	1.10
Al_2O_3	.13	.51	1.50	.10	.031	1.30	.49	.47	2.90	.20	3.25
K_2O	---	---	.25	---	---	.25	---	---	.25	---	1.50
TiO_2	.004	.013	.012	.004	---	.07	.013	.016	.27	.006	.35
V_2O_5	---	---	---	---	---	---	---	---	---	---	---
Cr_2O_3	.0005	.0005	.0008	.0005	.0005	.00087	.0005	.00085	.0023	.0005	.0064
MnO	.022	.050	.036	.01	.06	.11	.10	.11	.15	.10	.17
Fe_2O_3	.14	.26	.21	.09	.13	.73	.29	.28	1.53	.24	1.75
CoO	---	---	---	---	---	---	---	---	---	---	---
NiO	---	.001	.0017	---	---	.0024	---	---	.0022	---	.0044
CuO	.0005	.00066	.0022	.00088	.00082	.0075	.0023	.0013	.0020	.0058	.0032
SrO	.017	.017	.014	.018	.0081	.0084	.038	.039	.013	.0098	.014
ZrO_2	---	---	---	---	---	.002	---	---	.0051	---	.0057
Ag_2O	---	---	---	---	---	---	---	---	.0002	---	.0002
BaO	---	---	---	---	---	.14	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---

GRAYS HARBOR, JEFFERSON, MASON, AND PACIFIC COUNTIES

Oxide \ Field No.	GH 1	GH 2	J 1-1	M 1-1	M 1-2	Pf 1-1	Pf 1-2	Pf 2-1	Pf 2-2	Pf 2-3
Na_2O	.73	5.07	.86	1.17	1.27	.56	.47	.32	.32	.14
Al_2O_3	2.11	9.90	3.59	2.81	3.48	2.12	2.21	1.50	1.62	.78
K_2O	---	.40	.71	.90	---	1.20	3.0	.90	1.05	---
TiO_2	.054	.62	.11	.078	.22	.092	.13	.063	.072	.048
V_2O_5	.039	.031	.0084	.036	.032	.0056	.011	.0092	.0064	.0059
Cr_2O_3	.0017	3.20	.0030	.0023	.0041	.0015	.0023	.0014	.0015	.0009
MnO	3.7	.18	.35	6.84	3.00	.21	.055	.026	.021	.01
Fe_2O_3	2.30	3.61	.81	4.99	4.14	1.44	1.39	.87	.93	.61
CoO	.0028	.0053	---	.0053	.006	---	---	---	---	---
NiO	.033	.024	.003	.066	.044	.001	.001	.001	.001	.001
CuO	.035	.020	.0026	.035	.037	.0025	.0041	.0045	.0057	.0052
SrO	.020	.016	.019	.022	.02	.024	.056	.081	.096	.14
ZrO_2	.0096	.020	.010	.012	.013	.0048	.0087	.002	.002	.002
Ag_2O	.0013	---	---	.0023	.0010	.0002	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---

SAN JUAN COUNTY

Oxide \ Field No.	SJ 1-1	SJ 2-1	SJ 4-1	SJ 4-2	SJ 5-1	SJ 5-2	SJ 6-1	SJ 7-1	SJ 7-2	SJ 7-3	SJ 7-4	SJ 7-5	SJ 7-6	SJ 8-1	SJ 9-1	SJ 9-2
Na_2O	---	---	.05	---	---	---	---	---	---	---	---	---	---	---	---	---
Al_2O_3	.08	.41	.099	.14	.046	.16	.34	.35	.34	.099	.075	.023	.25	.35	.28	.48
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.006	.034	.013	.015	.0036	.012	.071	.062	.031	.012	.0048	.002	.094	.025	.01	.023
V_2O_5	.003	.003	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Cr_2O_3	.00055	.0062	.00099	.00099	.00093	.0050	.0025	.0041	.0050	.0025	.0020	.0020	.0044	.0007	.00067	.0007
MnO	.009	.18	.052	.052	.25	1.00	.80	.16	.40	.064	.09	.032	.13	.10	.09	.26
Fe_2O_3	.12	1.46	.12	.21	.13	.60	.44	.43	.52	.15	.26	.19	.49	.41	.40	.67
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	---	.004	---	---	---	.0026	.0032	.0014	.002	.0018	.001	.001	.0018	.001	.001	.0018
CuO	.0010	.0075	.0016	.0021	.0017	.0026	.0028	.0026	.0031	.0024	.0025	.0024	.0016	.0022	.0038	.0027
SrO	.015	.014	.022	.014	.067	.056	.021	.025	.026	.026	.022	.015	.031	.012	.013	.010
ZrO_2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Ag_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

