FIGURE 57. — West side of the largest limestone body, Red Cross deposit. View looking southeast, 1959.

A fifth limestone outcrop lies about 125 feet east of the main quarry. It forms a low ridge trending northeast-southwest and is surrounded by glacial drift and soil. Limestone is exposed over a length of 235 feet and a width of 50 feet. The limestone weathers white and is heavily overgrown with moss and other vegetation. East of this limestone body is a drift-covered flat area and then the steep western slopes of a ridge of greenstone and gneissic amphibolite. The Devonian rocks may be in fault contact with these older rocks.

Quality. — The limestone ranges in quality from calcium to high calcium. The presence of chert is indicated by relatively high percentages of silica. A sugary texture indicative of dolomite appears to be present in some hand specimens, but the presence of dolomite is not proved by the chemical analyses. It may be present but restricted or local in distribution and minor in amount.

Chemical analyses of Red Cross limestone

Sample no.	Location	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
1/ SJ 19-1	SW side of outcrop 1 ----	120	91.92	0.52	40.60	51.64	0.25	5.89	0.82	0.011
1/ SJ 21-1	Outcrop 4 ------	40	97.06	0.29	42.64	54.53	0.14	1.84	0.31	0.001
1/ SJ 22-1	Outcrop 3 ------	22	96.47	0.46	41.90	54.20	0.22	2.36	0.28	0.006
1/ SJ 23-1	Outcrop 5 ------	235	96.63	0.33	41.36	54.29	0.16	4.31	1.05	0.018
2/			97.5		42.83	54.62	0.11	1.91	3/ 0.42	

1/ Samples collected for this report, Mark Adams, analyst.
2/ Dolmage, V. (1948, private report, p. 9). Analysis by G. S. Eldridge & Co. Ltd.
3/ Fe_2O_3=0.13, Al_2O_3= 0.29

Ownership and development. — The limestone is owned by Gordon C. Clauson, of Seattle (Everett Lime Company). It was formerly owned and operated by the Roche Harbor Lime and Cement Company. In 1943 the quarry produced an average of 150 tons of limestone per day, which was hauled by truck to West Sound and shipped by barge to pulp mills. Reportedly, the quarry was operated for a period of 3 years but was shut down during World War II because of a shortage of truck tires. Some recent drilling has been done in the quarry, and much of the loose rock has been hauled away. Red Cross No. 4, to the south, has also been drilled, and some overburden has been removed from it.

References. — Northern Pacific Railway Co. (1941, unpublished notes, p. 14), Guard (1943, unpublished field notes), Mathews (1947, p. 53).

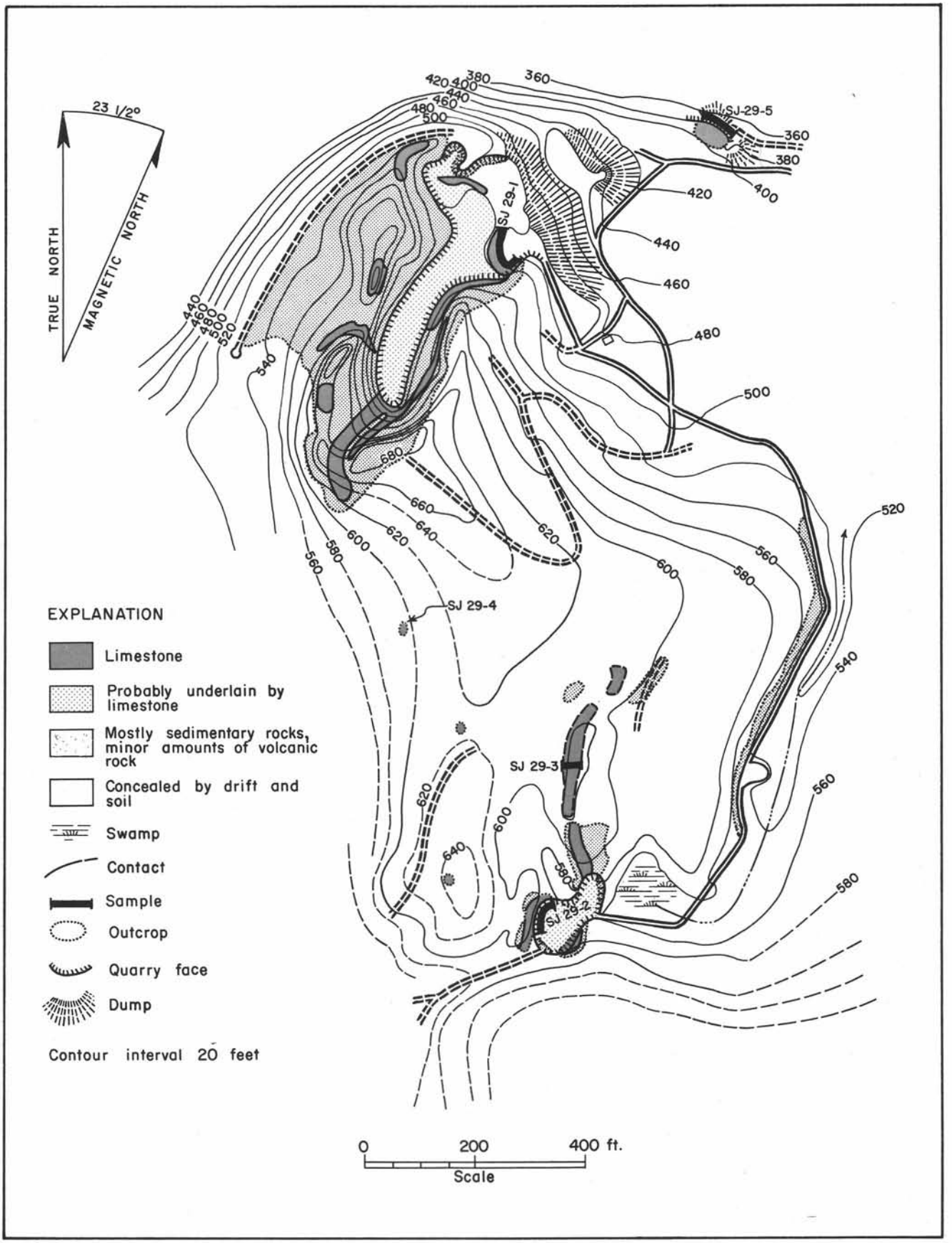


FIGURE 58.—McGraw-Kittinger deposit. NE¼NW¼sec. 2, T. 36 N., R. 2 W. Geology by W. R. Danner, C. F. McKillop, and A. M. Rivisto. Plane table and compass and tape survey.

McGraw-Kittinger Quarry

Location, size, and accessibility. — The McGraw-Kittinger "ledge" is in the NE¼NW¼ sec. 2, T. 36 N., R. 2 W., on a bluff on the north slope of Mount Woolard at an altitude between 380 and 680 feet. Two main outcrop areas and a few small isolated exposures make up the occurrence. The largest limestone body is about 1,000 feet long and averages about 60 feet in thickness. The smaller of the two main bodies is approximately 600 feet long and ranges from 10 to 40 feet in thickness. The limestone is accessible by 1 to 1½ miles of quarry access road from a county road. From the county road ¼ mile of steep graveled road extends down to a scow-loading dock on East Sound at "Dolphin." The terrain is covered with a dense second growth of trees and brush.

Geology and description. — The northerly one of the two McGraw-Kittinger limestone lenses was described, before development, by McLellan (1927) as a ledge of limestone 20 to 40 feet wide exposed for about 200 feet in a northeasterly

FIGURE 59. — Upper quarry, McGraw-Kittinger deposit. View looking southwest, 1959. Limestone overlain and underlain by ribbon chert, volcanic rocks, and argillite. Limestone dips steeply to the south.

direction. At present, limestone is exposed along a northeasterly strike for about 1,000 feet, although it is not known whether this is one continuous body, because part of the area along the strike is covered with quarry debris. It appears also that the main limestone bed is split into a number of mostly parallel blocks by faulting. This has given rise to the impression that the body is much thicker than it actually is. However, originally it may have been as much as 50 or 60 feet thick. The southerly dip averages about 50° in the quarry floor but is more gentle along the quarry rims. Most of the limestone has been removed by quarrying; a few slabs remain on the high ridge at the north end of the quarry. The strike is approximately N. 30° E., but is quite variable.

What is believed to be a second limestone bed, only a few feet thick, is exposed high on the south wall of the quarry above the main bed.

The McGraw-Kittinger limestone deposit is in a sequence of argillites, ribbon cherts, and volcanic rocks striking northeast-southwest and dipping steeply southward across the south central part of Orcas Island. Volcanic rocks are not as abundant in this sequence as in other limestone-bearing rock groups on the island. A light gray green vesicular and dense-textured volcanic flow crops out beneath the limestone at the northeast end of the northern ridge of the quarry.

The limestone is mostly crystalline in texture and gray in color. Locally, small parts of the outcrop have a dense texture. The limestone commonly has a very glassy luster on what appear to be prominent cleavage planes. In many places the limestone also has a peculiar fanlike structure that resembles the impression of a large fan-shaped palm leaf. This structure occurs in several of the Orcas Island limestone bodies, and especially in those aligned in a northeastward-trending belt of outcrops extending from West Sound to the northwest side of Mount Constitution. A similar structure occurs also in the limestone quarry on Boulder Creek, near Maple Falls in western Whatcom County.

McLellan (1927) states that the McGraw-Kittinger limestone ledge "is of scientific interest because it was formed largely by the Carboniferous coral Lithostrotian." He tentatively assigned a Mississippian age to the limestone on the basis of this fossil occurrence. The writer could find no corals in the limestone, and there is no record of anyone other than McLellan finding any fossils in this vicinity.

A second limestone body, very similar in appearance to that just described, is about 600 feet to the south and may be the same body repeated by folding or faulting. A volcanic flow similar to that under the northern limestone outcrop occurs here also. The "palm-leaf" structure is very pronounced in this limestone outcrop and shows up especially well where the limestone has been broken into blocks by quarrying. No attitude could be accurately measured, but the limestone appears

Chemical analyses of McGraw-Kittinger 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
SJ 29-1	Lower level, main quarry ---	70	96.17	0.56	42.05	54.03	0.27	2.44	0.60	0.172
SJ 29-2	South side, second quarry -	70	97.56	0.52	42.69	54.81	0.25	0.61	0.49	0.218
SJ 29-3	North part, south limestone	40	98.02	0.19	42.62	55.07	0.09	0.93	0.17	0.175
SJ 29-4	North of three small outcrops	Composite	97.99	0.63	43.02	55.05	0.30	0.85	0.25	0.092
SJ 29-5	North end, northernmost outcrop ------	60	98.54	0.33	43.10	55.36	0.16	0.48	0.21	0.105

to dip steeply to the southeast and is broken by faulting. Its exposed width is between 20 and 40 feet, and, except for one break, it can be traced for a distance of almost 600 feet.

Three small isolated limestone outcrops occur between the two main bodies. The most northerly of these covers an area of about 100 square feet and consists of small knobs of white crystalline limestone protruding from the drift-covered hillside. Limestone float occurs higher up on the hillside, but no outcrops have been found. The middle exposure is an outcrop about 45 square feet in area and is similar in appearance to the first. The southern exposure occupies only about 6 square feet, and ribbon chert and volcanic rocks crop out around it.

Quality. — The limestone of the McGraw-Kittinger occurrence is generally a high-calcium type, but magnesium and siliceous impurities are visible locally.

Ownership and development. — The limestone property is owned by Mrs. Elsie Westerman of Seattle. It was not developed until some time after 1927. It was subsequently worked by the Westerman Lime and Rock Quarry and the Hidalgo Lime Company, and is being worked at present by the Everett Lime Company, Gordon C. Clauson, President, of Seattle, which leases the property from Mrs. Westerman. Production is reported to have been about 20,000 tons per year, the rock having been shipped to Everett for use in pulp mills. Formerly some of the limestone was ground for use as fertilizer. The rock is now being shipped by scows from a dock on the west side of East Sound, about $1\frac{1}{4}$ miles by road from the main quarry.

A large quarry 400 feet long and from 60 to 210 feet in width with several levels, has been developed on the main northern limestone outcrop. The quarry walls are in some places 150 feet in height. In 1959 it was the opinion of the operators that the quarry could produce for only a few more years. Considering the high walls and the dip of the limestone south under bedrock, this belief is well founded. The southern limestone body has a small quarry developed on it, but the limestone may be too narrow for much further development. It is probable that no great tonnage of limestone remains in this occurrence and that the deposit will be exhausted in a few years.

References. — Shedd (1913, p. 204), McLellan (1927, p. 99, 167), Glover (1936, p. 56), Mathews (1947, p. 53), Valentine (1960, p. 54).

West Sound Quarries

Location, size, and accessibility. — The West Sound limestone deposits are in the NE$\frac{1}{4}$ sec. 9, T. 36 N., R. 2 W. They are a series of outcrops and quarries extending northeastward for approximately 1,700 feet from the shore north of White Beach Bay on West Sound to the north side of the West Sound road. The limestone is not proven to be continuous over this length and is probably broken into separate blocks by faulting. Its thickness ranges from 20 to 80 feet. The occurrence as a whole is mostly worked out. It is accessible by about 1,400 feet of private quarry road along the west side of the quarries. This private road joins the West Sound road about $2\frac{1}{2}$ miles from Orcas Landing and $\frac{1}{2}$ mile from the community of West Sound. The quarries are easily accessible by boat, as they are just a few hundred feet east of the east side of West Sound. The limestone extends from sea level to approximately 117 feet in altitude. Second-growth trees and dense brush cover the terrain.

Geology and description. — The deposits consist of a long narrow limestone lens or group of lenses interbedded in a sequence composed of sheared argillite, ribbon chert, and volcanic rocks. This limestone strikes in general N. 20°-30° E. and dips 10°-60° SE. The attitudes exhibit great local variation. Faulting is prominent in the quarries.

The southernmost outcrops occur on beach cliffs and consist of three limestone bodies. The northern one of these is a lens about 2 feet thick and 25 feet long dipping gently southeastward. It is underlain by greenish-gray ribbon chert and overlain by greenstone, tuff, and minor amounts of ribbon chert and argillite. A small 6-inch layer of limestone interbedded in volcanic rocks and argillite lies a few feet to the south and forms the second outcrop. Still farther south, the third outcrop is about 10 feet long and 2 feet thick. It pinches out in chert and argillite to the south and is cut off by a fault at its north end. It dips gently to the southeast. Glacial drift covers the area inland from the beach and conceals any extension of these outcrops.

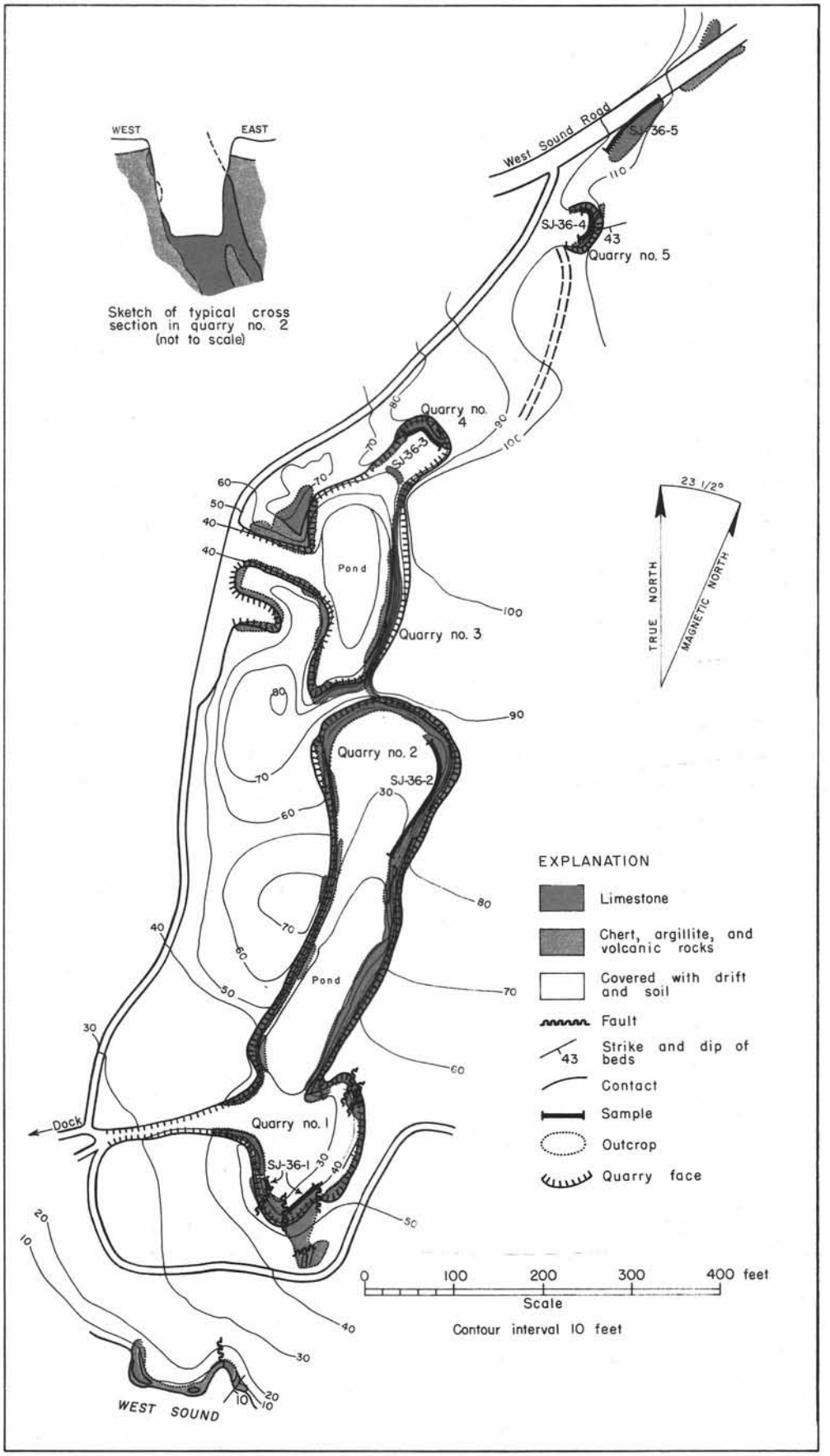


FIGURE 60. — West Sound deposit. NE¼ sec. 9., T. 36 N., R. 2 W. Geology by W. R. Danner, C. F. McKillop, and A. M. Rivisto. Plane table and compass and tape survey.

The next limestone exposure to the north is at the southern end of the largest quarry. Here several faults have broken the limestone into blocks, the largest one of which extends about 75 feet to the south of the quarry. Near the southern end of this block a pit dug into it encountered shale at a depth of 2 feet below the surface. To the east, volcanic rock is in contact with the limestone.

In the main part of the quarry, limestone is exposed mostly at the bottom of the east quarry wall to a height ranging from 5 to 20 feet. It is overlain by as much as 20 feet of bedrock and as much as 5 feet of glacial drift. Several faults of small vertical displacement but unknown horizontal displacement cut the quarry walls. These faults appear to strike N. 70°-80° E.; they dip steeply southeastward or are vertical. They were not mapped. The west quarry face exposes mostly chert, argillite, and overlying glacial drift. The main quarry contains a pond that has been used as a swimming pool; the depth of the water is unknown. A 30-foot wall of limestone separates the main quarry from the next quarry to the north.

The second quarry, to the north of the main quarry, continues along the strike of the same eastward-dipping limestone bed. This quarry, however, appears to have been worked at an earlier date. Its floor is partly covered with vegetation and a shallow pond. Argillite and ribbon chert underlie the limestone on the east wall, and glacial drift overlies it. In the northwest corner of the quarry, in the entrance cut, contorted green ribbon chert is overlain by red argillite, which in turn is overlain by limestone. Part of the limestone is a breccia composed of cemented crystalline limestone fragments. The only foreign rock in the breccia is bright red jasper in fragments up to 1 foot in width and 1 to 3 inches in thickness. The source of this jasper is unknown.

At the north end of the quarry is a small, higher level cut overgrown with vegetation. Its north wall exposes limestone with an interbedded lens of argillite. Northeastward from this quarry, limestone crops out in a low mound along the south side of the West Sound road. It apparently extends underneath the road, as the next outcrop is on the north side of the road along the line of strike.

The limestone of West Sound is typically gray in color and finely crystalline in texture. Rarely is the limestone only partly crystalline, and where it is, a few oölites can be seen in thin section. No definite organic remains have been found, although material resembling crinoidal debris was seen in a few thin sections. The age of this limestone is unknown, but it is believed to be Paleozoic and most probably Permian.

Quality. — Most of the limestone is high in calcium, and visible impurities are not common.

Chemical analyses of West Sound 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
SJ 36-1	South end of Quarry 1 ------	60	98.48	0.35	41.92	55.33	0.17	4.20	0.42	0.046
SJ 36-2	North end of Quarry 2 ------	130	98.54	0.33	43.03	55.36	0.16	0.40	0.32	0.044
SJ 36-3	North end of Quarry 4 ------	50	98.61	0.35	43.42	55.40	0.17	0.41	0.56	0.205
SJ 36-4	East end of Quarry 4 ------	60	99.00	0.23	43.68	55.62	0.11	0.38	0.14	0.032
SJ 36-5	South side of West Sound road ----------	80	99.07	0.27	43.59	55.66	0.13	0.15	0.15	0.051

Ownership and development. — The deposit was owned and operated formerly by the Roche Harbor Lime and Cement Company. That company began quarrying it around 1936, and the rock was sold to pulp mills. Since 1957 it has been owned by the Everett Lime Company, Mr. Gordon Clauson, president, Seattle.

Five quarries have been developed on the property, and most of the easily obtainable limestone has been removed. Only scraps of limestone remain. Exploration might reveal additional limestone under drift cover between quarries 4 and 5.

The limestone from these quarries was hauled by truck to a wharf on West Sound a few hundred feet west of the southernmost quarry. Limestone containing jasper fragments similar to those of this property was used in decorative stone work on the south summit of Mount Constitution in Moran State Park. However, it is not known for certain whether this occurrence was the source. Possibly, also, quarries developed on limestone bodies to the northeast of West Sound produced some jasper-fragment breccia.

References. — McLellan (1927, p. 168), Mathews (1947, p. 52), Valentine (1960, p. 54).

Double Hill Deposit No. 1

Location, size, and accessibility. — The Double Hill No. 1 limestone deposit is in the SE¼ sec. 15, T. 37 N., R. 2 W., on the south side of Double Hill about 3/4 mile west of the community of East Sound. Limestone outcrops occur at estimated altitudes between 280 and 440 feet. The occurrence consists of three bodies of partially silicified limestone. One body is approximately 170 feet long and 100 feet wide; the second, about 20 feet long and 15 feet wide; and the third is 250 feet long and 30 to 50 feet wide. The outcrops can be reached by following a rough farm road for ¼ mile from its junction with the East Sound-West Sound road at the SE. cor. sec. 15 to the ruins of an old farmhouse. A poor trail, once a wagon road, can be followed 200 feet north from the farmhouse to the southernmost of the three exposures. The other two outcrops can be reached by following the trail farther north up a narrow valley for 300 feet to the first one and 100 feet farther to the second one. The area is covered with second-growth trees and in places is very brushy.

Geology and description. — The deposit consists of at least three lenticular outcrops of partially silicified limestone. Bedrock in the immediate vicinity is poorly exposed but appears to consist mainly of volcanic rocks and graywacke. Limestone outcrops are heavily covered with moss.

The most southerly limestone body is so poorly exposed that its dimensions can be only roughly estimated. Its maximum length northeast-southwest is 170 feet, and its maximum width is about 100 feet. All contacts are with glacial drift and soil. Limestone is exposed vertically for about 40 feet.

The limestone is white to light gray on fresh surfaces and weathers to a gray color. It is finely crystalline to dense in texture and in places is richly fossiliferous.

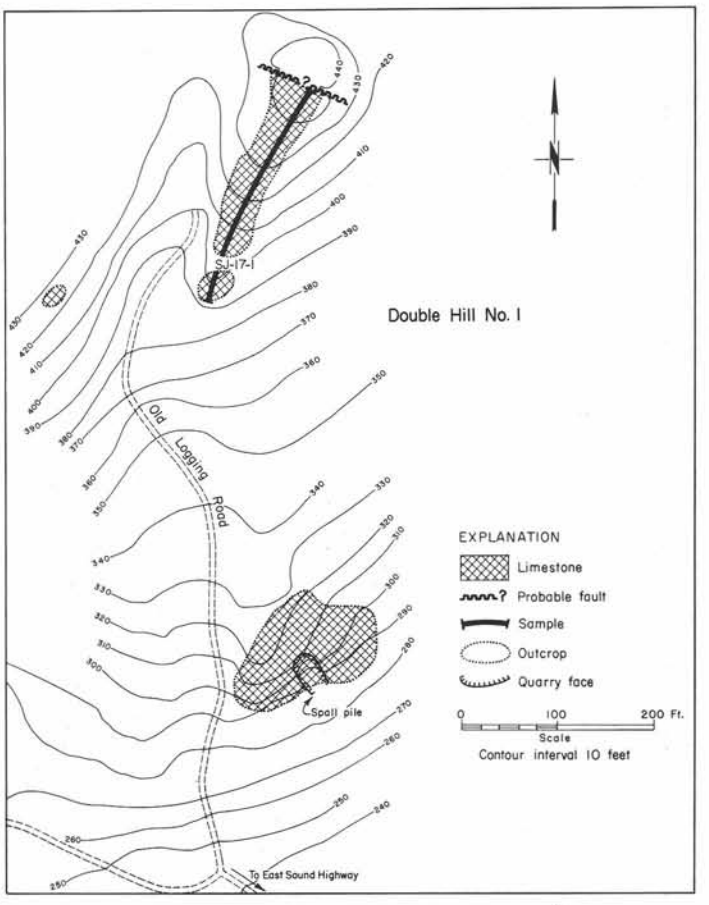


FIGURE 61. — Double Hill No. 1 deposit. SE¼ sec. 15, T. 37 N., R. 2 W. Geology by W. R. Danner, C. F. McKillop, and A. M. Rivisto. Compass and tape survey.

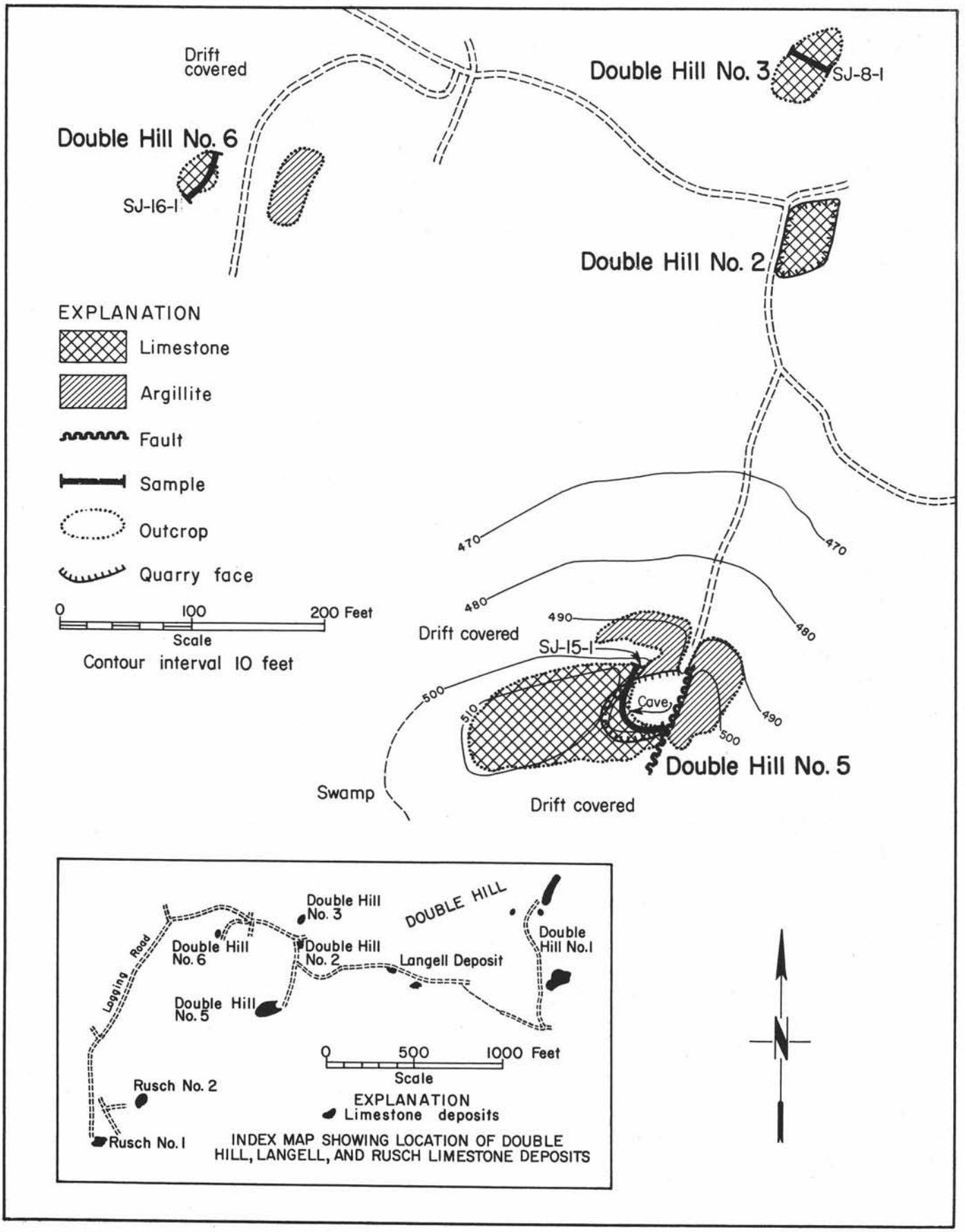


FIGURE 62. — Double Hill Nos. 2, 3, 5, and 6 limestone deposits, Orcas Island, and index map of limestone deposits of the Double Hill area. Geology by W. R. Danner, C. F. McKillop, and A. M. Rivisto. Compass and tape survey.

It contains a considerable amount of argillaceous material. However, chert (jasperoid), which appears to be of replacement origin, is the most abundant impurity. In thin section the limestone is seen to be mostly organoclastic in texture. Fossils include fusulinids, bryozoans, crinoid debris, algal fragments, and a few brachiopod shell fragments. The fusulinids Pseudofusulinella and Schwagerina and the bryozoan Rhomboporella were identified and indicate an early Permian age for the limestone.

A second body of limestone is exposed on an east-facing hillside 400 feet northwest of the first. It crops out over an area about 20 feet long north-south and 15 feet wide, and is very cherty.

A third limestone body is exposed as an almost continuous outcrop along the crest of a west-facing hillside about 300 feet northeast of the most southerly body. It can be traced northeastward for about 250 feet, to where it appears to be cut off by a northwest-trending fault. Along the trace of this fault is a narrow trench across the ridge crest. North of this trench the ridge continues as an outcrop of volcanic rock for a few hundred feet, then slopes down steeply northward in a large scarp. The limestone body on this ridge has a maximum width of about 50 feet and is exposed vertically for about 25 feet. The limestone has been largely replaced by jasperoid, and it is estimated that from 65 to 75 percent of the outcrop is silica. Permian fossils similar to those found in the most southerly outcrop are contained in the limestone.

Quality. — This occurrence contains too much silica to be of economic value.

Chemical analysis of Double Hill 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
SJ 17-1	250	53.40	0.56	23.74	30.00	0.27	45.07	1.08	0.032

Ownership and development. — The property is owned by Nova Langell of East Sound, Orcas Island, Wash. A small abandoned quarry is on the southeast side of the most southerly outcrop. It was cut about 25 feet into the limestone, and its west face is between 25 and 30 feet high. A small pile of spalls of argillaceous and siliceous limestone is at the quarry entrance. According to Mr. Langell, this limestone was worked briefly 60 to 80 years ago and the quarried rock was hauled by a tramline down the steep hillside toward the east to a limekiln on the beach of East Sound.

Double Hill Deposit No. 2

Location, size, and accessibility. — The Double Hill No. 2 limestone deposit is approximately in the center of the SE¼ sec. 14, T. 37 N., R. 2 W., on the west side of the southern part of Double Hill and just northwest of the pass between Double Hill and Lookout Mountain. Limestone crops out at an altitude of about 460 feet above sea level. A vegetation-covered quarry about 50 feet long north-south and 40 feet wide probably still has limestone on its floor, now concealed with debris. The only limestone exposed is in a long narrow cut along the north wall of the quarry. The limestone can be reached by following a farm road starting at the East Sound-West Sound highway at the SE. cor. sec. 15 and continuing up this road for ¼ mile to an abandoned farmhouse, then continuing up the road (now impassable to vehicles) past this farmhouse and to the west for a distance of about 1,500 feet, up and over the pass between Lookout Mountain and Double Hill. The deposit can also be reached by the West Beach road, starting ½ mile north of East Sound village and following the main road for a little over 1 mile to a logging road branching off to the south in the south-central part of sec. 15. This road is followed about 1/5 mile to an intersection. The east fork at the intersection is followed about ¼ mile to the quarry.

The area is covered with second-growth trees and is very brushy. The quarry floor is overgrown with alder trees and nettles and is usually covered with water during rainy weather.

Geology and description. — Very little is known about the geology of this limestone due to lack of exposure and to thick vegetation and soil cover. Quarrying has removed almost all limestone that may have been visible in the original outcrop; the only remaining exposure is along the north side of the quarry, where an 8- to 10-foot quarry wall exposes a finely crystalline to clastic-textured gray to light blue gray to black limestone. Any extension of limestone to the north is concealed by soil and glacial drift. The east side of the quarry contains numerous loose blocks of limestone partly covered with soil, and the west and south quarry walls are formed of soil and glacial drift with a heavy vegetative cover.

In thin section the limestone shows a finely crystalline to clastic texture. The finely crystalline limestone in one sample contains fossil specimens of an unidentified dasycladacean alga. The clastic-textured limestone contains algae fragments, stromatoporoids, echinoid spines, crinoid debris, fragments of unidentified fossils, oölites, and pellets. The geologic age of the limestone is unknown.

Quality. — The limestone rubble left around the quarry appears to be of good quality and has few visible impurities. No samples were taken for chemical analysis because of the small size of the occurrence and the lack of outcrop.

Ownership and development. — The owner of the property and date of quarry operation are unknown. A local resident stated that the limestone was quarried about 20 years ago for paper rock and originally formed a knob about 20 to 30 feet high. The quarry appears to be exhausted, but nothing is known about possible extensions of limestone under cover around the quarry or whether limestone exists beneath the quarry floor.

Double Hill Deposit No. 3

Location, size, and accessibility. — The Double Hill No. 3 limestone deposit is in approximately the center of the SE¼ sec. 15, T. 37 N., R. 2 W., on the west side of the southern part of Double Hill. It is about 300 feet northwest and downslope from the pass between Double Hill and Lookout Mountain. It lies about 120 feet north of the Double Hill No. 2 limestone and forms an isolated knob over 40 feet high on a north-facing slope; the outcrop is about 60 feet long north-south and 30 feet wide. The deposit contains about 6,000 tons of limestone. It is surrounded by an extremely dense growth of alder, nettle, blackberry, and wild rose. The limestone is most easily reached by hiking eastward about 200 feet from the logging road leading from the west to the Double Hill No. 2 deposit.

Geology and description. — The limestone forms a pinnacle-like outcrop with very steep to almost vertical slopes, particularly on its north side. It appears to be either the remnants of an old quarry operation or the remains of a limestone body that is almost eroded away or dissolved by ground water. No contacts with other rocks were visible, and no bedding could be recognized in the limestone. The base of the outcrop and much of its surface is covered with vegetation. A partly filled sinkhole is at the base of the outcrop on its west side.

The limestone is light gray in color and dense to finely crystalline in texture. In thin section some specimens examined show an organoclastic texture. Fossil fragments consist of the remains of crinoids, bryozoans, algae, ostracods, and brachiopods. Foraminifera are common and include Eostafella, Ozawainella, Endothyra, and Tetrataxis. Most likely, the limestone is Early Pennsylvanian in age.

Chemical analysis of Double Hill No. 3 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
SJ 8-1	Center of outcrop, east-west ------	30	94.96	0.67	42.48	53.35	0.32	3.60	0.56	0.044

Jasperoid is present as an impurity, forming numerous irregular masses in the limestone.

Quality. — The limestone is of good quality except for the siliceous impurities.

Ownership and development. — The owner of this limestone is unknown. There is a possibility that it was quarried at one time, and this may account for the unusual shape of the outcrop and its steep sides. However, no recognizable quarry could be found and no debris or remains of machinery were in evidence. About 6,000 tons of limestone could be quarried above the general ground level, but the limestone is probably too siliceous to be valuable for most uses.

Double Hill Deposit No. 4

Location, size, and accessibility. — The Double Hill No. 4 limestone occurrence is in the SW¼ sec. 14, T. 37 N., R. 2 W., on a hillside about 200 feet east of the East Sound road, at an estimated altitude of 230 feet. The occurrence consists of two narrow beds of limestone: one, usually less than 6 feet in width, traceable for almost 150 feet up the hillside; and a second, ranging from 5 to 35 feet in width, thought to be continuous for almost 250 feet. The limestone can be reached by climbing up the hillside from a small parking area on the west side of the East Sound highway approximately ½ mile south of the road junction at the west end of East Sound village. The hillside is covered with a partly open stand of second-growth trees and patches of brush, and has a few small cliffs and knobs of bedrock.

Geology and description. — The occurrence comprises two narrow lenticular beds of mostly crystalline magnesian limestone. The western bed has a maximum width of 6 feet at its south end and appears to thin along its strike and eventually pinch out. It is bounded by a fault contact with argillite on its east side at the south end. The west side, also in contact with argillite, strikes about N. 34° W. and dips 60° NE. A short distance to the west of this bed is an outcrop of what appears to be an altered diorite.

The second limestone bed has a maximum width of 35 feet at its southern end and is traceable in discontinuous, poorly exposed outcrops for a distance of almost 250 feet. It thins to about 5 feet in width along the strike. It strikes northwestward, then bends gently around to the northeast and strikes almost east-west before it finally disappears. Apparently it is bounded by a fault on each side at its south end, and these faults strike toward each other and cut off any extension of the limestone to the south.

The country rock consists of argillite, ribbon chert, serpentine, and basic volcanic rocks. Small pods of limestone only a few feet in area are exposed to the east and south of the main beds and are also exposed in roadcuts along the East Sound road.

The limestone is light gray to blue gray and buff in color and mostly crystalline in texture. Much of the outcrop has a fine-grained saccharoidal appearance typical of small crystals of dolomite in a magnesium-rich limestone. A hand specimen with crystalline texture, stain-tested by the potassium chromate method, showed a dolomite matrix

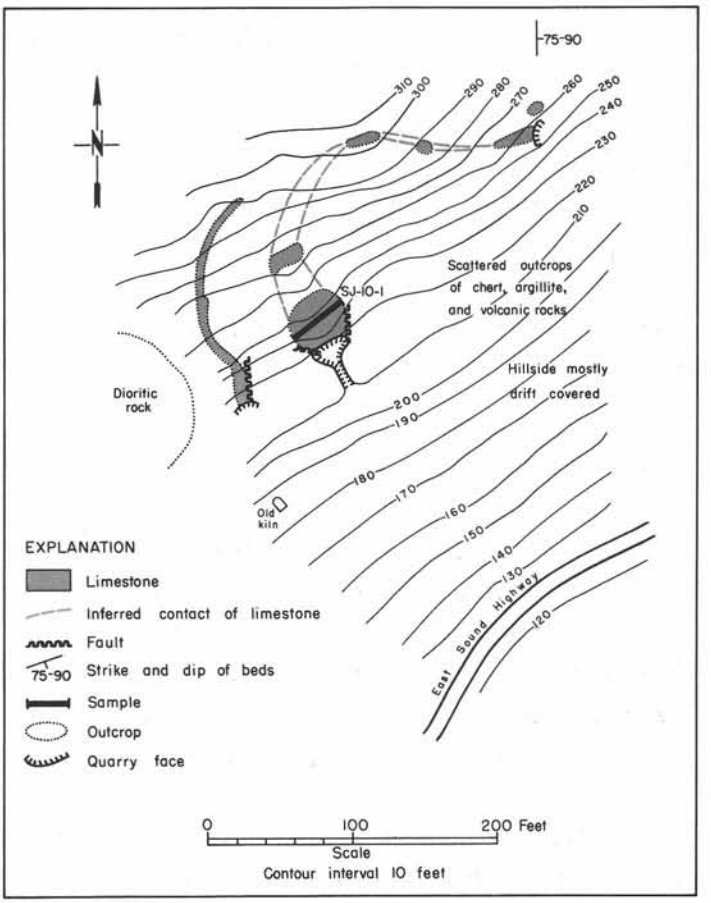


FIGURE 63. — Double Hill No. 4 deposit. SW¼ sec. 14, T. 37 N., R. 2 W. Geology by W. R. Danner, C. F. McKillop, and A. M. Rivisto. Compass and tape survey.

cut by numerous veinlets of calcite. A specimen partly crystalline in texture was examined in thin section and was found to contain numerous crystals of dolomite where the texture was crystalline, but otherwise was dense or finely clastic. It also was cut by numerous calcite veinlets.

In thin section, some of the dense-textured limestone was seen to contain numerous specimens of the middle Permian fusulinid Misellina. The limestone is therefore regarded as younger in age than the early Permian limestone found a short distance to the northwest in the Double Hill No. 1 occurrence.

When freshly broken, much of the limestone of this area gives off a strong bituminous odor.

Quality. — The sugary texture seen in the outcrops suggests that most of the limestone contains a considerable amount of dolomite. Silica in the form of jasperoid is a common impurity.

Chemical analysis of Double Hill No. 4 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
SJ 10-1	South end of eastern bed ----------	35	82.57	13.58	42.59	46.39	6.50	1.99	2.53	0.455

Ownership and development. — The owner of this property is unknown. A local resident stated that at one time a tramline extended down the hill from this limestone and across the road to a large kiln on the beach below. The ground trace of part of this tramline can still be seen. The tramline also extended farther uphill toward the northwest to the small quarry on the Double Hill No. 1 limestone occurrence. A small pot kiln is just downhill from the limestone outcrops and was probably built during a still older period of operation. It is composed of rough blocks of limestone and other rocks cemented together lining a semicircular depression in the sidehill. The remains of the kiln are 9 feet long and 8 feet wide and extend to a depth of 8 feet. Argillaceous rocks in the walls of the kiln have been burned a brick red.

Three small quarries were found; one is at the south end of the western limestone bed, and the other two are at each end of the eastern bed. It seems probable that only a few hundred tons of limestone at the very most was taken from these quarries, as they are quite small. The remaining limestone is too small in quantity and too impure to be of any economic value.

Double Hill Deposit No. 5

Location, size, and accessibility. — The Double Hill No. 5 limestone deposit is just southwest of the center of sec. 15, T. 37 N., R. 2 W., at an altitude of about 500 feet above sea level, and is about 350 feet southwest of the pass between Double Hill and Lookout Mountain. The outcrop is about 130 feet long and 60 feet wide; it contains approximately 6,500 tons of limestone, if the exposed depth of 15 to 20 feet is assumed for the entire occurrence. The deposit is accessible by an almost overgrown quarry access road extending 250 feet southwest from a junction with the road to Double Hill No. 2 quarry about 75 feet south of the latter quarry. The area is covered with brush and second-growth trees, but contains a few partly grass covered rock knolls.

Geology and description. — The limestone forms a low, almost east-west-trending knoll bordered on the north and south by argillite and glacial drift. A northeast-trending fault cuts off extension of the limestone to the east, and on the west the limestone disappears beneath a cover of glacial drift and probably pinches out in the surrounding argillites and graywackes. The limestone is light bluish gray in color and dense to finely crystalline in texture. It is cut in places by calcite veinlets and is also intensely jointed and fractured. Recrystallized limestone on the north and south sides of the quarry contains streaks of black bituminous matter and when freshly broken gives off a strong bituminous odor.

Structures of possible organic origin, resembling stromatoporoids, were found in the limestone in several places and suggest a Devonian age.

Overlain by a large loose block of limestone, an entrance to a small cave is exposed in the west wall of the quarry. The cave's first room is about 2 to 2½ feet high and 2 to 5 feet wide and extends westward into the limestone for an estimated 20 to 30 feet. A smaller passageway can be seen leading deeper into the outcrop.

Quality. — Small amounts of chert or jasperoid are common in the limestone; otherwise it appears to be of good quality.

Chemical analysis of Double Hill No. 5 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
SJ 15-1	West face of quarry ---------	75	95.08	0.69	42.23	53.42	0.33	3.03	0.56	0.003

Ownership and development. — The owner of this deposit and the date of development are unknown. One small quarry about 50 feet long, 40 feet wide, and 10 to 20 feet deep was developed at the east end of the limestone outcrop. The floor of this quarry is overgrown with alder and other vegetation and is covered with water during the wet part of the year. About 6,500 tons of limestone might still be obtained from this occurrence.

Double Hill Deposit No. 6

Location, size, and accessibility. — The Double Hill No. 6 limestone occurrence is just west of the center of the SE¼ sec. 15, T. 37 N., R. 2 W., west of Double Hill on the northwest side of Orcas Island, at an altitude of about 460 feet above sea level. The outcrop is about 40 feet long northeast-southwest, 25 feet wide, and 5 to 10 feet high. Limestone exposed on the surface amounts to less than 400 tons. The outcrop can be reached by following the westerly one of two old logging roads leading south, starting about 275 feet west of the northwest corner of the Double Hill No. 2 quarry. This road is followed southward and then southwestward for about 225 feet. At this place the limestone is visible in a low, vegetation-covered mound about 25 feet west of the road. The area is heavily overgrown with second-growth trees and brush.

Geology and description. — The limestone forms a low, brush-covered mound rising from swampy ground in the central part of a small, gently sloping valley. The land rises to the east and west. An intermittent stream occupies the valley and has probably caused some solution of the limestone. Moss coats the limestone, which also has a large number of growing shrubs, trees, and fallen trees covering it. The limestone outcrop appears to be a mound of almost separated limestone blocks. Alluvium and soil surround it, and the nearest bedrock outcrop is an exposure of argillite on a hillside 30 to 40 feet to the east.

Chemical analysis of Double Hill No. 6 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
SJ 16-1	East side of outcrop -------	40	76.48	0.37	34.09	42.97	0.18	22.22	0.60	0.044

The limestone is light gray to gray in color and mostly crystalline in texture. One specimen examined in thin section has an organoclastic texture and contains fragments of fossil crinoids, bryozoans, and corals, along with fragments of calcite. The age is unknown. Gray jasperoid is common in the outcrop. The limestone weathers to a white or light-gray color. When limestone from some parts of the occurrence is freshly broken, a faint bituminous odor is present.

Quality. — The limestone has a high silica content in the form of jasperoid.