SAN JUAN COUNTY - Continued

Field No. / Oxide	SJ 10-1	SJ 11-1	SJ 13-1	SJ 14-1	SJ 15-1	SJ 16-1	SJ 17-1	SJ 18-1	SJ 19-1	SJ 20-1	SJ 21-1	SJ 22-1	SJ 23-1	SJ 24-1	SJ 25-1	SJ 26-1
Na_2O	---	---	---	---	---	---	---	.24	---	---	---	.075	.13	---	---	.44
Al_2O_3	.55	.17	.41	.35	.27	.20	.25	.51	.29	.49	.13	.14	.47	.19	.064	.90
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.044	.0096	.023	.016	.014	.011	.019	.033	.0092	.031	.004	.0028	.024	.042	.048	.034
V_2O_5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Cr_2O_3	.0065	---	.00058	.0005	---	.0005	.0012	.0005	---	---	---	---	---	.0007	.0008	.0030
MnO	.16	.80	.37	.20	.21	.16	.50	.14	.34	.09	.15	.19	.26	.049	.17	.08
Fe_2O_3	.51	.29	.60	.18	.26	.43	1.13	.41	.30	.37	.14	.17	.44	.31	.10	.45
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	.0018	---	.0018	.0014	.0016	.0016	.0022	.001	---	---	---	---	---	---	---	.001
CuO	.0047	.0025	.0050	.0025	.0027	.0049	.016	.0026	.0015	.0024	.0016	.0024	.0019	.0017	.0019	.0030
SrO	.017	.0089	.0077	.011	.013	.017	.0092	.014	.0086	.013	.042	.0052	.010	.024	.02	.022
ZrO_2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	.002
Ag_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Field No. / Oxide	SJ 27-1	SJ 27-2	SJ 27-3	SJ 27-4	SJ 28-1	SJ 28-2	SJ 29-1	SJ 29-2	SJ 29-3	SJ 29-4	SJ 29-5	SJ 30-1	SJ 30-2	SJ 30-3	SJ 31-1	SJ 32-1
Na_2O	.05	.11	.40	.05	.05	.18	---	---	---	---	---	---	---	---	---	---
Al_2O_3	.25	.25	.92	.10	.56	.42	.087	.047	.021	.041	.022	.17	.13	.21	.22	.14
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.02	.049	.16	.011	.05	.039	.015	.0088	---	.004	.0028	.036	.013	.041	.031	.018
V_2O_5	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	---
Cr_2O_3	.00074	.0022	.0012	.00089	.0013	.00096	.0005	.0005	---	---	---	.00083	.002	.0014	.0029	.0005
MnO	.75	.17	.43	.07	.23	.34	.021	.037	.032	.061	.032	.80	.29	.023	.24	.086
Fe_2O_3	.77	.49	.83	.28	.54	.59	.17	.11	.046	.12	.064	.46	.56	.38	.52	.21
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	.001	.001	.001	---	---	.001	---	---	---	---	---	---	---	---	---	---
CuO	.0021	.0016	.0019	.0012	.0051	.0049	.0012	.0010	.0014	.00072	.0010	.0019	.0022	.0020	.0019	.0029
SrO	.018	.055	.015	.036	.014	.034	.022	.042	.038	.028	.031	.028	.034	.040	.024	.014
ZrO_2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Ag_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	.00055
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

SAN JUAN COUNTY - Continued

Oxide \ Field No.	SJ 32-2	SJ 32-3	SJ 32-4	SJ 32-5	SJ 32-6	SJ 32-7	SJ 33-1	SJ 33-2	SJ 34-1	SJ 34-2	SJ 35-1	SJ 36-1	SJ 36-2	SJ 36-3	SJ 36-4	SJ 36-5
Na_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Al_2O_3	.11	.21	.04	.13	.21	.15	.15	.40	.011	.024	.016	.034	.04	.02	.04	.029
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.0088	.026	.0036	.0088	.011	.019	.008	.019	---	.0032	.002	.0044	.0076	.018	.0076	.0056
V_2O_5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Cr_2O_3	.0005	.0005	.0005	.0005	.0005	.0005	.0005	.0005	.0005	.0005	.0005	.0005	.0005	.0005	---	---
MnO	.04	.06	.027	.14	.45	.14	.20	.057	.13	.032	.09	.11	.04	.22	.076	.016
Fe_2O_3	.19	.34	.099	.18	.25	.68	.25	.45	.16	.081	.072	.30	.09	.33	.12	.063
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
CuO	.0033	.0034	.0054	.0030	.0048	.0025	.0016	.0029	.00066	.0013	.00094	.0023	.0011	.0017	.0023	.0017
SrO	.024	.027	.015	.022	.013	.034	.010	.014	.015	.014	.018	.02	.02	.021	.035	.020
ZrO_2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Ag_2O	.00071	.00033	.00033	---	---	---	---	---	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Oxide \ Field No.	SJ 37-1	SJ 37-2	SJ 38-1	SJ 38-2	SJ 39-1	SJ 39-2	SJ 39-3	SJ 40-1	SJ 40-2	SJ 41-1	SJ 42-1	SJ 42-2	SJ 42-3	SJ 43-1	SJ 43-2	SJ 44-1
Na_2O	---	---	---	---	---	---	---	---	---	---	---	---	.15	---	---	---
Al_2O_3	.091	.13	.035	.23	.11	.07	.039	.15	.055	.017	.046	.12	.14	.22	.28	.15
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.0076	.0068	.0024	.016	.006	.0088	.0028	.014	.0044	---	.0056	.039	.024	.024	.030	.021
V_2O_5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Cr_2O_3	---	---	---	---	.00061	.0012	.00051	---	---	.00077	.0010	.0007	.00058	.0005	.00064	.00058
MnO	.058	.015	.027	.081	.37	.058	.016	.40	.061	.025	.008	.16	.02	.25	.11	.098
Fe_2O_3	.12	.15	.088	.26	.23	.23	.10	.24	.18	.19	.092	.30	.27	.37	.40	.18
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
CuO	.0018	.0037	.0022	.0019	.0033	.0019	.0024	.0047	.0025	.0017	.0021	.0024	.0024	.0029	.0040	.002
SrO	.0098	.011	.0056	.0098	.020	.035	.035	.011	.015	.027	.021	.021	.035	.021	.018	.23
ZrO_2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Ag_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