Ownership and development. — The owner of this property is unknown. The limestone has not been developed, and the deposit appears to be too small in size and too high in silica to be of commercial value. Also unknown is the depth and extent of the limestone under alluvium and soil.

Rusch Deposit No. 1

Location, size, and accessibility. — The Rusch No. 1 limestone deposit is thought to be just north of the south boundary of sec. 15, T. 37 N., R. 2 W., almost on the line between the SW¼ and SE¼ of the section, at an estimated altitude of 410 feet above sea level. It contains an abandoned quarry 40 to 50 feet wide and 100 feet long. The quarry is probably exhausted, as very little limestone remains exposed on the quarry walls. It can be reached by following a logging road 0.4 mile south from its junction with the West Beach-East Sound road on the north side of Double Hill. The last part of this road parallels a field on the west. The limestone is approximately 2 miles by road from East Sound.

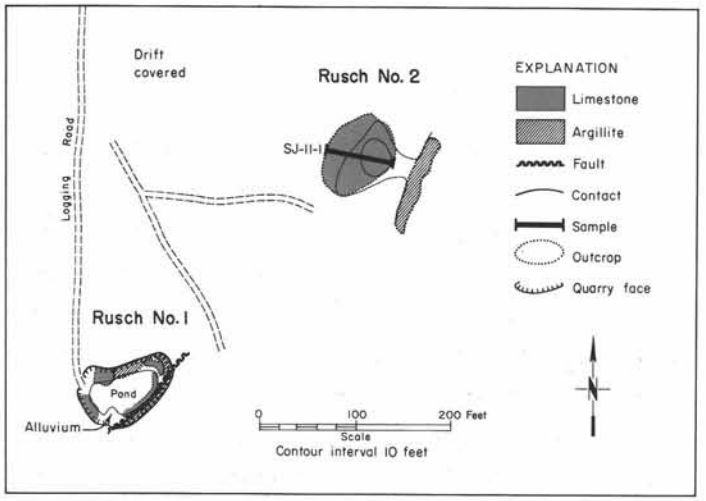


FIGURE 64. — Rusch No. 1 and No. 2 deposits. SE¼ sec 15, T. 37 N., R. 2 W. Geology by W. R. Danner, C. F. McKillop, and A. M. Rivisto. Compass and tape survey.

Geology and description. — The Rusch No. 1 limestone occurrence consists of a small amount of limestone in the walls of an abandoned quarry at the east end of a stump-covered field. Limestone is exposed at the west end of the quarry on both sides of the entrance, and at various places on the east and south walls. Along the south wall the limestone is only a few feet thick and is separated from argillite by a fault zone filled with black gouge. At the east end of the quarry the limestone is overlain by 3 feet of argillite and glacial drift. The argillite lies horizontally above the limestone at the north end of the exposure but dips steeply to the south in the south part of the exposure. At least two solution cavities, from 6 inches to 1 foot in width and of unknown length, penetrate the limestone on the south quarry wall.

The limestone is crystalline to dense in texture and light gray to gray blue in color. It is cut by white calcite veinlets. Limestone on the dump at the quarry entrance contains tiny siliceous granules on weathered surfaces. Along the north wall of the quarry near the northeast corner is a bed of argillaceous limestone that, where weathered, contains organic structures similar to stromatoporoids. These structures are partially silicified. In thin section, some of the limestone is organoclastic in texture and contains a few oölites. Most of it is partially recrystallized and in places slightly silicified.

On the quarry floor is a semipermanent pond inhabited by Pacific Coast newts (Triturus granulosus).

Quality. — No samples were collected for chemical analysis, but limestone on the dump and in the quarry walls appears to be of good quality except for varying amounts of secondary silica.

Ownership and development. — Local residents stated that the owner of the property was a Mr. Rusch, who lived in Arizona. No information could be obtained about the operator of the quarry or the date on which it was opened. Alder

trees an inch or more in diameter are growing on the quarry floor. The occurrence appears to be exhausted and is of no economic value.

Rusch Deposit No. 2

Location, size, and accessibility. — The Rusch No. 2 limestone deposit is about 225 feet northeast of Rusch No. 1, at an estimated altitude of 425 feet above sea level in the SW¼SE¼ sec. 15, T. 37 N., R. 2 W. The outcrop is about 85 feet long northeast-southwest, 65 feet wide, and contains about 2,000 tons. It can be reached by hiking through the woods on a bearing of about N. 50° E. for 225 feet from the Rusch No. 1 abandoned quarry or by following an overgrown and abandoned logging road starting about 200 feet north of the Rusch No. 1 quarry and following the road's east fork 200 feet almost due east to where the limestone outcrop can be seen to the north. The area is covered with dense brush and second-growth trees.

Geology and description. — The limestone outcrop is a west-facing knob projecting from a steep west-sloping hillside consisting of graywacke. An apron of limestone talus surrounds the outcrop. The limestone is light gray in color and crystalline in texture. The moss-coated outcrop knob is about 15 feet in maximum height. No fossils were visible, and the age of the limestone is unknown.

Quality. — The limestone is of good quality but contains silica as a minor impurity.

Chemical analysis of Rusch No. 2 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
SJ 11-1	East-west across top of outcrop	70	97.63	0.27	43.30	54.85	0.13	1.10	0.50	0.041

Ownership and development. — The owner of the property is unknown. There has been no development. The occurrence is probably too small to be of much economic value.

Langell Deposit

Location, size, and accessibility. — The Langell limestone deposit is in approximately the NW¼SE¼SE¼ sec. 15, T. 37 N., R. 2 W., in a small intermittent stream valley between Lookout Mountain on the south and Double Hill on the north, about 4/5 mile southwest of East Sound village. Its altitude is estimated to be between 310 and 360 feet above sea level. The limestone is in or immediately adjacent to the streambed and consists of two small areas of scattered outcrops about 110 feet apart. One of these outcrop areas is about 70 feet long and 20 feet wide; the other is about 40 feet long and less than 10 feet wide. They can be reached by following a farm road about ¼ mile from its intersection with the East Sound-West Sound road in the SE. cor. sec. 15. The farm road extends up the hillside to the ruins of an old farmhouse. From the farmhouse one follows a poor trail across a field and then a partly washed out logging road for a total distance of approximately 700 feet. The logging road parallels the intermittent streambed in which are the limestone outcrops. The limestone is in the midst of a dense cover of salmonberries, nettles, and other water-loving vegetation and is difficult to locate.

Geology and description. — The lower of the two limestone outcrop areas is in the intermittent streambed and consists of small exposures and large individual boulder-like masses of limestone surrounded by alluvium. Several small sinkholes and cavelike openings are present. One of the latter exposes argillite underneath limestone. One small cave extends back into the hillside about 10 feet and has a mud floor.

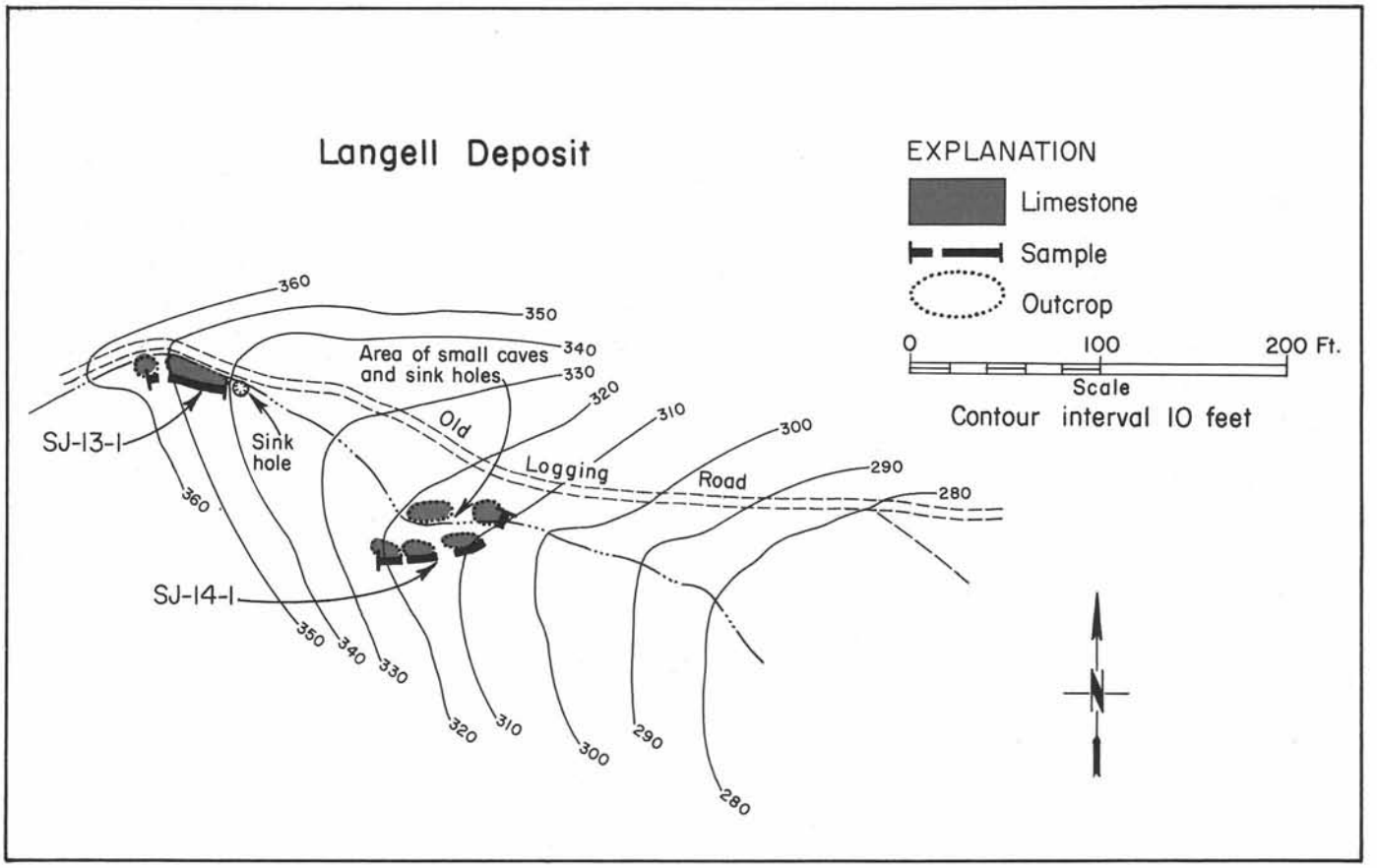


FIGURE 65. — Langell deposit. SE¼ sec. 15, T. 37 N., R. 2 W. Geology by W. R. Danner, C. F. McKillop, and A. M. Rivisto. Compass and tape survey.

Approximately 110 feet upstream is a second outcrop area consisting of two limestone exposures about 10 feet apart. The total length of these is 40 feet. On the south bank of the streambed and below the limestone is an opening about 18 by 6 inches leading down about 10 feet vertically, then bending to the northeast and extending an unknown distance in that direction.

The limestone in this occurrence is blue gray to white on fresh surfaces and weathers white. It is finely crystalline to dense in texture and contains argillaceous and cherty material. No fossils are visible on weathered surfaces, but thin sections show structures similar to those of stromatoporoids. The age of the limestone is unknown. Except for one small exposure of argillite underlying it, the relations to bedrock are also unknown.

Quality. — Much of the limestone has a high silica content, and because of the small size of the occurrence it is doubtful that much pure material could be obtained.

Chemical analyses of Langell 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
SJ 13-1	West ----------	40	85.42	0.35	37.36	47.99	0.17	13.34	1.05	0.012
SJ 14-1	East ----------	70	91.26	0.50	40.97	51.27	0.24	6.84	0.60	0.013

Ownership and development. — The limestone is owned by Nova Langell, of East Sound, Orcas Island, Wash. It has had no development. It appears to be too small in size to have any economic value. However, overlying soil, drift, and alluvium will have to be removed to determine the true size of the limestone body.

Englehartson Deposit

Location, size, and accessibility. — The Englehartson limestone body is in the N½SE¼ sec. 20, T. 37 N., R. 2 W., at an estimated altitude between 110 and 210 feet above sea level on a steep, north-facing hillside above the waters of President Channel. It consists of a poorly exposed lenticular body of limestone that is approximately 375 feet long northeast-southwest and has a maximum width of 125 feet. Between 30,000 and 40,000 tons of limestone are exposed. This occurrence is difficult to locate without a guide. It can be found by following limestone float from the beach up the steep brushy hillside for about 300 feet. Another way to reach the limestone is to follow an old overgrown logging road from the beach south up the hillside in the south part of the NE¼ sec. 20, to a barbed-wire fence, and then to follow a very faint logging road southward. A lower fork of this road is downhill from the limestone, and an upper fork crosses the limestone outcrop. The area is covered with an exceptionally dense growth of brush and second-growth trees.

Geology and description. — The deposit is one of several lenticular bodies of limestone in a sequence composed predominantly of volcanic rocks and graywackes of Early Pennsylvanian and Middle Devonian age. Small amounts of ribbon chert, shale, and sandstone also occur in the sequence. The rocks trend northeastward and have moderately steep dips to the southeast. An exposure of chert on the beach below and north of the limestone strikes N. 30° E. and dips 60° SE. The Englehartson limestone body is poorly exposed but is believed to be a lenticular northeast-striking bed having a maximum thickness near 50 feet and a moderate dip to the southeast under volcanic rocks.

The limestone is light gray in color and organoclastic to crystalline in texture. It contains numerous small masses of jasperoid, some of which, where weathered, contain traces of crinoid columnals and bryozoan fragments. In thin section, one specimen was seen to be composed of oölites and fossil fragments and to contain foraminifers similar to Eostaffella and Endothyra, indicating an Early Pennsylvanian or possible Late Mississippian age. Much of the limestone of this bed gives off a strong bituminous odor when freshly broken.

The limestone crops out as a low, moss-covered knob on the side of a steep and very brushy slope. It is exposed at the base of a large stump and in several prospect holes in the vicinity. Chert and argillite are associated with the limestone. A few hundred feet to the south is another, smaller outcrop that has an exposure of about 300 square feet. It was uncovered several years ago, when the property was logged. Volcanic rocks crop out to the north and west of it; glacial drift and soil cover the area to the south and east. Another small limestone outcrop lies about 200 feet farther south and is exposed over an area of about 400 square feet. As the area between the three outcrops described above is covered with drift and soil, it is not known whether they are connected. The general lenticular nature of other Paleozoic limestone bodies in this area would suggest that they are probably not connected.

Chemical analyses of Englehartson limestone

Sample no.	Location	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
1/ SJ 9-1	North-south ---	350	82.41	0.81	36.68	46.30	0.39	15.95	0.78	0.023
2/			72.30		32.08	40.56	0.02	26.04	3/ 1.18	

1/ Sample collected for this report, Mark Adams, analyst.

2/ Dolmage, V. (1948, private report, p. 9). Analysis by G. S. Eldridge & Co. Ltd.

3/ Fe_2O_3 = 0.82, Al_2O_3 = 0.36.

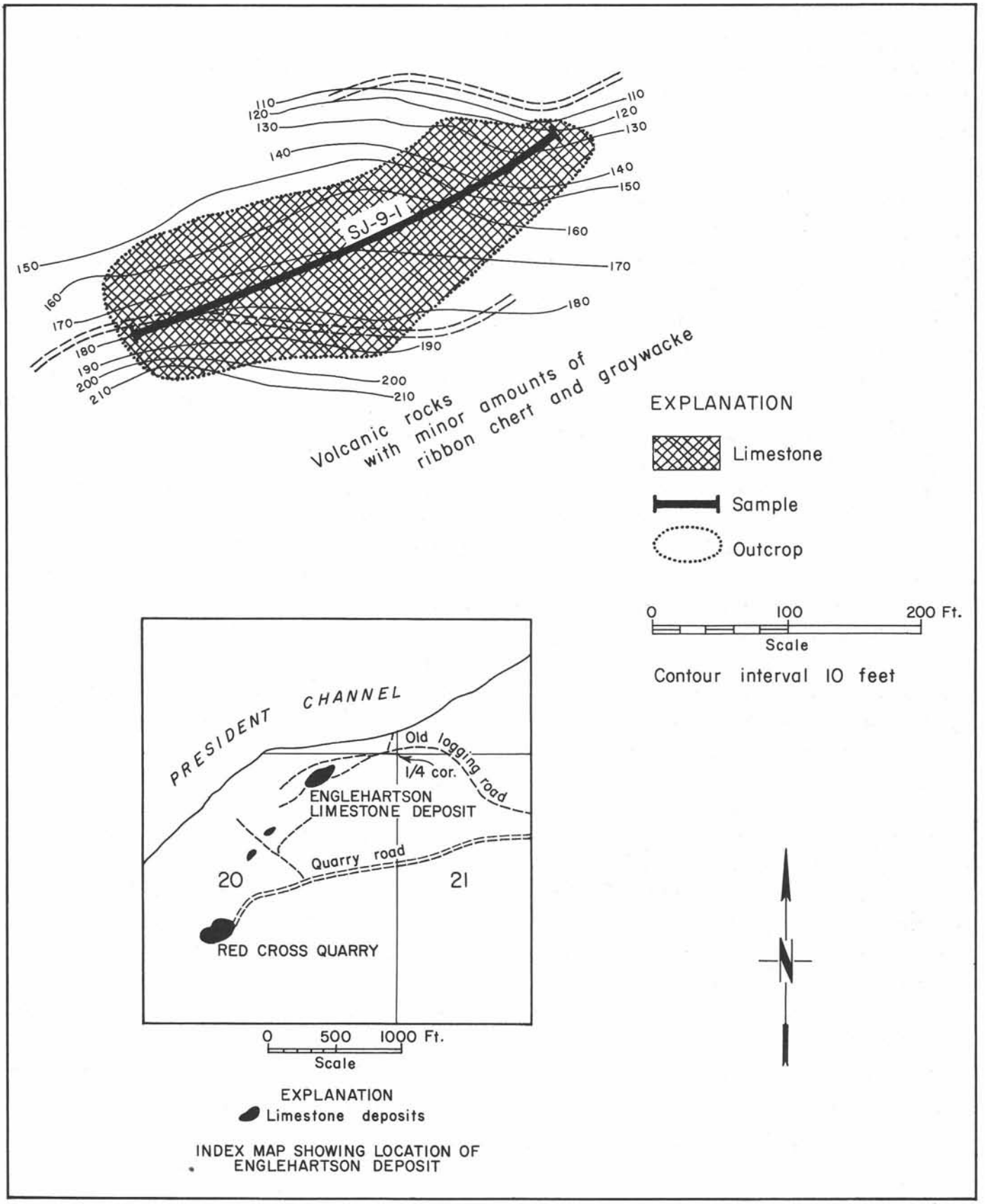


FIGURE 66.—Englehartson deposit. SE¼ sec. 20, T. 37 N., R. 2 W. Geology by W. R. Danner, C. F. McKillop, and A. M. Rivisto. Compass and tape survey.

Quality. — Parts of the limestone have a high silica content.

Ownership and development. — Most of the limestone constituting this occurrence is owned by Mrs. W. G. Englehartson, who lives to the east of the outcrop area in the NE¼SW¼ sec. 21, T. 37 N., R. 2 W. The southerly one of the two smaller outcrops was formerly owned by the Roche Harbor Lime and Cement Company, but it is now owned by Gordon C. Clauson, of Seattle. None of these limestone outcrops has ever been developed. The largest deposit might support a small short-lived operation, but it should be drilled and sampled to determine quality and quantity.

Reference. — Danner (1948, unpublished private report).

East Sound Quarry

Location, size, and accessibility. — The East Sound limestone occurrence is in the NE¼SW¼ sec. 14, T. 37 N., R. 2 W., on the north side of the East Sound highway about 475 feet south from the road junction at the west side of the village of East Sound. It consists of an abandoned quarry about 90 feet long, 50 feet wide, and 25 feet deep. Only two small exposures of limestone are visible in the quarry. One, on the west side of the quarry floor, is about 40 feet long and about 1 foot high; the other outcrop, on the east wall of the quarry, is about 3 feet long. The quarry, which is a little over ¼ mile southwest of the center of East Sound village, is easily accessible from the East Sound highway, which is next to the quarry rim on the south side.

Geology and description. — Very little can be said about the geology of this limestone because of the lack of exposure. Limestone is exposed only in the floor of the quarry, over a small area; argillite is exposed in the northwest corner of the quarry floor; and the rest is covered with debris, glacial drift, soil, and vegetation. The hillside to the west and north contains outcrops of volcanic rocks. To the east on the beach similar volcanic rocks are exposed, and to the north on the beach these volcanic rocks are in fault contact with a sequence of indurated graywacke and argillite. On the beach cliffs to the south are exposures of amphibolite gneiss.

The limestone is dark gray to black on fresh surfaces and weathers to a light-gray color. It is dense to partly crystalline in texture and is cut by white calcite veinlets. Black carbonaceous shale is interbedded with the limestone. No fossils are visible in the quarry outcrops, but limestone float on the beach below the quarry contains poorly preserved and partially silicified fossils that resemble corals. No definite age could be assigned to this limestone.

Quality. — This deposit was not sampled because of its small size. In hand specimen the limestone appears to contain a considerable amount of argillaceous and carbonaceous material. Limestone float on the beach contains some jasperoid.

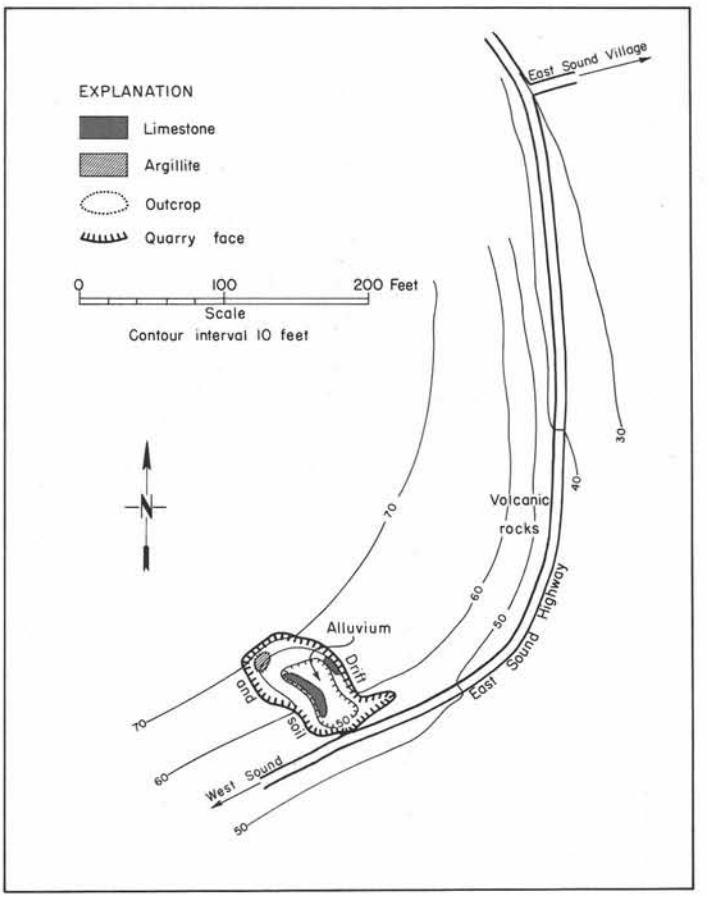


FIGURE 67. — East Sound deposit. NE¼SW¼ sec. 14, T. 37 N., R. 2 W. Geology by W. R. Danner, C. F. McKillop, and A. M. Rivisto. Compass and tape survey.

Ownership and development. — The owner of the limestone is unknown. The date of development of the property is also unknown, but the quarry is thought to be quite old. It is heavily overgrown with brush and is used as a garbage dump. A small abandoned limekiln on the beach below and east of the quarry may have been built to burn limestone from it. The sandstone blocks used in the walls of this kiln are highly weathered, and many of them are almost half disintegrated. The limestone quarry is considered to be exhausted and of no commercial value.

Fowler Deposit No. 1

Location, size, and accessibility. — The Fowler No. 1 limestone deposit is in the SW¼NE¼ sec. 22, T. 37 N., R. 2 W., on the south side of the East Sound-West Sound highway just southwest of its intersection with the Orcas Landing road. The limestone forms a small south-facing knob about 70 feet long and 50 feet wide. It is 20 feet high on its south side and contains less than 3,000 tons of limestone in surface exposure. It is easily accessible, being only about 15 feet from a main road and approximately 1½ miles south of East Sound village. The limestone outcrop is mostly covered with brush and trees.

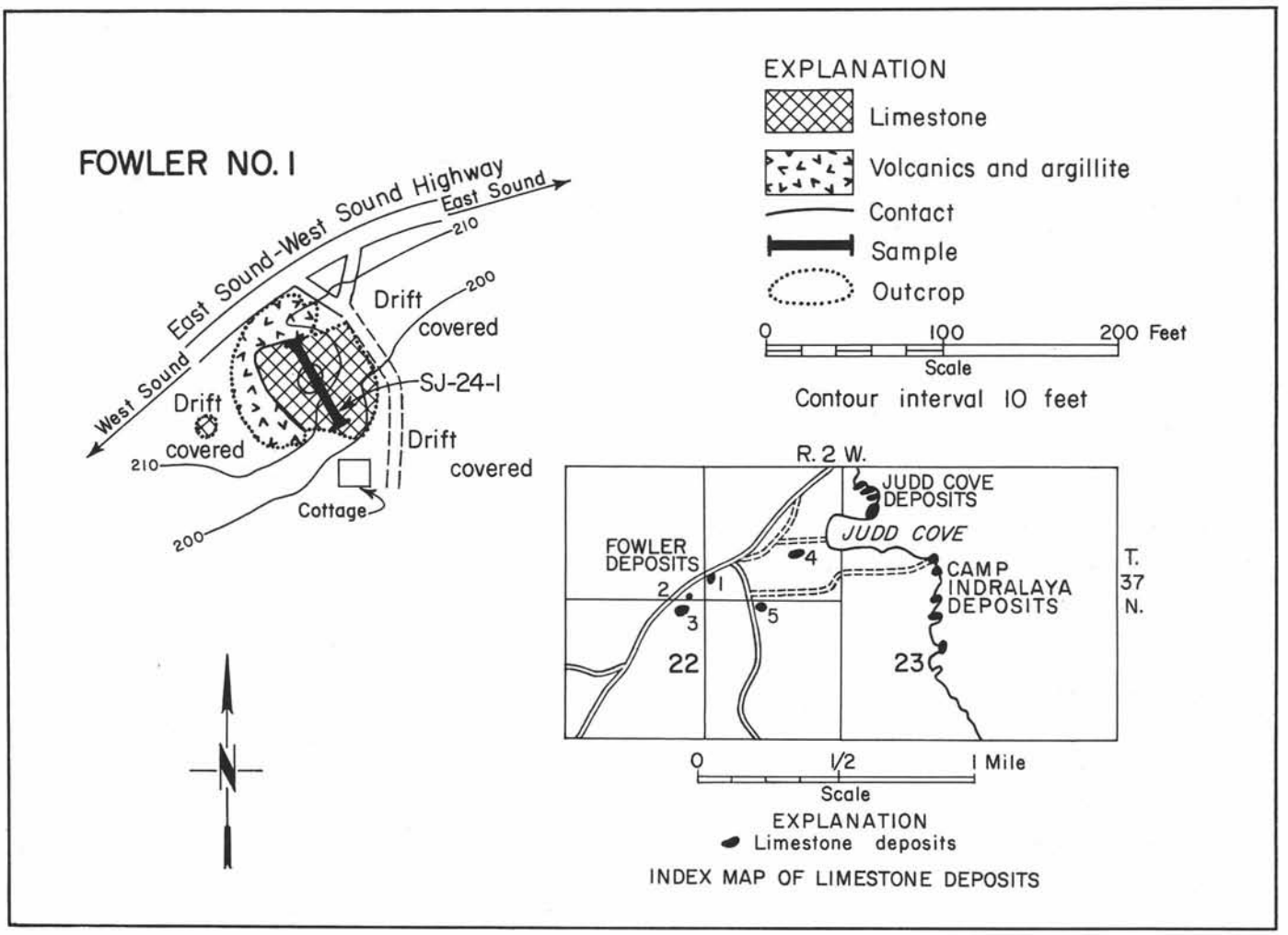


FIGURE 68. — Fowler No. 1 deposit. SW¼NE¼ sec. 22, T. 37 N., R. 2 W. Geology by W. R. Danner, C. F. McKillop, and A. M. Rivisto. Compass and tape survey.

Geology and description. — The limestone appears to be a lenticular body interbedded in a sequence composed predominantly of sheared volcanic rocks. These crop out along the north and west sides of the limestone. About 35 feet to the southwest is another small exposure of limestone, about 2 feet square, surrounded by soil and glacial drift. It is not known whether this is an outcrop or a partly buried boulder.

The limestone is massive in appearance, white to dark gray blue in color, and crystalline in texture. The outcrop surface is moss covered. When freshly broken, the limestone gives off a bituminous odor. No fossils were seen. The age is unknown but is probably Permian.

Quality. — The limestone of this occurrence appears to be of good quality, containing only a minor amount of silica.

Chemical analysis of Fowler 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
SJ 24-1	70	96.81	0.85	43.17	54.39	0.41	1.38	0.82	0.112

Ownership and development. — The limestone is owned by H. E. Fowler, who lives on the property. The deposit has not been developed. It is probably too small to be of any economic value, and its nearness to a highway and inhabited buildings would hinder any development.

Fowler Deposits No. 2 and No. 3

Location, size, and accessibility. — The Fowler No. 2 limestone occurrence is thought to be in the SE¼NW¼ sec. 22, T. 37 N., R. 2 W., and the Fowler No. 3 is adjacent to it in the NE¼SW¼ of the same section. Both are in a gently south
West Sound highway. The Fowler No. 2 limestone body forms a knoll about
of 8 feet on its south side. The Fowler No. 3 limestone body is about 140
ly for about 20 feet. It contains an estimated 10,000 tons in outcrop. Both
ss pastures for about 1,000 feet from the Fowler farm buildings or by walking
ay. The outcrops of No. 3 and part of No. 2 are covered with brush. The
ep pasture.

No. 2 limestone occurrence is a bedrock knoll surrounded by soil and glacial
the east and west are composed of cherty argillite, ribbon chert, and vol-
ular body striking northeast and dipping moderately to the southeast. A small
utcrop; it penetrates the limestone only a short distance before its roof slopes
blue in color and dense to crystalline in texture. It weathers to a light gray.
were found in dense-textured limestone on the top of this outcrop, but speci-

135 feet southeast of Fowler No. 2. It consists of buff-weathering limestone,
herty in outcrop as is Fowler No. 2. It also appears to be a lenticular body
under cover to connect with Fowler No. 2 to the north is not known. It is
ll exposed.

gh-calcium limestone, but Fowler No. 3 has argillaceous and siliceous
m.

Effective July 1, 1967, the Division of Mines a
Geology of the Washington Department of Conservation,
transferred to the Department of Natural Resources, in
accordance with Senate Bill 143 that passed the last sessi
of the legislature.

Temporarily, at least, we are remaining in our
present quarters, but our new mailing address will be:

Department of Natural Resources
Bert L. Cole, Commissioner of Public Lands
Division of Mines and Geology
P. O. Box 168
Olympia, Washington 98501

Chemical analyses of Fowler No. 2 and No. 3 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)
SJ 25-1	Fowler 2 --	21	97.95	0.73	43.23	55.03	0.35	0.69	0.35	0.150	270	610	1/	70
SJ 26-1	Fowler 3 --	90	86.54	2.75	39.30	48.62	1.31	7.86	2.37	0.290				

1/ Less than 30.

Ownership and development. — The limestone outcrop area is owned by H. E. Fowler, who lives on the property to the east of the exposures. The limestone has not been developed. The larger of the two deposits contains more impurities than the smaller, but it would seem worth while to drill these outcrops and the area between to ascertain whether they are large enough to support a small quarry. However, there is no geologic evidence on the surface to indicate that the limestone bodies are any larger in area than they show in outcrop.

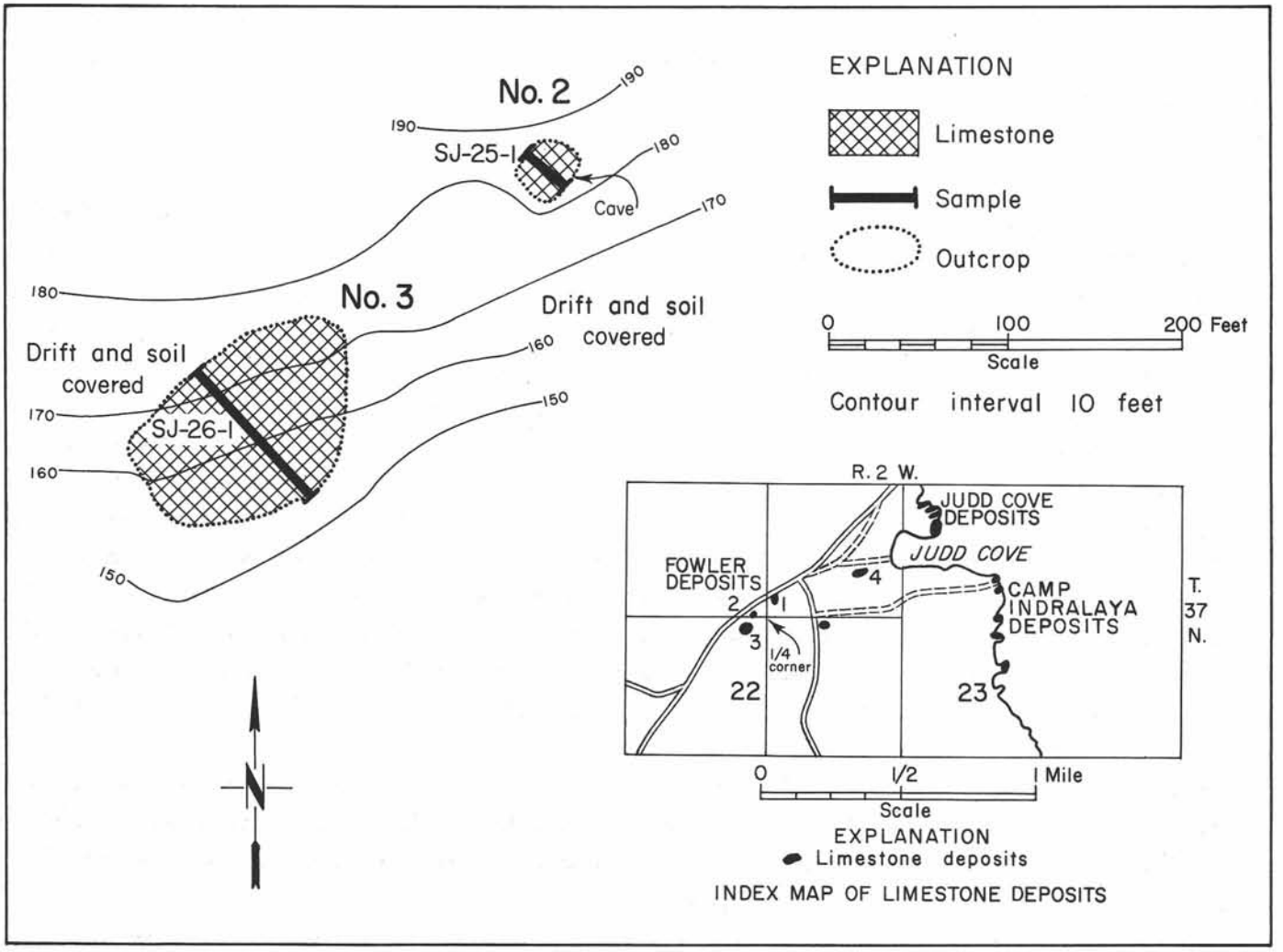


FIGURE 69. — Index map of limestone deposits in secs. 22 and 23, T. 37 N., R. 2 W., and map of Fowler No. 2 and No. 3 deposits. SE¼NW¼ and NE¼SW¼ sec. 22, T. 37 N., R. 2 W. Geology by W. R. Danner, C. F. McKillop, and A. M. Rivisto. Compass and tape survey.

Judd Cove Deposit

Location, size, and accessibility. — The Judd Cove limestone deposit is in the NW¼NW¼ sec. 23, T. 37 N., R. 2 W., on the peninsula forming the north side of Judd Cove, in Fishing Bay on the northwest side of East Sound. The occurrence is composed of numerous small lenticular beds of limestone. The bed that has the greatest exposed length is about 200 feet long, but the width of this particular body commonly does not exceed 20 feet. Another outcrop is about 60 feet long and has a maximum exposed width of 40 feet. The average width of most outcrops is from 5 to 10 feet.

The area is accessible by boat and is about 1 mile southwest across East Sound from the village of East Sound. The area can be reached over land by following an eastward-heading private road extending ¼ mile to the head of Judd Cove from the East Sound highway at the junction of the East Sound-West Sound and East Sound-Orcas Landing highways. The limestone outcrops are reached by hiking a few hundred feet to the northeastern part of the peninsula.

Geology and description. — The deposit is composed of four or five small lenses of limestone interbedded in a faulted and sheared sequence of submarine-deposited basalts, ribbon cherts, and argillites. To the north the sequence is separated from amphibolite gneiss and diorite by a drift- and soil-covered area. Drift conceals bedrock to the south, at the head of Judd Cove. The limestone beds pinch and swell along strike and contain interbedded argillaceous material.

In the northern part of the peninsula the beds appear to strike mostly northeast-southwest and to dip to the southeast, but to the south the strike changes to northwest-southeast and the dip to the southwest. Faults, apparently of small displacement, are numerous.

The side of the peninsula facing the water consists of rock cliffs as much as 50 feet in height. The top of the peninsula is gently sloping and is covered with second-growth trees and brush.

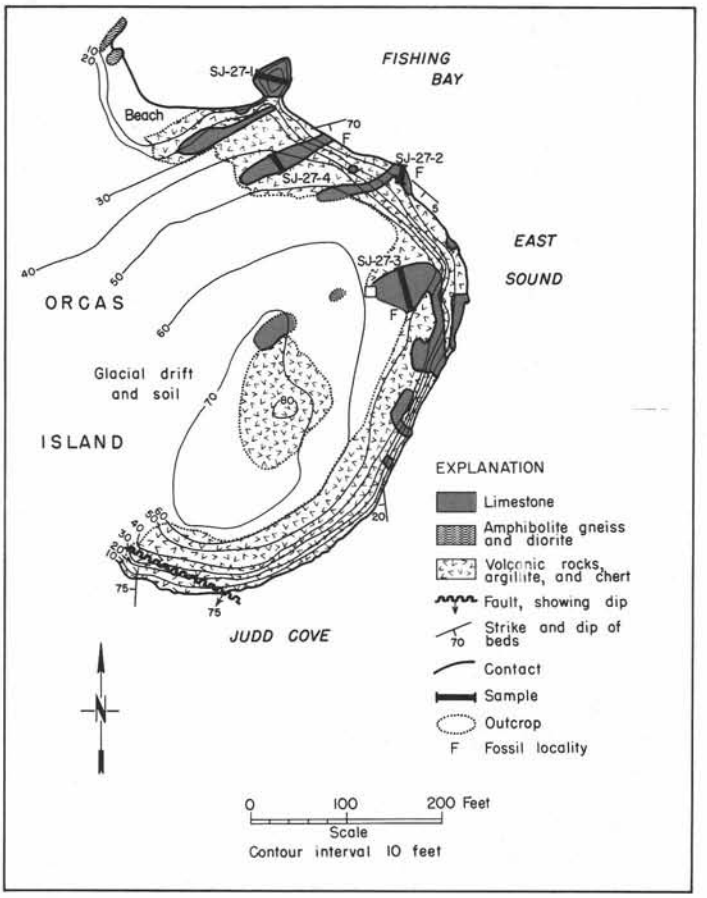


FIGURE 70. — Judd Cove deposits. NW¼NW¼ sec. 23, T. 37 N., R. 2 W. Geology by W. R. Danner, C. F. McKillop, and A. M. Rivisto. Compass and tape survey.

Chemical analyses of Judd Cove 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
SJ 27-1	North point -----	30	87.71	0.43	39.18	49.28	0.21	9.99	1.16	0.054
SJ 27-2	Bed 2 ---------	10	92.18	2.82	42.12	51.79	1.35	3.33	0.90	0.010
SJ 27-3	Cliff top -------	40	92.77	0.73	40.65	52.12	0.35	4.81	1.33	0.062
SJ 27-4	North cliff ------	15	97.06	0.60	42.94	54.53	0.29	1.40	0.36	0.028

The limestone is dark gray to light gray in color and dense to crystalline in texture. It weathers to a light-gray or buff color. Jasperoid, carbonaceous masses, and argillaceous material occur with the limestone as impurities. Some parts of the northern limestone beds consist of a fusulinid coquina. The Permian fusulinids Schwagerina and Yabeina have been identified from these beds, and other genera may be present.

Quality. — The quality of the different outcrops is quite variable. Impurities such as jasperoid and argillaceous material are visible in most of the limestone.

Ownership and development. — The area is owned by H. E. Fowler, who lives ¼ mile to the west. There has been no development. The limestone bodies are too small and impure to be of economic value.

Reference. — McLellan (1927, p. 168).

Fowler Deposit No. 4

Location, size, and accessibility. — The Fowler No. 4 limestone occurrence is in the SE¼NE¼ sec. 22, T. 37 N., R. 2 W., on a steep north-facing slope just south of the private road leading to Judd Cove. It consists of five small outcrops around an abandoned quarry. The largest outcrop is a lenticular bed about 60 feet long and 7 to 10 feet thick. The quarry can be reached by climbing up a steep hillside from the road a slope distance equal to a horizontal distance of about 50 feet and a vertical distance of 40 feet. The area is covered with second-growth trees and dense brush.

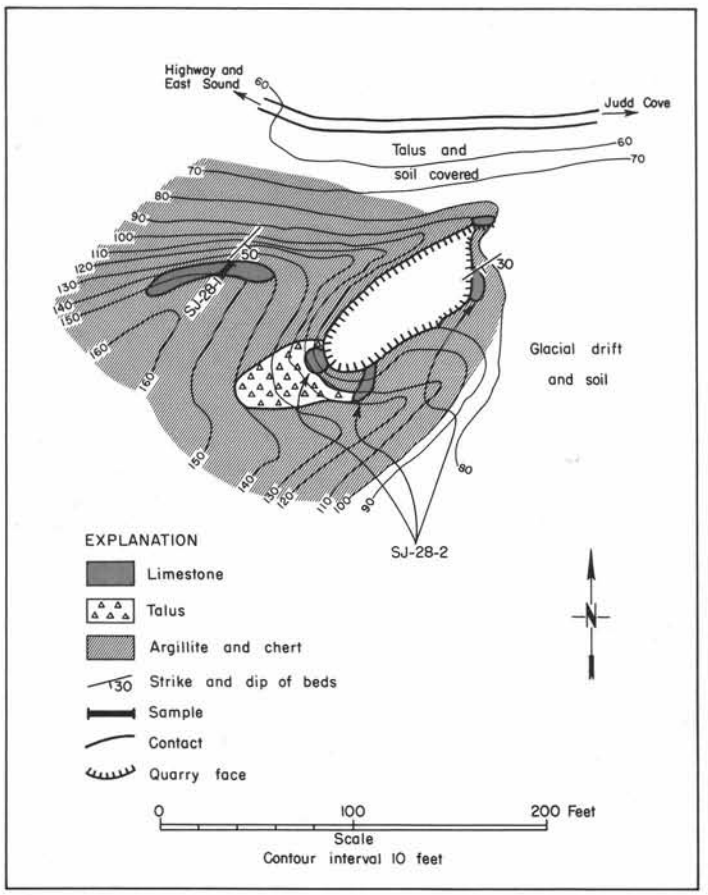


FIGURE 71. — Fowler No. 4 deposit. SE¼NE¼ sec. 22, T. 37 N., R. 2 W. Geology by W. R. Danner, C. F. McKillop, and A. M. Rivisto. Compass and tape survey.

Geology and description. — The occurrence before quarrying consisted apparently of one or more lenticular limestone beds in a sequence of argillite and chert. This sequence strikes N. 40°-70° E. and dips at angles of 30°-60° SE. Only remnants of the original limestone body are left, and these are small scraps on the walls of the quarry and on the cliffs immediately to the west.

On the west side of the quarry is a small outcrop of blue-gray crystallized limestone, roughly about 4 feet square. It is partly covered with talus fallen from the argillite above. When freshly broken, this limestone emits a strong bituminous odor. Smaller limestone outcrops are found on the south and east walls of the quarry and at the entrance on the north side. In thin section the limestone is seen to be mostly crystalline in texture, but it contains poorly preserved organic structures.

A bed of crystalline light-gray, blue-gray, and reddish-gray limestone is exposed on a cliff to the west of the quarry. It dips about 50° southeastward into the cliff face under argillite and chert. The limestone can be traced for 60 feet before it pinches out. Vertically, it is exposed for 7 to 10 feet.

The age of this limestone is unknown, and no definitely identifiable fossils were found. The quarry lies on the northeast side of a small steep-sided hill.

Quality. — The Fowler No. 4 limestone is impure and siliceous. The silica content is due in part to the growth of authigenic silica.

Chemical analyses of Fowler No. 4 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
SJ 28-1	Ledge north of quarry --------	10	84.55	0.60	37.29	47.50	0.29	13.33	0.93	0.100
SJ 28-2	Quarry walls ----	Composite	84.87	0.58	37.62	47.68	0.28	13.31	0.74	0.078

Ownership and development. — The property is owned by H. E. Fowler, who lives to the west at the main road intersection. Limestone from this quarry apparently was hauled eastward to a small limekiln at the head of Judd Cove. Only the ruins of this kiln remain. There is very little limestone left in the quarry, and the occurrence can be considered to be exhausted. The date of the development and the persons involved are unknown.

Fowler Deposit No. 5

Location, size, and accessibility. — The Fowler No. 5 limestone occurrence is in a field a few feet south of the Camp Indralaya road in the NW¼SE¼ sec. 22, T. 37 N., R. 2 W., near the junction of the Camp Indralaya road and the East Sound-Orcas Landing road. Two small limestone outcrops only a few square feet in area and about 50 feet apart compose the occurrence. It can be reached by going about 100 feet east from the highway on the Camp Indralaya graveled road and then going a few feet south of the fence paralleling the road, into a pasture.

Geology and description. — Limestone is exposed in two small outcrops about 50 feet apart north-south, on the east side of a gently sloping knoll composed in part of volcanic rocks and ribbon chert. The limestone is white to light gray in color and crystalline in texture. Its altitude is unknown. The limestone exposures are too small to give any idea as to the true size or shape of the body.

Quality. — The few square feet of outcropping limestone was sampled by taking chips and is of high-calcium type.

Chemical analysis of Fowler No. 5 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
SJ 31-1	Composite	96.83	0.62	42.22	54.40	0.30	1.48	0.92	0.210

Ownership and development. — The property is owned by H. E. Fowler, who lives a short distance to the northwest at the main road intersection. There has been no development, and the outcrop is too small to be of any economic value. Because of poor exposure, drilling or stripping would have to be done to determine the actual size of the deposit.

Camp Indralaya Deposit

Location, size, and accessibility. — The limestone outcrops at Camp Indralaya are in the NW¼ sec. 23, T. 37 N., R. 2 W. They consist of eight or more small limestone pods exposed on the beach cliffs south of Judd Cove on the northwest side of East Sound. The largest bed is exposed along the beach for a distance of 35 feet and may extend inland for approxi-

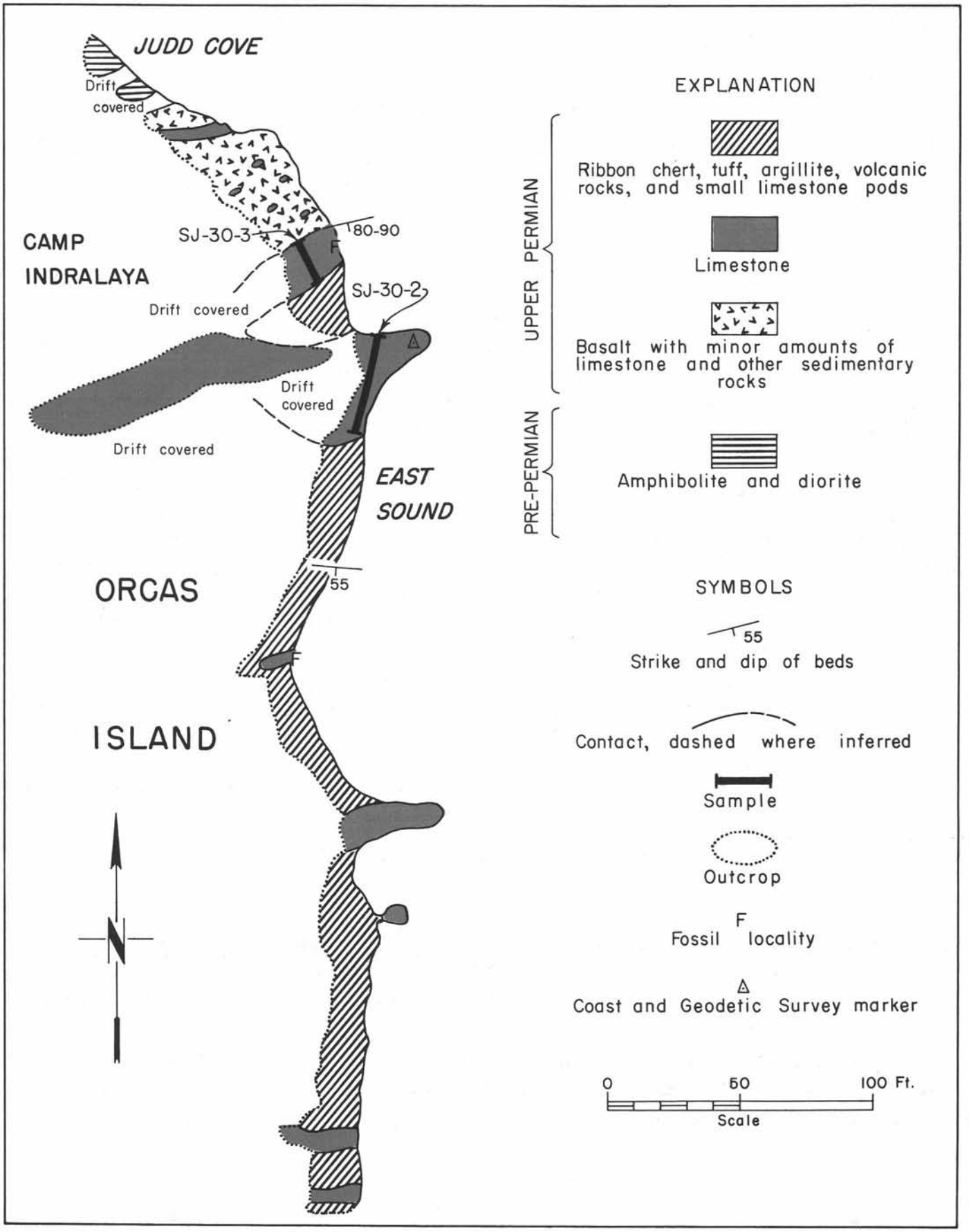


FIGURE 72. — Camp Indralaya deposits. NW¼ sec. 23, T. 37 N., R. 2 W. Geology by W. R. Danner and C. F. McKillop. Compass and tape survey.

mately 150 feet. However, there is doubt that it is continuous over this distance, and it appears to thin inland. Other beds generally range from 5 to 15 feet in thickness.

The limestone outcrops are accessible by boat and are about 1 mile south of East Sound village. They can be reached over land by turning east from the East Sound-Orcas Landing highway about 1½ miles southwest of East Sound village and following the Camp Indralaya graveled road ½ mile to the camp, then by hiking a few hundred feet to the beach cliffs. A trail follows along the top of the cliffs to the south, and most parts of the beach are accessible at low tide. The area inland from the outcrops is covered with dense second-growth trees and brush and is mantled with glacial drift.

Geology and description. — The limestone bodies of this occurrence consist of a series of lenticular beds and pods interbedded with argillite, ribbon chert, and with submarine extruded basalts and tuffs. The sequence dips southward from 0 to 90°. The rocks are highly sheared. North of this occurrence, on the south side of Judd Cove, the sequence overlies amphibolite gneiss and diorite. The nature of the contact is unknown. To the south, the limestone-bearing sequence is in fault contact with similar gneisses and diorite, and a prominent serpentine and gouge zone marks the boundary.

The northernmost bed of limestone is about 7 feet thick. It is underlain by basalt and is overlain by 2 feet of interbedded limestone and argillite, above which is several feet of basalt containing small limestone pods or fragments. Above this is a bed of limestone 15 to 17 feet thick composed of large and mostly recrystallized Permian fusulinids. This bed is overlain by several feet of chert, argillite, and volcanic rocks. Above this is a bed of limestone about 35 feet thick. Limestone is poorly exposed inland for a distance of 150 feet, but there is no visible connection with the beds on the beach. To the south for the next 300 feet are cherts, chert breccias, chert grits, argillites, and flow and fragmental volcanic rocks. Small limestone bodies are interbedded with these other rocks. Some of the exposures are intensely sheared and broken by small faults. Outcrops are exposed vertically for 8 to 30 feet.

About 1,000 feet farther south is another small limestone body, about 17 feet thick, exposed for 30 feet or more along the shore. It also contains Permian fusulinids. Underlying it are vesicular pillow lavas, green tuffs, red argillites, and chert breccias.

The limestone exposed along this shore is gray in color and weathers to a light buff. It is dense to crystalline in texture and is in part a fusulinid coquina. It contains specimens of the Permian fusulinid Yabeina, as well as smaller unidentified foraminifers, and is believed to be late Permian in age.

Calcareous tufa coats the rocks of the beach cliffs where springs emerge along fault contacts with underlying crystalline igneous and metamorphic rocks.

Quality. — The limestone appears to be of high quality. Argillaceous interbeds are visible at a few places.

Chemical analyses of Camp Indralaya 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
SJ 30-1	Southernmost outcrop ------	30	95.19	0.98	42.27	53.48	0.47	2.69	0.80	0.120
SJ 30-2	Bed 3 ---------	35	93.80	3.40	43.12	52.70	1.63	1.61	0.73	0.055
SJ 30-3	Bed 2 ---------	17	96.61	0.64	43.10	54.28	0.31	1.20	0.65	0.024

Ownership and development. — The limestone is on property of Camp Indralaya, of the Orcas Island Foundation, a society believing in theosophy. There has been no development. The limestone beds are too small to be of any economic value.

Pineo Deposits No. 1 and No. 2

Location, size, and accessibility. — The Pineo No. 1 and No. 2 deposits are in the E½ sec. 3, T. 36 N., R. 2 W., on the northwest side of a northwest ridge of Mount Woolard. The occurrence contains two abandoned quarries, the larger of which is about 250 feet long, 100 feet wide, and 10 to 30 feet deep, and the smaller of which is about 100 feet long, 75 feet wide, and 10 to 15 feet deep. The quarries can be reached by following a good graveled road about 3/4 mile east and north from its intersection with the Orcas Landing-East Sound road at the common corner of secs. 3, 4, 9, and 10, then going up a steep and rough logging road ½ mile northeast to the quarries, at an altitude of 450 to 500 feet. The terrain is covered with dense brush and second-growth trees.

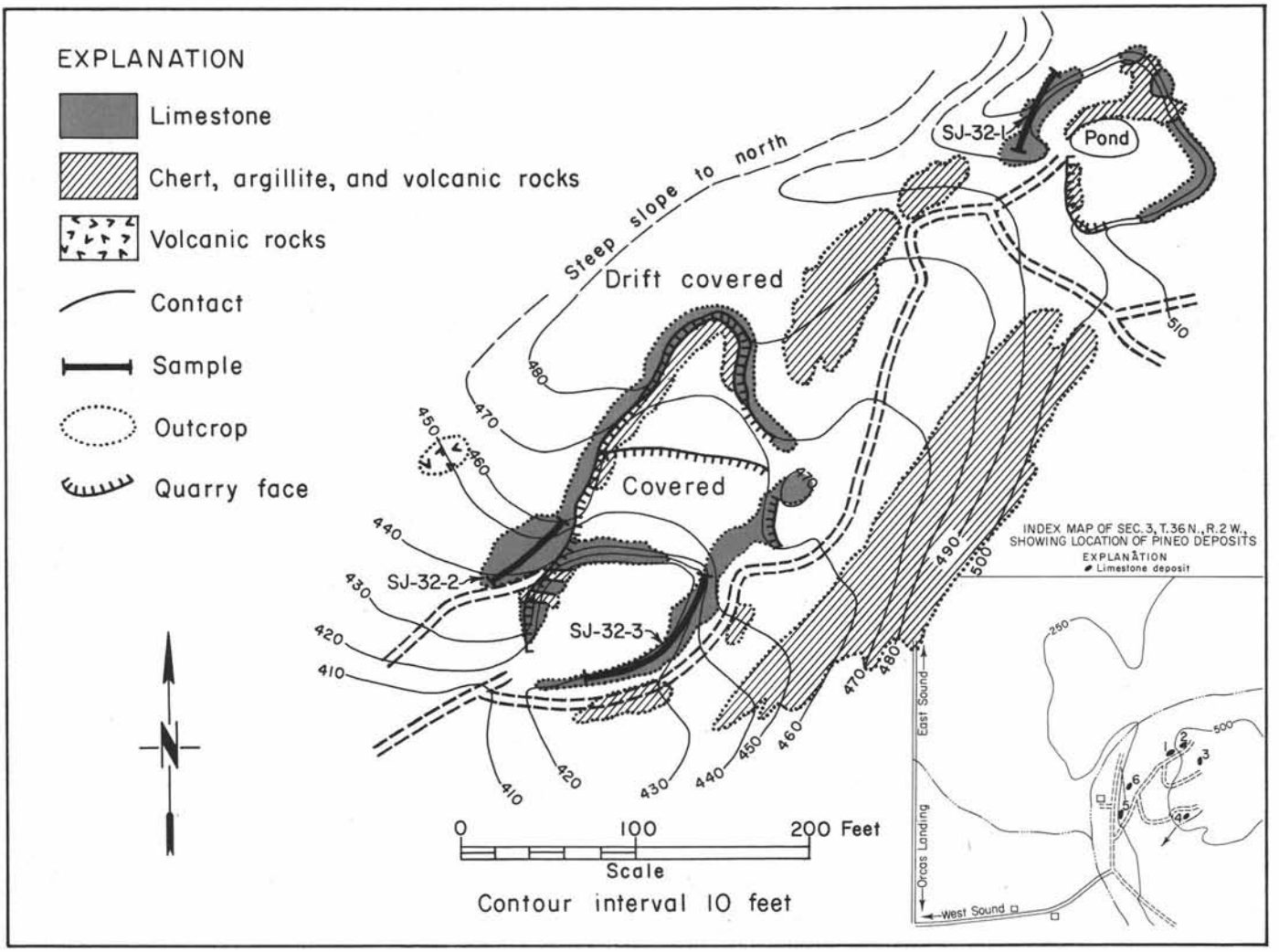


FIGURE 73. — Pineo No. 1 and No. 2 deposits. E½ sec. 3, T. 36 N., R. 2 W. Geology by W. R. Danner, C. F. McKillop, and A. M. Rivisto. Compass and tape survey.

Geology and description. — Pineo No. 1 is the lower of two limestone occurrences cropping out on a northeastward-trending bench on a steep northwest slope. It appears to consist of one or more lenticular beds striking northeast-southwest and dipping gently southeast in the north part and steeply southeastward in the south part of the outcrop. It is underlain by volcanic rocks and is interbedded with and overlain by argillite, ribbon chert, and volcanic rocks. There is considerable shearing in places, and it may be that the sedimentary rock exposed along the north face of the quarry is actually fault-zone material.

Pineo No. 2 lies 200 feet northeast of Pineo No. 1 and, although smaller, it is similar in structure to No. 1. The limestone is underlain by sheared argillite. The dip is southerly and is gentle in the northern part of the quarry and steep in the southern part.

Between the two quarries is an area of gentle slope mostly covered with glacial drift and quarry waste, but two areas of sedimentary and volcanic rocks are exposed. The limestone in the Pineo No. 1 and No. 2 deposits is gray in color and mostly crystalline in texture. No fossils were found. In thin section some of the limestone appears dense and contains traces of shell fragments, but nothing diagnostic. The age is unknown.

These limestone outcrops are along strike between the West Sound and McGraw-Kittinger bodies and are believed to be part of a persistent limestone-bearing belt striking northeast-southwest across Orcas Island.

A few hundred tons of limestone is still in place along the north rims of both quarries. An additional small tonnage is present along the south rims, where the limestone dips steeply beneath bedrock overburden.

Quality. — The limestone appears to be mostly of high quality.

Chemical analyses of Pineo No. 1 and No. 2 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
SJ 32-1	Pineo 2 ---------	50	98.07	0.83	42.86	55.10	0.40	0.84	0.42	0.240
SJ 32-2	NW. side of Pineo 1, southern part	55	98.11	0.73	43.34	55.12	0.35	0.86	0.33	0.100
SJ 32-3	SW. side of Pineo 1, southern part	90	96.88	0.91	42.89	54.43	0.44	1.34	0.70	0.160

Ownership and development. — The property is owned by R. A. Pineo, who lives in the valley to the west. About 1934-36 the two quarries were operated by a Mr. Gregory for pulp rock, which was shipped to the Soundview Company in Everett. The quarry floors are now overgrown with willow and alder and are partly covered with water during wet weather.

Reference. — Glover (1936, p. 57).

Pineo Deposit No. 3

Location, size, and accessibility. — The Pineo No. 3 occurrence is in the NE¼SE¼ sec. 3, T. 36 N., R. 2 W., about 500 feet south of Pineo No. 1 and No. 2. It is in the next valley to the south of the other two deposits, at an estimated altitude of 600 feet. It consists of two small areas of limestone float about 50 feet apart. There is no definite outcrop. The limestone is accessible by about ½ mile of bulldozed logging track from the Pineo No. 1 road. The area has been logged recently.

Geology and description. — This occurrence consists of two small areas covered with a few square feet of loose limestone blocks. The two areas are about 50 feet apart, and the surface between them is covered with soil and glacial drift. The limestone is white to light gray in color and crystalline in texture. A line joining the two exposures runs N. 25° W.

The presence of this limestone float indicates that there may be limestone beneath the surface, but the area would have to be stripped of soil cover to find it. The float occurs along the east side and crest of a small north-south-trending ridge on a larger south-sloping valley side. No further indications of limestone were found in the immediate vicinity. Cherty argillite is exposed to the north.

Quality. — Limestone float specimens sampled for analysis are of high quality.

Chemical analysis of Pineo 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
SJ 32-4	Composite	98.68	0.69	43.73	55.44	0.33	0.27	0.16	0.107

Ownership and development. — The property is owned by R. A. Pineo, who lives in the valley to the west. There has been no development. The occurrence is apparently too small to be of any economic value, but its high quality would tend to indicate that its size should be determined by stripping of drift and soil overburden.

Pineo Deposit No. 4

Location, size, and accessibility. — The Pineo No. 4 limestone occurrence is in the $NE\frac{1}{4}SE\frac{1}{4}$ sec. 3, T. 36 N., R. 2 W., on the north side of a small intermittent stream that is on the west side of the northwest extension of Mount Woolard. Scattered outcrops of limestone lie in an area about 50 feet long and 10 to 20 feet wide. The occurrence can be reached by following a bulldozed logging track for about $\frac{1}{4}$ mile from its junction with the Pineo quarry road near the spring that supplies the Pineo farm with its drinking water. The outcrop lies just south of the "cat" road, on a relatively flat benchlike area. The property has been logged recently.

Geology and description. — Limestone is exposed flush with the surface in scattered outcrops along the crest of a small northeast-southwest-trending ridge about 10 to 15 feet higher than the surrounding terrain. At the southwest end of the ridge a knob of limestone 3 feet high and 5 feet wide has been uncovered by stripping. The limestone is blue gray in color and crystalline in texture. It is covered with as much as 10 feet of glacial drift and alluvial sediments. The shape and extent of the limestone body are unknown.

Quality. — A composite sample made up of chips taken from all outcrops was relatively high in magnesium oxide.

Chemical analysis of Pineo No. 4 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
SJ 32-5	Composite	94.37	4.68	43.41	53.02	2.24	0.50	0.65	0.170

Ownership and development. — The property is owned by R. A. Pineo. A 6-foot-deep trench has been dug across the limestone-bearing ridge northeast of the last outcrop, but no bedrock is exposed in it. Some stripping has been done southward along the ridge for the purpose of enlarging existing outcrops, but it has revealed mostly glacial drift and alluvial sediments. The depth of overburden (6 feet or more) and apparent small size make the deposit appear to be uneconomic. However, there has been insufficient exploration to reveal the actual dimensions.

Pineo Deposit No. 5

Location, size, and accessibility. — The Pineo No. 5 limestone occurrence is in the NW¼SE¼ sec. 3, T. 36 N., R. 2 W., near the base of the steep west side of the northwest ridge of Mount Woolard. The altitude is approximately 250 feet above sea level. A lenticular bed of limestone about 13 feet thick is exposed for a distance of about 38 feet on a cliff face. It is adjacent to the private road of R. A. Pineo near the entrance to his yard. It is accessible by about 3/4 mile of graveled road extending eastward from the junction with the Orcas Landing-East Sound road at the common corner of secs. 3, 4, 9, and 10.

Geology and description. — The limestone forms an irregular-shaped lens pinching out at both ends and exposed in a north-south-trending, almost vertical cliff face. At the north end the limestone crops out at the top of the cliff, and at the south end it slants downward about 15 feet below the top. Limestone is exposed for about 38 feet along the cliff face and has a maximum thickness of 13 feet. It is irregular in thickness along its strike. It dips southeastward back into the cliff and is overlain by chert and argillite. The limestone is blue gray in color and dense to crystalline in texture. It is more blue in color and somewhat less crystalline than the other Pineo occurrences. In thin section it is seen to contain numerous thin filament-like shell fragments and a few small, poorly preserved foraminifers (?) in a lime mud matrix. Nothing could be specifically identified, but it is thought that the limestone is probably of Permian age.

Quality. — The sample analyzed indicates a high-quality limestone, but numerous thin stringers of cherty argillite are visible in the outcrop.

Chemical analysis of Pineo No. 5 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
SJ 32-6	38	97.38	0.56	42.75	54.71	0.27	1.62	0.49	0.192

Ownership and development. — The property is owned by R. A. Pineo. The limestone was quarried at one time, and the quarry is now in part overgrown with trees and brush. The operation was a small one and apparently short lived. The quarry extended back into the cliff face about 25 feet, to where bedrock overburden made further quarrying uneconomic. The limestone body remaining is too small and has too much overburden to be of any further economic value.

Pineo Deposit No. 6

Location, size, and accessibility. — The Pineo No. 6 limestone occurrence is in the NW¼SE¼ sec. 3, T. 36 N., R. 2 W., on a steep west-facing hillside about 300 to 350 feet in altitude. The outcrop is a few hundred feet northeast of the farm of R. A. Pineo. It is exposed for about 20 feet north-south and 3 feet vertically. It can be reached by climbing up the hillside on a bulldozed logging road that runs just below the outcrop. Toward the south this logging road joins R. A. Pineo's private road, which in turn joins a gravel-surfaced county road leading 3/4 mile west to the Orcas Landing highway.

Geology and description. — The limestone is poorly exposed but probably consists of a small lenticular bed dipping southeastward into the hillside. It may be a continuation to the northeast of a belt of limestone lenses, of which the Pineo No. 5, a few hundred feet to the south, is a part. Chert and argillite crop out above and below the limestone, which is bluish gray in color and mostly crystalline in texture. Only a few hundred pounds of limestone is exposed in the outcrop.

Quality. — A composite sample along the strike of this bed is of fairly good quality.

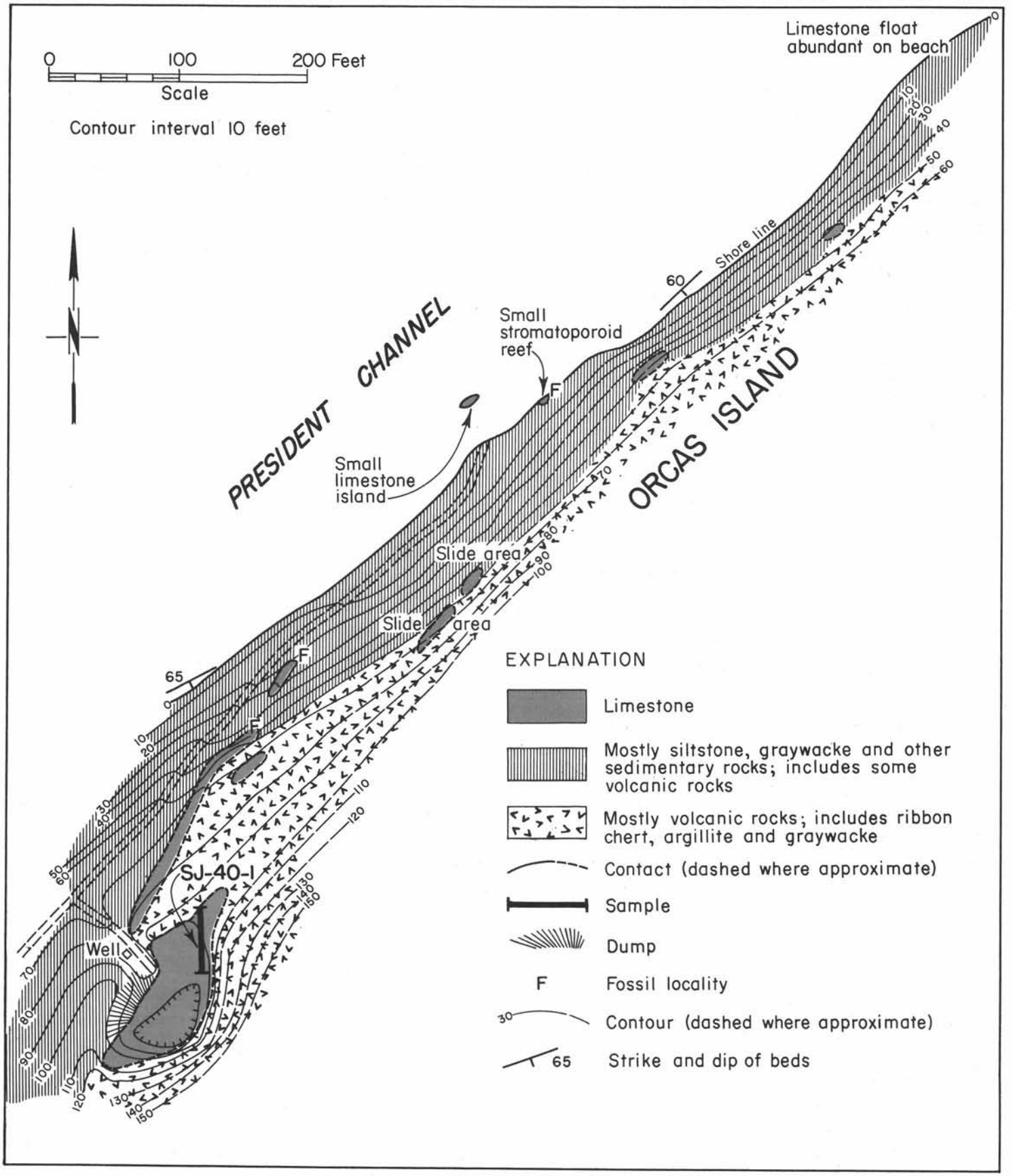


FIGURE 74. — Orcas Lime Company, north quarry. SW¼SE¼ sec. 30, T. 37 N., R. 2 W. Geology by W. R. Danner, C. F. McKillop, and A. M. Rivisto. Compass and tape survey.

Chemical analysis of Pineo No. 6 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
SJ 32-7	20	97.57	0.41	43.01	54.83	0.20	1.18	0.75	0.130

Ownership and development. — The property is owned by R. A. Pineo. There has been no development, and the exposure is too small to be of any economic value.

Orcas Lime Company Quarries

Location, size, and accessibility. — The Orcas Lime Company occurrence is in the $SW\frac{1}{4}SE\frac{1}{4}$ sec. 30 and $NE\frac{1}{4}NW\frac{1}{4}$ sec. 31, T. 37 N., R. 2 W., on cliffs above President Channel on the northwest coast of Orcas Island. The occurrence consists of two relatively large limestone lenses, which have been largely removed by quarrying, and several small pods and lenses of little or no economic value. The northern one of the two largest outcrops is about 150 feet long and ranges in width from 15 to 50 feet. The southern outcrop is approximately 200 feet long and 70 feet wide. The outcrops, on the northwest coast of Orcas Island, are accessible by boat. The northern outcrop is at an altitude of about 90 feet above sea level and was accessible by about 600 feet of road from the beach below. The road is now partly washed out and is covered with slide debris. The same road continues south and east of the outcrop to join the Soderberg quarry road in the $NE\frac{1}{4}$ sec. 31, a distance estimated to be about 3/4 mile. This road is also steep and is now impassable because of slides, fallen trees, and washouts. The southern quarry can be reached from the water by landing on the beach below and climbing approximately 50 to 80 feet up a steep quarry dump to the quarry entrance. It can also be reached on land by following the road leading west from the Soderberg quarries, in the $NE\frac{1}{4}$ sec. 31, to the ruins of the Orcas Lime Company camp on top of the beach cliff, and from there by climbing down a steep and dangerous trail to the beach and then climbing up the dump to the quarry. An alternative route follows a very faint trail south from the bend in the road at the east end of the camp, along the steep hillside to the north rim of the quarry. This part of the coast of Orcas Island has precipitous slopes, is densely forested, and has very thick underbrush, all of which make geologic study extremely difficult.

Geology and description. — The Orcas Lime Company occurrence consists of a series of limestone lenses and pods striking northeast-southwest almost parallel to the coastline and dipping steeply into the precipitous bluffs and cliffs in a southeasterly direction. The limestone is overlain mostly by volcanic rocks consisting of spilite flows and breccias and is

Chemical analyses of Orcas Lime Company 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
SJ 40-1	N. face, north quarry --------	55	96.76	0.41	42.52	54.36	0.20	1.51	0.77	0.009
SJ 40-2	E. side, south quarry --------	150	98.39	0.20	43.01	55.28	0.10	0.48	0.27	0.006

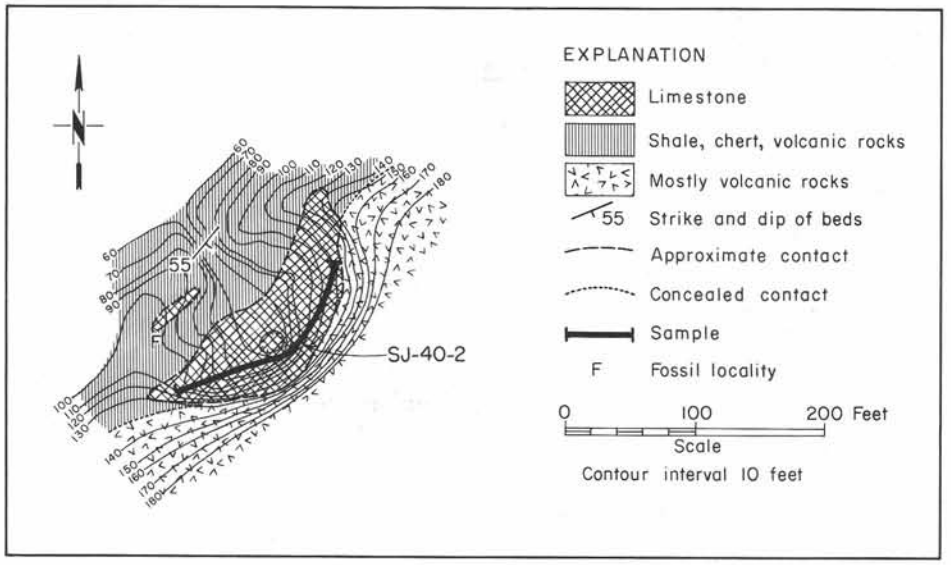


FIGURE 75. — Orcas Lime Company, south quarry. NE¼NW¼ sec. 31, T. 37 N., R. 2 W. Geology by W. R. Danner, C. F. McKillop, and A. M. Rivisto. Compass and tape survey.

underlain by sedimentary rocks composed of graywacke, conglomerate, siltstone, ribbon chert, and argillite with interbedded volcanic flows. The economic value of the limestone bodies is limited, because they are short and they dip into the steep hillside beneath bedrock overburden. The southern quarry is probably the most spectacular quarry on the San Juan Islands; it may be described as being developed on an elliptical limestone body that was literally hollowed out, so that today the high east face of the quarry overhangs the quarry floor several feet. Water dripping onto the quarry floor from the overhanging east wall has coated pebbles and plant material with travertine and also has developed small rounded concretionary bodies similar to cave pearls. A red alder catkin, perfectly preserved by a coating of travertine, was found in a puddle on the quarry floor. Encrustations of gypsum are common on the surface of the chert and argillite exposed in the cuts at the quarry entrance.

The two largest limestone bodies are about 1,000 feet apart and do not appear to be connected. Several other, small lenses crop out to the north on the steep hillside. Their approximate position is indicated on the map, but they were not studied in detail. Most of them are thin lenticular bodies, few of which are more than 10 or 15 feet thick. One is continuous for several hundred feet. A few small limestone pods, mostly a few square feet in area, crop out along the beach. Some of these may be boulders that have rolled down from the cliffs above and have become imbedded in the beach sands. One small island about 60 feet offshore appears to be a limestone outcrop. It is about 15 feet long and 3 feet high.

The limestone of this property is light gray to buff in color and varies in texture from oölitic and clastic to dense and crystalline. On the bottom of the southwest side of the southern quarry, where the limestone is argillaceous, specimens of the brachiopods Atrypa devoniana types A and B, Productella,

FIGURE 76. — Face of southern quarry, Orcas Lime Company. View looking south. Limestone dips steeply to the east (left), and further quarrying would require underground operation. 1959.

the stromatoporoid Amphipora, and the gastropod Euryzone were collected. North along the beach is a small reef composed of the stromatoporoid Idiostroma, and numerous boulders of Amphipora-bearing limestone occur along the beach. These are probably derived from lenses on the steep hillside above. The first outcrop north of the northern quarry contains numerous poorly preserved brachiopods of the genus Atrypa. The fossil evidence indicates a late Middle Devonian age for the limestone.

The sedimentary and volcanic rocks between the two largest quarries contain numerous small cavelike openings associated with their joint systems. Where the road crosses this part of the sequence, footsteps of people walking over the ground give a hollow sound, as if there were caves below.

Quality. — Most of the limestone of these bodies is of high quality, but locally it is argillaceous.

Ownership and development. — The property was formerly owned and quarried by the Orcas Lime Company. It is now owned by Miss Ruth Brown, of Four Winds, Deer Harbor, Wash. There are three abandoned limestone quarries and a limekiln on the cliffs above the beach. The quarries were worked into the hillside down the dip of the limestone to the point where they were considered to be too dangerous for further development because of the high overhanging east face and to be uneconomic because of the increasing amount of bedrock overburden to be removed. The occurrence is no longer of economic value.

Reference. — McLellan (1927, p. 94, 168).

Killebrew Lake Deposit

Location, size, and accessibility. — The Killebrew Lake limestone deposit is in the west part of the SE¼ sec. 13, T. 36 N., R. 2 W., on the east slope of a small hill at the southwest side of the junction of the private road to Guthrie (Cadden) Cove and the Killebrew Lake road. Near the top of the hill, limestone is exposed in a small cut 7 feet high and about 8 feet long. It is at an altitude estimated to be 400 feet above sea level. The occurrence consists of two thin lenticular beds of limestone; of these, the upper one is 1 foot thick and the lower one is 1½ feet thick. They are separated by 1½ feet of calcareous argillite. The limestone can be reached by hiking a short distance up the steep hillside from the Guthrie Cove road, but the occurrence is difficult to locate because the terrain is covered with second-growth trees and dense brush. The occurrence is about 2 3/4 miles by road east of Orcas Landing.

Geology and description. — The rock sequence in this area consists mostly of fine-grained clastic sedimentary rocks, and the small hill containing the limestone is made up mostly of bedded argillite. The strike ranges from N. 85° E. to N. 10° W., and the dip is 45°-65° S. The only other limestone found in the vicinity was a bed about 8 inches thick exposed in a roadcut on the west side of the Guthrie Point road 280 feet from its junction with the Killebrew Lake road. The limestone is finely crystalline in texture, and no trace of organic material was seen. It is bluish gray in color and is cut by calcite veinlets.

The extent of these limestone beds along strike is unknown. Because of poor exposure they could be traced for only a few feet.

Quality. — The limestone is of high quality.

Chemical analysis of Killebrew Lake 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
SJ 48-1	Composite	93.50	0.33	41.38	52.53	0.16	0.90	0.74	0.027

Ownership and development. — The property is owned by Ted White, who lives at Guthrie Cove. At some time a small cut was made on the sequence of two limestone beds, but the history of the operation or exploration is unknown. The

occurrence is too small to be of economic value. An old limekiln and a limestone quarry are reported to exist on Grindstone Harbor, to the southwest, but their presence was not confirmed. Small pods of argillaceous limestone, unfossiliferous and partially recrystallized, are reported by students of the University of Washington 1958 Field Camp to occur on Diamond Hill to the east.

Reference.—Ripplinger (1958, unpublished manuscript, University of Washington Dept. of Geology Field School report).

Moran State Park Deposit

Location, size, and accessibility.—The Moran State Park "limestone" occurrence is in the NW¼SW¼ sec. 29, T. 37 N., R. 1 W., in a small stream valley on the west side of the park at an altitude of approximately 1,150 feet. The outcrop area is just below the trail leading from the park headquarters to Hidden Ridge. The main outcrop is about 800 feet long north-south and averages less than 20 feet in width. It is exposed vertically for 18 to 20 feet. The limestone is accessible by about 3/4 mile of good trail from Moran State Park campground, the trail rising about 600 feet in this distance. The area is heavily forested but contains a few relatively open rocky areas.

Geology and description.—This occurrence consists of a peculiar orange-weathering carbonate rock interbedded in a sequence of argillite, chert, and volcanic rocks. The main body is exposed along the east side of a small stream and appears to be a lens composed of poorly bedded slabby layers 1 to 2 inches thick. North of the main outcrop, small pods occur for over 200 feet upstream and contain interbedded paper-thin layers of a rock that resembles serpentine.

The fresh surfaces of the carbonate are buff colored and have a sugary to dense texture. Weathered surfaces are orange and rusty brown in color. The occurrence resembles "silica-carbonate" rock found in fault zones near Granite Falls, in western Snohomish County. Carbonate float is abundant in the streambed below the outcrop. Some float specimens consist of small irregular pods of the carbonate embedded in fragments of chert. The carbonate-bearing sequence strikes in general about N. 40° E. and dips about 40° SE.

Quality.—The rock is high in magnesium, silica, and iron. The high silica content is indicated by sparks given off from the rock when it is struck with a hammer.

Chemical analysis of Moran State Park 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
SJ 92-1	Along strike	80	43.09	17.97	28.26	24.21	8.60	32.87	6.51	0.265

Ownership and development.—The occurrence is owned by the Washington State Parks and Recreation Department. There has been no development. The carbonate body is too small and impure to be of any economic value, but it is noteworthy because of its unusual composition.

Reported Ryman Limestone Occurrence

Mr. Bert Ryman reported finding specimens of limestone float at one time on his property in the SW¼ sec. 21, T. 37 N., R. 2 W., in the northwest part of Orcas Island. This area was examined briefly, but no limestone was found in place or as float.

Reported Crow Valley Limestone Occurrence

In about 1958 two wells were drilled in Crow Valley at the eastern edge of the Turtleback Range. One was drilled as a water well in a field in the NW¼SE¼ sec. 33, T. 37 N., R. 2 W. The second was drilled as a wildcat oil well in a field north of the home of F. H. Boddington at West Sound, in the SE¼SW¼ sec. 4, T. 36 N., R. 2 W. The logs of these wells are supposed to have been similar and showed, according to local residents, 80 feet of overburden, then 100 feet of limestone underlain by 30 to 40 feet of "country rock." Other statements are to the effect that only 30 feet of limestone was encountered. These reports have led to speculation that the 1.3 miles of terrain between the two holes is underlain by a 100-foot layer of limestone. Specimens of the limestone were reported to have been sent to a cement company in Seattle, but the company involved would make no comment concerning the material.

The southern well site was examined, but as no limestone cuttings could be found on the ground, the reported limestone, if present, will have to be verified by further investigation. However, it appears unlikely that limestone underlies this area. All the roadcuts and outcrops along the west side of this part of Crow Valley are in diorite or diabasic igneous rocks, as also are the outcrops along the beach at West Sound to the southeast of the southern "oil well." It appears probable that the same rocks underlie the west side of Crow Valley, where the two wells were drilled. There is a remote possibility that some of the limestone-bearing sequences of Permian age that crop out to the north might extend into this part of the valley under the alluvial cover. However, it is extremely unlikely that a limestone body as large as the one interpreted from the well logs actually exists. In 1947, traces of oil were found in Crow Valley, in a water well, but it is considered to be a freak occurrence.

Reference. — Livingston (1958, p. 39).

Reported Lehman Occurrence

An investigation was made of a reported occurrence of limestone on the property of Carl Lehman, of Deer Harbor. A few small pods of dense to crystalline-textured gray limestone were found in a small ridge of volcanic rocks and argillite trending north-south in the NW¼ sec. 6, T. 36 N., R. 2 W. The largest outcrop seen covered an area of only about 3 square feet.

Caldwell Point Deposit

Location, size, and accessibility. — The Caldwell Point limestone occurrence is in the SE¼ sec. 17, T. 36 N., R. 2 W., on the southwest side of West Sound, opposite north Double Island and north of Caldwell Point. The limestone crops out in a beach cliff and is exposed down dip alongshore a distance of about 30 feet. It has a thickness of 3 to 4 feet. The outcrop can be traced up the steep slope for a horizontal distance of about 40 feet. The occurrence is accessible by boat and is 2 miles southwest of West Sound village. On land it can be reached by following a private road to its terminus at summer homes east of Caldwell Point and then hiking north ¼ mile overland to beach cliffs directly opposite the south side of north Double Island.

Geology and description. — Limestone occurs as a lens interbedded with argillite and chert. The sequence strikes N. 10°-30° E. and dips 10°-45° SE. At least three smaller lenticular pods of limestone are exposed within a distance of 25 feet to the south. Chert is exposed to the north. The shoreline consists of small rock cliffs extending down into the water. The upper slopes are heavily covered with brush.

At water level are several blocks of limestone that may have broken loose naturally from the outcrop but appear more likely to be a result of an attempt to quarry it. The limestone is gray in color and crystalline in texture; irregular patches of white insoluble material stand in relief on the weathered surfaces. No fossils were visible, and the age is unknown.

Quality. — The limestone is of good quality though slightly siliceous.

Chemical analysis of Caldwell Point 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
SJ 73-1	30	97.52	0.29	42.93	54.79	0.14	1.28	0.39	0.008

Ownership and development.—The property is owned by Kirk McLaughlin, who lives to the west at Pole Pass. The limestone was drilled by Roche Harbor Lime and Cement Company several years ago, and the drill hole is reported to have run out of limestone 14 feet into the face. Mr. McLaughlin's father burned limestone from this outcrop to obtain lime to mix with sand for the foundation material of his barn. Limestone is reported to have been found in a well dug in this part of the island, but the exact location is unknown. The limestone body is too small to be of economic value.

Reference.—McLellan (1927, p. 168).

Four Winds Deposit

Location, size, and accessibility.—The Four Winds limestone occurrence is in the NE¼NW¼ sec. 17, T. 36 N., R. 2 W., in a small cove on the west side of West Sound, north of Victim Island. Outcrops only a few square feet in area occur on the beach at the base of beach cliffs. The largest limestone outcrop is 10 feet wide and about 60 feet long. The occurrence is accessible by boat. It can be reached overland by going to the shore end of the pier at Four Winds camp. The largest limestone body lies on the shore, adjacent to the pier.

Geology and description.—The occurrence is composed of lenses of brown- to gray-weathering limestone striking northwest-southeast and dipping to the southwest. They are interbedded in ribbon chert and argillite. The largest bed is 5 to 6 feet thick and contains a few stringers of black shale. It strikes N. 85° W. and dips 25° SW. To the north, on both sides of the boys' camp swimming pool, are thin-bedded limestone and chert sequences as much as 4 feet thick. Individual limestone layers are from 1 to 4 inches thick. A thin-section study of the limestone showed two types of rock. One type is a crystalline dolomite, and the other is a limestone largely recrystallized but in places retaining parts of an original dense texture with thin filament-like shells of pelecypods and small round bodies that might be radiolaria replaced by calcite. The age is thought to be Permian. Where limestone and chert are interbedded, they are strongly contorted.

Quality.—No sample was taken for chemical analysis because of the small size of the limestone bodies.

Ownership and development.—The property is owned by Miss Ruth Brown, of Four Winds camp. The limestone bodies are too small to be of any economic value. They are partly covered with water at high tide.

Deer Harbor Deposit

Location, size, and accessibility.—The Deer Harbor limestone occurrence is in the SW¼NE¼ sec. 18, T. 36 N., R. 2 W., on the beach on the southeast side of Deer Harbor Bay, about ½ mile south of the village of Deer Harbor and 7/8 mile north of Pole Pass. It is on the north side of a small cove. A thin bed of limestone is partly exposed for a distance of 110 feet and averages between 2 and 4 feet in width. It is accessible by boat and also can be reached by hiking from the Deer Harbor–Pole Pass road over the top of a bluff to the beach below.

Geology and description.—The occurrence consists of a pinching and swelling bed of light-gray-weathering, dense to crystalline-textured limestone. The limestone is cut by calcite veinlets and contains irregular carbonaceous and cherty layers and also irregular masses of insoluble material thought to be dolomite. The limestone strikes northeast under 8 to 10 feet of glacial sediments that form the bluff along this part of the coast, then parallels the base of the bluff for 50 feet before trending southwestward onto the beach and disappearing under beach rubble. A large part of the outcrop is covered at high tide. The limestone dips to the south and is underlain by sheared tuffaceous shales and overlain by volcanic rocks.

Quality. — The limestone is relatively high in magnesium and silica.

Chemical analysis of Deer Harbor 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
SJ 74-1	50	90.06	4.20	42.02	50.60	2.36	4.30	0.67	0.013

Ownership and development. — The owner of the property is unknown. There has been no development. The deposit is too small and impure to be of any economic value and is covered with water at high tide. Landes (1902) states that: "Lime is being burned near Deer Harbor by two companies, one the Eagle Lime Company operating one kiln of 120 barrels capacity and the other, the Island Lime Company operating a kiln of 80 barrels capacity."

References. — Landes (1902, p. 187), McLellan (1927, p. 168).

Soderberg Quarries

Location, size, and accessibility. — The Soderberg limestone deposit is in the SE¼ sec. 30, T. 37 N., R. 2 W., on the west coast of Orcas Island at the base of the steep western slope of Orcas Knob, at an altitude of about 400 feet above sea level. It consists of two partly quarried lenticular bodies of limestone, the northern one of which is referred to as the Big Soderberg "ledge" and the southern one as the Little Soderberg "ledge." Limestone in the Big Soderberg is exposed for a length of 300 feet, is about 50 feet wide, and is exposed vertically for about 40 feet. The Little Soderberg deposit is about 250 feet long, has a maximum width of 50 to 60 feet, and is exposed vertically for about 30 feet. The two limestone bodies are about 200 feet apart. The outcrops are easily accessible by about 1¼ miles of narrow dirt road starting from the West Sound-Deer Harbor highway at the head of Massacre Bay, at the common corner of secs.31 and 32, T. 37 N., R. 2 W., and secs. 5 and 6, T. 36 N., R. 2 W. The area consists of barren rocky slopes, dense second-growth trees, and areas of thick brush. Part of it was logged between 1948 and 1956.

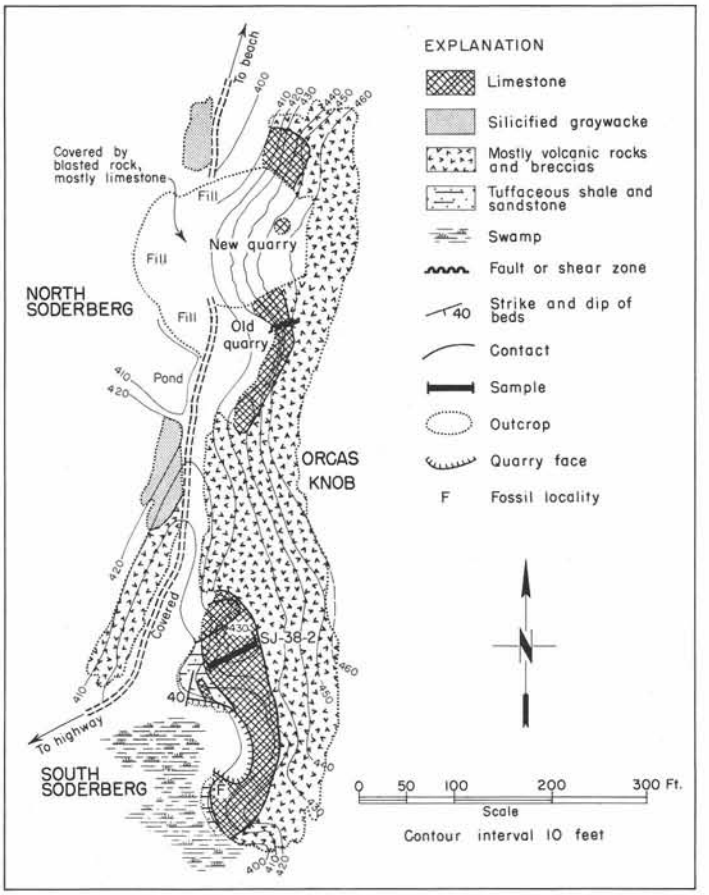


FIGURE 77. — Soderberg deposits. SE¼ sec. 30, T. 37 N., R. 2 W. Geology by W. R. Danner, C. F. McKillop, and A. M. Rivisto. Compass and tape survey.