SAN JUAN COUNTY - Continued

Field No. / Oxide	SJ 44-2	SJ 45-1	SJ 46-1	SJ 47-1	SJ 48-1	SJ 50-1	SJ 50-2	SJ 51-1	SJ 51-2	SJ 51-3	SJ 51-4	SJ 52-1	SJ 52-2	SJ 53-1	SJ 54-1	SJ 55-1
Na_2O	---	---	---	---	---	1.00	.53	---	---	---	---	---	---	---	.082	.05
Al_2O_3	.05	.058	.10	.075	.25	2.32	1.35	.026	.025	.047	.026	.026	.041	.070	.68	.075
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.0056	.0044	.0068	.008	.008	.14	.063	.002	.002	.006	.0064	.002	.0028	.006	.047	.010
V_2O_5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Cr_2O_3	.0005	.00064	.0005	.0010	.00093	.0028	.0022	---	---	---	---	---	.0005	.0005	.0010	.0005
MnO	.045	.17	.095	.12	.095	.30	.26	.12	.054	.046	.022	.055	.14	.04	.44	.038
Fe_2O_3	.078	.16	.15	.27	.31	1.03	1.08	.084	.052	.09	.074	.07	.073	.11	.66	.11
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	---	---	---	---	---	.002	.002	---	---	---	---	---	---	---	.0034	---
CuO	.0013	.0024	.0010	.0013	.0035	.017	.015	.0018	.0011	.0014	.0025	.0016	.0014	.0012	.013	.0012
SrO	.025	.017	.036	.032	.038	.024	.011	.0098	.013	.015	.013	.011	.014	.015	.0098	.014
ZrO_2	---	---	---	---	---	.002	.002	---	---	---	---	---	---	---	.003	---
Ag_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Field No. / Oxide	SJ 56-1	SJ 56-2	SJ 56-3	SJ 57-1	SJ 58-1	SJ 58-2	SJ 59-1	SJ 59-2	SJ 60-1	SJ 60-2	SJ 60-3	SJ 61-1	SJ 61-3	SJ 62-1	SJ 63-1	SJ 63-2
Na_2O	---	.05	.05	.05	.05	.05	---	.05	---	---	---	.075	---	---	---	---
Al_2O_3	.029	.058	.10	.052	.13	.10	.029	.27	.14	.075	.22	.31	.21	.12	.087	.70
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.0024	.0068	.012	.006	.010	.0084	.0044	.010	.012	.0028	.029	.025	.022	.012	.0092	.10
V_2O_5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Cr_2O_3	---	---	.0005	---	.0005	.0005	---	.0007	.0005	.0005	.0005	.0015	.0007	.0005	.0005	.0021
MnO	.05	.074	.17	.045	.22	.085	.028	.13	.12	.18	.50	.15	.097	.027	.037	.04
Fe_2O_3	.055	.081	.14	.13	.16	.15	.052	.48	.18	.13	.59	.98	.59	.19	.14	1.22
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	---	---	---	---	---	---	---	---	.001	.001	---	.002	---	---	---	.0024
CuO	.00088	.0012	.0026	.0010	.0019	.0016	.00088	.011	.0038	.0011	.0020	.013	.0024	.0019	.0025	.0089
SrO	.018	.015	.024	.017	.014	.014	.011	.011	.014	.015	.018	.015	.017	.015	.035	.028
ZrO_2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Ag_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
BaO	---	---	---	---	.15	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

SAN JUAN COUNTY - Continued

Oxide \ Field No.	SJ 64-1	SJ 64-2	SJ 65-1	SJ 65-2	SJ 65-3	SJ 66-1	SJ 67-1	SJ 67-2	SJ 67-3	SJ 68-1	SJ 68-2	SJ 69-1	SJ 70-1	SJ 71-1	SJ 71-2	SJ 71-3
Na_2O	---	---	---	---	.10	---	---	---	.98	.55	.06	.06	---	---	---	---
Al_2O_3	.24	.34	.28	.30	.40	.23	.058	.24	2.37	1.97	.21	.21	.21	.11	.14	.16
K_2O	---	---	---	---	---	---	---	---	.75	1.13	---	---	---	---	---	---
TiO_2	.079	.093	.021	.020	.04	.037	.0068	.032	.052	.036	.018	.039	.026	.006	.006	.024
V_2O_5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Cr_2O_3	.00077	.0010	.00055	.0005	.0005	.0028	.0005	.00096	.0067	.0074	.00077	.0012	.00064	.0005	.0005	.0019
MnO	.077	.065	.13	.14	.11	.019	.062	.06	.097	.10	.045	.23	.074	.03	.024	.075
Fe_2O_3	.51	.52	.52	.50	.50	.34	.18	.32	3.55	1.28	.22	.65	.35	.13	.09	.21
CoO	---	---	---	---	---	---	---	---	.0014	---	---	---	---	---	---	---
NiO	.001	.001	.0024	.003	.0022	.001	.001	.001	.0072	.0026	.002	.0026	.0016	---	---	.0014
CuO	.0014	.0016	.0029	.0033	.0022	.0018	.0024	.0025	.024	.0038	.0031	.0055	.0029	.0014	.0021	.0014
SrO	.017	.021	.018	.022	.021	.055	.031	.033	.022	.050	.036	.048	.052	.027	.024	.025
ZrO_2	---	---	---	---	---	---	---	---	.011	.0054	---	---	---	---	---	---
Ag_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Oxide \ Field No.	SJ 71-4	SJ 72-1	SJ 72-2	SJ 72-3	SJ 73-1	SJ 74-1	SJ 75-1	SJ 76-1	SJ 76-2	SJ 76-3	SJ 76-4	SJ 77-1	SJ 77-2	SJ 77-3	SJ 77-4	SJ 78-1
Na_2O	.05	.05	.14	.49	---	---	.075	---	---	---	---	.068	.075	.05	.06	---
Al_2O_3	.16	.50	1.15	1.40	.12	.17	.42	.68	.39	.58	.53	1.15	1.07	.79	1.35	.47
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.0092	.14	.11	.12	.026	.0088	.021	.059	.04	.035	.034	.11	.15	.031	.084	.027
V_2O_5	---	---	---	---	---	---	---	---	---	.0033	.0039	.010	.012	.0062	.003	.0053
Cr_2O_3	.0049	.00086	.0027	.0018	.0005	.0005	.00083	.0036	.0017	.0016	.0017	.0016	.0017	.0010	.0019	.0016
MnO	.028	.052	.11	.05	.038	.19	.13	.07	.08	.062	.075	.087	.085	.05	.09	.032
Fe_2O_3	.88	1.13	1.56	1.41	.34	.53	.81	1.07	.84	.94	.90	.67	.68	.42	1.29	.59
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	.0014	.0028	.002	.0024	.0018	---	.0018	.0016	.001	.0024	.0022	.0018	.0012	.001	.0026	.0012
CuO	.0023	.0054	.0047	.0094	.0037	.0025	.007	.0057	.0081	.010	.011	.0031	.0026	.0018	.014	.0043
SrO	.018	.036	.025	.025	.024	.015	.16	.013	.014	.017	.013	.0056	.0098	.0098	.013	.064
ZrO_2	---	.002	.002	.002	---	---	---	.002	---	---	---	---	---	---	---	---
Ag_2O	---	---	---	---	---	---	---	---	---	---	---	.0015	.0016	.0012	.0015	.0015
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	.038	---

SAN JUAN COUNTY - Continued

Field No. / Oxide	SJ 79-1	SJ 79-2	SJ 79-3	SJ 79-4	SJ 79-5	SJ 79-6	SJ 80-1	SJ 80-2	SJ 81-1	SJ 82-1	SJ 82-2	SJ 83-1	SJ 84-1	SJ 85-1	SJ 85-2	SJ 86-1
Na_2O	---	---	.13	---	.05	---	.25	.067	---	---	---	---	---	---	---	---
Al_2O_3	.56	.21	.85	.21	.66	.39	.93	1.05	.055	.05	.065	.06	.10	.053	.038	.063
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.029	.012	.051	.0088	.052	.026	.053	.053	.018	.0048	.008	.0072	.0096	.0064	.002	.0056
V_2O_5	.0053	.0053	.0053	.0048	.0059	.005	.005	.0053	---	---	---	---	---	---	---	---
Cr_2O_3	.0005	.0005	.0005	.0005	.00083	.0005	.0017	.0017	.0005	.0005	.0005	.0005	.0005	.0005	.0005	---
MnO	.08	.045	.48	.072	.062	.067	.045	.05	.072	.024	.017	.027	.10	.028	.024	.031
Fe_2O_3	.69	.26	.56	.36	.49	.52	1.16	.85	.12	.098	.098	.19	.19	.13	.13	.24
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	.0012	.0012	.001	.001	.001	.001	.0038	.0018	.001	---	---	.001	.001	.001	.001	.001
CuO	.0029	.0016	.0027	.0028	.0033	.0023	.0099	.005	.0028	.0025	.0012	.0020	.0031	.0023	.0031	.0036
SrO	.013	.014	.011	.011	.011	.028	.011	.015	.034	.025	.024	.029	.028	.052	.018	---
ZrO_2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Ag_2O	.00088	.0010	.00038	.00044	.0018	---	---	.0023	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	.023	---	---	---	---	---	---	---	---	---	---	---	---	---

Field No. / Oxide	SJ 87-1	SJ 88-1	SJ 89-1	SJ 90-1	SJ 91-1	SJ 92-1
Na_2O	---	---	---	.11	.075	---
Al_2O_3	.39	.12	.19	3.13	.16	.59
K_2O	---	---	---	1.72	---	---
TiO_2	.025	.0048	.014	.22	.020	.059
V_2O_5	---	---	---	.009	---	.0034
Cr_2O_3	---	.00054	.00077	.0045	.00099	.0021
MnO	.078	.078	.11	.55	.028	.55
Fe_2O_3	.33	.16	.24	1.98	.21	3.15
CoO	---	---	---	---	---	---
NiO	.001	.001	.001	.0044	.001	.0034
CuO	.0031	.0033	.0024	.012	.0025	.023
SrO	---	.028	.027	---	.038	---
ZrO_2	---	---	---	.0084	---	.0036
Ag_2O	---	---	---	---	---	---
BaO	---	.43	.36	---	---	---
PbO	---	---	---	---	---	---