Geology and description. — The limestone deposits consist of lenticular bodies enclosed in volcanic rocks and breccias of Devonian age. The enclosing sequence strikes northeast-southwest along the west coast of Orcas Island and dips steeply to moderately toward the east and southeast.

The northern (Big Soderberg) body was quarried many years ago, and the most accessible limestone was removed. The remaining limestone

FIGURE 78. — Little Soderberg quarry. View looking south, 1964.

dips underneath the steep west face of Orcas Knob, and as the quarry face is worked eastward and down dip an increasingly high and steep face of overburden and bedrock will lie above it. At one place a fault or shear zone cutting the limestone is exposed, but it appears to have only a small amount of displacement. Where it is exposed, the shear zone surface and that of the limestone around it are covered with tiny opaque, reddish-orange crystals of gypsum. The overhang of the old quarry face protects the crystals from solution by rainwater.

The limestone is dark blue gray, dark gray, and white in color and crystalline in texture. No fossils are visible.

The Little Soderberg, or southern, limestone body is underlain by tuffaceous shale and sandstone and is overlain by volcanic rocks and breccia. It dips about 40° eastward. It appears to be a thinner bed than the Big Soderberg and was not quarried as extensively as the latter. The limestone is gray to dark gray in color and mostly crystalline. At the south end, at the base of the outcrop, an argillaceous brown-weathering limestone contains poorly preserved remains of stromatoporoids, mostly of the genus Amphipora. Fragmental remains of brachiopods and other fossils are present but not well enough preserved for identification. The limestone is thought to be of Devonian age.

FIGURE 79. — Big Soderberg quarry, north end. View looking east, 1964.

The slope in back of the Little Soderberg quarry and above it is not as steep as that to the north at the Big Soderberg, but nevertheless it will limit quarrying to only a short distance eastward and down dip.

Quality. — There are no visible impurities in the Soderberg limestone bodies except for the argillaceous beds near the base of the Little Soderberg. The limestone is mostly of good quality.

Chemical analyses of Soderberg 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
SJ 38-1	Big Soderberg quarry floor ---	Composite	97.72	0.459	43.10	54.90	0.22	1.22	0.14	0.030
SJ 38-2	Little Soderberg ----	60	95.63	0.188	42.02	53.73	0.09	2.74	0.69	0.012

Ownership and development. — The Soderberg property was owned originally by J. Soderberg. Later it was acquired by the Henry Cowell Company, of San Francisco, and is now owned by Mrs. Ruth E. Winter, of Vancouver, British Columbia. The Big Soderberg limestone body was examined by the writer in 1948, and at that time it was almost hidden by a dense growth of brush. McLellan (1927) mentions that it had been quarried "several years ago," previous to his visit. The limestone was trammed down to the beach to the north. The Little Soderberg limestone body was quarried some time after 1927 and before 1948, and apparently the rock was hauled south by road to West Sound.

The Big Soderberg quarry was reopened by the Everett Lime Company, of Seattle, in 1958 and was still being quarried in April of 1962. The limestone was hauled by truck south to West Sound, where it was put on barges to be shipped to paper mills. Because of its attractive appearance—a dark background with numerous finely crystalline calcite veinlets—some of this rock has been used for decorative stone in fireplaces. It takes a good polish.

The Big Soderberg limestone body is now becoming very difficult to quarry because of the high face and overburden. The Little Soderberg body still contains a few thousand tons of recoverable limestone.

References. — McLellan (1927, p. 168), Mathews (1947, p. 54).

Imperial Limestone Quarry

Location, size, and accessibility. — The Imperial limestone deposit is in the $SW\frac{1}{4}$ and $NW\frac{1}{4}$ sec. 31, T. 37 N., R. 2 W., on the west coast of Orcas Island at an altitude of about 130 feet above sea level. It consists of at least four limestone outcrops, the northern one of which is exposed for about 100 feet northeast-southwest and has a maximum width of about 45 feet. About 150 feet south of it is a small outcrop about 35 feet long and 20 feet wide composed in part of limestone blocks. One hundred feet southeast of the second outcrop is an old quarry on a limestone body about 175 feet long northeast-southwest and 120 feet wide. Two hundred and twenty-five feet southeast of the quarry is an outcrop about 60 feet long northeast-southwest and 15 feet wide. The outcrops are accessible by a rough dirt road that branches to the left off the Soderberg quarry road about 1,500 feet north of its junction with the West Sound-Deer Harbor highway. This dirt road, which is suitable only for trucks or jeeps, can be followed westward about 1 mile to the limestone outcrop. The limestone can also be reached by boat and then by about 500 feet of dirt road extending up the hillside from an old limekiln on the beach cliff below the quarry. The area is mostly covered with a dense second growth of brush and trees and contains some barren rock outcrops.

Geology and description. — The northern outcrop consists of a low mound of crystalline gray limestone with a face about 10 feet high on the west side and with very little relief on the other sides. The occurrence is underlain by volcanic

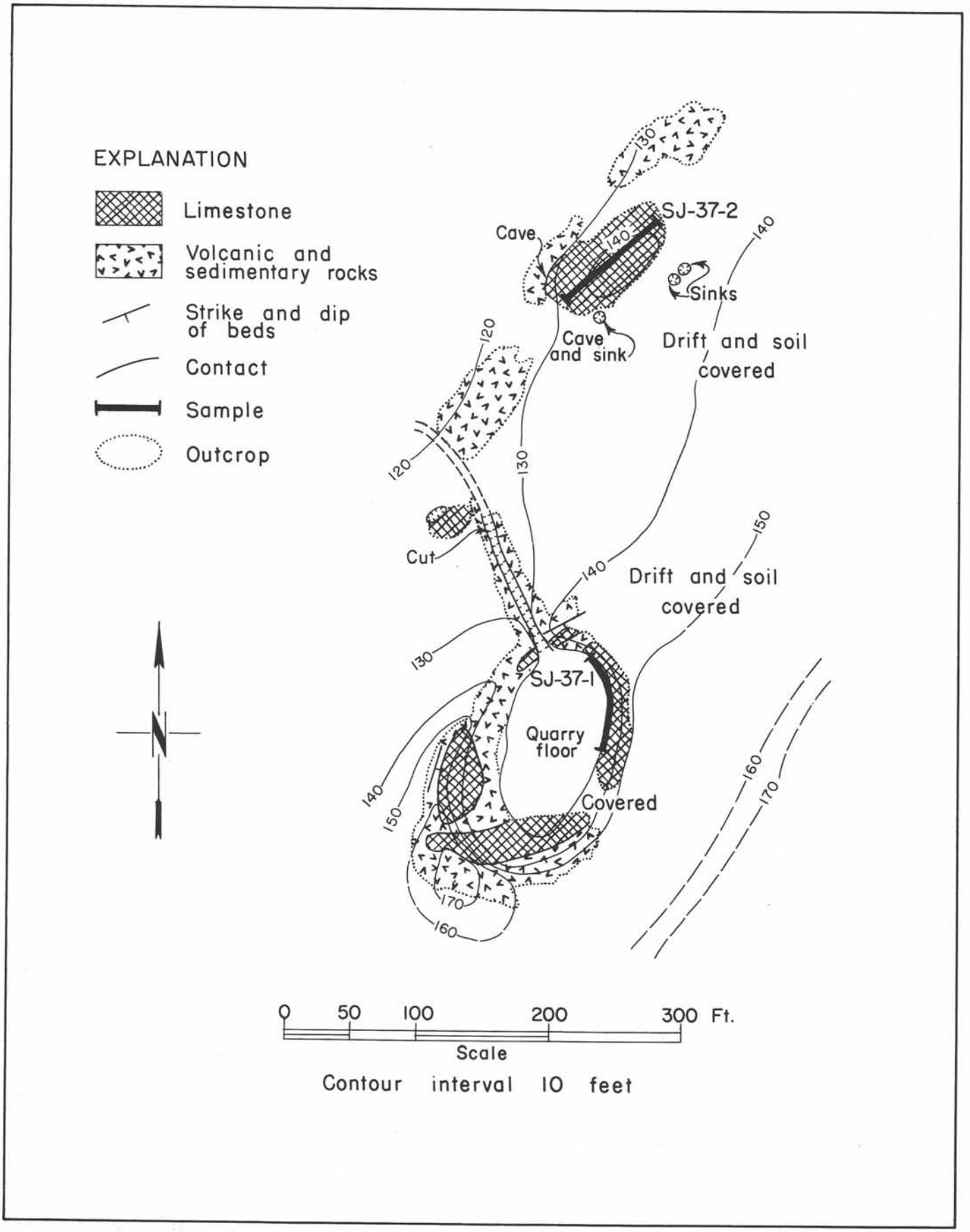


FIGURE 80.—Imperial limestone deposit. SW¼ and NW¼ sec. 31, T. 37 N., R. 2 W. Geology by W. R. Danner, C. F. McKillop, and A. M. Rivisto. Compass and tape survey.

rocks and argillite, but the overlying bedrock is concealed by soil and glacial drift. The attitude of the limestone is not known for certain, but it appears to strike northeast-southwest and to dip gently eastward. The limestone body is lenticular in shape. About 20 feet east of it are two small sinkholes, which indicate a probable extension of the limestone under the soil cover in that direction. The base of the west limestone face contains a small cave that penetrates about 15 feet northward into the limestone. In 1959 a small sinkhole opened up at the southeast corner of this limestone outcrop and revealed the entrance to a cave that extends northward almost 100 feet.

The next outcrop to the south forms a low mound just south of the entrance to the drainage cut into the old quarry. It consists in part of a jumble of limestone blocks, and along its west side where it appears to have been quarried it contains several small solution cavities.

The largest outcrop, which has been mostly quarried away, consists of a lenticular bed of limestone underlain and overlain by volcanic rocks and sedimentary rocks and containing a small flow of volcanic rock interbedded within it. The limestone pinches out to the south in the south face of the quarry, but its extension northeastward and down dip to the east is concealed by soil and glacial drift. There might be several hundred or several thousand tons of limestone under cover in this direction, but stripping or drilling is required to determine its extent. The ground to the north is a small area of flat pastureland and, if underlain by limestone, would not present any major obstacles to quarrying. However, no sinkholes are present, so it may be that the limestone pinches out rapidly in this direction. Several small solution cavities are visible in the quarry walls.

The fourth outcrop (not mapped) lies about 225 feet to the southeast of the quarry and near the base of the west-facing hill overlooking the Imperial limestone deposits. It consists of an elongate low mound of limestone about 4 feet high. Volcanic rocks are exposed a few feet to the east, but all contacts of the limestone with bedrock are concealed. Three small cave openings have been found along the west side of the outcrop.

The limestone is bluish gray in color and crystalline in texture. No fossils have been found in the quarries, but small fragments of limestone are interbedded with other rocks exposed in the beach cliffs and near the crest of a ridge to the east, and these fragments contain poorly preserved fossil corals believed to be of either Devonian or Pennsylvanian age.

Quality. — The limestone is high in calcium.

Chemical analyses of Imperial limestone

Sample no.	Location	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
1/ SJ 37-1	South outcrop, NE. quarry face	80	98.64	0.229	42.80	55.42	0.11	0.70	0.38	0.009
1/ SJ 37-2	North outcrop ---	100	98.00	0.33	43.45	55.06	0.16	0.63	0.32	0.009
2/	Unknown -------		97.21		43.11	54.44	0.31	1.14	Trace	

1/ Samples collected for this report, Mark Adams, analyst.
2/ Shedd (1913, p. 205).

Ownership and development. — The Imperial property is owned by Miss Ruth Brown, Four Winds, Deer Harbor, Wash. It was owned formerly by the Imperial Lime Company and the Henry Cowell Company but was shut down some time prior to 1927. The ruins of a large limekiln and several buildings are on the beach cliff below the quarry.

Although this occurrence is small, the high quality of the limestone might make it worth while to determine the size of the unquarried outcrop and to ascertain what quantity of limestone lies concealed north of the abandoned quarry. The remaining tonnage might be large enough to support a small operation.

References. — Shedd (1913, p. 204-205), McLellan (1927, p. 168), Halliday (1963, p. 54-56).

Soderberg Beach, West Coast of Orcas Island Occurrences

Location, size, and accessibility. — The limestone occurrences at Soderberg beach are in the NW¼ sec. 29 and the NE¼ sec. 30, T. 37 N., R. 2 W., along the west coast of Orcas Island north of Orcas Knob. The outcrops are on the beach, in the beach cliffs, and a short distance inland. At least 10 small limestone bodies were found, as much as 120 feet in length and 23 feet in width. The bodies are easily accessible by boat, but they can also be reached by hiking about ¼ mile down an abandoned and steep logging road from the Soderberg quarries to the shore and then hiking north along the beach. Inland, except for a few barren rocky cliffs and knobs, the area is covered with dense second-growth trees and brush.

Geology and description. — The limestone outcrops along the Soderberg beach appear to be pods and lenses interbedded with basaltic lava flows, water-laid tuffs, ribbon chert, breccias, argillites, and lithic sandstones. The sequence strikes N. 60°-90° W. and dips 35°-70° SW. To the north along the coast are outcrops of a fine- to coarse-grained quartz diorite that appears to be intrusive into the volcanic and sedimentary rocks. There is also one outcrop of amphibolite typical of the pre-Devonian basement complex, and it is in fault contact with the sedimentary and volcanic rocks. To the south, the limestone-bearing sequence is cut by large dikes of porphyritic quartz albite dacite.

The limestone is mostly dense to clastic in texture but has been partially recrystallized. It is light gray in color. When freshly broken, the limestone in most outcrops emits a strong bituminous odor. Permian fusulinids and calcareous algae occur in at least one locality.

Description of individual outcrops. — Starting at the south, the first outcrop is a 2-foot-thick bed of blue-gray crystalline limestone interbedded with green tuffaceous sandstone. Offshore is a small island with a similar layer of limestone about 2 feet thick but interbedded with volcanic rocks. The next outcrop north consists of two small pods of limestone, one exposed on the beach and one on the bank above the beach. Maximum thickness is about 2 feet.

About 50 feet farther north is a limestone bed about 15 feet thick surrounded by beach gravel. To the northeast of it, limestone is exposed for about 30 feet in small discontinuous outcrops in the bed of an old logging road. Possibly not all of this limestone is in place. About 250 feet farther north is exposed another small limestone body, which is interbedded with a fine-grained clastic breccia. Green chert fragments predominate in the breccia. Limestone fragments are also present and are over a foot in diameter, crystalline in texture, and emit a strong bituminous odor when broken.

North of this is a point composed mostly of breccia, and north of it is a bed of gray limestone striking out onto the beach. This bed can be traced for over 120 feet to the north. It reaches a maximum thickness of 23 feet and is exposed vertically to a height of 12 feet. It narrows to the north and appears to pinch out in a shear zone. It is overlain and underlain by volcanic rocks. Interbedded with it is a layer of chert and tuffaceous shale up to 1 foot thick. At the top of the limestone bed are small irregular lenses of limestone interbedded in chert and sedimentary rocks. These lenses contain Permian calcareous algae and fusulinids including the genus Schwagerina. About 100 feet farther north is a pod of limestone exposed for about 50 feet. It is 10 feet thick and is exposed as much as 10 feet vertically. North of here are other small pods of limestone in ribbon chert and volcanic rocks, then approximately 8 feet above the beach is a limestone bed about 4 feet thick exposed for a distance of about 50 feet. It is interbedded with chert and cherty argillite. Then for about 100 feet is a beach cliff as much as 25 feet in height composed of volcanic rocks. North of this is a bed of limestone about 40 feet long and as much as 4 feet wide. Volcanic rocks 20 or more feet thick overlie it.

Quality. — Most of these small pods and lenses are of good-quality limestone.

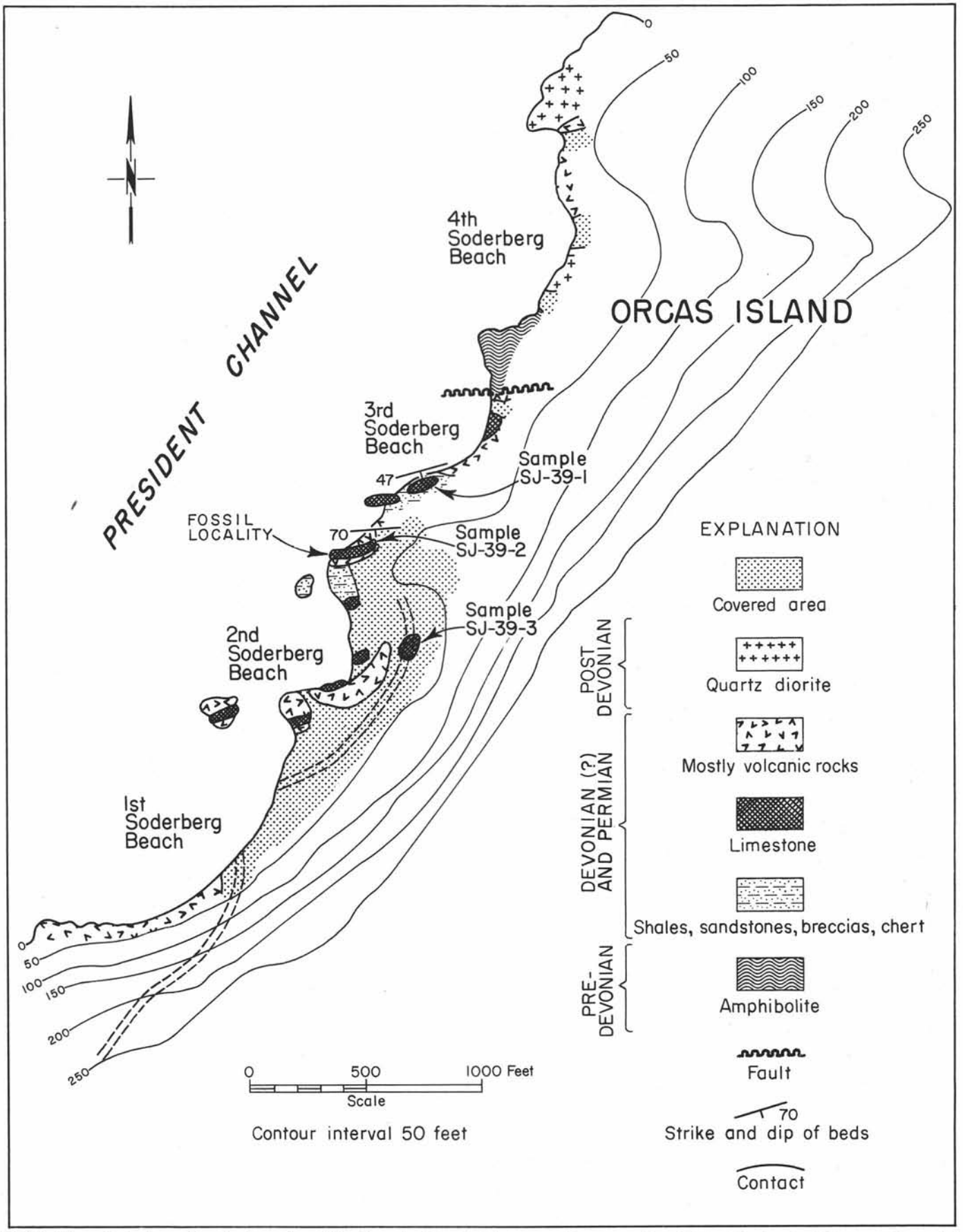


FIGURE 81. — Soderberg Beach deposits. Geology by W. R. Danner. Base map from U.S. Geological Survey Orcas Island quadrangle.

Chemical analyses of Soderberg Beach 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
SJ 39-1	Second outcrop from north ----	50	97.38	0.56	42.65	54.71	0.27	0.90	0.72	0.158
SJ 39-2	Largest bed ----	23	97.68	0.459	43.61	54.88	0.22	0.69	0.45	0.108
SJ 39-3	Roadcut -------	30	97.56	0.31	42.97	54.81	0.15	0.80	0.33	0.068

Ownership and development. — The property is owned by Miss Ruth Brown, Four Winds, Deer Harbor, Wash. There has been no development. The limestone bodies are too small to be of any economic value.

Langdon Deposit (North Part)

Location, size, and accessibility. — The north part of the Langdon deposit is on the east side of East Sound, in the NE¼ sec. 25, T. 37 N., R. 2 W. It consists of a bed of limestone ranging in thickness from 5 to 24 feet and extending from the shore of East Sound southeastward for a distance of 400 feet. The limestone is accessible by boat where it crops out at the water's edge 2 miles southeast of the village of East Sound. The occurrence can be reached on land by following a private road south for a quarter of a mile from its junction with the Olga-East Sound highway at the intersection of secs. 19, 24, 25, and 30. The last one-eighth of a mile of the private road is overgrown and partly covered by slide debris. The limestone outcrop is on the shore a few hundred feet northwest of the road. It lies on the east side of a small open bay, and to the south of it is a peninsula composed of crystalline igneous and metamorphic rocks.

Geology and description. — This limestone body is thought to be a continuation of the limestone bed exposed to the south, in the southern part of the Langdon occurrence, and to represent its outcrop on the north limb of an anticlinal fold. The core of the fold consists of gneissic amphibolites and crystalline igneous rocks exposed along the beach to the southwest. However, the thickness of strata between the core and the limestone on the north flank is much less than the thickness between the limestone and core to the south, and this, along with some difference in the overlying lithology, may indicate that the two are not the same but represent two different limestone beds. The structure may be much more complicated than just a simple anticline.

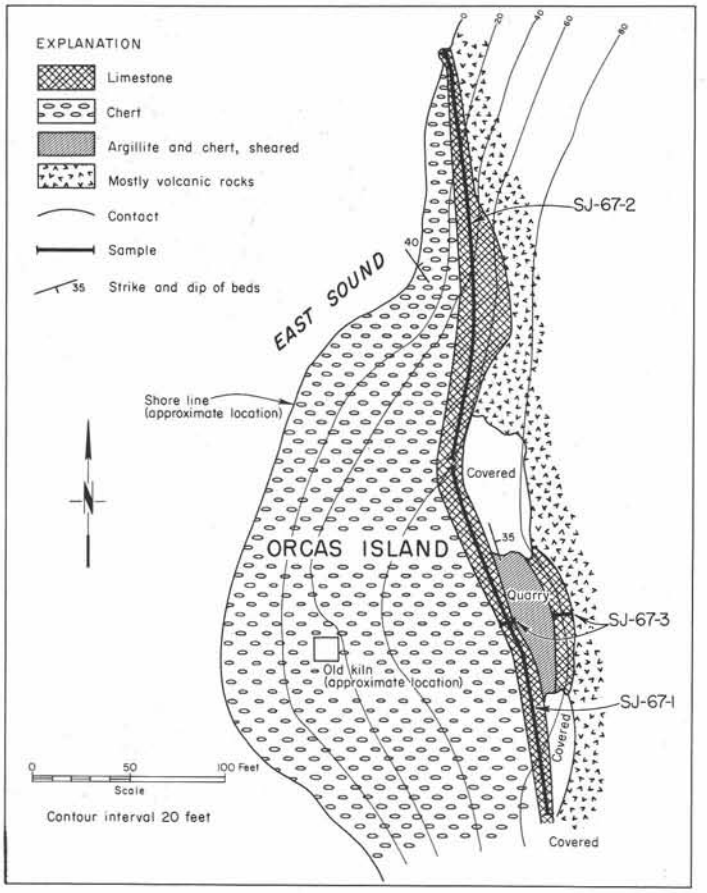


FIGURE 82. — Langdon deposit (north part). NE¼ sec. 25, T. 37 N., R. 2 W. Geology by C. L. Smith, E. A. Adams, and C. F. Royse, Jr. Compass and tape survey.

The north part of the Langdon limestone body strikes northwestward and dips at varying angles to the northeast. It thins to the northwest, where it disappears into East Sound, and apparently pinches out to the southeast in a relatively flat drift- and soil-covered area.

The limestone is underlain by contorted ribbon cherts and is overlain by what appears to be dense-textured volcanic rocks enclosing minor amounts of interbedded sedimentary rocks. In a small quarry near the south end of the outcrop the limestone is split into two beds by a mass of sheared argillite.

The limestone is gray in color and crystalline in texture. No fossils have been found, and the age is unknown.

Quality. — The limestone is variable in composition and in some places is highly siliceous.

Chemical analyses of Langdon 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	Na_2O (ppm)	K_2O (ppm)	TiO_2 (ppm)	S (ppm)
SJ 67-1	South part ---	185	97.79	0.209	42.93	54.94	0.10	0.84	0.41	0.180				
SJ 67-2	North part --	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	Thickness of bed in quarry	20	25.09	1.60	11.33	14.10	0.77	68.03	4.51	0.205				

Ownership and development. — The area is owned by the Crown Zellerbach Company, of Seattle. It was formerly owned by the Washington Pulp and Paper Company. This outcrop, or the southern part of the Langdon limestone, was first quarried about 1862 by George R. Shotter, a Canadian. A small settlement known as Port Langdon was built between the two parts of the outcrop. An abandoned limekiln about 12 feet square and 20 feet high still exists on the property but is rapidly falling to pieces.

The occurrence is too small to be of any further economic value.

References. — Shedd (1913, p. 204), Glover (1936, p. 56), Guard (1943, unpublished field notes), McDonald (1959, p. 3).

Langdon Deposit (South Part)

Location, size, and accessibility. — The south part of the Langdon deposit is on the steep slope of the east side of East Sound in the SE$\frac{1}{4}$ sec. 25, T. 37 N., R. 2 W. It consists of a bed of limestone striking from the beach inland in a northeasterly direction for about 700 feet. The bed has a width ranging from 25 to 50 feet. North of the end of this outcrop a quarry was developed on still another limestone outcrop. In the quarry are remnants of limestone up to 15 feet in thickness.

The limestone is accessible by boat where it crops out on the beach and is about 2$\frac{1}{2}$ miles southeast by water from the village of East Sound. It can be reached on the land by following a private road from its intersection with the Olga-East Sound road, at the common corner of secs. 19, 24, 25, and 30, south 1/8 mile to its junction with an old logging road and by following this road, now largely overgrown, about $\frac{1}{2}$ mile south to the vicinity of the quarries, which then can be located by hiking through dense brush toward the high shore cliffs. The limestone extends from sea level to an altitude of 300 feet and is exposed on a very steep west-facing slope that continues down to the shores of East Sound.

Geology and description. — The main (southern) part of the deposit is a bed of light-gray to bluish-gray crystalline limestone that strikes northeastward and dips 40°-45° SE. into the steep hillside. It is underlain and overlain by ribbon chert. The sequence appears to be folded into small open ripple-like anticlines and synclines striking northwest. The limestone is strongly jointed, and many joint surfaces are coated with calcite crystals. No fossils have been found in place, but one rounded dense-textured limestone fragment found on the quarry floor was thin-sectioned and found to contain numerous fossil

fragments, one of which was identified by Dr. Helen Duncan of the U.S. Geological Survey as a stenoporoid bryozoan. She thought it might represent the genus Dyscritella, "species of which occur in the Mississippian and Permian."

The northern part of this occurrence consists of three small remnants of a larger limestone lens exposed on the walls of a quarry. The limestone appears similar in color and texture to that of the southern outcrop. The contacts between the limestone and overlying and underlying chert and argillite seem to be in part composed of zones of shearing. In the quarry wall were seen three small solution channels penetrating an unknown distance back into the quarry face. The largest opening was about 2 feet wide and 5 inches high.

Limestone has been reported to occur in the bed of the logging road to the northeast, but none was seen. Another report states that limestone was noted to the northeast in the bed of the old East Sound-Olga road, but this occurrence may have been covered

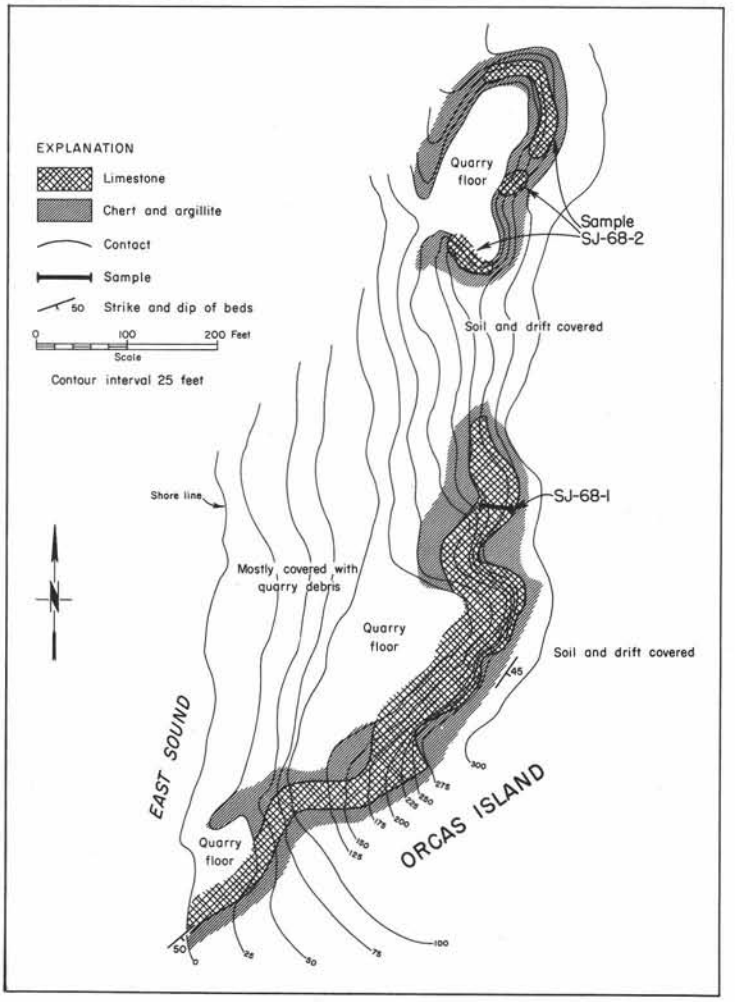


FIGURE 83. — Langdon deposit (south part). SE¼ sec. 25, T. 37 N., R. 2 W. Geology by W. R. Danner, C. L. Smith, E. A. Adams, and C. F. Royse, Jr. Compass and tape survey.

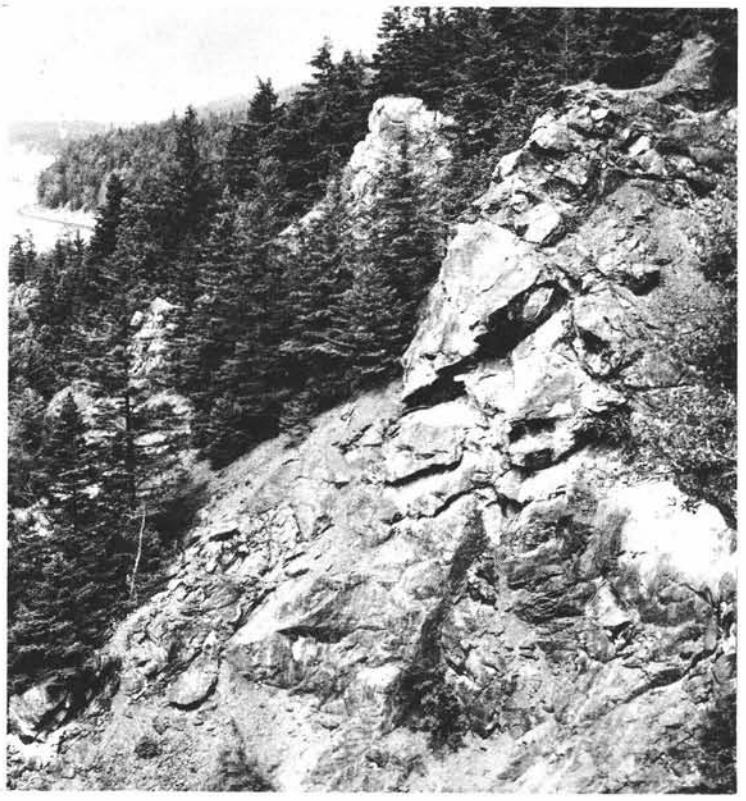


FIGURE 84. — South part of Langdon deposit. View looking north at rim of quarry. East Sound at left.

or blasted away when this portion of the road was rebuilt. It is believed that the Langdon limestone deposit is a continuation of a belt of limestone lenses extending from West Sound northeast across Orcas Island. Red jasper fragments were found in limestone debris on the quarry floor and are similar to those exposed in the West Sound quarry.

Quality. — The limestone is mostly of good quality, but some of it is high in silica.

Ownership and development. — The south part of the Langdon deposit is owned by the Crown Zellerbach Company, of Seattle. It may have been part of the original quarrying operation of George R. Shotter, a Canadian who started operations in this area in 1862. In 1874 the property was sold to Daniel McLachlan and Robert Caines, and later it was owned by the Tacoma Smelter. Limestone was shipped to the smelter for flux.

Chemical analyses of Langdon limestone (south 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
SJ 68-1	Thickness of bed ----	50	86.11	2.17	39.16	48.38	1.04	9.36	1.41	0.092
SJ 68-2		Composite	97.01	0.41	42.50	54.50	0.20	1.77	0.58	0.130

There are three large quarries, two on the southern part of the outcrop and one on the northern part. The largest of the southern quarries has a face over 100 feet high, and there is limestone remaining in the walls and on the quarry floor. It might be worked for a few thousand tons, but the expense of working on the steep hillside and the increasing amount of bedrock overburden would probably make it unprofitable. Several small quarries might be worked up the side of the hill along the strike of the limestone. The northern quarry faces average about 25 feet in height, and the quarry exposes so little limestone it is considered to be exhausted. Local residents report that the southern quarry floor was drilled a few years ago, but the results of this are not known. If the drill holes went down vertically, they would show only a few feet of limestone, as the bed dips to the southeast.

The ruins of an old limekiln are on the beach to the northwest of the quarries. Another kiln is reported to have existed in the early days of the quarrying operation, but its location is unknown.

References.—Shedd (1913, p. 204), McLellan (1927, p. 167), Glover (1936, p. 56), McDonald (1959, p. 3).

Entrance Mountain Deposit

Location, size, and accessibility.—The Entrance Mountain deposit is in the NE¼NE¼ sec. 6, T. 36 N., R. 1 W., at an altitude of about 750 feet on the steep northwest slopes of Entrance Mountain, on the east side of East Sound. It consists of a series of small limestone pods 1 to 5 feet in width cropping out over a strike length of 100 feet. The occurrence can be reached by following bulldozed spur logging roads up the steep hillside from the main logging road that starts from the Rosario road at the west end of Cascade Lake. To reach the largest outcrop requires hiking a few hundred feet up a steep forested slope above a spur road.

Geology and description.—The occurrence consists of at least six small pods of limestone aligned in a north-south direction over a distance of 100 feet. The outcrops are on a more gently sloping part of a steep west-facing hillside between steeper parts above and below. The limestone is crystalline in texture, white to light gray in color, and is laced with a network of black carbonaceous stringers. The age is unknown. A very small outcrop of conglomerate containing limestone pebbles was found on the shore of Cascade Lake to the east.

Quality.—The limestone is carbonaceous and siliceous.

Chemical analysis of Entrance Mountain 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
SJ 70-1	100	93.43	0.37	40.97	52.49	0.18	4.72	0.96	0.236

Ownership and development. — The owner of the property is unknown. There has been no development. The occurrence is too small to be of any economic value.

Reference. — McLellan (1927) (shown on geologic map but not mentioned in text).

Olga Deposit

Location, size, and accessibility. — The Olga limestone deposit is in the SW¼ sec. 8, T. 36 N., R. 1 W., on the east coast of East Sound northwest of the village of Olga. Several small pods of limestone are exposed on beach cliffs from 5 to 20 feet above the water. The largest lens is 32 feet long and about 5 feet wide. It is accessible by boat or can be reached by hiking along beach cliffs for about ½ mile northwest of Olga or by hiking south from Rosario logging roads.

Geology and description. — The deposit consists of several small limestone lenses in a chert and argillite sequence. Other small limestone lenses associated with volcanic rocks and sediments occur to the south along the coast. Most of the limestone bodies appear to dip steeply into bedrock. The limestone is crystalline in texture and gray in color. No fossils were seen, and the geologic age is unknown. The most northerly lens crops out on a steep slope at the head of a small peninsula. It is about 13 feet long and only 1 to 5 feet wide. About 70 feet to the south is the largest limestone lens, which has a length of about 32 feet and a maximum thickness of 5 feet. It strikes southwestward into the water and appears to pinch out inland to the northeast.

Quality. — The limestone is of poor quality and is high in magnesium and silica.

Chemical analysis of Olga 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
SJ 69-1	Composite	78.83	16.84	42.58	44.29	8.06	4.14	1.21	0.027

Ownership and development. — The property is owned by Loretta N. Shull, Florence Hoberg, Juanita Wanser, and Dan Shull. There is no indication of development. The limestone lenses are too small to be of any economic value.

Newhall Deposit

Location, size, and accessibility. — The Newhall limestone deposit is on the east coast of East Sound, in the NW¼ sec. 8, T. 36 N., R. 1 W. The main part of the occurrence consists of three or four small lenses of limestone, the largest of which is 100 feet long, reaches a maximum width of 35 feet, and has a vertical exposure of 34 feet. They are accessible by boat a distance of a little over 5 miles southeast from East Sound and 1½ miles northwest of Olga. The area can also be reached by hiking along the beach, and is within ¼ mile of a logging road. It lies at an altitude between 10 and 80 feet above sea level.

Geology and description. — The deposit consists of a series of pods and lenses interbedded with ribbon chert, volcanic rocks, and argillite. The sequence strikes 10°-40° NE. and dips 10°-30° SE.

The southernmost lens is 100 feet long north-south and reaches a maximum thickness of 35 feet. Shale is interbedded with it in parts of the outcrop. It is underlain by 2 feet of shale, under which is about 20 feet of ribbon chert. It is overlain by chert. The west side of the outcrop has been quarried and consists of an almost vertical face 34 feet high. Two small solution cavities are exposed in this face. About 70 feet to the northeast is another small, chert-enclosed limestone

body about 20 feet long and 5 to 10 feet wide. Eighty-five feet to the north is still another limestone body, about 85 feet long and from 5 to 10 feet wide. It is exposed vertically for about 10 feet. Below it to the west, exposed between altitudes of 10 to 50 feet, is an area about 120 feet long and 40 to 50 feet wide that is composed of large blocks and smaller fragments of limestone. It looks as if some of the limestone may consist of talus debris from an outcrop to the east above it, but part of it looks like outcrop. To the northeast along the strike at least two other, smaller limestone pods were found a few hundred feet from the main outcrop.

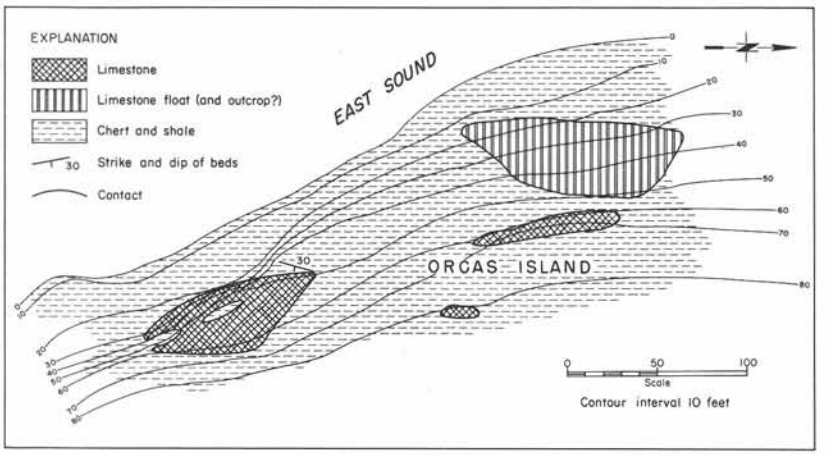


FIGURE 85.—Newhall deposit. NW¼ sec. 8, T. 36 N., R. 1 W. Geology by W. R. Danner, C. L. Smith, E. A. Adams, and C. F. Royse, Jr. Compass and tape survey.

The limestone is coarsely crystalline in texture, gray in color, and contains white veinlets of calcite. Black carbonaceous stringers and irregular small masses of dolomite are associated with it. No fossils were found, and the age is unknown.

Quality.—The limestone is mostly of high quality.

Chemical analyses of Newhall 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
SJ 71-1	Main body ------	180	97.41	0.64	43.30	54.73	0.31	0.86	0.32	0.012
SJ 71-2	North-south, talus ? --------	110	98.00	0.689	43.41	55.06	0.33	0.41	0.30	0.018
SJ 71-3	Small lens ------	15	98.13	0.418	42.90	55.13	0.20	1.19	0.50	0.039
SJ 71-4	Beach material --	Composite	97.49	0.79	43.24	54.77	0.38	0.87	0.26	0.015

Ownership and development.—The property is owned by Loretta N. Shull, Florence Hoberg, Juanita Wanser, and Dan Shull. Mrs. Shull lives in the nearby village of Olga. A small amount of quarrying was done at one time, and blocks of limestone from this operation remain on the beach. A small limekiln was erected on the property, but no trace of it remains today. The occurrence is too small to be of economic value.

Reference.—McLellan (1927, p. 167).

Rosario Deposit

Location, size, and accessibility.—The Rosario limestone deposit is in the SW¼ sec. 5, T. 36 N., R. 1 W., on the east coast of East Sound, on a steep hillside about 200 feet above and an estimated 150 feet inland from the shore. The occurrence is composed of three thin lenticular beds, 200, 150, and 90 feet feet in length, respectively, and ranging in width from 2 to 8 feet.

The property can be reached by boat at a log dumping site south of Rosario and then by climbing up the steep hillside to the outcrops, or it is accessible overland by climbing up or down from logging spur roads above and below the outcrops.

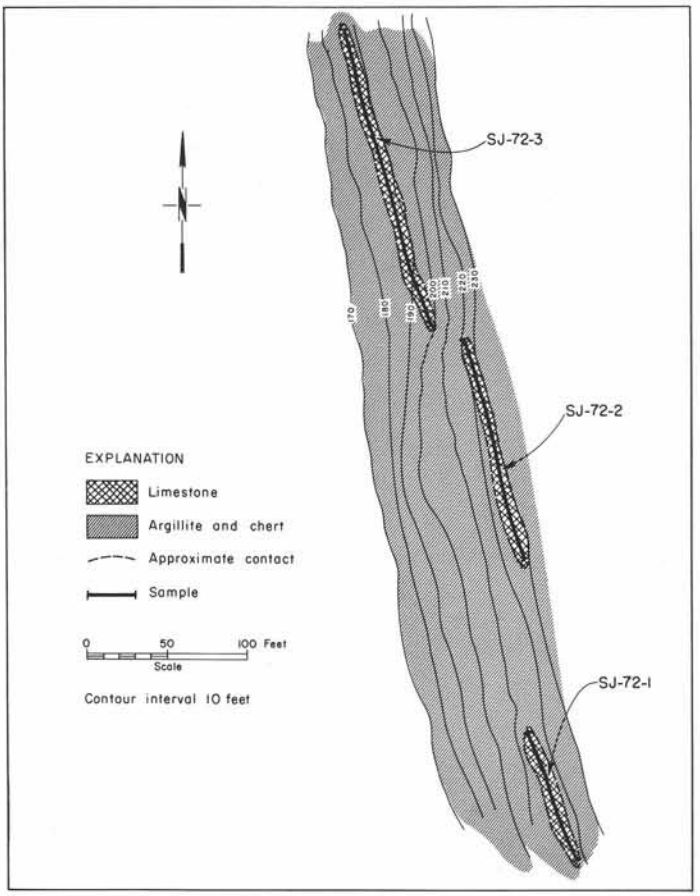


FIGURE 86. — Rosario deposit. SW¼ sec. 5, T. 36 N., R. 1 W. Geology by W. R. Danner, C. L. Smith, E. A. Adams, and C. F. Royse, Jr. Compass and tape survey.

It is about 0.8 mile by water from Rosario. The outcrops are difficult to locate, and the area of outcrop is precipitous and brush covered. The area has been logged recently.

Geology and description. — The southernmost limestone lens is exposed along a steep drift-covered side hill for a distance of 90 feet north-south and vertically between 5 and 10 feet. Dark blue-gray argillite crops out above and below the limestone. The limestone dips about 10° to 20° into the hillside. The hillside slope levels off 25 to 30 feet above the limestone outcrop.

The limestone bed is between 2 and 8 feet wide and pinches out at both ends. It strikes N. 20° W. and dips eastward. About 100 feet to the northeast is a second limestone bed about 150 feet long and 2 to 6 feet thick. It strikes about N. 15° W. and dips eastward. It is overlain and underlain by argillite and chert. The third limestone lens starts about 20 feet west and downslope from the second and can be traced for approximately 200 feet. It ranges in thickness from 4 to 8 feet and strikes about N. 16° W. It is also overlain and underlain by argillite and chert.

The limestone is dark gray in color, finely crystalline in texture, and contains visible argillaceous interbeds. Calcareous tufa coats the surface of the limestone outcrop in some places and is found cementing talus below the outcrop on the beach.

Quality. — The limestone is siliceous and slightly argillaceous.

Chemical analyses of Rosario 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
SJ 72-1	South ----------	90	90.95	0.75	40.63	51.10	0.36	5.99	1.53	0.033
SJ 72-2	Middle ---------	150	81.54	0.66	36.74	45.81	0.32	14.32	1.97	0.034
SJ 72-3	North ----------	200	82.78	3.82	38.30	46.51	1.83	11.35	2.02	0.032

Ownership and development. — The owner of the property is unknown, and there has been no development. The position of the limestone on a steep slope with bed rock overburden, its small width, and its high silica content make it an uneconomic occurrence.

Buck Mountain Deposit No. 1

Location, size, and accessibility. — The Buck Mountain No. 1 limestone deposit is in the NW¼NW¼ sec. 17, T. 37 N., R. 1 W., in a roadcut on the northeast side of Buck Mountain, above the northeast coast of Orcas Island. It consists of a small outcrop about 2 feet thick, exposed vertically for about 3 feet. It is accessible by about 0.8 mile of good logging road from Buckhorn Lodge.

Geology and description. — The occurrence is a small, poorly exposed limestone pod with no visible bedrock contacts. Siltstone and shales in adjacent roadcuts strike from N. 5° to N. 10° W. and dip 45°-70° NE. The limestone is buff-weathering and gray in color and mostly crystalline in texture.

Quality. — The limestone is argillaceous in composition.

Chemical analysis of Buck Mountain 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
SJ 75-1	Composite	80.63	0.73	35.94	45.30	0.35	16.94	1.13	0.039

Ownership and development. — The owner is unknown, and there has been no development. The limestone body is too small to be of any economic value but indicates the presence of a limestone-bearing sequence in this area.