SKAGIT COUNTY

Oxide \ Field No.	St 1-1	St 1-2	St 1-3	St 2-1	St 2-2	St 3-1	St 4-1	St 5-1	St 6-1	St 8-1	St 8-2	St 9-1	St 9-2	St 10-1	St 11-1	St 11-2
Na_2O	.11	.14	.21	---	---	---	.083	---	---	.20	---	---	.15	.075	.05	.05
Al_2O_3	.23	.34	.74	.56	.41	.075	.64	.18	.13	.80	.34	.25	.61	.42	.68	1.01
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.011	.015	.026	.046	.014	.0032	.021	.0044	.004	.030	.008	.0052	.016	.0092	.022	.045
V_2O_5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	.0045	.0067
Cr_2O_3	.0005	.00042	.00074	.0010	.00074	---	---	---	---	---	---	---	---	---	---	---
MnO	.01	.015	.019	.053	.025	.062	.043	.03	.053	.027	.03	.09	.042	.09	.042	.095
Fe_2O_3	.15	.24	.33	.41	.45	.19	.48	.12	.14	.39	.32	.16	.37	.21	.45	.63
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	---	.001	.001	.001	.001	.001	.0014	---	---	---	---	---	---	.001	.002	.002
CuO	.00088	.0026	.0017	.00088	.00077	.0012	.0020	.00072	.00077	.00099	.00082	.0006	.00066	.00082	.0039	.0038
SrO	.024	.025	.012	.015	.015	.009	.010	.011	.010	.0098	.0098	.009	.013	.0083	.024	.055
ZrO_2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Ag_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Oxide \ Field No.	St 11-3	St 11-4	St 11-5	St 11-6	St 11-7	St 11-8	St 11-9	St 12-1	St 12-2	St 12-3	St 12-4	St 13-1	St 13-2	St 14-1	St 14-2	St 15-1
Na_2O	---	---	.071	.05	.05	.19	---	---	.12	.74	.22	---	---	---	.59	---
Al_2O_3	.36	.35	.92	.70	.56	1.37	.23	.43	.85	2.36	.94	.075	.22	.17	2.03	.075
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.018	.016	.056	.030	.037	.052	.0076	.027	.037	.10	.041	.0048	.0088	.012	.087	.002
V_2O_5	.0067	.0051	.0064	.011	.0064	.007	.003	.003	.0051	.0064	.003	.003	.003	---	---	---
Cr_2O_3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	.0024	---
MnO	.053	.033	.057	.053	.063	.04	.02	.053	.04	.05	.03	.022	.051	.063	.05	.021
Fe_2O_3	.34	.27	.74	.71	1.00	.83	.11	.40	.85	1.33	.67	.077	.17	.18	.95	.10
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	.001	.001	.001	.0028	.0017	.0012	.001	.001	.0016	.0018	.001	---	---	---	---	---
CuO	.0016	.0012	.0026	.0038	.0039	.0030	.0005	.0014	.0070	.0078	.0043	.00099	.0012	.0016	.0047	.0012
SrO	.025	.024	.021	.022	.052	.035	.010	.040	.013	.031	.025	.0091	.011	.0082	.011	.0096
ZrO_2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Ag_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

SKAGIT COUNTY - Continued

Oxide \ Field No.	St 15-2	St 15-3	St 16-1	St 16-2	St 16-3	St 16-4	St 17-1	St 17-2	St 17-3	St 17-4	St 17-5	St 18-1	St 18-2	St 18-3	St 18-4	St 18-5	St 19-1
Na_2O	---	---	---	.083	---	---	---	---	---	---	.53	.05	.05	1.42	.46	.05	---
Al_2O_3	.11	.093	.48	1.13	.38	.30	.28	.27	.15	.43	2.61	.29	.79	4.34	1.31	.70	.10
K_2O	---	---	---	---	---	---	---	---	---	---	.70	---	---	---	---	---	---
TiO_2	.0044	.0048	.017	.0092	.014	.008	.01	.012	.0038	.016	.08	.015	.032	.18	.041	.032	.0072
V_2O_5	---	---	---	---	---	---	---	---	---	---	---	---	---	.013	---	---	---
Cr_2O_3	---	---	---	---	---	---	---	---	---	---	.0012	---	---	.0014	.0005	.0005	.0005
MnO	.027	.024	.03	.024	.027	.032	.025	.016	.038	.021	.12	.027	.015	.092	.024	.019	.20
Fe_2O_3	.21	.14	.37	.29	.27	.20	.34	.27	.11	.32	1.73	.19	.43	2.61	.55	.46	.21
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	---	.001	---	---	---	---	---	---	---	---	.0024	---	.001	.0018	---	---	---
CuO	.0010	.0006	.00099	.0005	.00088	.0012	.0014	.0012	.0006	.0014	.0070	.00083	.0011	.012	.0013	.0012	.0014
SrO	.008	.010	.011	.009	.0082	.0088	.01	.017	.007	.013	.021	.0084	.015	.0098	.017	.020	.013
ZrO_2	---	---	---	---	---	---	---	---	---	---	---	---	---	.0045	---	.0048	---
Ag_2O	---	---	---	---	---	---	---	---	---	---	.0005	---	---	.00071	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Oxide \ Field No.	St 22-1	St 22-2	St 22-3	St 23-1	St 23-2	St 23-3	St 24-1	St 24-2	St 24-3	St 24-4	St 24-5	St 25-1	St 25-2
Na_2O	---	.05	---	.14	.083	.38	.05	---	---	---	---	3.50	2.9
Al_2O_3	.83	1.06	.17	.98	1.02	3.69	.25	.087	.087	.25	.21	9.06	8.06
K_2O	---	---	---	---	---	.82	---	---	---	---	---	1.35	1.88
TiO_2	.026	.047	.0044	.039	.035	.10	.011	.012	.002	.01	.008	.76	.65
V_2O_5	.003	.0056	---	.003	.003	.010	---	---	---	---	---	.042	.033
Cr_2O_3	.00083	.0013	.0007	.0011	.0009	.0013	.0007	.0007	.0005	.0005	.0005	.00067	.0015
MnO	.028	.024	.034	.024	.012	.045	.012	.011	.007	.018	.019	.12	.14
Fe_2O_3	.58	.35	.27	1.11	.51	1.71	.29	.31	.22	.50	.42	2.58	2.11
CoO	---	---	---	---	---	---	---	---	---	---	---	.0036	.0024
NiO	.0018	.0016	---	.001	.001	.001	.001	---	---	---	---	.0052	.0028
CuO	.0041	.008	.00066	.0020	.0023	.0021	.0013	.0013	.00094	.0013	.0013	.024	.024
SrO	.0098	.012	.015	.016	.011	.018	.010	.011	.0094	.0084	.0092	.010	.016
ZrO_2	---	---	---	---	---	---	---	---	---	---	---	.015	.011
Ag_2O	---	.0002	---	---	---	---	---	---	---	---	---	.0019	.0015
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---

SNOHOMISH COUNTY

Oxide \ Field No.	Sh 1-1	Sh 2-1	Sh 3-1	Sh 3-2	Sh 3-3	Sh 4-1	Sh 4-2	Sh 4-3	Sh 4-4	Sh 4-5	Sh 5-1	Sh 5-2	Sh 9-1	Sh 10-1	Sh 10-2	Sh 11-1	Sh 11-2
Na_2O	.05	.82	.57	.18	.20	---	---	---	---	.05	---	---	.12	---	.067	.06	.071
Al_2O_3	.053	1.72	2.32	.68	.85	.19	.062	.038	.050	.17	.14	.12	.46	.30	.41	.28	.90
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.005	.03	.096	.021	.033	.016	.008	.0034	.0072	.0092	.01	.006	.03	.020	.022	.013	.025
V_2O_5	---	---	---	---	---	---	---	---	---	---	---	---	.0056	.003	.003	.003	.003
Cr_2O_3	.0005	.0005	.0013	.00074	.0011	.0005	---	.0005	---	---	---	---	.0005	---	.0005	.0005	.00093
MnO	.039	.085	.13	.14	.15	.068	.063	.068	.10	.034	.055	.029	.18	.043	.043	.043	.067
Fe_2O_3	.11	.54	1.67	.42	.59	.19	.12	.17	.16	.20	.33	.24	5.22	.56	.51	.39	.85
CoO	---	---	---	---	---	---	---	---	---	---	---	---	.0017	---	---	---	---
NiO	---	---	---	---	---	---	---	---	---	---	---	---	.015	.001	.001	.001	.001
CuO	.0019	.0037	.0040	.0014	.0019	.0016	.0013	.0015	.0012	.0016	.0020	.0011	.0040	.0010	.0021	.0022	.0046
SrO	.014	.034	.0098	.034	.015	.015	.018	.017	.020	.013	.012	.015	.034	.014	.013	.017	.017
ZrO_2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Ag_2O	---	---	---	---	---	---	---	---	---	---	---	---	.0012	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Oxide \ Field No.	Sh 11-3	Sh 11-4	Sh 11-5	Sh 11-6	Sh 12-1	Sh 12-2	Sh 12-3	Sh 12-4	Sh 12-5	Sh 13-1	Sh 14-1	Sh 14-2	Sh 14-3	Sh 14-4	Sh 14-5	Sh 14-6	Sh 14-7
Na_2O	.06	1.47	2.28	2.28	---	---	---	---	---	---	---	.05	.05	.05	.05	---	---
Al_2O_3	.56	2.26	3.04	2.06	.081	.14	.025	.07	.017	.19	.31	.26	.42	.24	.46	.37	.23
K_2O	---	---	1.73	1.13	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.016	.16	.84	.32	.0064	.017	.0036	.0052	.002	.01	.053	.050	.058	.04	.092	.064	.052
V_2O_5	.003	.0078	.029	.012	.003	.003	---	---	---	---	---	.003	.003	.003	.003	.003	---
Cr_2O_3	.0015	.0051	.0050	.0022	.0025	.0048	.0005	.0012	.0015	.12	.0016	.0012	.00099	.0010	.0013	.0010	.0010
MnO	.10	.12	.19	.17	.08	.11	.027	.032	.16	.18	.12	.095	.20	.07	.073	.073	.083
Fe_2O_3	.92	2.84	6.82	6.14	.15	.37	.23	.25	.80	1.20	.46	.48	.58	.35	.49	.33	.34
CoO	---	.001	.0022	.0013	---	---	---	---	---	.0077	---	---	---	---	---	---	---
NiO	.001	.003	.0048	.0026	---	---	---	---	---	.04	---	---	.001	.001	.001	.001	---
CuO	.0068	.019	.028	.016	.0010	.0017	.0012	.00093	.0028	.018	.0019	.0012	.0026	.00082	.0021	.0014	.0013
SrO	.012	.012	.014	.0063	.024	.034	.021	.021	.014	.0048	.014	.015	.014	.017	.011	.015	.015
ZrO_2	---	.0063	.011	.0081	---	---	---	---	---	.008	---	---	---	---	---	---	---
Ag_2O	---	.00066	.0015	.0014	---	---	---	---	---	.00099	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