Buck Mountain Deposit No. 2

Location, size, and accessibility. — The Buck Mountain No. 2 limestone deposit is in the NE¼ sec. 17, T. 37 N., R. 1 W., on the east slopes of Buck Mountain below Day Lake. It is along the northeast coast of Orcas Island just above and south of the main east coast logging road. The largest outcrop is 140 feet long, its maximum width is 40 feet, and it is estimated to contain between 15,000 and 20,000 tons of limestone. Two smaller outcrops, if continuous, form a body that is 125 feet long and has a maximum width of 30 feet. The area can be reached by following a logging road along the northeast coast of Orcas Island for a little over 1½ miles south from Buckhorn Lodge. The terrain slopes steeply eastward toward the water and is logged land now covered with small second-growth trees and dense brush.

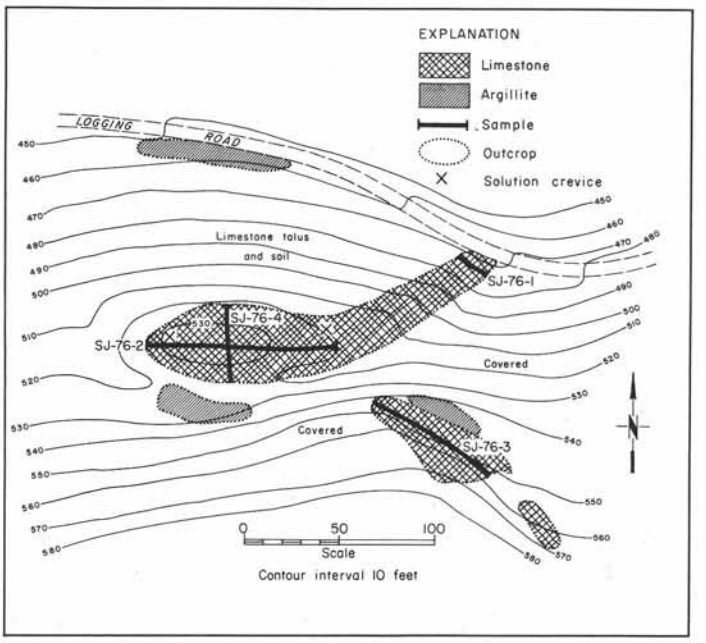


FIGURE 87. — Buck Mountain deposit No. 2. NE¼ sec. 17, T. 37 N., R. 1 W. Geology by W. R. Danner, C. L. Smith, E. A. Adams, and C. F. Royse, Jr. Compass and tape survey.

Geology and description. — The occurrence consists of two lenticular bodies of argillaceous limestone exposed on a steep hillside. The larger body is exposed at its north end in a logging road cut and trends southwest to west, forming a small knob on the steep slope. Its contacts are not visible, although argillite is exposed within a few feet of the south side of the outcrop at its west end. To the north, between the outcrop and the logging road, is a steep brushy slope covered with lime-

stone talus that conceals the contact of the outcrop in that direction. This area may be in part underlain by limestone, as it appears to be a dip slope.

There are two large cracks or solution crevices on the outcrop. One at the west end extends down vertically more than 12 feet. A smaller one, at the center of the outcrop, contains small stalactites on its walls.

The limestone is white to buff in color and finely crystalline in texture. It contains no visible fossils. When freshly broken, it gives off a strong bituminous odor.

Twenty-five feet to the south on the steep hillside are two other outcrops of similar-appearing limestone. The larger outcrop extends for 125 feet to the southeast and is separated from a smaller outcrop by a 25-foot covered interval that is believed to be underlain by limestone. The limestone disappears under glacial drift and soil 30 feet farther south and is believed to pinch out.

Quality. — The outcrops are composed largely of argillaceous limestone high in silica.

Chemical analyses of Buck Mountain No. 2 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)
SJ 76-1	Roadcut -----	20	76.87	1.42	34.53	43.19	0.68	20.10	1.43	0.021	160	420	260	240
SJ 76-2	North-south -	85	75.98	3.51	35.15	42.69	1.68	18.84	1.34	0.020				
SJ 76-3	South pod ---	65	53.04	0.56	23.75	29.80	0.27	44.12	1.89	0.027				
SJ 76-4	East-west ---	40	48.14	3.00	30.57	27.05	1.44	29.48	1.46	0.014				

Ownership and development. — The owner of the property is unknown. There has been no development. The limestone is too high in silica to have any economic value for uses other than for cement rock.

Mount Constitution Deposit

Location, size, and accessibility. — The Mount Constitution limestone occurrence is in the SE¼SW¼ sec. 16, T. 37 N., R. 1 W., on the northeast slopes of Mount Constitution just west of the junction of the main logging road with two abandoned spur roads. The outcrop forms a small knob and consists of a limestone lens about 325 feet long and from 50 to 100 feet wide. It is exposed vertically for about 50 feet and is estimated to contain between 50,000 and 60,000 tons.

The limestone is accessible by a logging road and is about 2½ miles southeast of Buckhorn Lodge. It is in recently logged terrain on which are a few trees and brush. Two abandoned logging roads branch off the main road at this locality, one going northwest and the other southwest.

Geology and description. — The occurrence consists of a small, almost east-west-trending ridgelike knob of argillaceous limestone. Its attitude could not be determined accurately, but Smith (1961) indicates that it is on the south limb of a syncline and dips 45° to 50° N. It forms the major part of a ridge about 350 feet long and 125 feet wide. The limestone is dense to fragmental in texture. It is dark gray on fresh surfaces and weathers to a buff color. Argillaceous material interbedded with the limestone gives it a lumpy or nodular appearance. Fossils are scarce, but crinoid stems, bryozoans, corals, and fusulinids have been found. A cast of the thorax and pygidium of a small trilobite was found in the outcrop in 1960 by Evan Adams, a student at the University of Washington. The fusilinids are identified as types indicating an Early Pennsylvanian age. On a hillside to the west a 1-foot bed of dark-gray dense-textured limestone was found in a sequence of argillite. This limestone weathers to a reddish-brown color.

Quality. — The occurrence contains visible chert and argillaceous impurities. The limestone in the northwestern part of the outcrop is more argillaceous than that exposed in the other parts.

Chemical analyses of Mount Constitution 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)
SJ 77-1	East-west --	325	80.54	0.48	36.32	45.25	0.23	15.80	2.00	0.032	300	490	810	256
SJ 77-2	North-south	100	89.21	0.43	40.33	50.12	0.21	7.41	1.91	0.019				
SJ 77-3		Single specimen	88.34	0.56	39.68	49.63	0.27	9.14	1.17	0.015				
SJ 77-4		Single specimen	49.98	0.43	23.07	28.08	0.21	45.45	3.00	0.054				

Ownership and development. — The owner of the property is unknown. There has been no development. The limestone may be too impure to be of economic value.

References. — University of Washington Department of Geology (1958, unpublished field camp report), Smith (1961, unpublished thesis, University of British Columbia).

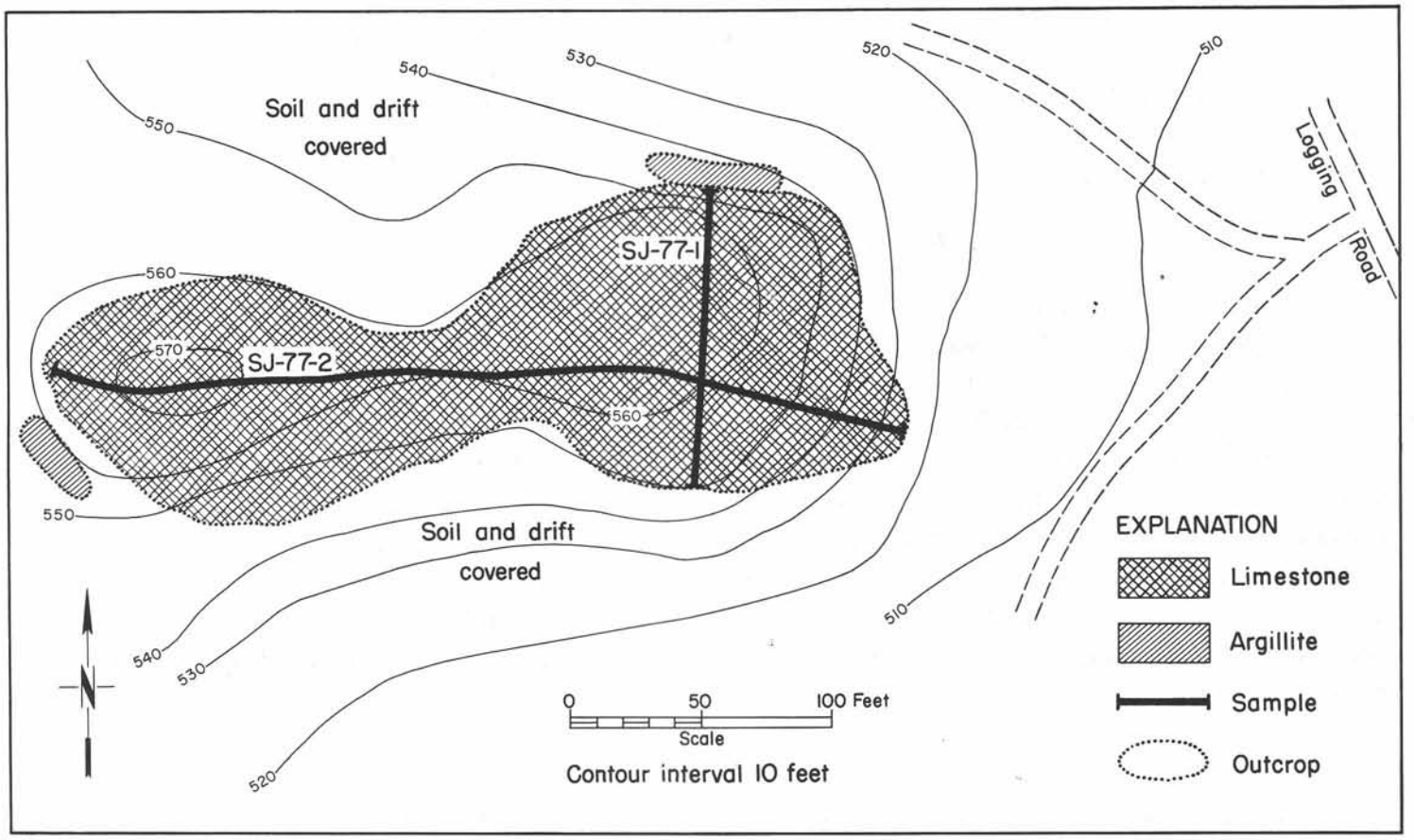


FIGURE 88. — Mount Constitution deposit. SW¼ sec. 16, T. 37 N., R. 1 W. Geology by W. R. Danner, E. A. Adams, and C. F. Royse, Jr. Compass and tape survey.

Raccoon Point Deposit

Location, size, and accessibility. — The Raccoon Point limestone occurrence is on beach cliffs in the NE¼ sec. 17, T. 37 N., R. 1 W., on the northeast coast of Orcas Island at a small point believed to be the same as that designated as Raccoon Point on the Orcas Island quadrangle of the United States Geological Survey topographic series. It consists of a

limestone bed 10 to 20 feet thick cutting across two small "peninsulas" over a distance of about 50 feet. The occurrence can be reached by hiking from Buckhorn Lodge south along the beach at low tide, a distance of about 1½ miles, or by hiking 500 feet down the hillside from a logging road through dense brush to the beach cliff.

Geology and description. — The limestone of this occurrence is a thin lenticular bed dipping steeply eastward into the beach cliffs at Raccoon Point. The bed is cut off down dip by a fault. Cherty argillite, volcanic rocks, and graywacke overlie and underlie the limestone. When freshly broken, it emits a strong bituminous odor. It is a splotchy, brownish gray in color and has a sugary crystalline texture. Small lenses of argillaceous rock are interbedded with it. No fossils were found, and the age is unknown.

Quality. The limestone contains argillaceous impurities.

Chemical analysis of Raccoon Point 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
SJ 78-1	20	94.39	0.33	41.91	53.03	0.16	3.29	1.02	0.014

Ownership and development. — The owner of the property is thought to be the Llewelyn Jenkins Estate. An old abandoned farm is east of the occurrences, on top of the beach cliff. There has been no development. The limestone is too small to be of any economic value.

Northeast Coast of Orcas Island Occurrences

Numerous small pods and lenses of limestone are exposed along the northeast coast of Orcas Island. Many of these are impure dense argillaceous limestones that weather to a buff color. Others are dense to crystalline in texture, gray in color, and weather to a light gray. These latter limestones are purer. None of the bodies are very large, and most of them are exposed over only a few square feet.

At one locality about 3/4 mile south of Buckhorn Lodge, several small knobs of limestone stick up through the beach gravels at low tide. This limestone contains numerous partially silicified fragments of fossil shells, but they have not yet been identified. Some of the limestone has been replaced by translucent brown chalcedony.

Where a logging road spur extends down to the beach just southeast of Buckhorn Lodge, there are numerous boulders and fragments of limestone float. Their origin is unknown, but they may have come from higher up on the steep slopes of Buck Mountain or may have been part of a small limestone body either now covered or blasted away during construction of the local logging road.

Payton Deposit

Location, size, and accessibility. — The Payton limestone deposit is in the north-central part of sec. 19, T. 37 N., R. 1 W., at an estimated altitude between 500 and 630 feet on the northwest slopes of Mount Constitution, on the east side of Orcas Island. It is composed of four partly quarried lenses of limestone, the largest of which is about 180 feet long and has a maximum width of 125 feet. The area can be reached by about 2 miles of highway from East Sound village to the junction with the old Mount Constitution road (Day Lake road) and then 0.9 mile up this road to the quarry road leading south for about 0.1 mile. The quarry road is now mostly overgrown with vegetation. The terrain is rocky and covered with brush and second-growth trees.

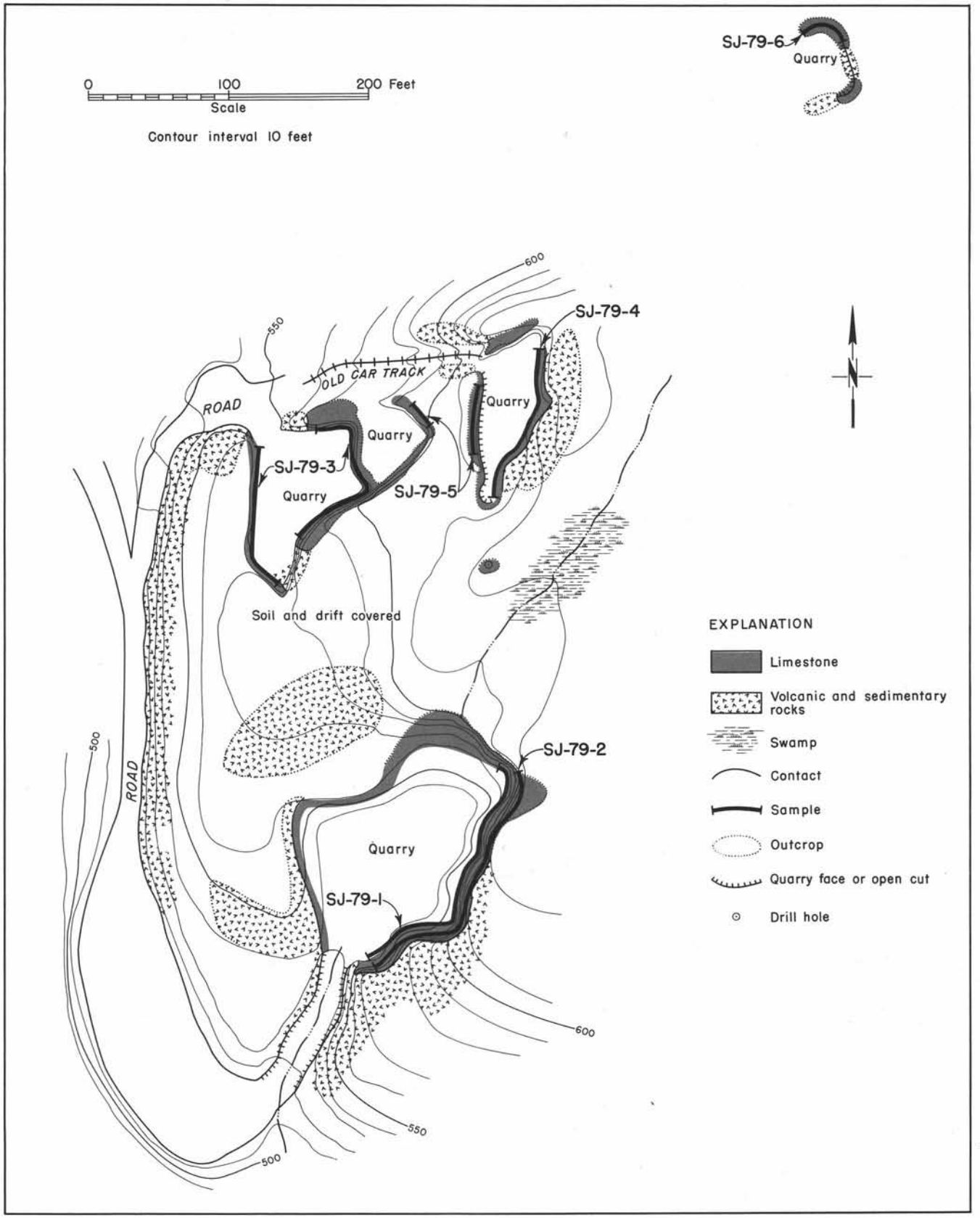


FIGURE 89. — Payton deposit. Sec. 19, T. 37 N., R. 1 W. Geology by W. R. Danner, E. A. Adams, and C. F. Royse, Jr. Compass and tape survey.

Geology and description. — The occurrence consists of a complex of limestone pods and lenses interbedded in volcanic rocks, chert, and argillite. In the main quarry area there are two principle limestone outcrops. The southern one of these is exposed on a southwestward-sloping hillside and is about 180 feet long and between 90 and 125 feet wide. It lies along a bearing of about N. 30° E. Volcanic rocks and sedimentary rocks crop out on its north and south sides. A small intermittent stream apparently flowed across it before quarrying was started, and now drains out through the quarry entrance on the west.

The limestone is crystalline in texture, gray in color, and is cut by numerous white calcite veinlets. It is sheared in places and contains carbonaceous, argillaceous, and siliceous impurities. Its age is unknown. One poorly preserved fossil colonial coral was found, but it has not been identified. A few vugs containing calcite crystals were noted in blocks on the quarry floor. The limestone appears to dip steeply to the northwest.

Another area of outcrop, 150 feet to the northwest, is about 250 feet long and ranges in width from 25 to 125 feet. Two quarries have been worked on this part of the deposit, but there is a covered area 25 to 50 feet wide between outcrops, so it is not known whether the limestone is continuous. One small limestone outcrop is between this part of the property and the previously described body to the south, indicating a possible continuation between them, but drilling and stripping would have to be done to prove any connection. A drill hole was noted in this outcrop, but nothing is known about what it revealed or who drilled it. The limestone in the northern part of the area is similar in appearance to that of the southern outcrop.

Three hundred feet to the northeast, on the side of a stream valley is a small limestone outcrop that apparently was quarried at one time. This outcrop exposes limestone and other rocks for a length of about 60 feet and is 15 to 25 feet wide. The outcrop is coverd with thick brush and is difficult to find.

About 400 feet to the north of the main limestone outcrop area are a few small bodies of limestone exposed in logging road cuts, and several hundred feet farther north is another small limestone body exposed in the bed of the Day Lake road.

Quality. — The limestone is of fair quality but is siliceous in places.

Chemical analyses of Payton 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
SJ 79-1	South quarry ---	225	93.78	1.96	41.70	52.69	0.94	2.85	1.38	0.020
SJ 79-2	South quarry ---	225	97.63	0.35	42.71	54.85	0.17	1.59	0.28	0.011
SJ 79-3	West ----------	200	92.73	1.35	41.15	52.10	0.65	4.39	1.53	0.180
SJ 79-4	Northeast -----	90	97.15	0.75	43.02	54.58	0.36	1.37	0.45	0.006
SJ 79-5	Between quarries	Composite	94.44	0.89	41.87	53.06	0.43	3.23	0.91	0.007
SJ 79-6	4th quarry -----	35	95.31	1.90	42.61	53.55	0.91	1.79	1.07	0.011

Ownership and development. — The owner of the property is unknown. Four quarries were developed on it, and apparently there were two periods of operation. The earlier operation used a small rail-and-car system, and the later one apparently used trucks. The limestone quarries are exhausted now, but further exploration might reveal a few hundred tons in the areas between the quarries.

References. — McLellan (1927, p. 167), Glover (1936, p. 56), Guard (1943, unpublished field notes).

Wright Deposit

Location, size, and accessibility. — The Wright limestone body is in the NE¼NE¼ sec. 19, T. 37 N., R. 1 W., at an estimated altitude of 900 feet on the northwest side of Mount Constitution. It is to the southeast of a large swampy area and is about 1/8 mile south of the Day Lake road. It is difficult to find. At one time a wagon road led to the south, just west and at the base of the small hillside on which most of the limestone is exposed, but now the trace of this road is very faint. The deposit consists of a lenticular bed or beds of impure argillaceous limestone exposed for at least 400 feet. In only a few places is the width more than 10 or 15 feet. The outcrop can be reached by going up the old Mount Constitution road (Day Lake road) starting 2 miles from East Sound village on the east side of the East Sound-Moran State Park highway, and following this road for about 2 miles to the east side of a large flat swampy area, then by hiking south along an old overgrown logging road to a small pass. The main limestone body lies on the hillside to the east of this pass, but fossiliferous argillaceous limestone also crops out in one small area to the west.

Geology and description. — The limestone of this deposit is exposed as a swelling and pinching body near the top of a northwest-facing steep hillside and can be traced for at least 400 feet along this hillside. In the northern part of the outcrop the limestone is exposed in places to a height of 15 to 20 feet on the face of a 50- to 60-foot-high cliff. Above and below is a sequence of cherty argillite containing interbedded smaller lenses of impure limestone. The sequence strikes northeast-southwest and dips steeply to the southeast. To the southeast along the top of the hill the sediments have been baked to a chert-like hornfels in contact with a medium-grained granitic rock.

The limestone is not the usual gray limestone of the San Juan Islands but is dark gray-buff in color and weathers to a brownish-buff color. It appears in hand specimen to be dense textured, but in thin section is organoclastic and oölitic. In thin section it is also seen to contain microfossils, most of which are fusulinids of Early Pennsylvanian age.

To the west, on the east-facing slope opposite the main limestone body, is a small, poorly exposed area of shaly limestone containing fragments of the typical large Pennsylvanian-age crinoid columnals.

A few hundred feet farther up the Day Lake road a small roadcut contains exposures of a highly weathered, impure and crystalline-textured limestone that contains poorly preserved remains of unidentified colonial corals. The limestone is interbedded with a sequence of argillite and sandstone and appears to be a small lens only a few square feet in area.

Quality. — The limestone of this occurrence is impure and argillaceous.

Chemical analyses of Wright 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
SJ 80-1	South part ------	80	66.78	0.71	29.95	37.52	0.34	30.10	1.92	0.028
SJ 80-2	North part ------	150	76.77	1.50	34.86	43.13	0.72	19.05	2.05	0.023

Ownership and development. — The property is owned by C. R. Wright. There has been no development, and the limestone is too thin and impure to be of any economic value.

References. — No references are known. The limestone outcrop was found by students of the University of Washington Field Course in the summer of 1958.

Flaherty Deposit No. 1

Location, size, and accessibility. — The Flaherty No. 1 limestone deposit is in the SW¼NW¼ sec. 30, T. 37 N., R. 1 W., near the top of a benchlike area on a western spur of Mount Constitution and about 1 mile northwest of Cascade Lake. The altitude is estimated to be about 700 to 730 feet above sea level. The occurrence consists of a lens of limestone about 105 feet long that has a maximum width of 60 feet. The outcrop is almost flush with the ground surface. It can be reached by following a recently bulldozed logging road from the Flaherty residence about 4,000 feet north from the East Sound-Moran State Park highway. The outcrop is difficult to find.

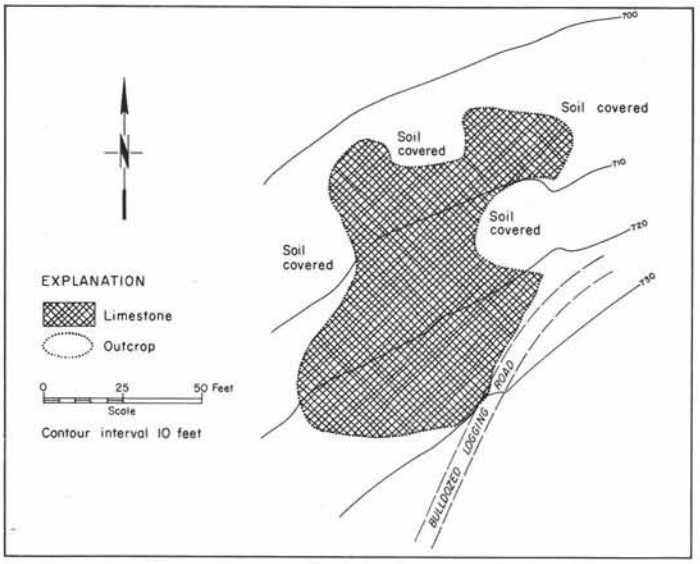


FIGURE 90. — Flaherty No. 1 deposit. NW¼ sec. 30, T. 37 N., R. 1 W. Geology by W. R. Danner, C. L. Smith, E. A. Adams, and C. F. Royse, Jr. Compass and tape survey.

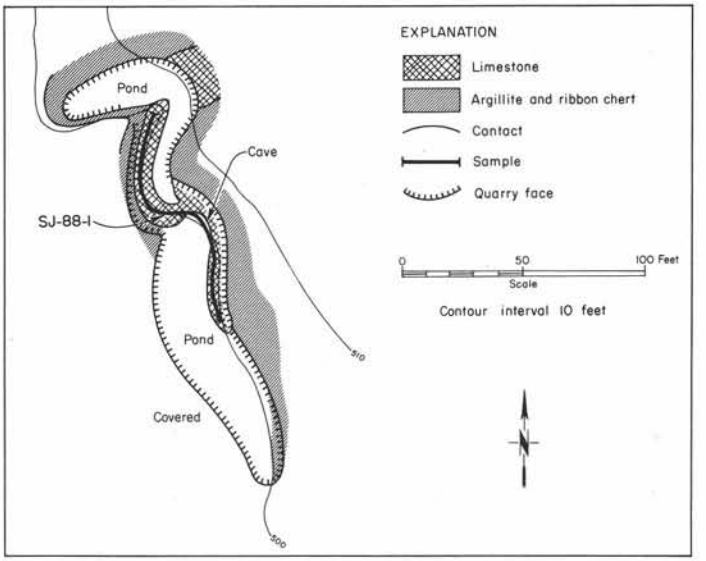


FIGURE 91. — Flaherty No. 2 deposit. SW¼ sec. 30, T. 37 N., R. 1 W. Geology by W. R. Danner, C. L. Smith, E. A. Adams, and C. F. Royse, Jr. Compass and tape survey.

Geology and description. — The limestone forms a small, low knob exposed mostly by recent logging operations. It is almost flush with the surrounding ground surface but on its northwest corner stands 2 to 3 feet above the general level of the area. It is gray to white in color and crystalline in texture. Weathered surfaces show a finely spaced joint pattern. No inclusions or impurities were seen in the outcrop. No contacts with bedrock are visible, but ribbon chert crops out in surrounding areas and strikes about N. 50° E. and dips 50° SE. The limestone is exposed vertically on the hillside for a distance of about 25 feet.

Quality. — The limestone is high in calcium.

Chemical analysis of Flaherty 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
SJ 81-1	Composite	97.72	0.39	43.15	54.90	0.19	0.81	0.50	0.130

Ownership and development. — The owner of the property is unknown. The limestone is too small to be of any economic value.

Flaherty Deposit No. 2

Location, size, and accessibility. — The Flaherty No. 2 limestone deposit is in the SW¼ sec. 30, T. 37 N., R. 1 W., on a hillside east and above East Sound. A small abandoned quarry is at the north end of a pasture. Limestone is exposed in the quarry walls for about 120 feet north-south and has a maximum width of about 30 feet. The area is accessible by about 3½ miles of paved road from East Sound village or 4 miles of paved road from the village of Olga, to the south. A few hundred feet of private road leads north across the pasture to the outcrop. The quarry floor is covered with water, and the quarry is overgrown with a dense cover of vegetation.

Geology and description. — The occurrence consists of a small lenticular bed of limestone striking about N. 45° W. and dipping 45° NE. At the north end of its outcrop it changes strike abruptly to the northeast. It is overlain by sheared argillite and underlain by ribbon cherts. The limestone is blue gray in color and crystalline in texture. Traces of fossil crinoid columnals are visible in a few places. Near the central part of the east face of the quarry a small solution cavity about 2 feet in diameter extends back into the limestone an unknown distance. Local residents report that this limestone body contained a small cave before it was quarried.

Quality. — The limestone is high in silica in most parts of its outcrop.

Chemical analysis of Flaherty 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
SJ 88-1	120	92.20	0.31	40.47	51.80	0.15	6.30	0.64	0.066

Ownership and development. — The property is owned by Mrs. Agnes Flaherty and contains two adjacent small quarry pits. One is filled with a pond and the other with a swamp. The outcrop area is heavily overgrown with vegetation. The history and date of operation is unknown. The quarry probably produced only a few thousand tons, and is now considered to be exhausted.

Flaherty Deposit No. 3

Location, size, and accessibility. — The Flaherty No. 3 limestone occurrence is approximately in the SE¼NW¼ sec. 30, T. 37 N., R. 1 W., at an estimated altitude of 800 feet, just below the top of a prominent benchlike area on a 1,400-foot-high mountain north of Cascade Lake. It consists of a small lens of limestone exposed for about 70 feet north-south, with a maximum exposed width of 16 feet and a vertical exposure of about 15 feet. It can be reached by 3½ miles of paved road from East Sound village or about 4 miles of paved road from Olga; then by following a private logging road north across a pasture past the Flaherty No. 2 quarry and up onto the mountainside for about 1,500 feet. The limestone outcrop is above the second branch logging road to the right. It is exceedingly difficult to find, and the area has been logged recently.

Geology and description. — The occurrence consists of a small limestone lens in ribbon chert. The limestone forms a 12-foot scarp facing west on the hillside. There is a steep slope above and below. The limestone dips eastward into the hill under chert, and quarrying could be carried on eastward about 20 feet before bedrock overburden would attain a thickness of as much as 1 foot. Two small sinkholes or pits are on top of the limestone exposure. A small prospect pit in chert was observed several feet south of the outcrop. The limestone is light gray in color and crystalline to dense in texture. No fossils were visible. Ribbon chert northeast of the limestone outcrop strikes N. 15° W. and dips 65° NE., and it is believed that the limestone has a similar attitude.

Quality. — The limestone is relatively high in silica.

Chemical analysis of Flaherty 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
SJ 89-1	70	95.90	0.60	42.19	53.88	0.29	2.06	0.74	0.043

Ownership and development. — The property is owned by Mrs. Agnes Flaherty. There has been no development, and the limestone body is too small to be of any economic value. It was prospected at one time, and one or more pits were dug to try to determine its size.

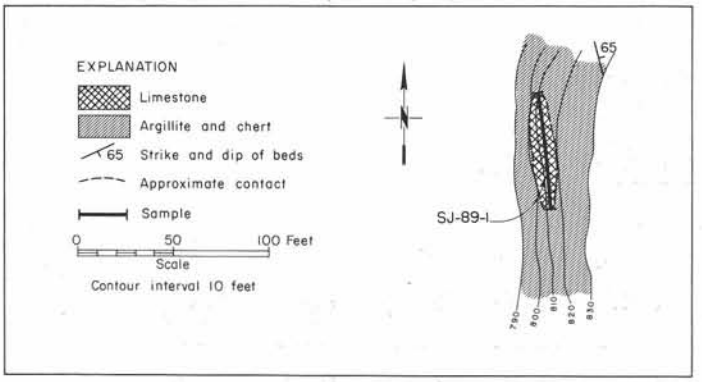


FIGURE 92. — Flaherty No. 3 deposit. NW¼ sec. 30, T. 37 N., R. 1 W. Geology by W. R. Danner, C. L. Smith, E. A. Adams, and C. F. Royse, Jr. Compass and tape survey.

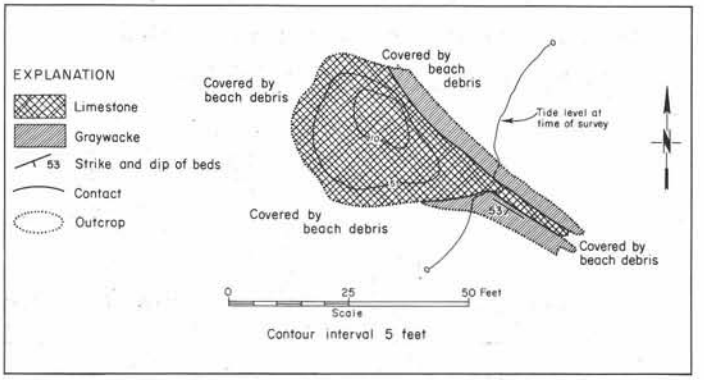


FIGURE 93. — Lawrence Point deposit. NW¼ sec. 31, T. 37 N., R. 1 E. Geology by W. R. Danner, C. L. Smith, E. A. Adams, and C. F. Royse, Jr. Compass and tape survey.

Lawrence Point Deposit

Location, size, and accessibility. — The Lawrence Point deposit is in the NW¼NW¼ sec. 31, T. 37 N., R. 1 E., on the southeast shore of Orcas Island just west of Lawrence Point. Exposed on the beach, it consists of a knob of limestone about 40 feet long that has a maximum width of 25 feet and a height of 12 feet. It contains about 500 tons of limestone. The area can be reached by hiking along a beach trail on top of the beach cliff or on the beach itself for about ½ mile east of the Lawrence Point resort. It is accessible also by boat. The base of the outcrop is covered with water at high tide.

Geology and description. — The limestone forms an isolated knob on the beach and is known locally as "the boulder." However, it is a limestone outcrop, and a thin extension of it about 2 feet thick strikes southeast under the water for at least 20 feet. Where interbedded with argillite at its southeast side, the limestone strikes N. 60° W. and dips 53° SW. It is underlain by graywacke. The limestone is crystalline in texture, light gray in color, and contains stringers of black carbonaceous material and veinlets and irregular masses of white calcite. It appears to be part of a narrow down-dropped fault block. Its extension on the beach is hidden by beach rubble, and its extension into the beach cliff by an area of glacial deposits and soil. On each side of this covered area are outcrops of igneous and metamorphic rocks believed to belong to the pre-Devonian basement complex of the San Juan Islands.

Quality. — The limestone is of good quality but is slightly siliceous.

Ownership and development. — The owner is unknown. The limestone body is too small to be of any great economic value but would involve little expense to blast and load onto a barge.

Chemical analysis of Lawrence Point 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
SJ 86-1	Composite	98.20	0.16	43.05	55.17	0.08	1.19	0.37	0.004

Chuckanut Lime Company Quarry

Location, size, and accessibility. — The Chuckanut Lime Company limestone deposit is in the SW¼ sec. 23, T. 37 N., R. 1 W., on the steep northeast coast of Orcas Island. A small body of limestone about 25 feet long, 6 to 10 feet wide, and exposed vertically for 10 feet is all that is still visible in an old quarry. It can be reached by following a single-lane logging road leading north for a little over 1 mile from its intersection with the road to Lawrence Point in the NW¼ sec. 36, then hiking down to the beach on a washed-out and overgrown branch road just south of the outcrop. The area slopes steeply down to the water and is very brushy and heavily wooded. Parts of the hillside have been logged in recent years.

Geology and description. — The remains of the old Chuckanut Lime Company quarry are so covered with vegetation and logging debris that it is impossible to determine the geology. The only limestone in place is at the northeast corner of the quarry. However, blocks and fragments of limestone are present along the west and south sides and an outcrop of argillite and graywacke is in the rim at the southwest side of the quarry. Bedrock outcrops on the beach cliffs to the east have a general attitude of N. 85° W. and a dip of about 45° to the southwest. These rocks consist mostly of massive to poorly bedded sheared graywackes, cut in at least one place by a dike of volcanic rock.

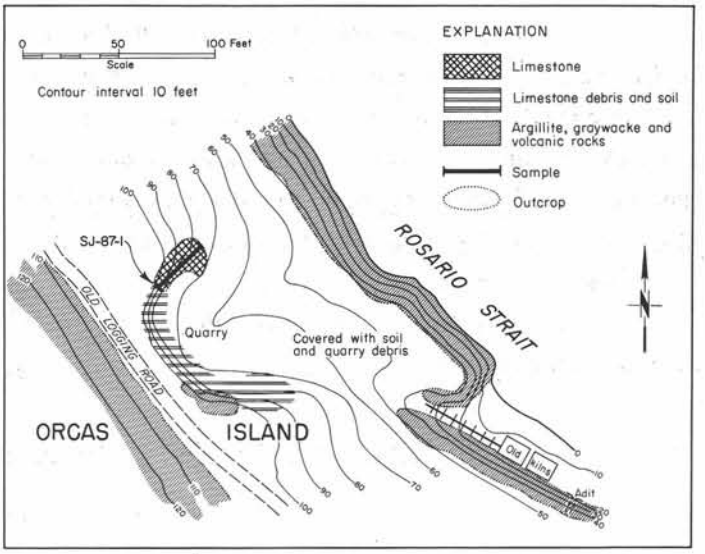


FIGURE 94. — Chuckanut deposit. SW¼ sec. 23, T. 37 N., R. 1 W. Geology by W. R. Danner, C. L. Smith, E. A. Adams, and C. F. Royse, Jr. Compass and tape survey. Contouring approximate only.

The limestone is dense to clastic in texture and light brownish gray in color. Some of it is partially recrystallized. Several specimens of the limestone examined in thin section show a clastic texture and contain fragments of volcanic rock, an occasional quartz grain, and tuffaceous material mixed with grains of clastic calcite. Some of the limestone is partially silicified. The only fossils seen were a fragment of an echinoid spine, some crinoid debris, and some poorly preserved structures that closely resemble stromatoporoids. The age of this limestone is unknown, but it is believed that the fusulinid illustrated by McLellan (1927, p. 127) came from this outcrop, as the clastic texture of the limestone in his thin section is similar. The fusulinid is too poorly preserved for identification but appears most likely to be an early Permian form.

Numerous water-worn boulders and fragments of limestone are present on the beach in the vicinity of the quarry.

Quality. — Limestone samples from the quarry and from the float on the beach were analyzed and appear to be partially silicified.

Ownership and development. — At one time the limestone was owned by the Chuckanut Limestone Company. The present owner is unknown. Some time before 1925 the quarry was abandoned. The ruins of two stone limekilns still remain

Chemical analysis of Chuckanut 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
SJ 87-1	25	94.69	0.25	42.05	53.20	0.12	3.41	0.93	0.009

on the property, and there are parts of old iron rails leading from the kilns to the quarry. A few feet to the south of the kilns a small adit extends several feet into argillite and graywacke. Its purpose is unknown.

If the limestone conforms to the regional bedrock dip, it dips into the steep hillside under bedrock overburden. It is probable that the quarry is now exhausted and of no further economic value.

Reference.—McLellan (1927, p. 106, 168).

Limestone in Lower Cretaceous Rocks of San Juan County

Spieden Island

Thin beds of limestone interbedded with shale crop out along the north coast of Spieden Island, just east of Spieden Bluffs. Few of the limestone beds exceed 1 foot in thickness, but individual beds may extend 15 or 20 feet along strike. All are lenticular in shape and pinch out along strike. Some beds are calcarenites containing sand-size grains of calcite, quartz, and rock fragments, but most are dense textured and argillaceous. A few of the limestone layers and adjacent shale beds contain the fossils Buchia crassicolis, Homolsomites stantoni (McLellan), and other ammonites and pelecypods, and also belemnites. The overlying conglomerates and sandstones, which make up the major part of the Spieden Formation, contain numerous fragments of limestone.

Many limestone fragments are lying on the beach near the outcrops and give the false impression that limestone occurs here in large quantities.

Limestone in Upper Cretaceous Rocks of San Juan County

Lopez Island

Thin-bedded calcarenites crop out on the south shore of Lopez Island east of Iceberg Point. They are interbedded with black shales and graywackes, and nowhere appear to be pure enough to be of economic value. In thin section they are seen to be composed of calcite grains, sharp angular quartz grains, and fragments of serpentine, plagioclase, and muscovite in a finer grained calcareous and argillaceous matrix. The sequence dips northward and strikes almost east-west. Above the calcarenites are pillow lavas that contain interbedded lenses of red and green calcareous argillite. Near the community of Richardson, red calcareous argillites interbedded with the pillow lavas contain foraminifers including Globigerina and possibly Globotruncana or Globorotalia (V. Standish Mallory, written communication, 1959).

Stuart, Sucia, and Orcas Islands (Nanaimo Group)

The Nanaimo Group of Late Cretaceous age consists mostly of conglomerates, sandstones, and shales, in part of marine origin and in part of continental origin. Associated with the marine shales are lenticular beds and concretionary bodies of argillaceous limestone. Very few of the limestone beds exceed 1 foot in thickness, and most of them do not extend more

than a few feet along strike, although a series of discontinuous lenses may have a fairly large areal extent. The limestone is bluish gray to brownish gray in color and dense in texture. Rarely is it fossiliferous.

Outcrops containing limestone were noted on the north shore of Orcas Island to the east of Point Doughty and on the northwest coast of the same island just south of Point Doughty. At the latter locality there are numerous specimens of calcified wood. The wood has been tentatively identified as Cupressoxylon (Glenn Rouse, oral communication, 1958).

Similar limestone beds occur on the north side of Stuart Island on the beach just east of Prevost State Park boat landing and on Sucia Island on the peninsula forming the south side of Fossil Bay. At all localities they are too small and impure to be of any economic value.

Chemical analysis of Stuart Island limestone

(Mark Adams, analyst)

Sample no.	Location	Sample length	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
SJ 90-1	North shore	Composite	49.70	9.22	23.29	27.92	4.42	29.16	15.17	0.316

WHATCOM COUNTY

Whatcom County extends from the Strait of Georgia eastward 90 miles to the crest of the Cascade Mountains and is 25 miles wide north-south. It is underlain by metamorphic, igneous, and sedimentary rocks ranging in age from pre-Devonian to late Cenozoic. Approximately 425 square miles of the western part of the county is covered with Pleistocene glacial, interglacial, and alluvial deposits.

Except for a few small concretionary bodies of calcareous claystone or argillaceous limestone in the Late Jurassic-Early Cretaceous Nooksack Group, all the limestone deposits in the county are of Paleozoic age. They are interbedded in a sequence known as the Chilliwack Group, which is composed mostly of marine clastic sedimentary rocks and volcanic rocks and which forms a northwest-southeast-striking belt of outcrop across the county, ranging in width from 14 miles in the south to 27 miles in the north. The Pleistocene volcano Mount Baker erupted almost in the middle of the Chilliwack outcrop belt and covers about 75 square miles of it. To the north and west of Mount Baker in an area of about 275 square miles, Mesozoic and Cenozoic rocks lie on top of the Chilliwack Group.

Limestone in the Chilliwack Group is of Devonian, Pennsylvanian, and Permian age. The Devonian limestone forms small coral-stromatoporoid reefs or banks and beds of dense-textured argillaceous,partly silicified, high-calcium to calcium limestone and calcareous shale. Five outcrops of the reef limestone have been quarried, but only one is still being worked, and it is used for pulp rock. The Devonian limestone does not constitute a large reserve of high-quality limestone.

The Pennsylvanian limestones form thick lenticular beds of calcium limestone that is commonly argillaceous and contains a considerable amount of secondary silica in the form of jasperoid or replacement chert.

They are most suitable for cement rock, and the largest accessible deposit on Red Mountain has been quarried for this purpose since 1928. Two smaller Pennsylvanian limestone bodies, one of which is still being worked, have been quarried for pulp rock. No large and easily accessible deposits of limestone of Pennsylvanian age are available for development, but two large areas of outcrop are known to exist in relatively inaccessible mountainous areas of the Chilliwack outcrop belt. One is on Black Mountain, and the other is in the vicinity of Ridley Creek, west of Mount Baker.

Permian limestones are known to occur only in the extreme northern part of the Chilliwack Group outcrop belt on Black Mountain and northeastward. They are quite variable in quality and contain argillaceous material,secondary silica,

and beds ranging from 10 to 27 percent magnesia. None of the Permian limestones have been exploited, and their variable composition and inaccessibility make them uneconomic under present conditions.

The Chilliwack rocks extend north across the Canadian boundary into the Chilliwack and Fraser River valleys of British Columbia and southeastward into Skagit County, in Washington.

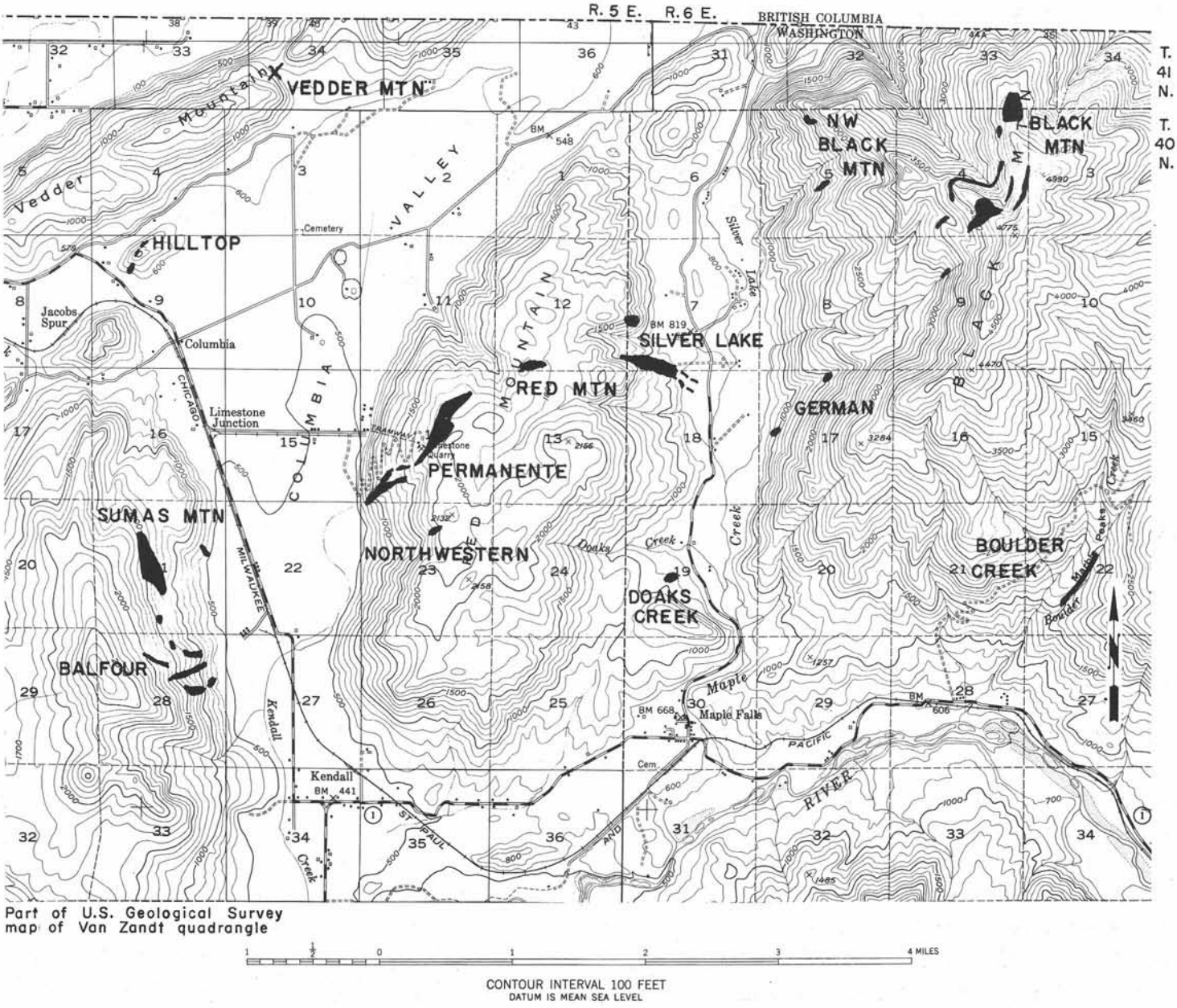


FIGURE 95. — Limestone deposits of northwestern Whatcom County.