WHATCOM COUNTY

Oxide \ Field No.	W 1-1	W 1-2	W 2-1	W 3-1	W 4-1	W 5-1	W 5-2	W 5-3	W 5-4	W 6-1	W 6-2	W 6-3	W 6-4	W 6-5	W 7-1	W 7-2
Na_2O	---	.05	---	.19	---	---	---	---	.05	.05	---	.082	---	---	---	.05
Al_2O_3	.39	.042	.26	.85	.23	.047	.013	.012	.023	.26	.37	.40	.34	.20	.27	.72
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.022	.0032	.011	.045	.013	.024	---	---	.0096	.02	.013	.11	.017	.014	.028	.04
V_2O_5	---	---	---	.0075	---	---	---	---	---	---	---	.0098	---	---	---	.012
Cr_2O_3	.0005	---	---	.0011	---	---	---	---	---	---	---	.0015	.00074	.005	.00096	.00096
MnO	.094	.03	.058	.16	.092	.014	.008	.01	.021	.065	.060	.30	.076	.13	.12	.072
Fe_2O_3	.32	.12	.29	.59	.25	.13	.046	.022	.063	.31	.34	.74	.29	.38	.39	.46
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	.001	.001	---	.001	.001	---	---	---	---	---	.001	.001	.001	---	.001	.001
CuO	.0032	.0012	.0049	.0057	.0024	.0025	.0017	.0015	.0018	.0014	.002	.0025	.0042	.0015	.0031	.0054
SrO	---	.0072	.0063	.027	.0089	.027	.011	.011	.011	.008	.0087	.010	.0048	.0074	.0091	.020
ZrO_2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Ag_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Oxide \ Field No.	W 7-3	W 7-4	W 7-5	W 7-6	W 7-7	W 8-1	W 9-1	W 9-2	W 10-1	W 10-2	W 11-1	W 12-1	W 12-2	W 13-1	W 15-1	W 15-2
Na_2O	.13	---	---	---	---	---	---	---	.86	.30	.14	.05	.05	.05	.05	.05
Al_2O_3	.67	.24	.41	.24	.14	.40	.61	.62	2.29	1.06	.42	.31	.39	.31	.64	.56
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.058	.021	.017	.0092	.010	.019	.029	.035	.18	.066	.029	.018	.020	.022	.035	.029
V_2O_5	---	---	---	---	---	---	.0076	.0081	.0092	---	---	---	---	---	.0084	---
Cr_2O_3	.0012	.00067	.00055	.0005	.00096	.00055	.0007	.00083	.0019	.00064	.0005	.0005	.0005	.0005	.0012	.00099
MnO	.10	.16	.046	.044	.043	.055	.14	.13	.065	.05	.027	.18	.13	.072	.095	.067
Fe_2O_3	1.02	.38	.38	.28	.32	.55	.65	.85	1.64	.57	.40	.32	.39	.26	.56	.54
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	.0034	.0018	.001	---	.001	.001	.0026	.0026	.0026	.001	---	.001	---	---	.0018	.001
CuO	.0078	.0020	.0027	.0015	.0035	.0046	.0030	.0048	.0046	.0018	.002	.002	.0018	.0015	.0036	.0036
SrO	.017	.014	.015	.013	.015	.013	.021	.028	.013	.007	.022	.013	.011	.0098	.035	.036
ZrO_2	.002	---	---	---	---	---	---	---	.0051	.0039	---	---	---	---	---	---
Ag_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

WHATCOM COUNTY - Continued

Oxide \ Field No.	W 16-1	W 16-2	W 16-3	W 16-4	W 16-5	W 16-6	W 16-7	W 16-8	W 16-9	W 16-10	W 16-11	W 16-12	W 16-13	W 16-14	W 17-1	W 17-2
Na_2O	.11	---	---	---	.05	.31	---	---	---	---	---	.28	---	---	---	---
Al_2O_3	.58	.56	.17	.54	.80	.98	.18	.29	.35	.31	.31	.71	.39	.30	.07	.18
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.029	.023	.0088	.024	.032	.11	.012	.014	.018	.016	.015	.024	.024	.017	.0052	.013
V_2O_5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Cr_2O_3	.0005	.0005	---	.0005	.00099	.0005	---	---	.0005	---	.0005	---	---	---	.0005	.0011
MnO	.042	.062	.060	.042	.062	.062	.045	.10	.10	.09	.21	.12	.09	.09	.048	.083
Fe_2O_3	.42	.48	.29	.42	1.12	.95	.25	.31	.39	.37	.63	.41	.40	.36	.36	.58
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	.001	---	.0026	.001	.0024	---	---	---	---	---	---	---	---	---	.0026	.0028
CuO	.0015	.0045	.0042	.0029	.0075	.0025	.0023	.0015	.0019	.0025	.0042	.003	.0037	.0035	.0036	.0059
SrO	.0065	.0093	.0079	.0083	.0091	.011	.0094	.010	.010	.0084	.015	.0098	.011	.011	.0025	.0048
ZrO_2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Ag_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Oxide \ Field No.	W 18-1	W 18-2	W 18-3	W 18-4	W 18-5	W 18-6	W 18-7	W 18-8	W 18-9	W 19-1	W 19-2	W 20-1	W 20-2	W 21-1	W 22-1	W 23-1
Na_2O	---	---	.44	---	---	---	---	---	---	---	---	.26	.70	---	.20	---
Al_2O_3	.49	.099	2.48	.31	.26	.35	.30	.093	.05	.26	.37	.92	2.25	.40	.74	.52
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.052	.045	.24	.039	.015	.067	.016	.0044	.059	.012	.023	.056	.16	.020	.084	.028
V_2O_5	.003	.003	.015	.003	.003	.003	---	---	.0048	---	---	.0064	.0064	.003	.003	.003
Cr_2O_3	.0005	.0005	.0018	.0005	.0005	.0005	.0005	---	.0005	.0005	---	.0021	.0028	.0005	.0015	.0005
MnO	.15	.068	.10	.048	.038	.035	.24	.035	.04	.12	.12	.21	.15	.057	.30	.063
Fe_2O_3	.64	.68	2.74	.38	.35	.38	.31	.077	.44	.55	.45	1.14	2.37	.67	1.22	.57
CoO	---	---	.001	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	.001	.001	.0026	.001	.001	---	---	---	---	---	---	.004	.0094	.001	.0036	.0017
CuO	.0035	.0043	.0082	.0016	.0016	.0017	.0018	.0014	.0012	.0020	.0019	.0030	.0073	.0043	.0096	.0026
SrO	.015	.018	.0092	.012	.011	.011	.012	.0084	.0094	.013	.012	.014	.015	.013	.046	.012
ZrO_2	---	---	.0072	---	---	---	---	---	---	---	---	.002	.010	---	.002	---
Ag_2O	---	---	.001	---	---	---	---	---	---	---	---	---	.0002	.0002	.0002	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

WHATCOM COUNTY - Continued

Oxide \ Field No.	W 24-1	W 24-2	W 24-3	W 24-4	W 24-5	W 25-1	W 26-1	W 27-1	W 28-1	W 28-2	W 28-3	W 28-4	W 29-1	W 29-2	W 29-3	W 29-4	W 29-5
Na_2O	.082	---	---	---	---	.05	.05	---	---	.05	---	1.39	.068	---	.05	.05	---
Al_2O_3	.56	.86	.46	.85	.067	.058	.17	.12	.034	.28	.065	2.52	.38	.56	.26	.25	1.14
K_2O	---	---	---	---	---	---	---	---	---	---	---	.70	---	---	---	---	---
TiO_2	.029	.034	.025	.053	.0076	.012	.0056	.0064	.0036	.02	.0056	.23	.026	.010	.0092	.0068	.039
V_2O_5	.003	.003	.003	.003	---	---	---	---	---	---	---	.011	---	---	---	---	.003
Cr_2O_3	.0005	.00096	.00074	.0008	---	---	---	---	---	---	---	.0036	.0018	.0009	.00099	.0008	.0012
MnO	.10	.08	.11	.066	.11	.007	.019	.15	.25	.22	.16	.11	.045	.05	.073	.043	.04
Fe_2O_3	.53	1.46	1.04	.65	.40	.11	.099	.18	.16	.55	.17	1.98	.35	.46	.34	.23	.50
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	---	.0024	.001	.001	.003	---	---	---	---	---	---	.0032	---	---	---	---	---
CuO	.0021	.0075	.0064	.0035	.0015	.0014	.0005	.0012	.0012	.0018	.0095	.0069	.0021	.0013	.0018	.00094	.0019
SrO	.012	.013	.0092	.0090	.014	.022	.031	.011	.007	.011	.0077	.017	.010	.013	.013	.014	.021
ZrO_2	---	.002	---	---	---	---	---	---	---	---	---	.0069	---	---	---	---	---
Ag_2O	---	---	---	---	---	---	---	---	---	---	---	.0005	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

The metallic elements not detected in the spectrochemical analysis and the detectable limits (in percentages) of these elements are reported below:

Li_2O	0.02	In_2O_3	0.005	Er_2O_3	0.01
BeO	0.0005	SnO_2	0.002	Tm_2O_3	0.01
B_2O_3	0.003	Sb_2O_3	0.02	Yb_2O_3	0.005
Sc_2O_3	0.005	TeO_2	0.1	Lu_2O_3	0.01
ZnO	0.05	Cs_2O	1.0	HfO_2	0.05
Ga_2O_3	0.001	La_2O_3	0.01	Ta_2O_5	0.2
GeO_2	0.005	CeO_2	0.02	WO_3	0.05
As_2O_3	0.05	Pr_2O_3	0.01	Re_2O_7	0.01
Y_2O_3	0.002	Nd_2O_3	0.02	Os	0.01
Nb_2O_5	0.01	Sm_2O_3	0.01	Ir	0.02
MoO_3	0.001	Eu_2O_3	0.005	Pt	0.01
Ru	0.005	Gd_2O_3	0.02	Au	0.005
Rh	0.002	Tb_2O_3	0.01	Tl_2O_3	0.01
Pd	0.001	Dy_2O_3	0.02	Bi_2O_3	0.001
CdO	0.01	Ho_2O_3	0.01	ThO_2	0.2
				UO_2	0.2

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