Boulder Creek Deposit (Maple Falls Quarry)

Location, size, and accessibility. — The Boulder Creek limestone deposit is in the center of sec. 22, T. 40 N., R. 6 E., on the east side of a ridge known as Marble Peaks, on the west side of Boulder Creek. Limestone outcrops range in altitude from 1,560 feet to 1,980 feet above sea level. They consist of small lenticular masses of limestone as much as 300 feet long and 150 feet wide exposed in a northeast-southwest belt approximately 2,200 feet in length. The occurrence is

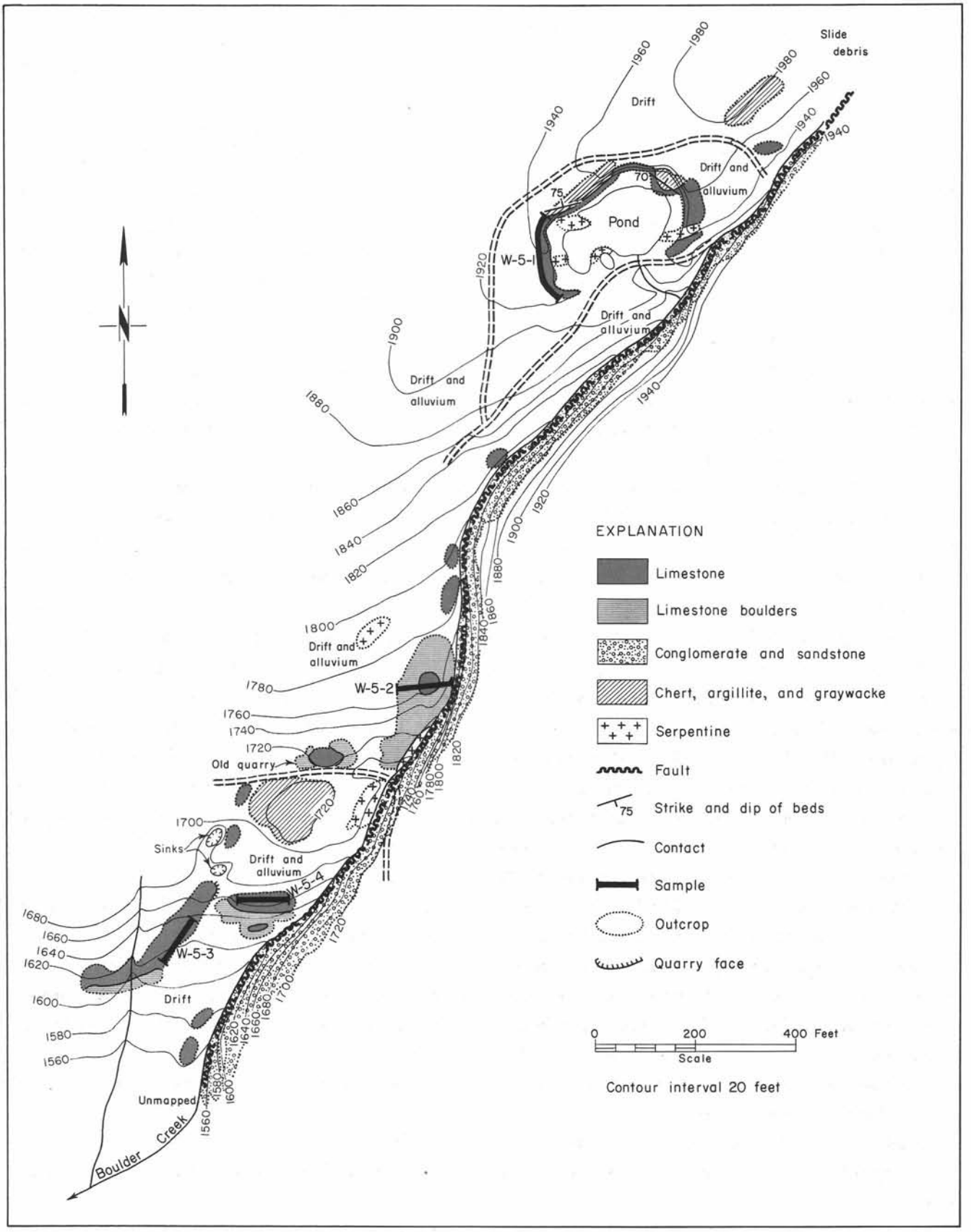


FIGURE 96. — Boulder Creek deposit. Sec. 22, T. 40 N., R. 6 E. Geology by W. R. Danner, C. F. McKillop, and A. M. Rivisto. Compass and tape survey.

accessible by about 2 miles of logging road that begins on the Mount Baker highway 2 miles east of Maple Falls at an altitude of about 610 feet. The first $1\frac{1}{4}$ miles of this road is gravel surfaced and normally in good condition. A branch road extends to the limestone from the main road in the $S\frac{1}{2}$ sec. 21 at the third switchback. This branch road is now overgrown with vegetation and it has partly slid away.

Geology and description. — The limestone is not well exposed but appears to consist of numerous small lenticular bodies interbedded in dark-gray chert, argillite, and graywacke and cut by dikes of dark-green lustrous serpentine. Glacial drift and alluvial deposits cover areas between outcrops to a depth of 20 feet or more, and most of the outcrops are knobs sticking up through these surficial materials. It is possible that the various outcrops are all part of one more-or-less continuous limestone bed, but a considerable amount of stripping of overburden would be required to prove this. It is more likely that the deposit is made up of small bodies not connected. Where visible, the contact between limestone and other rock is steep to the west or north, and it is thought that the limestone as a whole is in a sequence that has, in general, a steep westerly dip and a variable northeast-southwest strike.

Immediately east of the limestone on the steep east side of Boulder Creek are outcrops of dark-gray sandstone and conglomerate of the Paleocene (?)Chuckanut Formation. It is believed that a fault [Boulder Creek Fault (Miller and Misch, 1963, p. 171-173)] lies along the bed of Boulder Creek at this locality, separating the Chuckanut beds from the limestone-bearing sequence of older rocks to the west.

The limestone is light gray, gray, and white in color and mostly finely crystalline in texture. The only fossils that were observed are poorly preserved crinoid columnals. The age of the limestone is thought to be upper Paleozoic and most likely Pennsylvanian. In many places the limestone exhibits a peculiar fracture pattern that resembles a palm leaf in appearance. A similar pattern was observed in limestone at the McGraw-Kittinger quarry (south part), on Orcas Island. Its cause and significance are undetermined.

The northern part of the Boulder Creek limestone deposit contains a quarry about 200 feet long and 150 feet wide. Limestone is exposed in a large part of the quarry walls but dips steeply beneath chert, argillite, and graywacke on the north and west walls. To the south and northeast the limestone disappears under drift and alluvium. Two large serpentine dikes cut the southwest side of the quarry and converge to form a single dike on the northeast side. This serpentine has a brilliant luster and makes quite an attractive stone. One small outcrop of limestone is visible to the northeast of the quarry.

To the south, some 12 different outcrops are found. Of these, 8 are adjacent to Boulder Creek. Others are as much as 250 feet west of it. Some of these occurrences appear to consist of large limestone blocks that may be float and not bedrock. In one place there is a large accumulation of small limestone blocks resembling a talus deposit. Hodge (1938) described this accumulation as: "probably an old landslide mass which fell from the south end of the limestone band on the summit of Black Mountain. The limestone is a jumble of broken blocks, the largest of which is 275 by 250 feet and 150 feet high, forming a low ridge. . . . The deposit gives no evidence of being in place, and probably is not very deep."

Some of the limestone may well be of landslide origin, but it is doubtful that it came from the summit of Black Mountain, and certainly a large part of the limestone of the deposit appears to be in place. In places, limestone boulder deposits form a talus apron around the knoblike outcrops. The limestone as a whole may be broken up by faulting, and part of it may even be included in a fault zone separating Paleozoic and Cenozoic rocks.

Two prominent sinkholes are near the south end of the deposit along strike with a limestone outcrop and boulder belt about 450 feet long and 20 feet wide.

Quality. — The limestone tends to be fairly high in magnesium oxide in some places and also contains silica as an impurity. When it is hit with a hammer it often gives off sparks, indicative of minerals with a hardness of 6 or more in the Moh scale.

Ownership and development. — The limestone is owned by the Mitchell Bay Lime Company, formerly the Maple Falls Limestone Company. The occurrence is often referred to as the Maple Falls limestone quarry. Operations were discontinued about 1950, and the branch roads leading to the limestone from the main logging road extending up Boulder Creek are now

Chemical analyses of Boulder Creek limestone

Sample no.	Location	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
W 5-1	West side, north quarry[1]	180	99.02	0.33	42.97	55.63	0.16	0.67	0.32	0.200
W 5-2	Along strike[1]	120	99.16	0.20	43.12	55.71	0.10	0.37	0.26	0.248
W 5-3	Along strike[1]	100	98.48	0.39	43.37	55.33	0.19	0.09	0.09	0.150
W 5-4	Southern part of deposit[1]	100	98.54	0.39	43.10	55.36	0.19	0.40	0.37	0.209
	Unknown[2]		94.42		43.14	52.88	2.05	0.48	1.00	

[1] Samples collected for this report, Mark Adams, analyst.
[2] Shedd (1913, p. 216).

impassable. Several small quarries were developed on knobs and talus accumulations. The largest quarry is at the north end of the area, and its floor is now flooded. Several thousand tons of limestone still remains scattered in the various outcrops and talus accumulations, but because of dikes, thick drift and alluvium overburden, and the discontinuous nature of the outcrops, a profitable operation would be difficult. The talus deposits commonly contain much soil, sand, and gravel. Snow may cover the area to a depth of several inches during the winter months. Formerly the limestone was loaded onto trucks and hauled 2 miles to a railroad siding. Most of the rock was sold as pulp rock. It is reported that "marble" was taken from this deposit prior to 1915.

References. — Shedd (1913, p. 215-216), Hodge (1938, p. 44), Mathews (1947, p. 46-47), Moen (1962, p. 91-92), Miller and Misch (1963, p. 171-173).

Permanente Cement Company, Olympic Division, Red Mountain (Kendall Quarries)

Location, size, and accessibility. — The Permanente Cement Company property on Red Mountain consists of two quarry areas, one of which is now (1963) being operated and one of which has been abandoned for many years. The abandoned area is in the $SW\frac{1}{4}SW\frac{1}{4}$ sec. 14 and the $NW\frac{1}{4}NW\frac{1}{4}$ sec. 23, T. 40 N., R. 5 E., and the area currently being operated is in the $NE\frac{1}{4}SW\frac{1}{4}$, the $NW\frac{1}{4}SE\frac{1}{4}$, and the $NE\frac{1}{4}$ of sec. 14. The limestone extends from the east side of Columbia Valley in discontinuous outcrops northeastward to the western part of the top of Red Mountain. The outcrops range in altitude from 600 feet at the valley bottom to above 2,000 feet at the top of the mountain.

The lower quarry area is on a limestone outcrop that is traceable for about 860 feet northeast-southwest and has a width of approximately 100 feet at its south end and 300 feet at its north end. However, at least one-third of the larger width consists of interbedded or downfaulted rocks other than limestone. The vertical exposure is about 425 feet.

The upper quarry area has a continuous limestone exposure striking northeast-southwest for about 3,800 feet and ranges in width from 120 to 700 feet. The limestone is exposed vertically from about 1,575 feet to over 2,050 feet in altitude, or a distance of about 475 feet.

The limestone quarries are accessible by a good black-topped road extending about 1 mile east of the Sumas-Kendall highway at Limestone Junction to where the quarry road branches off to the south across a pasture area. The black-topped road continues east a few hundred feet to the company office and loading facilities.

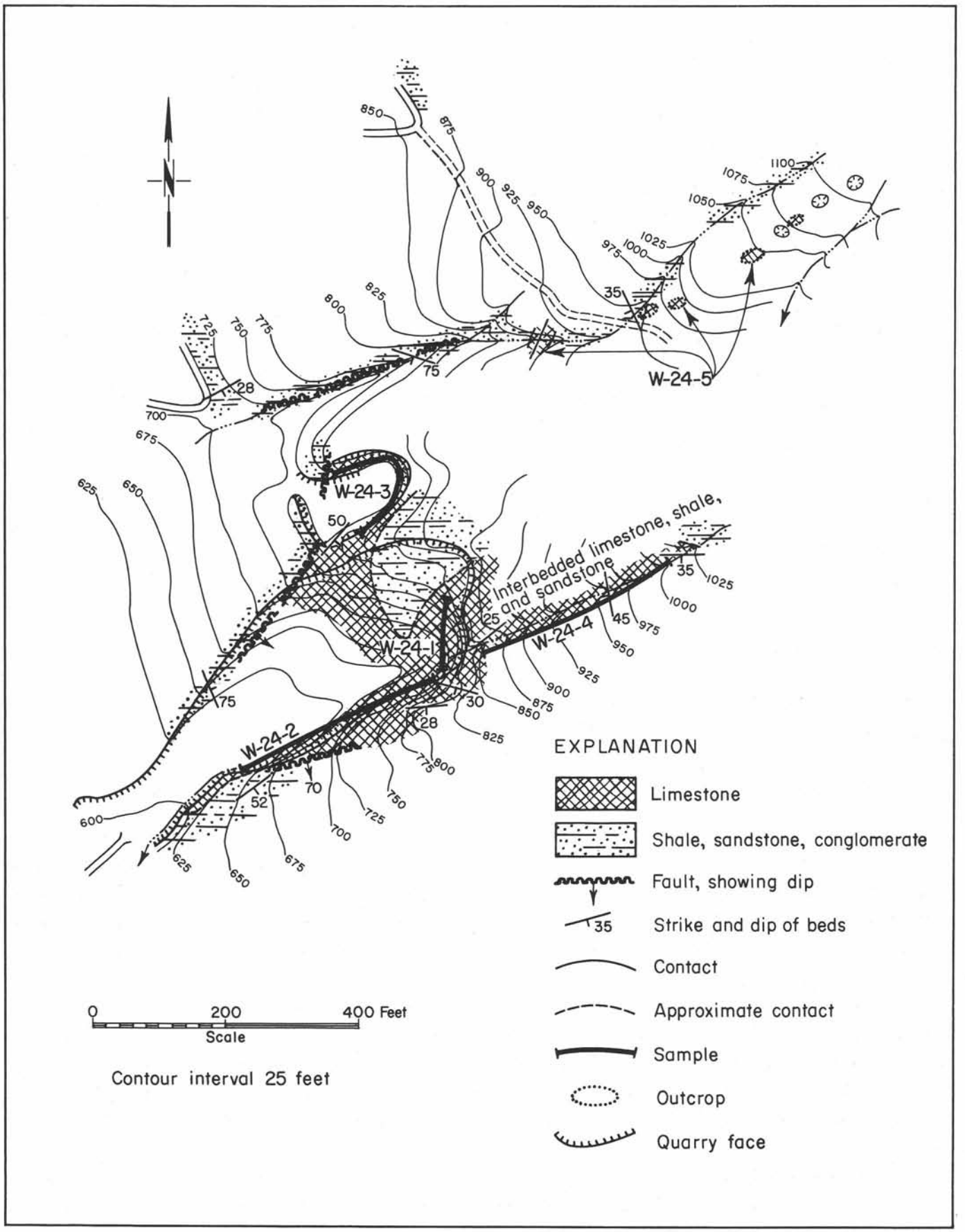


FIGURE 97. — Lower quarry area, Olympic Division, Permanente Cement Company. NW¼NW¼ sec. 23, and SW¼ sec. 14, T. 40 N., R. 5 E. Geology by W. R. Danner, C. L. Smith, E. A. Adams, and C. F. Royse, Jr. Compass and tape survey.

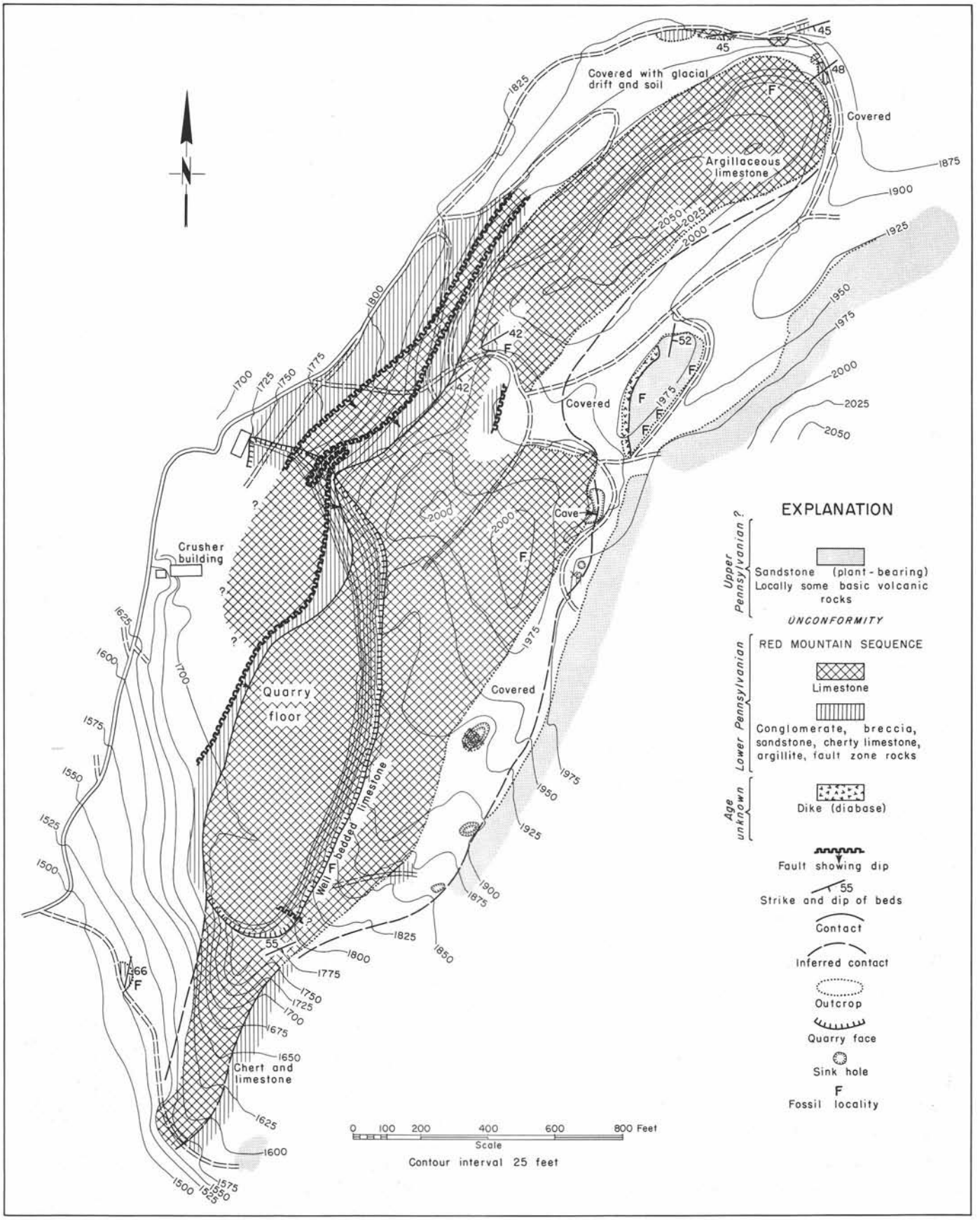


FIGURE 98.—Reconnaissance geologic map, upper quarry area, Olympic Division, Permanente Cement Company. Sec. 14, T. 40 N., R. 5 E. Geology by W. R. Danner, C. F. McKillop, and A. M. Rivisto. Base map in part from survey of R. G. Thompson, 1948, and in part from compass and tape survey of 1959.

The lower quarry area can be reached by following a graveled road south $\frac{1}{2}$ mile to where a narrow rough spur road leads farther south 0.1 mile to the old quarry entrance. Thick second-growth trees and brush surround the quarry. The upper northwestern part of this same quarry area is accessible also from the south end of the second switchback going up the mountainside on the upper working quarry road.

The upper working quarry area is accessible by 2.4 miles of steep but good graveled road switchbacking up the mountainside. The limestone is 34 miles by rail from Bellingham.

Geology and description

LOWER QUARRY AREA

This part of the deposit consists of a massive to well-bedded body of gray limestone that strikes generally northeast-southwest and dips 25°-50° SE. It is complexly crumpled into small folds and is cut by several faults. The north side of the quarry appears to be in part a fault surface, with the fault plane dipping about 60° SE. The footwall of the fault consists of northwestward-striking beds of shale, sandstone, and conglomerate that dip 70°-75° NE. At the south side of the quarry is a fault striking N. 65°-80° E. and dipping 70° SE. It cuts thin-bedded shaly limestone striking N. 45°-50° E. and dipping about 50° SE. Similar shaly limestones are exposed in the quarry walls to the northeast. At the northeast end of the quarry a large mass of shale and sandstone crops out on the rim and down the quarry face. It is not known whether this mass is interbedded or downfaulted into the limestone. It splits the limestone outcrop into two parts, the northwestern of which disappears under soil cover to the north, and the southern of which is exposed for several hundred feet up a small streambed to the east.

Much of the limestone of this deposit is argillaceous and well bedded. Large crinoid columnals are common, and some limestone beds exposed in the northern part of the quarry are composed almost entirely of crinoid debris. In the more shaly beds are poorly preserved brachiopods and bryozoans, as well as abundant crinoid remains. The sandstones along the north wall contain small amounts of carbonaceous material and a few small concretion-like structures, some of which resemble the "fruiting bodies" found in Pennsylvanian cyclothem sandstones of Ohio, Illinois, and other midwestern states.

Northeast of the quarry area one small exposure of limestone was found in a streambed, and small knoblike outcrops and some sinkholes indicate a continuation of the limestone to the northeast up the mountainside for at least 400 feet. This part of the limestone outcrop belt appears to be less than 50 feet wide, but it is too poorly exposed for determination of its width with certainty. The limestone and associated clastic sedimentary rocks are believed to be of Early Pennsylvanian age.

UPPER QUARRY AREA

The upper quarry area consists of a large lenticular limestone body striking northeast-southwest and dipping southeast. Along its northwest side it is underlain by a thin sequence of green sandstone and conglomerate. The conglomerate is composed mostly of layers of chert pebbles in a sandstone matrix, but locally there are breccias composed of chert, jasper, and volcanic rock fragments, along with crinoid debris. In thicker parts of the section, gray carbonaceous sandstone, coal, red shale, and other types of sedimentary rocks are present. A few plant imprints, small cone-shaped shells, and

FIGURE 99.—Upper Quarry, Olympic Division, Permanente Cement Company. View looking south, 1963.

pelecypods are the only fossils in the clastic sequence. From 25 to 100 feet beneath these rocks is a pronounced fault zone developed on carbonaceous shales, and below this is a fault slice of limestone 50 to 300 or more feet thick. It in turn lies in fault contact with thin-bedded calcareous argillites and sandstones.

The limestone is overlain unconformably by a dark-gray sandstone that contains locally interbedded basic volcanic rocks. The sandstone in a few places contains numerous plant stem fragments, some of which are Calamites and Sigillaria.

The limestone exposed in the quarry appears to be divisible into two parts: a lower massive unit and an upper well-bedded, more argillaceous unit. The bedded unit is best exposed in the upper part of the southeast face of the main quarry. To the north and south the limestone body as a whole becomes thinner and more argillaceous and contains a considerable amount of replacement chert, or jasperoid. The narrowing of the limestone outcrop toward the south is also due in part to a steeper dip. To the north the limestone outcrop ends rather abruptly in a soil-filled low area and appears to be thinner than elsewhere. It may pinch out or be cut off by faulting.

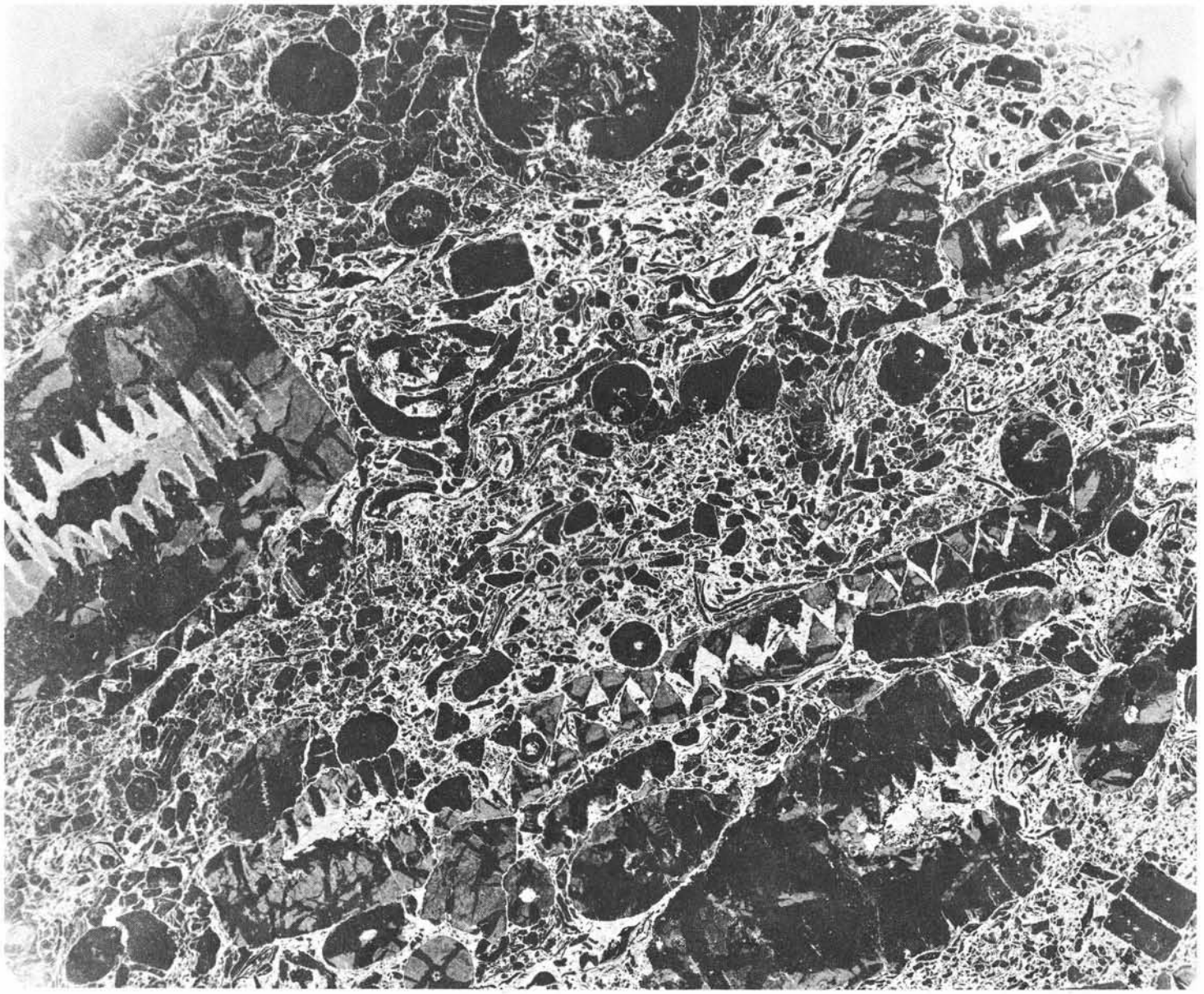


FIGURE 100.—Crinoidal organoclastic calcarenite, upper quarry, Olympic Division, Permanente Cement Company. Acetate peel, negative print. X 2 3/8.

Chemical analyses of Permanente Cement Company, Red Mountain limestone

Sample no.	Location	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3		P_2O_5	Alkali
					Analyses of samples collected for this report, Mark Adams, analyst							
W 24-1	Lower quarry area	110	88.53	1.609	39.65	49.74	0.77	8.74	0.97		0.024	
W 24-2	Lower quarry area	320	72.99	2.50	33.60	41.01	1.20	20.96	2.91		0.034	
W 24-3	North part, lower quarry area	200	81.43	2.25	36.90	45.75	1.08	14.90	0.86		0.026	
W 24-4	East stream bed	300	77.46	2.15	35.56	43.52	1.03	17.27	2.30		0.049	
W 24-5	NE. outcrops	Composite	90.40	6.10	43.22	50.79	2.92	2.56	0.38		0.020	
					Analyses from Permanente Cement Co., E. J. Baldwin, analyst							
	Upper quarry	Average, 1951			39.65	48.65	1.03	9.47	1.52			
	Upper quarry	Average, 1952			39.00	48.43	1.36	9.87	1.68			
	Upper quarry	Average, 1953			38.70	46.50	1.14	12.75	2.00			
	Upper quarry	Average, 1954			37.40	46.06	1.80	13.57	2.32			
	Upper quarry	Average, 1955			38.90	47.0	1.29	10.83	1.78			
	Upper quarry	4 months' average in 1959			40.56	48.94	1.51	7.19	Fe_2O_3 0.56	Al_2O_3 1.26		
Upper quarry area	Quarry face, middle	120-ft. hole			42.32	52.62	0.50	3.13	0.46	0.97		
	Quarry face, south	120-ft. hole			42.18	51.61	1.10	3.46	0.46	1.20		
	Quarry face, north	120-ft. hole			37.83	46.11	1.04	11.40	1.15	2.47		
	Quarry face, north	120-ft. hole			31.83	38.38	----	24.20	1.17	3.10		
	Middle north end, deposit	120-ft. hole			43.13	52.31	1.00	1.77	0.31	1.03		
	Siliceous shale, south				12.63	4.88	2.92	58.32	5.21	15.98		
	Shale, north				7.05	0.90	----	68.25	6.15	13.20		3-4
					Analyses from other sources							
Old lower quarry [1]	Unknown				39.36	49.99	0.54	7.50	0.71	1.17	0.037	
Upper quarry [1]	Bench 2				43.27	54.30	0.64	0.62	0.42	0.21	0.025	
Upper quarry [1]	Bench 3				43.02	54.84	0.008	1.14	0.38	0.41	0.023	
									R_2O_3			
Upper quarry [2]	Unknown		97.58	0.36				1.32	0.50			0.24
[3]	------ do				42.86	55.17	1.02	0.36	0.42			
[3]	------ do				41.14	43.27	17.06	7.58	1.42			
[3]	------ do				43.56	34.33	17.05	2.22	2.30			
[3]	------ do				42.66	55.86	Trace	0.60	0.30			
[3]	------ do				38.52	49.73	0.50	9.06	1.90			
[3]	------ do				42.14	55.22	Trace	1.80	0.58			
[3]	------ do				34.94	45.84	0.50	17.32	0.94			
[3]	------ do				40.84	53.07	0.50	3.94	1.18			
[3]	------ do				42.60	55.96	Trace	0.60	0.56			
[3]	------ do				43.36	55.25	----	0.46	0.40			
[4]	------ do		97.48	1.26				1.52	0.35			
[4]	------ do		98.72	0.26				1.37	0.42			

[1] Hodge (1938, p. 39).
[2] Shedd (1913, p. 211).
[3] Hodge (1938, p. 40).
[4] Landes (1906, p. 379).

The limestone in the central part of the occurrence dips more steeply on the north side than it does on the south, and this change in dip is in part responsible for the greater outcrop width. Where the dip is more gentle, the outcrop is the widest.

Along part of its southern side the limestone is bordered by a line of sinkholes. One of these is more than 90 feet in depth. The most northerly sink contains a small cave; an intermittent stream disappears into the ground near the cave entrance. North of the main quarry on the northeast side a small spring emerges from the limestone. So far, only a few small solution-enlarged joint cavities have been found in the quarry.

The limestone of this Red Mountain occurrence has long been noted for the large crinoid stems visible on weathered surfaces in the more argillaceous parts of the sequence. Many of the stems are found weathered out in the overlying soil. Bryozoans, horn corals, brachiopods, and pelecypods have also been found as fossils on weathered surfaces of the limestone. In thin section, much of the limestone is seen to be organoclastic and oölitic and to contain calcareous algae and the foraminifers Eostaffella, Ozawianella, Endothyra, and Tetrataxis. The limestone is believed to be Early Pennsylvanian in age and is part of a limestone sequence of similar age that can be traced in scattered outcrops northeastward across Red Mountain, onto Black Mountain, and into the Chilliwack Valley area of British Columbia.

Quality. — The composition of the limestone is quite variable, but high-quality rock is in sufficient quantity to be blended in with the more impure types. Localized areas high in magnesium oxide have been noted, and occasional lenses of shale occur.

Ownership and development. — This limestone was originally quarried some time before 1914 by the International Lime Company, and the limestone was used for the manufacture of hydrated lime. The plant had a capacity of 500 barrels of hydrated lime per day. In 1928 the property was bought by the Olympic Portland Cement Company and operated for cement rock until 1958, when the company became the Olympic Division of the Permanente Cement Company. In 1959, adjacent property was purchased to include all the main limestone body on the top of Red Mountain and to enable the quarry to be developed in the most economical manner. The limestone is shipped by rail to the cement plant at the north end of Bellingham.

When the quarry was acquired by the Permanente company in 1958, it was operated on single bench at the level of the crushing plant. The quarry face was as much as 240 feet in vertical height, and blast holes were drilled to the level of the quarry floor by churn drill. Blasting produced very poor fragmentation due to the nature of the rock, excessive burden per hole, and erratic hole spacing. Secondary drilling costs were high.

The limestone was crushed at the west side of the quarry and carried by aerial tramway down the steep mountainside approximately 1,700 feet horizontally and 1,200 feet vertically to a railroad bin. The crushing plant was limited to about 200 tons per hour, which was the capacity of the aerial tramway. The aerial tram has since been replaced with a gravity and belt conveyor system. Crushed rock is dropped 230 feet vertically to a stone box through a cased borehole 24 inches in diameter. From this box, the rock is conveyed to the tunnel portal and is discharged down the mountain slope a distance of about 1,000 feet on a 45° incline into a stockpile. The stockpile is equipped with a reclaim tunnel and conveyor, which carries the limestone into the railroad bin for shipping to the plant at Bellingham.

The churn drill has been replaced with a rotary drilling machine, which is reported to be giving a satisfactory performance. A mining plan to bench the quarry in 40-foot lifts is being developed, and continued study is being made to improve drilling procedures and to increase fragmentation.

Production of limestone from this operation in 1959 was about 40,000 tons per month. This is considerably more production than in previous years. A large part of the cement made from this limestone is shipped to Alaska, and in former years much was sent to British Columbia.

The composition of the quarry rock approximates that required for cement manufacture. When additional silica is required, it is obtained from a silica quarry 3 miles to the northwest. Clay is obtained from a pit about 4 miles northwest of the cement plant in Bellingham. This clay is under water and is dug and loaded into railroad cars by a railroad crane equipped with an orange-peel bucket. It is handled wet all the way.

References.— Landes (1906, p. 379-380), Eckel (1913, p. 361-362), Shedd (1913, p. 208-211), Glover (1936, p. 59), Hodge (1938, p. 28-41), Mathews (1947, p. 47-48), Libbey (1957, p. 83-84), Conners (1960, p. 58), Smith (1961, p. 9-26), Moen (1962, p. 89-91).

Red Mountain Deposit

Location, size, and accessibility. — The Red Mountain limestone deposit is mostly in the SW¼ sec. 12, T. 40 N., R. 5 E., but may extend southward into the NW¼ sec. 13. Outcrops occur on the top of Red Mountain near its north end at altitudes between 1,720 and 1,920 feet. The limestone has an outcrop area about 1,100 feet long and 100 to 325 feet wide. The greatest vertical exposure is 200 feet. It can be reached over about 4 miles of fair to poor logging road, starting from the Silver Lake road near the center of sec. 6, T. 40 N., R. 6 E., and climbing about 1,000 feet to the crest area of Red Mountain. The vicinity of the outcrop is covered in part with thick to open stands of second-growth trees. Some areas are very brushy, and the lowlands around the outcrop are covered with devils club.

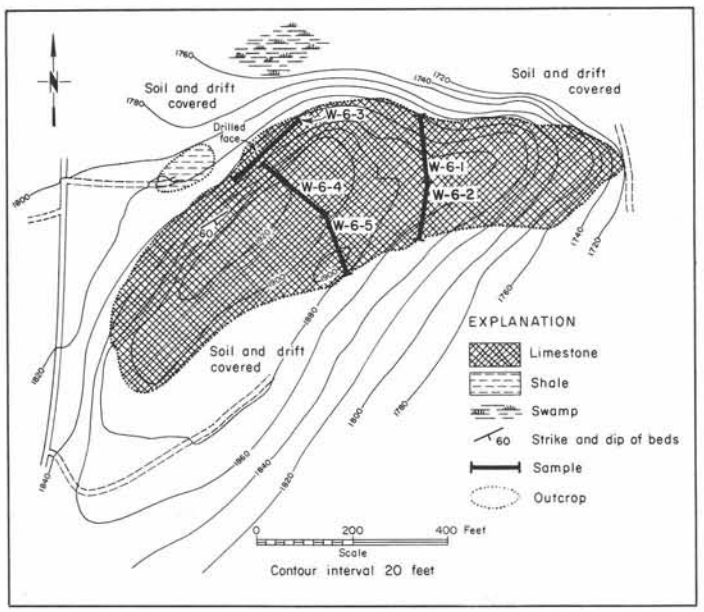


FIGURE 101. — Red Mountain deposit. SW¼ sec. 12, T. 40 N., R. 5 E. Geology by W. R. Danner, C. F. McKillop, and A. M. Rivisto. Compass and tape survey.

Geology and description. — The limestone is not too well exposed, but forms a small northeast-trending ridge with steep clifflike slopes on the north and a steep but somewhat gentler slope on the south. The ridge narrows and decreases rapidly in elevation toward the east. Outcrops are scattered along the ridge top and slopes and are abundant enough to make it reasonably certain that the area shown on the map is underlain mostly by limestone. In places, particularly near the east end and along the northwest side, small beds of shale are interlayered with the limestone. Irregular masses of jasperoid are also present.

At the west end of the outcrop area the beds of limestone and shale strike N. 55°-60° E. and dip about 60° SE. The limestone appears to consist of a large lenticular bed that pinches out to the northeast and southwest in shale. It is underlain by shale, but the overlying beds are not exposed. The outcrop area is surrounded on almost all sides by low, drift- and soil-covered marshy areas.

The limestone varies from dense textured and argillaceous to cherty, silty, and coarsely crinoidal. In some places it is well bedded. Many exposures show the fine sugary texture usually characteristic of replacement by dolomite, but these areas appear to be of limited extent. Large crinoid columnals are common fossils along the north side of the outcrop, a feature considered to be characteristic of some of the limestones of Early Pennsylvanian age in northwestern Washington. Small Pennsylvanian fusulinids, visible only in thin section, are also present. This age assignment would place the limestone on Red Mountain in the middle division of the Chilliwack Group. Some of the crinoid columnals are pastel pink in color, and the limestone containing them might make an attractive stone when polished.

Quality. — The limestone is argillaceous and cherty in places and locally shows dolomitization. The composition is quite variable.

Ownership and development. — Owner of at least part of the limestone is believed to be Pope and Talbot, Inc. A small face was blasted at the northwest side of the outcrop at one time, and a few holes were drilled into it. The body con-

Chemical analyses of Red Mountain 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)
W 6-1	North half, NE. end -----	130	92.98	2.40	42.26	52.24	1.15	3.68	0.68	0.022				
W 6-2	South half, NE. end -----	120	89.17	0.66	39.74	50.10	0.32	8.75	0.85	0.024				
W 6-3	North end -----	170	88.60	1.08	39.84	49.78	0.52	7.45	2.44	0.023	235	540	250	220
W 6-4	North side, west top -----	140	79.06	1.14	35.61	44.42	0.55	18.65	0.72	0.035				
W 6-5	South side, west top -----	120	94.71	1.69	42.72	53.21	0.81	2.57	0.83	0.030				

tains probably more than 2,000,000 tons of limestone, but the impurities in it make it suitable only for cement rock. Its ridge-like outcrop area provides several suitable quarry sites.

Reference. — Moen (1962, p. 96).

Silver Lake Deposit No. 1 (Maple Falls Quarry)

Location, size, and accessibility. — The Silver Lake No. 1 limestone deposit is in the SW¼ sec. 7, T. 40 N., R. 6 E., at the base of the east side of Red Mountain, about ½ mile southwest of Silver Lake. Outcrops range in altitude from about 800 to 1,180 feet above sea level. The limestone is poorly exposed but may consist of a lenticular bed at least 1,200 feet long and up to 150 feet in height. It could contain between 3,500,000 and 4,000,000 tons of limestone.

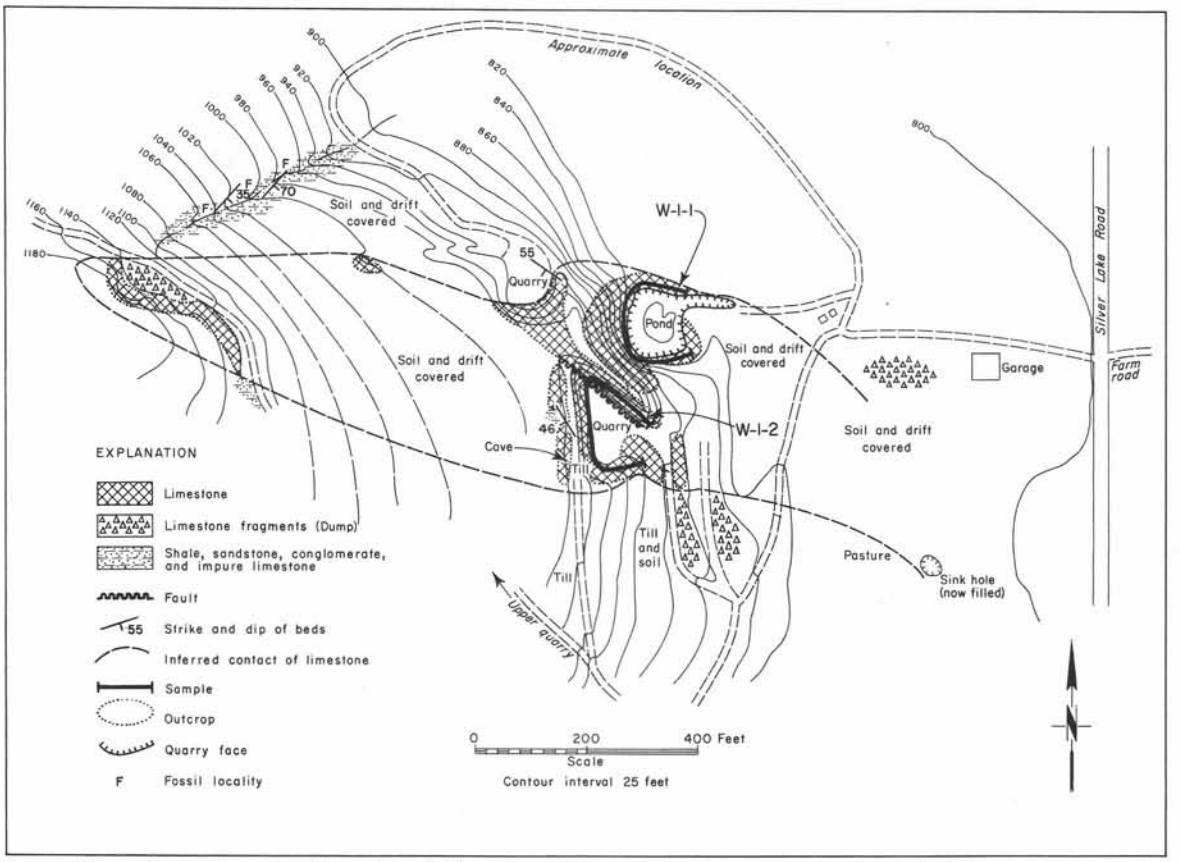


FIGURE 102. — Silver Lake deposit No. 1. SW¼ sec. 7, T. 40 N., R. 6 E. Geology by W. R. Danner, C. F. McKillop, and A. M. Rivisto. Plane table and compass and tape survey. August 1959.

FIGURE 103.—Silver Lake deposit No. 1. View looking west, August 1959.

The limestone outcrop is easily accessible by a graded gravel-surfaced road extending 3 miles north from the community of Maple Falls, on the Mount Baker highway. It is 27 miles by road east of Bellingham.

Geology and description.—The limestone appears to form a continuation along strike of the Lower Pennsylvanian limestone lenses that strike northeast-southwest across Red Mountain from the quarries of the Permanente Cement Company on the west. It appears to be a lenticular bed that pinches out to the west up on the steep hillside and disappears under a cover of glacial drift, soil, and alluvial deposits to the east in the broad valley of Maple Creek. Whether its apparent lenticular shape is due to its original pattern of deposition or whether it has been broken into its present shape by faulting could not be determined. Several small faults were observed in quarry faces on the deposit, but these faults appear to have only minor displacement. The limestone exhibits internal contortion and deformation, and some individual beds within it dip vertically and are overturned locally. Dips of 40° to 60° are common. The limestone body itself appears to strike northwest-southeast and to dip to the southwest, but sediments underlying it to the north strike northeast-southwest and dip at angles of 30°-80° SE.

The total extent of the limestone is concealed by a cover of soil and glacial deposits. Along the north border of the outcrop, 20 feet or more of glacial till is exposed adjacent to the limestone. Near the south side a similar thick till cover is present and small channels filled with several feet of till occur on top of the limestone.

The eastern extension of the limestone into the alluvium-filled valley of Maple Creek is indicated only by a sinkhole that, in the summer of 1959, developed in a pasture adjacent to the quarry. The hole was later filled in. Westward up the hillside a small outcrop area, believed to be a continuation of the limestone along strike, appears to thin and pinch out at about 1,180 feet in altitude. Farther west is a relatively flat marshy area covered with dense vegetation, and still farther west the hillside steepens and contains outcrops of clastic sediments and volcanic breccia. Shale and graywacke are believed to overlie the limestone, and good exposures of the limestone in a small streambed to the north show a sequence of graywacke, conglomerate, shale, and argillaceous gray limestone underlying it.

The limestone is light gray to dark blue gray in color and shows organoclastic, dense, and crystalline textures. In thin section much of the limestone is organoclastic in texture and is composed of broken fragments of crinoids, bryozoans, and brachiopods, along with other fossil debris. Large crinoid columnals over an inch in diameter are common in the quarries and are believed to be diagnostic of an Early Pennsylvanian age in northwestern Washington. The clastic sedimentary rocks and argillaceous limestones exposed in the small streambed north of the quarry are fossiliferous and contain crinoid and bryozoan fragments, productid brachiopods, gastropods, and other fossils. A few plant stem impressions were found also. Several hundred feet to the northwest a specimen of limestone float containing early Permian fusulinids was collected, but no outcrop of it was found on Red Mountain, and it may be a glacial erratic.

In places the limestone gives off a bituminous odor when freshly broken. The limestone contains visible chert and argillaceous and carbonaceous impurities.

Quality. — The limestone is variable in composition, and although parts of it are of high quality, other parts are argillaceous and contain jasperoid and magnesia. The western part of the outcrop contains more visible impurities than other parts.

Chemical analyses of Silver Lake No. 1 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)
W 1-1	NE. quarry ----	280	81.06	6.81	39.72	45.54	3.26	10.22	0.89	0.024	290	530	130	530
W 1-2	South quarry ---	320	97.52	1.67	43.62	54.79	0.80	0.50	0.18	0.030				

Ownership and development. — The property is owned jointly by Mrs. Virginia Lobdell, 6311 S.E. 27th, Mercer Island, Wash., and by Kiefer Fobes, Lock Box B, Ballard Station, Seattle. It is leased to Gordon Clausen, Mitchell Bay Lime Company, 1928 Milford Way, Seattle. The limestone is quarried for use as pulp rock. It is known as the Maple Falls quarry in some reports, but the same name was formerly applied to the limestone on Boulder Creek $3\frac{1}{2}$ miles to the southeast. The quarry operation was started about 1954 or 1955. When examined in July of 1959, this limestone had four adjacent quarries located on it.

References. — Banta (1956, p. 28), Moen (1962, p. 87-89).

Silver Lake Deposit No. 2

Location, size, and accessibility. — The Silver Lake No. 2 deposit is on a steep hillside on the crest of the north side of a canyon north of the Silver Lake No. 1 limestone in the $NW\frac{1}{4}SW\frac{1}{4}$ sec. 7, T. 40 N., R. 6 E. Outcrops occur at altitudes between 1,200 and 1,300 feet above sea level, and are found over a triangular area about 250 feet long northeast-southwest and 160 feet wide.

The limestone is reached by hiking up the steep, brushy hillside west of the "Day" farmhouse, now owned by Oliver Ferry, who lives on the next farm to the north. From the base of the hill the distance to the outcrop is between 300 and 400 feet. The limestone is about 3½ miles north of Maple Falls and about ½ mile west of the Silver Lake road. Second-growth trees and brush cover the surrounding terrain.

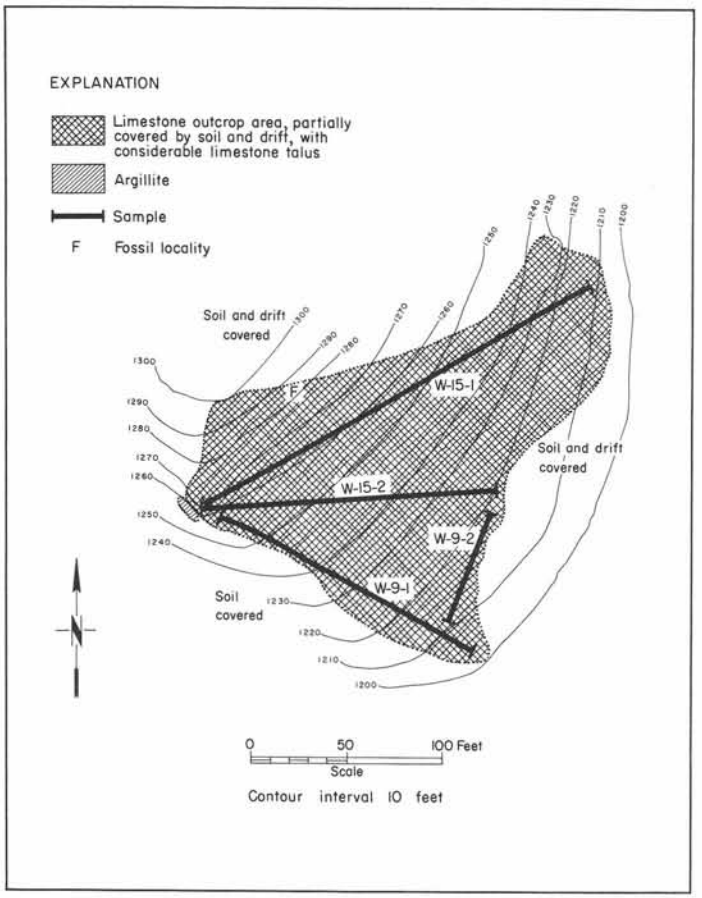


FIGURE 104.—Silver Lake deposit No. 2. NW¼SW¼ sec. 7, T. 40 N., R. 6 E. Geology by W. R. Danner, C. L. Smith, E. A. Adams, and C. F. Royse, Jr. Compass and tape survey.

Geology and description.—Exposures are quite poor, but the limestone is thought to consist of a lenticular bed striking northeast-southwest and dipping to the southeast. If this is the case, then the limestone forms a slablike body lying generally parallel to the hillside and does not have much depth. Outcrops occur as numerous small knobs and cliffs on the soil- and drift-covered hillside. A few sinkholes are present, and there are small areas of limestone talus. In one of these talus areas a strong draft of cold air issues from openings between limestone blocks, and this, along with the presence of a small tufa-depositing stream emerging from the hillside below the south outcrop area, indicates the possibility of a small cave system in the limestone.

Small outcrops of argillite are present west and north on the higher parts of the hillside above the limestone and in the canyon below it to the south. Large boulders of limestone, apparently derived from this exposure, rest in the canyon bottom a few hundred feet below to the south.

The limestone of this deposit is quite different in appearance from that of other deposits in the area and is dark gray to brownish gray when weathered and is dense textured. It contains irregular masses of secondary silica and has a bituminous odor when freshly broken. In places it contains numerous remains of thin-shelled, very poorly preserved pelecypods or brachiopods, but nowhere could these be broken out of the rock, and nothing but poorly preserved cross sections are visible. In 1960 Evan Adams collected from this limestone one incomplete silicified internal mold of a medium-sized brachiopod, but it could not be identified. Traces of other silicified brachiopods are present but not well preserved. In thin section, some specimens of the limestone are seen to

Chemical analyses of Silver Lake No. 2 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)
W 3-1	Float below deposit -----	Composite	87.25	1.65	38.98	49.02	0.79	7.92	2.16	0.076				
W 9-1	South side ----	150	89.14	0.96	40.70	50.08	0.46	7.70	1.48	0.050				
W 9-2	East end, south side ---	60	88.60	1.14	39.97	49.78	0.55	8.16	1.66	0.049	225	560	315	150
W 15-1	North-south --	230	85.16	2.15	40.12	49.53	1.03	7.81	1.30	0.045				
W 15-2	East-west ----	150	90.08	1.21	40.12	50.61	0.58	5.82	2.23	0.029				

be partially recrystallized, some have a peculiar mottled structure, and others contain what appear to be broken fragments of thin fibrous shells. The age of the limestone is unknown.

Quality. — The limestone is cherty and argillaceous and contains relatively high amounts of silica and other impurities. Some parts may be high in magnesium.

Ownership and development. — The owner is unknown, and there has been no development. The limestone might be used for cement rock, but seems to be too impure for other uses. It needs to be drilled to determine its depth, as the deposit may be too small to be of any economic value.

Reference. — Moen (1962, p. 97).

Balfour Deposits

Location, size, and accessibility. — The Balfour deposits consist of four separate abandoned quarry areas and three belts of limestone outcrops on the east side of Sumas Mountain, mostly in the north part of sec. 28, T. 40 N., R. 5 E. Limestone is exposed at the base of the mountain at an altitude of about 600 feet, and small discontinuous outcrops are found up to an altitude of 1,680 feet on the slope above.

It is difficult to determine the size of the limestone bodies that were quarried, as the quarry walls show much evidence of folding, faulting, and shearing and it appears that large quantities of wall rock were removed along with the limestone. The largest quarry is at least 400 feet long, about 120 feet wide, and 100 to 200 feet deep. It may have been as much as 800 or 900 feet in length, but the western part is filled with landslide debris or is in part a slumped landslide block.

The largest untouched outcrop west above the quarries is about 100 feet long, as much as 60 feet wide, and is exposed vertically for about 45 feet. It is part of a belt of small discontinuous limestone outcrops and sinkholes known to extend over a distance of 620 feet.

The limestone is accessible by a gravel-surfaced road that branches west off the Kendall-Sumas highway in the SW$\frac{1}{4}$ sec. 22 and extends for about $\frac{1}{4}$ mile southwest to an area of old houses. From there it continues as an unsurfaced road about $\frac{1}{2}$ mile to the southernmost quarries. A logging road, now mostly overgrown and impassable, branches off from the lower quarry road and extends up the mountainside for over a mile and has several short side spurs. It is still usable as a trail, giving partial accessibility to the upper parts of the quarries and outcrops higher on the hillside.

Geology and description. — The heavily forested soil- and drift-covered eastern slopes of Sumas Mountain furnish very few outcrops of bedrock. Logging road cuts and the abandoned limestone quarries contain a few excellent exposures and furnish a limited amount of information on the stratigraphy and structure. The limestone quarries and the limestone exposures extending to the northwest of the quarries form three distinct belts of limestone outcrops. It is not known for certain whether these three belts are three separate and distinct limestone units in the stratigraphic section or whether they represent one unit repeated by faulting and folding. The similarity in fossil content and the abundant evidence of faulting leads the writer to suggest that the limestone consists of either only one large lenticular bed or separate small lenses (all belonging to approximately the same stratigraphic position) repeated by faulting and folding.

The limestone ranges in color from a dark gray to black and weathers to a light gray. It is dense, crystalline, or organoclastic in texture. The darker limestones are commonly the most argillaceous. Thin layers consisting largely of crinoid debris occur at the northeast side of the most northern quarry (No. 4) and may occur elsewhere. Poorly to well-preserved fossil specimens of the colonial corals Plagiopora and Thamnopora, along with the stromatoporoids Amphipora and Stromatoporella and fragmentary remains of other corals, bryozoans, and brachiopods, occur in the quarries and most of the outcrops. The fossil suite indicates an early Late Devonian age for the limestone.

Thin-bedded shales, graywackes, and argillites, along with very minor amounts of chert and volcanic rocks, enclose the limestone and compose most of the outcrops on this part of the east slope of Sumas Mountain.

The general structure appears to consist of a homoclinally southward-dipping sequence with isoclinal folds and imbricate faults repeating the section.

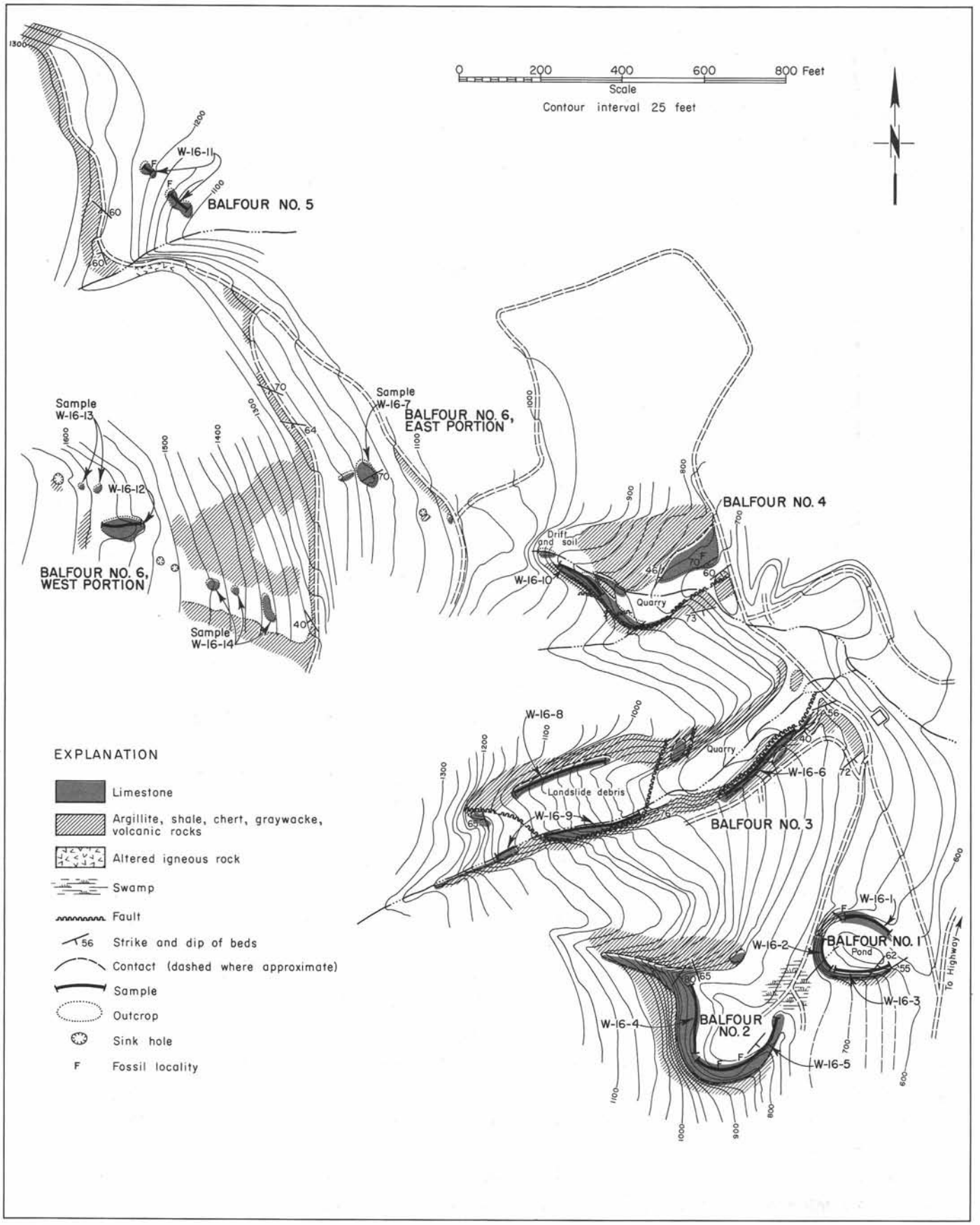


FIGURE 105. — Balfour limestone deposits. Sec. 28, T. 40 N., R. 5 E. Geology by W. R. Danner, C. L. Smith, E. A. Adams, and C. F. Royse, Jr. Compass and tape survey.

Descriptions of individual quarries and outcrop areas. — Seven quarries or outcrop areas compose the Balfour group of deposits.

BALFOUR NO. 1 QUARRY

The Balfour No. 1 is the lowest quarry of the group and is at the base of the steep east-facing slope of Sumas Mountain. It is circular in shape, and the floor is about 600 feet in altitude at the entrance on the east side, and the rim is 725 feet in altitude at the west end. The quarry is about 200 feet long east-west and 150 feet wide. A small stream falls over the southwest rim of the quarry, and a pond covers a major part of the quarry floor. Limestone is exposed on the north, southwest, and south quarry faces. On the south side it is overlain by about 4 feet of shale and cherty argillite striking N. 40°-55° E. and dipping 55°-65° SE. At the northwest side of the quarry is a bed of shale that is intensely sheared. Fossil corals are found in the limestone in the northwest part of the quarry near the rim.

BALFOUR NO. 2 QUARRY

Balfour No. 2 quarry is above and 150 feet to the southwest of quarry No. 1 and probably represents a continuation of the limestone of that quarry along strike. No. 2 quarry is roughly rectangular in shape and is about 200 feet long east-west and about 300 feet wide. Its entrance is at an altitude of about 726 feet, and the upper west rim is about 300 feet above. Limestone is exposed continuously around the south and west parts of the quarry wall. It is overlain by shale, which is overlain in turn by a coarse graywacke. The shale is slickensided and sheared. The limestone dips steeply underneath the overlying clastics. Small exposures of limestone in shale occur on the north quarry wall as remnant slabs and form in part a dip slope. To the northwest, leading down into the quarry, is a stream gully partly filled with talus and slide debris. Limestone is exposed up this gully on the south side for more than 200 feet. The limestone is overlain by shale and graywacke and dips beneath it. It looks as if limestone was quarried from this gully until bedrock overburden became too thick. Fossil corals are abundant in places along the south wall of the quarry. Hodge (1938, p. 42) describes the southern two quarries:

> The southernmost lens is the thickest of the three, being about 100 feet. The upper contact dips about 20° south, and the lower contact some 30° south. The strike is about N. 60° E. Two openings were made on this lens; the lower face [Balfour No. 1] is about 150 feet high, the upper [Balfour No. 2] about 200 feet. In both openings waste constituted about 50 percent of rock handled when operations ceased.

BALFOUR NO. 3 QUARRY

Balfour No. 3 quarry is the middle quarry of the group, and its entrance is at an altitude of about 725 feet, approximately 500 feet north of the west rim of Balfour No. 1. The quarry appears to extend to the southwest about 800 feet, but the westernmost 300 feet of this might be in part a landslide excavation, as slides have come down into the quarry from its west end. The quarry is long and narrow, and ranges from 100 to 200 feet in width. The walls are nearly vertical and are as much as 250 feet in height. A small stream flows through the quarry at the base of the south face.

Limestone is exposed in faulted beds on the north and south walls, but mostly on the south wall. The limestone appears to strike mostly northeast-southwest and it dips steeply (70°-75°) to the southeast. Faults occur underneath and above the limestone at various places on the south rim. Shale, graywacke, cherty argillite, and chert underlie and overlie the limestone, and near faults these rocks are commonly highly crumpled and deformed. Hodge (1938, p. 42) describes this limestone body as follows:

> The center opening is in a lens varying from 50 to 100 feet thick and standing nearly vertical between graywacke and slate walls. The lens was very irregular in trend. When the face reached a height of 200 to 225 feet, the limestone passed under schist and operations ceased.

BALFOUR NO. 4 QUARRY

The Balfour No. 4 quarry is in the northernmost of the Balfour quarries. Its entrance is at an altitude of about 725 feet, and the west rim is at an altitude of about 1,000 feet. The quarry is about 430 feet long east-west, and has a maximum width of 250 feet in its central part. The south quarry walls are up to 100 feet in height. Limestone exposed in the south walls dips steeply to the south and strikes northeast-southwest. It is separated in part from overlying argillites and chert by

a fault and is in turn cut by other faults. A small intermittent stream flows down the center of the quarry, and small amounts of limestone overlain by chert and argillite are exposed in the streambed. Most of the north face of the quarry is a dip slope on clastic sediments and chert, but at the northeast corner of the quarry a thin sequence of calcareous rocks overlies these beds. The first overlying carbonate bed is an organoclastic calcarenite composed of crinoid and bryozoan fragments. Overlying this unit is a black crumbly siltstone containing small crinoid columnals, and above this is a coral-bearing limestone bed. The corals are in part silicified. The three units combined are less than 2 feet thick.

The extreme west rim of the quarry has in part slid away, and about 50 feet of glacial drift and slope-wash debris is exposed overlying bedrock in the slide face. Hodge (1938, p. 41-42) describes this quarry:

> The most northerly opening is on a 50-foot bed dipping 60° south. The face was worked back to a height of about 150 feet, where hanging-wall schist overburden equalled limestone quarried. In addition, when operation ceased, 40 feet of glacial fluviatile deposits had to be stripped from the edge of the limestone bed.

BALFOUR NO. 5 DEPOSIT

The Balfour No. 5 deposit consists of two small limestone outcrop areas on the steep north slope of a small stream gully about 1,200 feet northwest of the west rim of Balfour No. 4 quarry. It can be reached by following an overgrown logging road from the entrance of Balfour No. 4 quarry, north and then southwest, then north again to a position about 50 feet above and 100 feet west of the outcrop.

The larger of the two outcrops is about 80 feet long northwest-southeast and has a maximum width of 30 feet. The second outcrop is 50 feet to the northwest; it is about 40 feet long and 15 feet wide. The limestone weathers to a light-gray color and contains poorly preserved and partially silicified Devonian corals. It appears that these two outcrops are part of a small lenticular limestone body striking northwest-southeast and dipping southwest. No additional outcrops could be found along the strike.

BALFOUR NO. 6 DEPOSIT. — (East part)

In a logging road cut 200 feet northwest of the west rim of Balfour No. 4 quarry is a small outcrop of limestone. The outcrop is surrounded by soil and drift and looks like a buried limestone boulder. About 60 feet to the northwest on the brushy hillside is a sinkhole about 5 feet across and 2 to 3 feet deep. Shale is exposed on its southeast rim. About 140 feet farther northwest is a knob of limestone about 60 feet long northwest-southeast and 40 feet wide. Just to the west of it is another small outcrop about 30 feet in length.

The limestone of these outcrops is well bedded, dense textured, and argillaceous. The outcrops are largely covered with moss and are believed to be a northwesterly extension of the Balfour No. 4 limestone body.

BALFOUR NO. 6 DEPOSIT. — (West part)

Starting at an altitude of about 1,400 feet, about 600 feet west between the line of strike of Balfour No. 3 and that of No. 4, is another belt of small limestone outcrops and sinkholes. The largest outcrop is a knob about 100 feet long and 50 feet wide that has a vertical exposure of about 45 feet. Its lowest exposure of limestone is at an altitude of about 1,575 feet. Five additional outcrops were found, two to the northwest and three to the southwest. They are aligned along a strike of about N. 55° W. The most northwesterly occurrence is a sinkhole that has chert exposed on its southwest rim.

To the west of this outcrop belt is a flat benchlike area on the mountainside. To the northwest is a steep north-facing slope. Shale and graywacke appear to underlie the limestone. Graywacke, conglomerate, and volcanic rocks overlie it.

Quality. — The limestone of these outcrops is variable in quality; some of it is composed of high-calcium limestone, whereas other parts of the outcrops are argillaceous and cherty.

Chemical analyses of Balfour limestone

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)
Samples collected for this report, Mark Adams, analyst														
W 16-1	Balfour No. 1, south side	130	93.89	0.58	41.90	52.75	0.28	3.81	0.96	0.004				
W 16-2	Balfour No. 1, west side	80	86.20	0.75	38.54	48.43	0.36	11.25	0.97	0.009				
W 16-3	Balfour No. 1, north side	140	96.45	0.37	42.70	54.19	0.18	2.16	0.64	0.010				
W 16-4	Balfour No. 2, west side	170	92.34	0.64	41.13	51.88	0.31	5.50	0.93	0.004				
W 16-5	Balfour No. 2, south side	275	84.63	0.96	37.80	47.55	0.46	11.87	2.00	0.023				
W 16-6	Balfour No. 3, south side	225	87.55	0.98	39.04	49.19	0.47	9.43	1.43	0.026				
W 16-7	Balfour No. 6, east part	Composite	96.04	0.54	42.67	53.96	0.26	2.43	0.47	0.010				
W 16-8	Balfour No. 3, upper east	240	95.49	0.37	42.59	53.65	0.18	2.70	0.76	0.012				
W 16-9	Balfour No. 3, upper west	250	94.60	0.96	42.32	53.15	0.46	2.76	0.84	0.008				
W 16-10	Balfour No. 4	130	96.20	0.48	42.73	54.05	0.23	2.06	0.62	0.007				
W 16-11	Balfour No. 5	110	90.74	0.20	40.25	50.98	0.10	7.33	1.05	0.010				
W 16-12	Balfour No. 6	100	91.54	0.37	40.68	51.43	0.18	6.25	1.22	0.006	210	565	200	73
W 16-13	Balfour No. 6, north	Composite	89.67	0.29	39.84	50.38	0.14	8.84	0.71	0.008				
W 16-14	Balfour No. 6, south	Composite	95.67	0.94	42.32	53.75	0.45	2.28	0.71	0.004				
Analyses from another source [1]														
	Average surface sample		93.71		42.14	52.48	0.30	3.04	0.76					
	Tunnel	Last 50 feet	86.53		39.16	48.46	1.01	8.96	2.44					

[1] Shedd (1913, p. 213).

Ownership and development. — The Balfour limestone bodies are owned by the Permanente Cement Company, of Bellingham. The area was originally owned by Balfour Guthrie & Company and was bought from them by The Olympic Portland Cement Company after it erected a cement plant in Bellingham in 1911. This latter company was purchased in 1959 by the Permanente Cement Company. Four quarries were started and operated on the property, and all were abandoned about 1929. Hodge (1938, p. 42) states that limestone from the lowest of the four quarries was handled by a railroad-type steam shovel of about 2-yard size. Quarry costs approximated $2.50 a ton. Shedd (1913, p. 212) states that a 100-foot tunnel was driven into the hillside on the limestone. Apparently this was prior to active quarrying.

The limestone of the quarried areas can be considered exhausted and of no further economic value. Limestone still remains down dip and under thick glacial drift or bedrock overburden, but would require underground mining. The limestone bodies are too small and broken up for this kind of expensive development.

The limestone outcrops on the hillside above the quarries are too small to be of any great economic value, but it might be worth while, if there was a shortage of limestone, to examine them in greater detail, especially the belt of outcrops comprising the western and eastern parts of Balfour No. 6.

The old limestone quarries are being filled gradually by landslides coming down from their higher western faces. Small streams flow into all the quarries during periods of wet weather.

References. — Shedd (1913, p. 212-213), Glover (1936, p. 59), Hodge (1938, p. 41-42), Northern Pacific Railway Co. (1941, unpublished notes, p. 14), Moen (1962, p. 94-95).

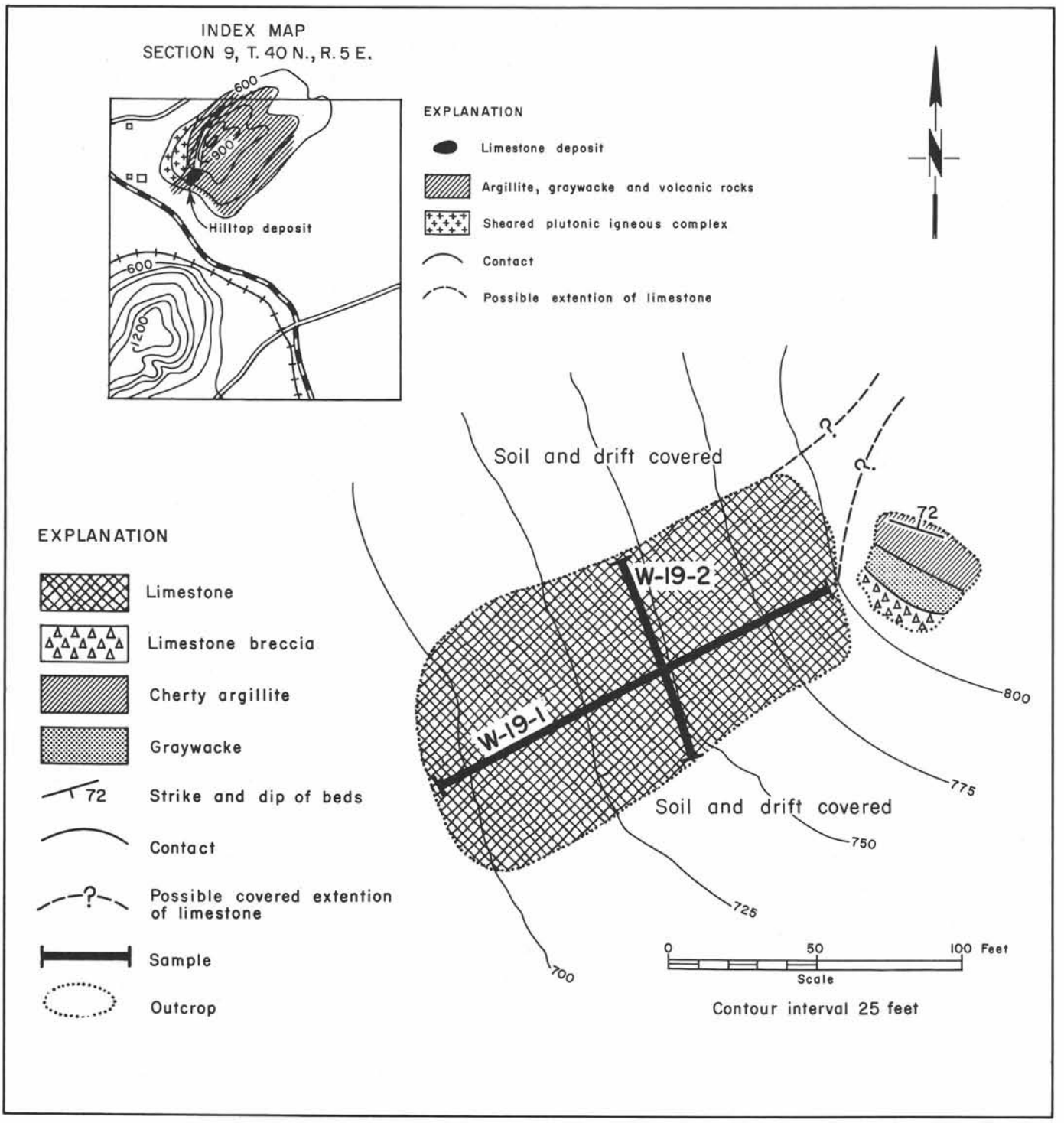


FIGURE 106.—Hilltop deposit. NW¼ sec. 9, T. 40 N., R. 5 E. Geology by W. R. Danner, C. L. Smith, E. A. Adams, and C. F. Royse, Jr. Compass and tape survey.

Hilltop Deposit

Location, size, and accessibility. — The Hilltop limestone occurrence is on the southwest side of an isolated steep-sided hill in the northwest part of Columbia Valley in the NW¼ sec. 9, T. 40 N., R. 5 E., at an altitude of 700 to 800 feet. The occurrence consists of a poorly exposed slablike body of limestone cropping out over an area about 70 feet wide north-south and 150 feet long northeast-southwest. Its thickness is unknown, but may be only a few feet. It can be reached from the Sumas-Kendall highway by crossing over fields for a distance of less than ¼ mile to the base of the steep hillside and then by climbing up about 100 feet to the limestone outcrop. The hill containing the limestone is about 6 miles by road from the town of Sumas. The slope containing the limestone is heavily brush covered.

Geology and description. — The main limestone outcrop area appears to be a thin slab of light-gray dense-textured limestone exposed on a steep hillside surface. It is underlain and overlain by a sequence of cherty argillite, graywacke, and andesitic volcanic rocks. At the southeast side of the limestone outcrop the strike is N. 73° W. and the dip is 72° NE. Along the north side of the limestone the attitude changes to a northeast strike and a southeast dip. Near the top of the north side of the hill are irregular boulder-like masses of limestone that appear to represent a continuation along strike of the limestone exposed on the southwest side of the hill. Here the surrounding sedimentary beds strike N. 40° E. and dip steeply to the south. The northwest part of the hill consists of a highly sheared igneous or metamorphic rock of dioritic compositon, shown as Yellow Aster Complex on a map published by Miller and Misch (1963).

The limestone is cherty and argillaceous and contains poorly preserved and partially silicified fossil corals. In thin section, some parts of the limestone are seen to be composed of a limy mud, whereas other parts are organoclastic and contain calcareous algal remains, echinoid spines, and small gastropods, as well as other organic debris. The limestone is believed to be of Devonian age.

Quality. — The limestone contains relatively high amounts of silica in the form of silty, argillaceous, and jasperoid impurities.

Chemical analyses of Hilltop 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
W 19-1	East-west ----	150	90.40	0.92	40.43	50.79	0.44	6.95	1.09	0.031
W 19-2	North-south --	70	92.47	1.15	41.32	51.95	0.55	5.05	0.82	0.021

Ownership and development. — The owner is unknown, and there has been no development. Drilling would be needed to determine the thickness of the limestone body, but it appears to be too small and impure to be of any economic value.

References. — Hodge (1938, p. 45), Moen (1962, p. 97), Miller and Misch (1963).

Limestone Under Columbia Valley

It is possible that the limestone outcrops on the east side of Sumas Mountain have extensions under the glacial fluviatile deposits filling the Columbia Valley. There is no indication, however, of such limestone occurrences. Hodge (1938, p. 44) calls attention to a line of "sink holes" in the area north of The Olympic Portland Cement Company, especially in sec. 10. These are thought more likely to be kettle depressions formed by stagnant ice in the outwash deposits. Similar depressions occur to the north near Cultus Lake in the continuation of the Columbia Valley into British Columbia.

Sumas Mountain Deposit No. 1

Location, size, and accessibility. — The Sumas Mountain No. 1 limestone occurrence is in the SE¼NE¼ sec. 21, T. 40 N., R. 5 E., at an estimated altitude of 500 feet at the base of the east side of Sumas Mountain. It consists of two small limestone outcrops, the larger of which is about 85 feet long northeast-southwest, 10 feet wide, and is exposed vertically for about 20 feet. The smaller outcrop is about 35 feet long, 5 feet wide, and is exposed vertically for about 10 feet. The limestone can be reached by hiking from the Kendall-Sumas highway about ¼ mile due west along the north side of a pasture or by hiking an old logging road, starting south from the county garbage dump in the northeast corner of sec. 21, and following the road south for about ½ mile, then taking a fork west up the hillside a short distance to a second fork and following the left branch south down the hillside to the base of Sumas Mountain and the outcrops.

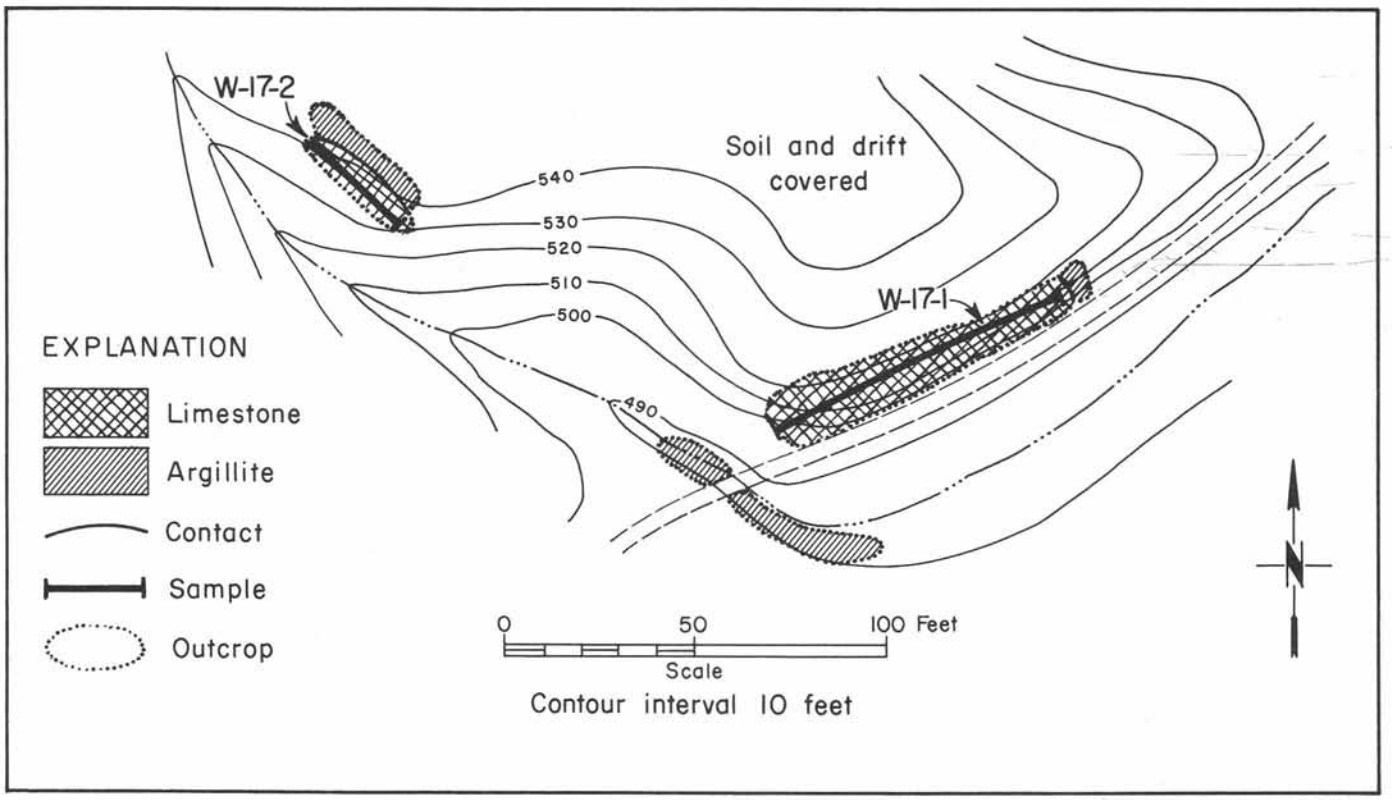


FIGURE 107. — Sumas Mountain No. 1 deposit. SE¼NE¼ sec. 21, T. 40 N., R. 5 E. Geology by W. R. Danner, E. A. Adams, C. L. Smith, and C. F. Royse, Jr. Compass and tape survey.

Geology and description. — The main limestone outcrop is in a logging road cut at the base of the east slope of Sumas Mountain. Below the road is a small stream that sinks into alluvial fill. The limestone is mottled buff and white in color and is mostly crystalline in texture. Much of it is argillaceous, and parts are dolomitic. Small and large crinoid stems similar to those found in Lower Pennsylvanian limestones in northwestern Washington are present, and the limestone is thought to be of Early Pennsylvanian age.

The outcrop is surrounded on all sides but the north by soil and glacial drift. Weathered argillite and soil mark the north contact. To the northwest is a small outcrop of similar-appearing limestone overlain by argillite. No attitude could be determined. A topographic mound to the north may also be underlain by limestone. A logging road immediately to the northwest shows at least 6 feet of glacial overburden on top of bedrock.

A 2-foot sequence of thin-bedded shale and dense limestone is exposed on the fourth switchback of an overgrown logging road on the hillside to the northwest. Impure, dense, maroon-colored argillaceous limestone is also present in roadcuts. The sequence is very similar to that of the Early Pennsylvanian section along the northeast coast of Orcas Island.

Quality. — The Sumas Mountain No. 1 limestone occurrence is high magnesian to dolomitic in composition, and parts of the outcrop are argillaceous.

Chemical analyses of Sumas Mountain No. 1 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
W 17-1	Roadcut ------	80	50.16	43.57	43.89	28.18	20.85	6.67	0.54	0.018
W 17-2	Creek -------	30	53.86	28.75	38.47	30.26	13.76	17.04	0.99	0.020

Ownership and development. — The owner is unknown, and there has been no development. The limestone appears too small and impure to be of any economic value. It might be worth while to dig a trench across the soil-covered hill north of the outcrop to ascertain whether limestone underlies this area.

Reference. — Moen (1962, p. 97).

Sumas Mountain Deposit No. 2

Location, size, and accessibility. — The Sumas Mountain No. 2 limestone deposit is in the west-central part of sec. 21, T. 40 N., R. 5 E., on the steep east slope of Sumas Mountain just west of Columbia Valley. The limestone outcrops start at an estimated altitude of 1,200 feet and extend northwestward up the mountainside a horizontal distance of 1,200 feet to an elevation of 1,800 feet. The occurrence consists of a sequence of beds of relatively pure limestone, argillaceous limestone, and limestone conglomerate interbedded with calcareous shale, argillite, chert, and sandstone, cropping out over an area at least 1,500 feet long northwest-southeast and 300 to 400 feet in width. Limestone is exposed vertically for about 600 feet. The area can be reached by following for about $\frac{1}{4}$ mile an abandoned and now mostly impassable logging road leading south from the county garbage dump in the NE. cor. sec. 21, then taking a right fork of this road up the hillside a short distance to another fork and following the south branch road down to a pasture and stream, then following the logging road up the hillside for over $\frac{1}{2}$ mile to its terminus on the steep north slope of a stream gully. The limestone crops out in the streambed below the end of this road and also to the north and south. Old and faint trails traverse the limestone outcrop area but are difficult to follow. The hillside is very steep in places and is covered in some areas with relatively open stands of second-growth timber and in other areas by dense brush.

Geology and description. — Except for the streambed, limestone outcrops are not plentiful. A sequence composed predominantly of massive and dense light gray blue to dark-gray argillaceous limestone makes up this occurrence. The limestone strikes in general about N. 35°-45° W. up the steep hillside. It dips 30°-45° SW. and in places is contorted and faulted. Interbedded with the limestone are beds of chert, shale, argillite, and sandstone. One outcrop of sandstone in the creekbed south of the end of the logging road leading to the deposit contains fragmentary plant remains.

The limestone section is reasonably well exposed in a streambed cutting east-west across the outcrop area. In this section about half of the limestone is argillaceous. Limestone outcrops in the form of small knobs occur on the steep hillside to the northwest, and it is thought that most of the area between the knobs might also be underlain by limestone. At the northwest part of the area the topography levels off to a gentle east-sloping bench that is dotted with several large sinkholes. One of these contains a small cave that at the time of examination (July) contained a pool of water. Subsequent exploration by Dr. William R. Halliday, of the National Speleological Society (written communication, Nov. 1960), revealed about 250 feet of passageway in this cave, and silicified corals were collected from the cave walls. Limestone outcrops can be traced to the northwest into a very brushy logged area, where the limestone appears to pinch out. To the southeast the limestone appears to extend almost to the next creek on Sumas Mountain, but this creekbed does not contain any limestone exposures

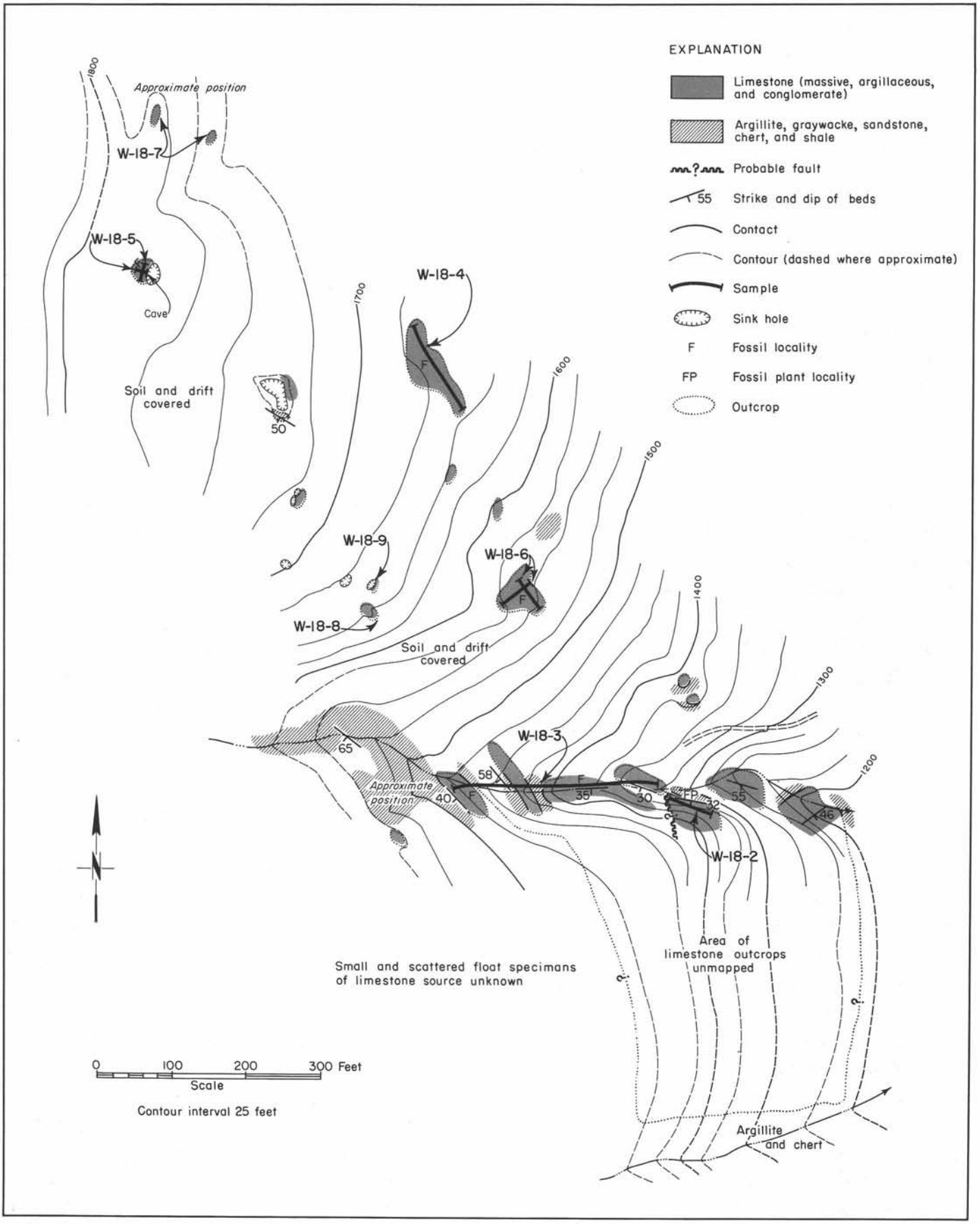


FIGURE 108.—Sumas Mountain No. 2 deposit. Sec. 21, T. 40 N., R. 5 E. Geology by W. R. Danner, C. L. Smith, E. A. Adams, and C. F. Royse, Jr. Compass and tape reconnaissance survey.

in that part of it aligned along the strike of the limestone. To the southwest there are small scattered pieces of limestone float on the hillside, but no limestone outcrops could be found. There may be some limestone higher up near the crest of the hill, but the immediate slopes contain only exposures of graywacke and other sedimentary rocks, as far as could be determined.

The limestone varies in color from light gray to dark gray and is generally dense textured, though in some outcrops it has been recrystallized. Several outcrops contain conglomerates composed of limestone pebbles. Fossil corals are common in these conglomerates and are similar to those of the Balfour limestones to the south. Some of the more argillaceous limestones contain poorly preserved remains of brachiopods, as yet unidentified. The geologic age of the Sumas Mountain No. 2 limestone is Devonian.

Quality. — The limestone is quite variable in composition; some parts are very argillaceous and some parts contain chert or jasperoid.

Chemical analyses of Sumas Mountain No. 2 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)
W 18-1	Upper part --	Composite	90.30	0.96	40.44	50.73	0.46	7.16	0.90	0.008	175	560	250	740
W 18-2	Along creek -	60	89.39	1.29	40.20	50.22	0.62	6.91	1.72	0.009				
W 18-3	Creekbed ---	270	58.15	2.19	26.12	32.67	0.15	33.61	7.45	0.072				
W 18-4	East side ----	140	95.28	0.48	41.92	53.53	0.23	2.61	1.46	0.008				
W 18-5	North side --	Composite	95.92	0.43	42.69	53.89	0.21	2.41	0.71	0.005				
W 18-6	Center ------	Composite	92.89	2.73	43.60	52.19	1.31	2.27	0.94	0.007				
W 18-7	Extreme north	Composite	96.95	0.37	43.10	54.47	0.18	1.48	0.52	0.090				
W 18-8	Center ------	Composite	98.38	0.41	43.45	55.27	0.20	0.26	0.16	0.004				
W 18-9	Center ------	Composite	94.92	0.29	42.21	53.33	0.14	3.15	1.03	0.007				

Ownership and development. — The owner of this property is unknown, and there has been no development. If the concealed areas between limestone outcrops are also underlain by limestone of similar quality, this occurrence might be of economic value because of its size. It should be trenched and drilled to determine more accurately its quantity and quality.

References. — Moen (1962, p. 96), Halliday (1963, p. 114-115).

Northwestern Lime Company North Deposit

Location, size, and accessibility. — The Northwestern Lime Company North limestone occurrence is approximately in the NE¼ sec. 23, T. 40 N., R. 5 E., near the crest of the steep west side of Red Mountain. It consists of a lenticular body of limestone about 120 feet long north-south and as much as 50 feet wide, exposed vertically for a distance of at least 70 feet. It was formerly accessible by about 0.8 mile of logging road starting at the south end of the uppermost switchback of the Permanente Cement Company quarry road. This logging road is now washed out at one place and is partly overgrown with small second-growth trees.

Geology and description. — The limestone appears to consist of a lenticular reef striking northeast-southwest and probably dipping steeply to the southeast. It is surrounded by glacial drift and soil though situated on a very steep slope. A short distance to the north is a roadcut in weathered and crumpled shale containing bands of ribbon chert. These rocks are intensely sheared and may represent a fault zone. The sequence strikes about N. 30° E. and dips 70° SE. To the south is a roadcut in a medium- to coarse-grained gabbroic rock that forms a northeast-trending dikelike body extending up the hillside and onto the crest of Red Mountain. It is poorly exposed.

The limestone crops out in a series of small steep bluffs extending from the logging road up the hillside to the northeast. It is not known for certain whether it extends below the road, but there are large knobs (boulders) of limestone sticking up through the slope debris for at least 50 feet below the road, and limestone talus extends downslope still farther. What appears to be a large, partly buried boulder of limestone lies north along the road a few feet from the main outcrop area.

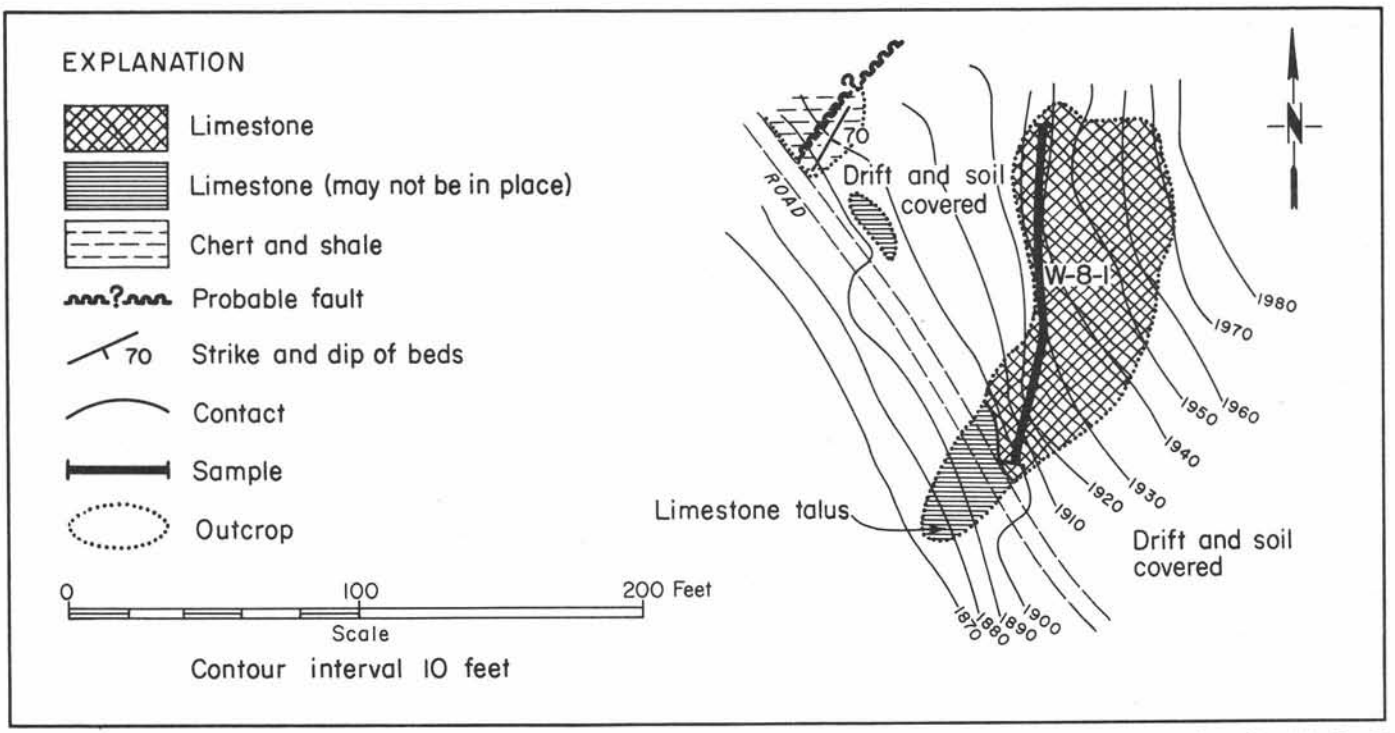


FIGURE 109.—Northwestern Lime Company North deposit. NW¼NE¼ sec. 23, T. 40 N., R. 5 E. Geology by W. R. Danner, C. F. McKillop, and A. M. Rivisto. Compass and tape survey.

A brief exploration of the crest of the mountain above the outcrop did not reveal any additional exposures of limestone, but the search was hampered by an unusually dense growth of small trees and brush.

The limestone is light blue gray in color and mostly dense in texture. It contains numerous layers of poorly preserved colonial corals and stromatoporoids, all of which may be partially silicified. The coral Plagiopora that is found in the Balfour quarries to the southwest is common and indicates an early Late Devonian age for this limestone.

Between the Devonian limestone and the Early Pennsylvanian limestone to the north in the Permanente quarries is a sequence consisting largely of massive or bedded graywacke. Where these graywackes are exposed in logging road cuts, they dip southward at angles of 30° to 72°. The Devonian limestone appears to lie above the Pennsylvanian rocks in the south-dipping section, but is probably separated from them by a fault. The location of this fault is not known for certain, but it may lie just to the north of the Devonian limestone.

Quality.—The partially silicified fossils in the limestone indicate a relatively high silica content, and some parts of the limestone exposed in outcrop are argillaceous.

Chemical analysis of Northwestern Lime Company North 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
W 8-1	North-south	120	89.28	0.64	39.84	50.16	0.31	8.52	1.08	0.011

Ownership and development.—The present owner of this limestone is unknown, and there has been no development. The deposit is too small to be of economic value. However, no exploration was made down the steep slope below the outcrop mapped in this survey.

Reference.—Moen (1962, p. 97).

Northwestern Lime Company South Deposit

Location, size, and accessibility. — The Northwestern Lime Company South limestone deposit is in the NE¼SW¼ sec. 23, T. 40 N., R. 5 E., on the rim of the steep west slope of Red Mountain and toward the east on a small knob.

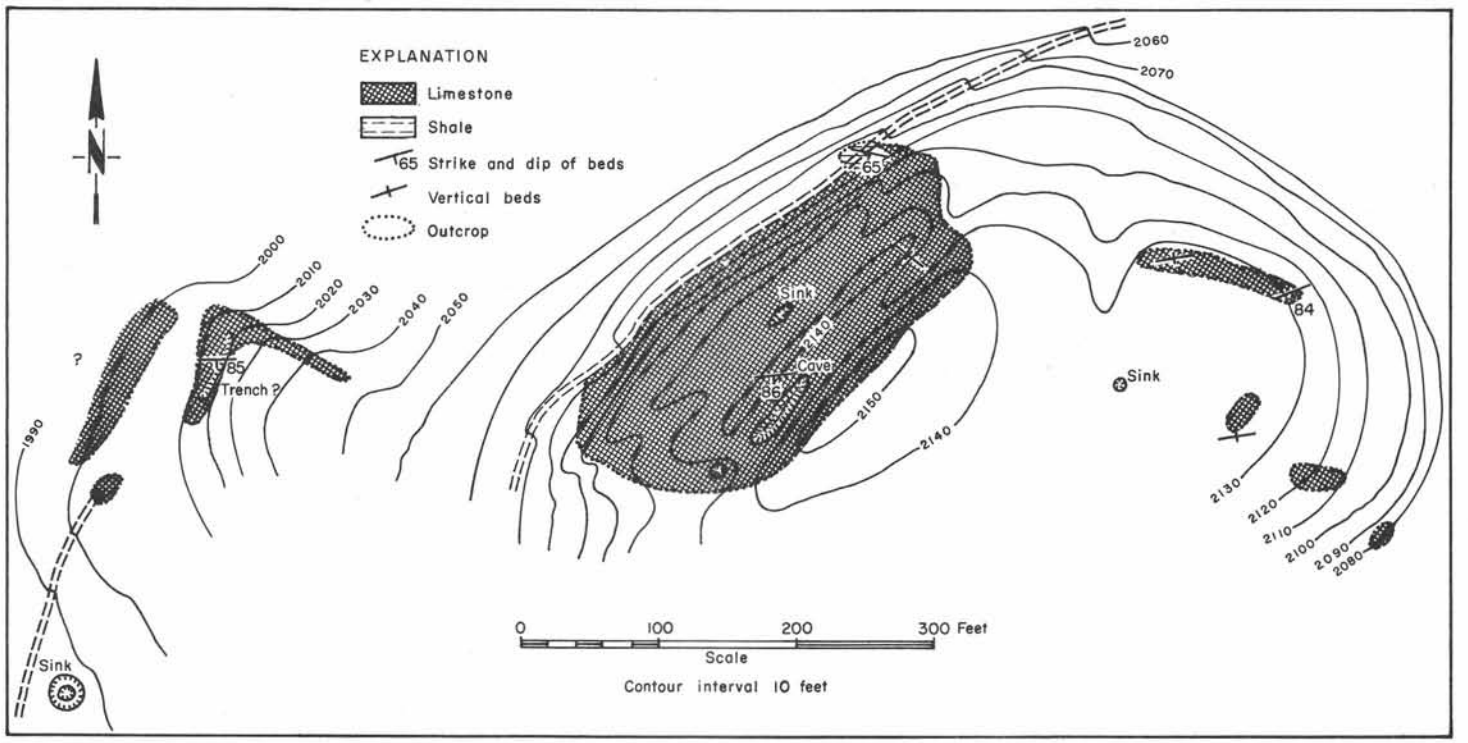


FIGURE 110. — Northwestern Lime Company South deposit. NE¼SW¼ sec. 23, T. 40 N., R. 5 E. Compass and tape survey, 1965, by W. R. Danner and Douglas Leighton.

The limestone was shown to the writer late in October 1965 by Wayne Rouleau, of Maple Falls. Time was not available for detailed mapping of the entire deposit nor exploration in the immediate vicinity, but it is believed that a major part of the limestone is included in the area mapped. Limestone is exposed for at least 1,000 feet east-west and has a width of 200 to 250 feet. It extends over a vertical distance of at least 175 feet from the highest point of exposure on the top of Red Mountain down to the rim of the steep west slope of the mountain.

The deposit is accessible by about 2½ miles of good logging road starting from the Mount Baker Highway in the NW¼ sec. 36, T. 40 N., R. 5 E. This road climbs about 1,500 feet, then an unused branch logging road can be followed northwestward for about ¼ mile to its intersection with a bulldozed track about ¼ mile in length leading to the outcrop. The area is covered with dense to open stands of second- and third-growth trees or brush.

Geology and description. — The deposit appears to consist of a lenticular reef or bank. It is interbedded in a sequence of silty radiolarian ?-bearing shale and lithic sandstone that is exposed along the bulldozed track east of the outcrop. Bedding in the limestone is well developed but irregular. Attitudes are mostly east-west, and the dips are vertical or inclined steeply to the south. The limestone is light gray blue in color and dense to crystalline in texture. A considerable amount of recrystallization has taken place in some parts of the outcrop. The limestone contains numerous layers of poorly preserved colonial corals and stromatoporoids. The fossils are silicified, but the replacement is not complete enough to preserve anything but the gross outline of the structure. Irregular masses of replacement chert also occur. Along the northern border of the deposit the limestone is argillaceous.

The major outcrop forms a prominent small hill on top of the west side of Red Mountain. On the west-central part of this hill an almost vertical walled trench striking northeast-southwest extends across the outcrop. This trench is about 250 feet long, 20 to 25 feet wide, and 15 to 20 feet deep. It may be an exploration trench made on the deposit during an earlier period of investigation, but its large size and numerous solution features such as sinkholes suggest that it might be a natural feature marking a fault or zone of shearing. A similar but less prominent depression parallels the trench to the north. The clogged entrance to a cave is in the bottom of the main trench near its west end. Shallow sinkholes occur in several places on the hill. The limestone outcrop hill has steep north and east slopes and gentle south and west slopes.

West of the hill, similar-appearing limestone crops out on a benchlike area above the steep slope of the west side of Red Mountain. A nearly east-west strike and a steep southerly dip characterize the limestone here also, but bedding is not very prominent in outcrop. A small trench appears to have been cut across one part of this exposure. Limestone crops out an unknown distance down the steep brushy slopes to the west.

Shedd (1913, p. 211) describes the property as follows:

> The limestone occurs in more or less isolated bodies of rather small extent with masses of what appear to be metamorphic rocks coming up between them. The limestone outcrops at various places along the hillside for a considerable distance. The appearance, however, is that the limestone simply lies on the face of the hill and does not have any very great thickness. Scarcely any work has been done here, and it is hard to say positively in regard to the extent of these deposits, but the indications are that they are not large.

Hodge (1938, p. 43) describes the the property further:

> The limestone band trends about N. 70° E. The dip of the bed is undetermined, but is probably nearly vertical. The lens is at least 250 feet wide, and may be wider; it terminates on the west at 1,400 feet elevation in a cliff about 100 feet high, which can be seen from the valley floor. The limestone is traceable over the edge of the summit plateau on Red Mountain at an elevation of 2,200 feet, and down into a swamp at 1,800 feet on the plateau.

Quality. — The partially silicified fossils and chert bodies in the limestone indicate a relatively high silica content. Parts of the limestone are also argillaceous. It is thought that the quality might be similar to that of the Doaks Creek deposit to the east. Depending upon the amount of silicification, the deposit might be used for cement, agricultural stone, or paper rock.

Chemical analysis of Northwestern Lime Company South limestone

Sample no.	Sample length (feet)	$CaCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3
1/	Hand specimen	97.07	43.17	54.36	Trace	1.44	0.92

1/ Shedd (1913, p. 211).

Ownership and development. — The property is on State land. In older references it is listed as belonging to the Northwestern Lime Company or to the Northwest Portland Cement Company. At one time the site was supposed to have been cleared and foundations constructed for a burning and crushing plant. Guard (1943, unpublished field notes) reports the limestone as having two prospect trenches cut across it. The deposit needs further exploration. The relatively steep road access is detrimental to its development.

References. — Shedd (1913, p. 211-212), Glover (1936, p. 59), Hodge (1938, p. 45), Guard (1943, unpublished field notes).

Doaks Creek Deposit (Mitchell Bay Lime Company Quarry)

Location, size, and accessibility. — The Doaks Creek limestone deposit is in the center of the W½ sec. 19, T. 40 N., R. 6 E., on the hillside south of Doaks Creek at an altitude estimated to be between 850 and 1,020 feet. It consists of an outcrop area approximately 525 feet long northeast-southwest and from 50 to 200 feet in width. The outcrop contains an estimated 250,000 tons of limestone. The occurrence is accessible by a single-lane logging road extending about ¼ mile west from the Silver Lake-Maple Falls highway at Doaks Creek.

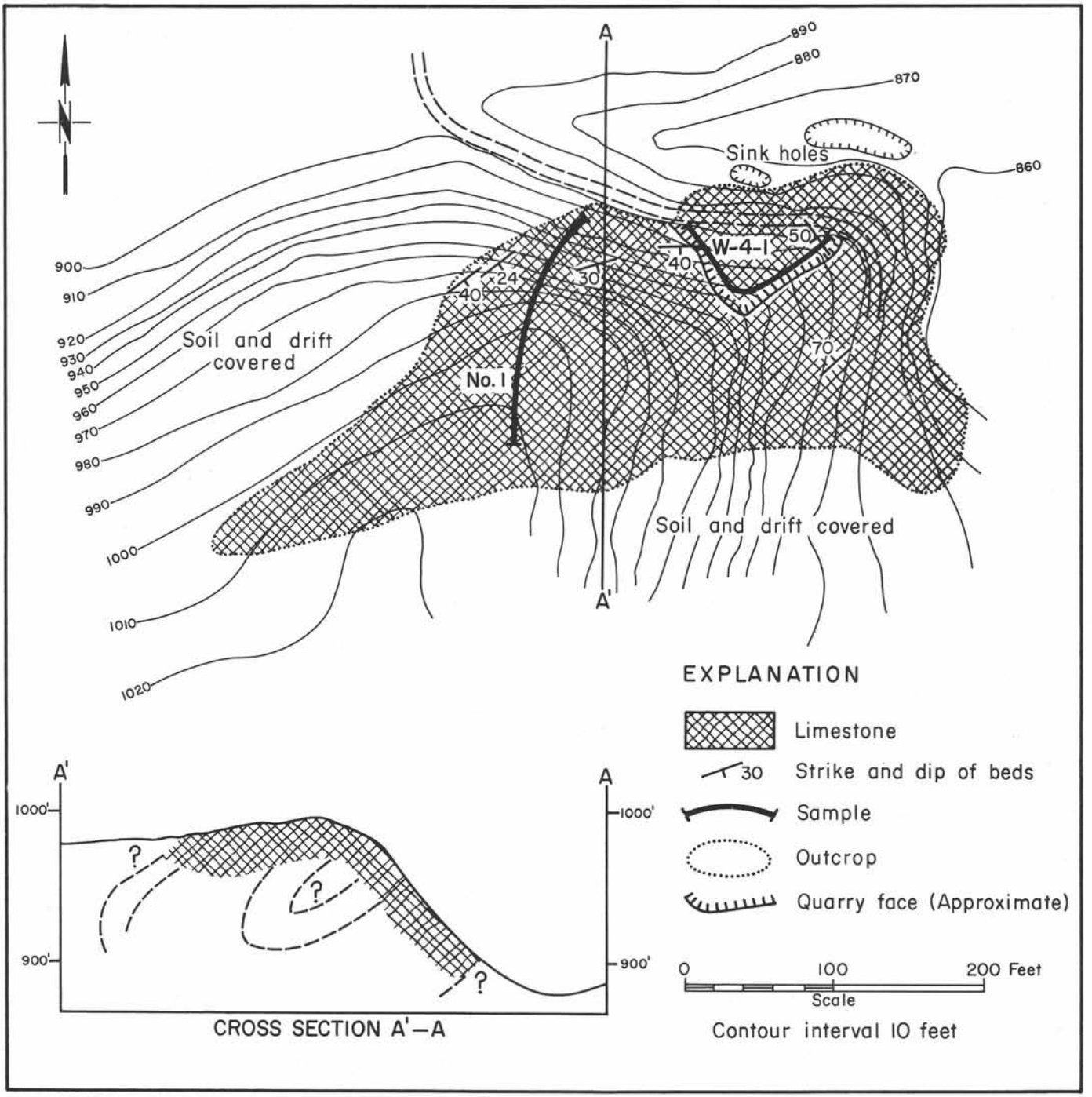


FIGURE 111. — Doaks Creek deposit. W½ sec. 19, T. 40 N., R. 6 E. Geology by W. R. Danner. Compass and tape survey, 1955, by W. R. Danner and Keifer Fobes, modified by Danner, 1959.

Geology and description. — The limestone consists of a lenticular body forming the main part of a small northeastward-trending ridge. Limestone is the only bedrock exposed in the immediate vicinity; the outcrop is bordered by soil and glacial drift on all sides. Graywacke, conglomerate, and volcanic rocks crop out several hundred feet to the west and southwest. The conglomerate contains large cobbles of granitic rocks and pebbles of limestone.

The limestone deposit is composed of alternating layers of dense gray limestone and somewhat thicker layers of coralline limestone. The body as a whole may be a small reef complex. The dense-textured limestone contains a large amount of clay, and it powders easily when struck with a hammer. The coral layers break into larger, irregular fragments. Where the limestone is weathered, many of the corals stand out in relief and are in part replaced by jasperoid. The coral layers have a maximum thickness of about 2 feet, but most are thinner.

The limestone body appears to strike about N. 50° E. and along the north side dips 20°-50° S. On the east side the strike changes to northwest and then to southwest. On the southeast side of the limestone the dip becomes steep to the northwest. This may indicate that the limestone body, at least in part, consists of a tightly folded and in part overturned syncline, or these changes may be at least in part due to the original shape of the reef mound.

A dike of green volcanic rock about 6 inches thick is exposed in the north and south walls of the quarry at the east end of the deposit. A slickensided shear zone is exposed on the south wall of the quarry and contains crumbly crystalline calcite, which in places is very porous and vuggy.

To the east of the outcrop are two sinkholes that may indicate an extension of the limestone in that direction. However, it appears unlikely that the limestone extends very far under the soil and drift overburden in any direction.

When freshly broken, some of the limestone emits a strong bituminous odor. Small areas of massive pyrite and a few pyritized fossils have been found.

The colonial corals Plagiopora and Thamnopora were identified in this deposit. The limestone also contains horn corals, stromatoporoids, brachiopods, ostracods, and crinoid debris. Some of the fossils are partially silicified, but in general none are well preserved. The limestone is believed to be of early Late Devonian age.

Quality. — The visible exposures of limestone contain clay and secondary silica, and it is unlikely that much of the limestone is of high-calcium type. A hand specimen sample dissolved in hyrochloric acid left 8 percent insoluble material by weight.

Chemical analyses of Doaks Creek limestone

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)
1/	NW. part ----	160				58.87	0.70	5.16	2/1.77					
3/ W 4-1	East side -----	120	95.92	0.64	42.57	53.89	0.31	2.43	0.55	0.010	250	550	65	840

1/ Northwest Laboratories, Seattle, T. H. Williams, analyst.
2/ Fe_2O_3=0.95, Al_2O_3= 0.82.
3/ Sample collected for this report, Mark Adams, analyst.

Ownership and development. — The limestone is owned by Kiefer Fobes, Lock Box B, Ballard Station, Seattle, Wash., and Mrs. Virginia Lobdell, 6311 S.E. 27th, Mercer Island, Wash. A small quarry was developed on the east end of the deposit between 1955 and 1959 by the Mitchell Bay Lime Company. It was being operated again during the summer of 1963, the limestone being trucked to Maple Falls for rail shipment to the Puget Sound Pulp and Timber Company in Bellingham.

References. — Danner, (1955, unpublished report), Danner (1957, p. 158-161), Moen (1962, p. 93-94).

German Deposit No. 1

Location, size, and accessibility. — The German No. 1 limestone deposit is in the SW¼NW¼ sec. 17, T. 40 N., R. 6 E., at an altitude estimated to be between 990 and 1,050 feet on the steep west slope of the central part of Black Mountain. It consists of an inverted triangle-shaped outcrop about 25 feet wide at the lower part, or apex, and 80 feet wide at the upper part, or base. It has an average width of about 50 feet and is exposed over a vertical distance of about 60 feet. The limestone can be reached by traveling approximately 1 mile of single-lane logging road starting at the M. German residence on the Silver Lake-Maple Falls highway about 2½ miles north of the village of Maple Falls, and going east across a stream and about 150 feet up the mountainside. The limestone is reached by a short spur road leading south from the main logging road a short distance above the stream.

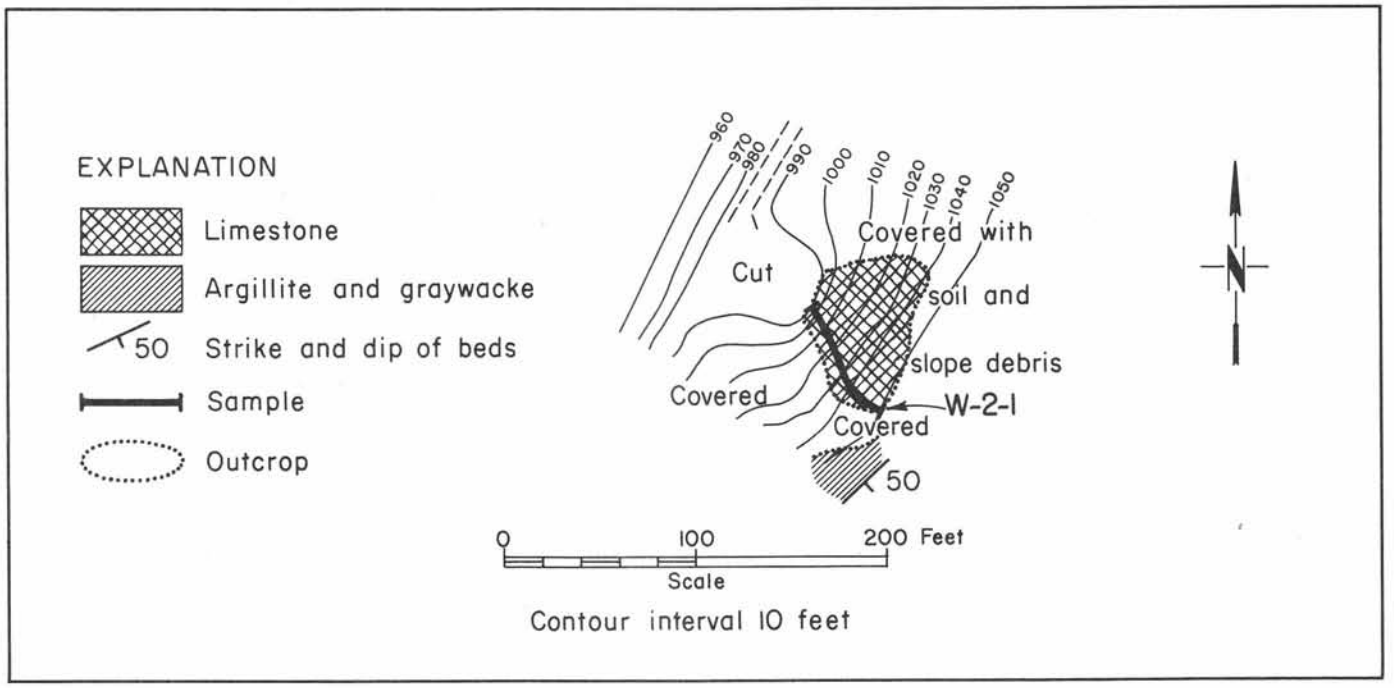


FIGURE 112. — German No. 1 deposit. SW¼NW¼ sec. 17, T. 40 N., R. 6 E. Geology by W. R. Danner and C. F. Mckillop. Compass and tape survey.

Geology and description. — The German (pronounced grrr-man) No. 1 limestone deposit consists of a lenticular body striking northeast-southwest and dipping at a high angle southeastward into the steep west slope of Black Mountain. Soil and slope debris cover the edges of the limestone on all sides, but the limestone is thought not to extend much higher than the present exposure. Argillite and graywacke cropping out on the steep hillside a few feet to the southeast strike N. 45° E. and dip 50° SE. These sedimentary rocks are thought to overlie the limestone. The limestone outcrop is practically flush with the steep slope surface.

The limestone is dense to crystalline in texture and contains layers of partly silicified corals. It is a lenticular reef or bank and is very similar in appearance to the Doaks Creek limestone body across the valley to the southwest. The corals Plagiopora and Thamnopora, along with poorly preserved horn corals and crinoid debris, were collected from the outcrop. The age is early Late Devonian.

Quality. — The limestone is argillaceous, and many of the fossils are partially silicified.

Ownership and development. — The deposit is owned by M. German, who lives a mile west of the outcrop on the east side of the Silver Lake-Maple Falls highway. A small cut has been opened at the base of the limestone to obtain talus for road surfacing, but no real development is known to have taken place. Although the extent of the limestone is concealed

Chemical analysis of German No. 1 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
W 2-1	South side	60	95.47	0.66	42.43	53.64	0.32	3.02	0.51	0.010

by slope debris along its strike, the deposit is thought to be too small to be of any economic value. Steep slopes above the deposit and the steep dip of the limestone beneath bedrock overburden would prevent it from being quarried for any distance.

Reference. — Moen (1962, p. 97).

German Deposit No. 2

Location, size, and accessibility. — The German No. 2 limestone occurrence is in the NW¼ sec. 17, T. 40 N., R. 6 E. The exposure is estimated to lie at an altitude between 1,420 and 1,480 feet on the steep west slope of the central part of Black Mountain. It lies almost ½ mile northeast and 500 feet above the German No. 1 occurrence, and consists of a

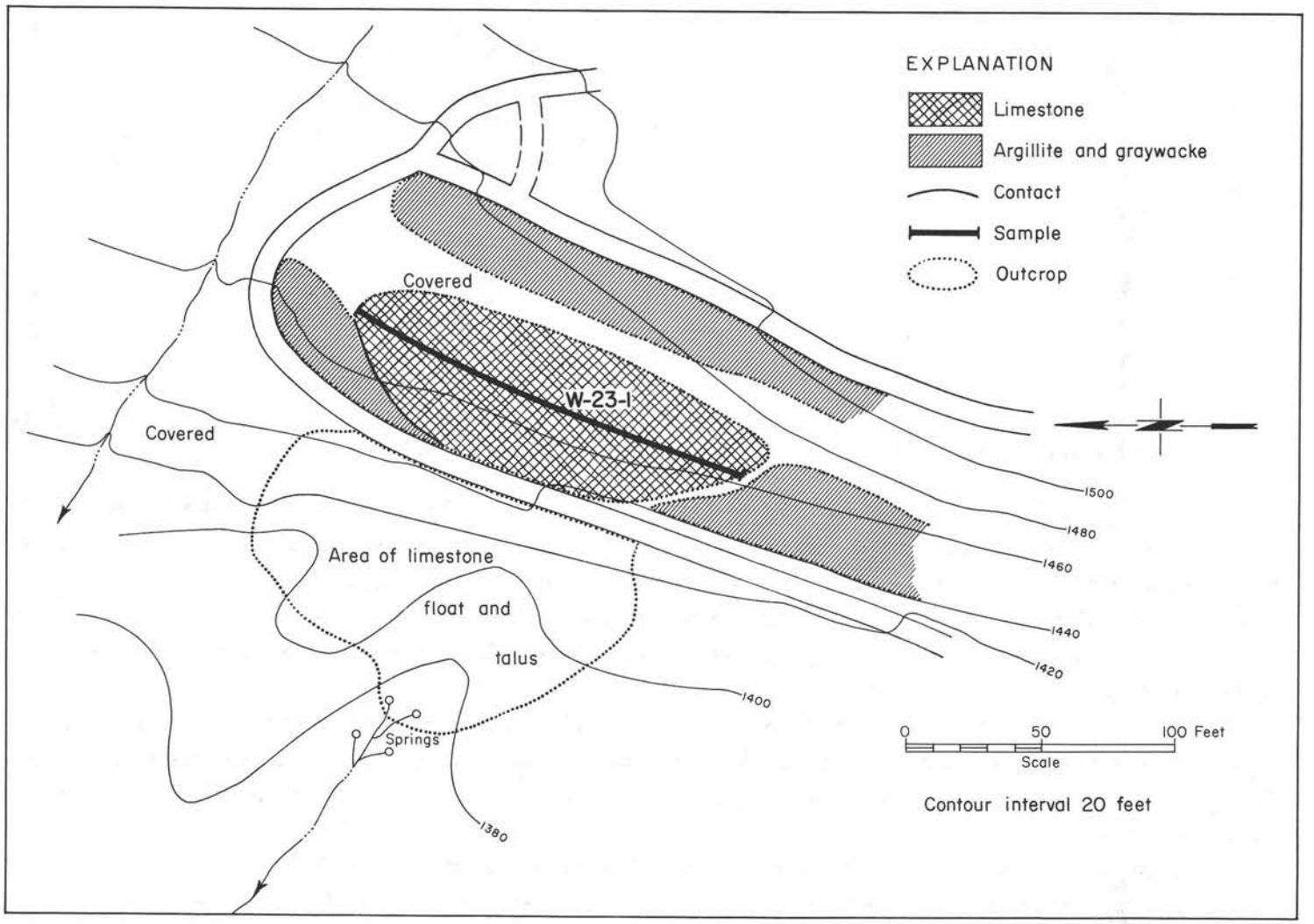


FIGURE 113. — German No. 2 deposit. NE¼NW¼ sec. 17, T. 40 N., R. 6 E. Geology by C. F. Royse, Jr., and C. L. Smith. Compass and tape survey.

poorly exposed lenticular body of limestone about 150 feet long northeast-southwest and about 60 feet wide. It is exposed vertically for at least 30 feet.

The limestone can be reached by a steep narrow logging road about 2 miles long, starting from the M. German residence on the east side of the Silver Lake-Maple Falls road about $2\frac{1}{2}$ miles by road north of Maple Falls village. A main logging road runs along the base of the outcrop, and a branch road leading south is about 35 feet above the highest limestone outcrop. The area is steep and covered with soil, glacial drift, talus, and a dense growth of brush and small trees.

Geology and description. — The limestone outcrop is poorly exposed but appears to be elliptical in outline. It is flush with the surface of a steep west-sloping hillside. Argillite and graywacke crop out above and to the north and south. No attitude was observed on the limestone, but the sedimentary rock sequence of the area strikes mostly northeast-southwest and dips steeply to the southeast.

The limestone is dense to crystalline in texture and gray in color. It contains interbedded and partially silicified coralline layers and masses of limestone pebble conglomerate and is thought to be a small lens-shaped reef complex correlatable with the German No. 1 and Doaks Creek limestones to the southwest. It contains early Late Devonian corals and stromatoporoids similar to those of the other Devonian reef complex limestones of the area. A few specimens of the supposed alga Calcisphaera were seen in thin section.

On the hillside a few feet below the limestone outcrop, water from a group of springs issues from the soil- and drift-covered slope. It is possible that this ground water flows through a small cave system in the limestone.

Quality. — Visible impurities in the outcrop consist of silicified corals and argillaceous material forming the matrix of the limestone conglomerate.

Chemical analysis of German No. 2 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
W 23-1	West side	150	91.42	0.25	40.83	51.36	0.12	6.49	0.82	0.016

Ownership and development. — The owner is unknown, and there has been no development. The occurrence is probably too small to be of any economic value. Its structure and position cause it to dip back into the steep hillside under bedrock overburden, and this would appreciably limit any quarry development.

Reference. — Moen (1962, p. 97).

Northwest Black Mountain Deposit No. 1

Location, size, and accessibility. — The Northwest Black Mountain No. 1 limestone deposit is thought to be in about the center of sec. 5, but may be in the $NW\frac{1}{4}NE\frac{1}{4}$ sec. 8, T. 40 N., R. 6 E., at an altitude estimated to be 2,000 feet. It is approximately 50 feet south of a small stream and 150 feet east of an old logging road extending north-south through the central part of sec. 5. It is 0.6 mile east of the northern end of Silver Lake and consists of three small knoblike outcrops, the largest of which is about 40 feet long northeast-southwest and 10 feet wide. The limestone is accessible by $2\frac{1}{2}$ to 3 miles of poor logging road starting at the Silver Lake-Maple Falls highway $2\frac{1}{2}$ miles north of the village of Maple Falls. The main north Black Mountain logging road is followed for 2 miles to an overgrown branch road leading north. This branch road is followed north over $\frac{1}{2}$ mile to a stream, the bed of which contains limestone float. The outcrop can be reached by hiking for a distance of 150 feet up the steep and very brushy hillside adjacent to the south side of this stream. The terrain is covered with an exceptionally dense growth of trees and brush.

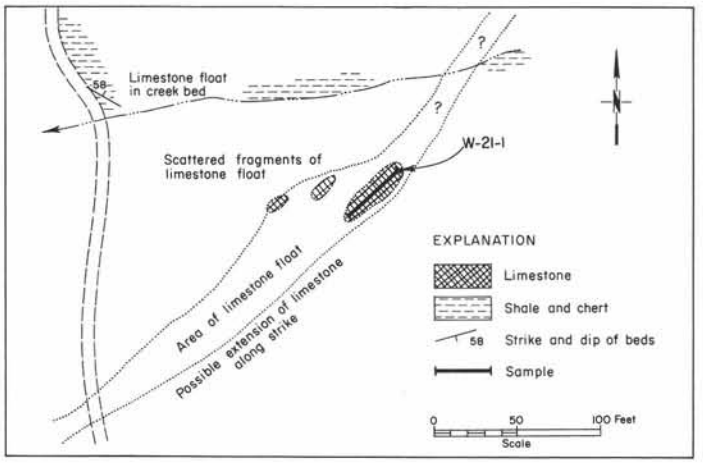


FIGURE 114. — Northwest Black Mountain No. 1 deposit. Center sec. 5, T. 40 N., R. 6 E. Geology by W. R. Danner. Reconnaissance sketch map.

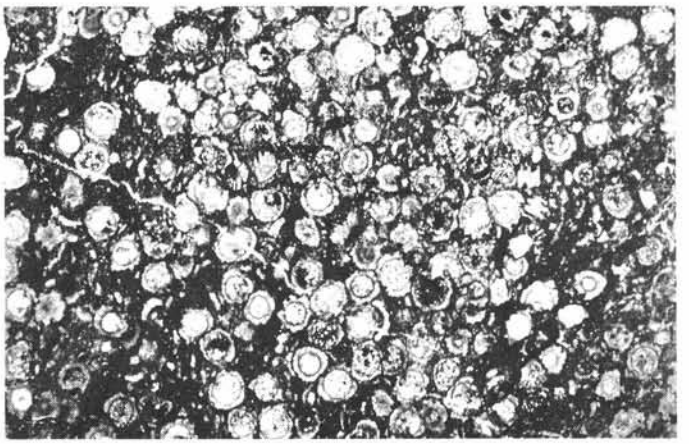


FIGURE 115. — Calcisphaera limestone, Northwest Black Mountain No. 1 deposit. Photomicrograph of Devonian Calcisphaera limestone. X 10.

Geology and description. — The exposures of this limestone are so poor that very little could be determined about it. It consists of three small outcrops, the largest of which stands up as an elongate low benchlike knob on the steep hillside. The two smaller outcrops are a few feet below and actually may be partly buried boulders. Fragments of limestone float are scattered along a northeast-southwest-trending area north and south of the outcrops and might mark an extension of them, but this is merely a guess. The limestone is light gray in color and contains a few partially silicified corals believed to be of Devonian age. In thin section, some of this limestone is seen to be organoclastic and composed of angular calcite fragments derived largely from broken fossils. It also contains a few angular quartz grains. A hand specimen, which appeared to be oölitic, in thin section was seen to be composed of a mass of the supposed algal structure known as Calcisphaera (Fig. 115), which is common in some limestones of Early Carboniferous and Middle and Late Devonian age around the world. The Northwest Black Mountain No. 1 limestone is thought to be of Late Devonian age and to be a correlative of the Doaks Creek and German limestones to the south.

Quality. — The limestone is of poor quality and contains visible argillaceous and secondary silica impurities.

Chemical analysis of Northwest Black Mountain No. 1 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
W 21-1	Scattered outcrops ----	40	88.64	0.39	39.34	49.80	0.19	9.61	0.79	0.014

Ownership and development. — The owner is unknown, and there has been no development. The outcrop should be prospected by trenching to determine its size and extent.

Reference. — Moen (1962, p. 97).

Northwest Black Mountain Deposit No. 2

Location, size, and accessibility. — The Northwest Black Mountain No. 2 limestone deposit is in the NW¼ sec. 5, T. 40 N., R. 6 E., at an estimated altitude of 2,300 feet on the steep northwest slope of Black Mountain, about 0.6 mile

northeast of Silver Lake. It consists of a sequence of thin-bedded impure argillaceous and gritty limestone exposed in a logging road cut for a distance of 225 feet. No exposures were found on the slopes immediately above and below the road, but limestone float of similar type fallen from the hillside above is present in a small stream gully to the southeast. The occurrence can be reached by following the main Black Mountain logging road, starting in sec. 18 and following it up about $2\frac{1}{2}$ miles to an abandoned and partly overgrown branch road leading north through the central part of sec. 5. Following this road about $1\frac{1}{2}$ miles, always taking the forks to the right, will bring one to the outcrop, which lies only a few feet from a road end.

Geology and description. — This occurrence consists of a bedded sequence of argillaceous limestone with interbeds of gritty limestone, calcareous graywacke, and conglomerate with calcareous cement. It is overlain and underlain by shales and graywackes. The sequence strikes about N. 80° E. and dips steeply to the northwest. An impression of a fossil plant resembling Calamites was found in the overlying shales, but it was not well preserved. The limestone itself contains numerous pelecypod or brachiopod shell fragments and echinoderm plates, but none of these is large enough to be identifiable or even to indicate for certain whether the geologic age is Paleozoic or Mesozoic. Just south of the outcrop is a gully containing a small intermittent stream that follows a zone of intense shearing believed to be a fault. South of this fault, roadcuts expose argillite and graywacke with interbedded chert and scattered lenses of marcasite a few inches in length. This sequence strikes in a direction similar to that of the limestone-bearing sequence to the north of the fault, but dips southward.

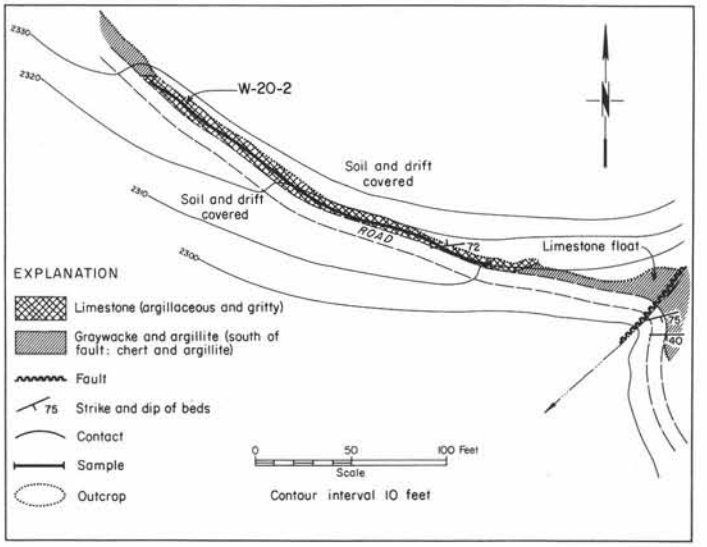


FIGURE 116. — Northwest Black Mountain No. 2 deposit. NW$\frac{1}{4}$ sec. 5, T. 40 N., R. 6 E. Geology by W. R. Danner, C. L. Smith, E. A. Adams, and C. F. Royse, Jr. Compass and tape survey.

Quality. — A sequence of chip samples taken along the roadcut indicate that the average composition of the limestone is just over 50 percent calcium carbonate. A selected sample that appeared to be of highest quality was composed of 78.90 percent calcium carbonate.

Chemical analyses of Northwest Black Mountain No. 2 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
W 20-1	Highest grade	Single specimen	78.90	1.44	35.70	44.33	0.69	15.72	2.65	0.066
W 20-2	Along roadcut	200	52.01	3.63	24.52	29.50	1.74	37.38	6.62	0.013

Ownership and development. — The owner of this limestone is unknown, and there has been no development. The limestone is too impure to be of any economic value.

Reference. — Moen (1962, p. 97).

Vedder Mountain Deposit

Location, size, and accessibility. — The Vedder Mountain limestone occurrence is in the SW¼ sec. 34, T. 41 N., R. 5 E., on the southwest side of a saddle extending northwest-southeast across Vedder Mountain about ½ mile south of the Canadian border at an estimated altitude of 900 feet above sea level. No limestone outcrops were found, but pieces of limestone float as much as 2 feet in diameter occur in the area. The locality can be reached by hiking up an old overgrown logging road for less than ½ mile from an unoccupied farm in the NE¼NW¼ sec. 3, T. 40 N., R. 5 E.

Geology and description. — Angular fragments of limestone up to 2 feet in diameter occur in a small gully adjacent to an old logging road. Smaller pieces of a similar-appearing limestone occur as float at the end of the logging road and up the hillside beyond, but no outcrop could be found. The limestone is light bluish gray in color, finely crystalline in texture, and contains a large amount of argillaceous and cherty material. It probably forms small pods and lenses in volcanic rocks, which, along with argillite, make up most of the bedrock outcrops in the area.

Quality. — Visible impurities indicate that the limestone is of poor quality.

Chemical analysis of Vedder Mountain 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
W 22-1	Float samples	Composite	74.83	1.40	33.47	42.04	0.67	21.23	2.11	0.076

Ownership and development. — The owner of the area is unknown, and there has been no development. The limestone is too impure and the source bed or beds (at present undiscovered) probably too small in size to be of any economic value.

Frost Creek Deposit

Location, size, and accessibility. — The Frost Creek limestone occurrence is in the E½ sec. 34, T. 41 N., R. 6 E., in the valley of Frost Creek, and extends northeastward into British Columbia on a northwest ridge of Isar Mountain. The occurrence was not visited during this investigation, and its size is unknown. It can be reached by going up Boulder Creek logging road near Maple Falls and hiking across country about 3½ miles to Frost Creek, or from the British Columbia side of the International Boundary by hiking about 2½ miles up Frost Creek. A new logging road going up Frost Creek on the Canadian side may be within 1 mile of the occurrence.

Geology and description. — Hillhouse (1956, p. 10) discovered this limestone and describes it briefly as follows:

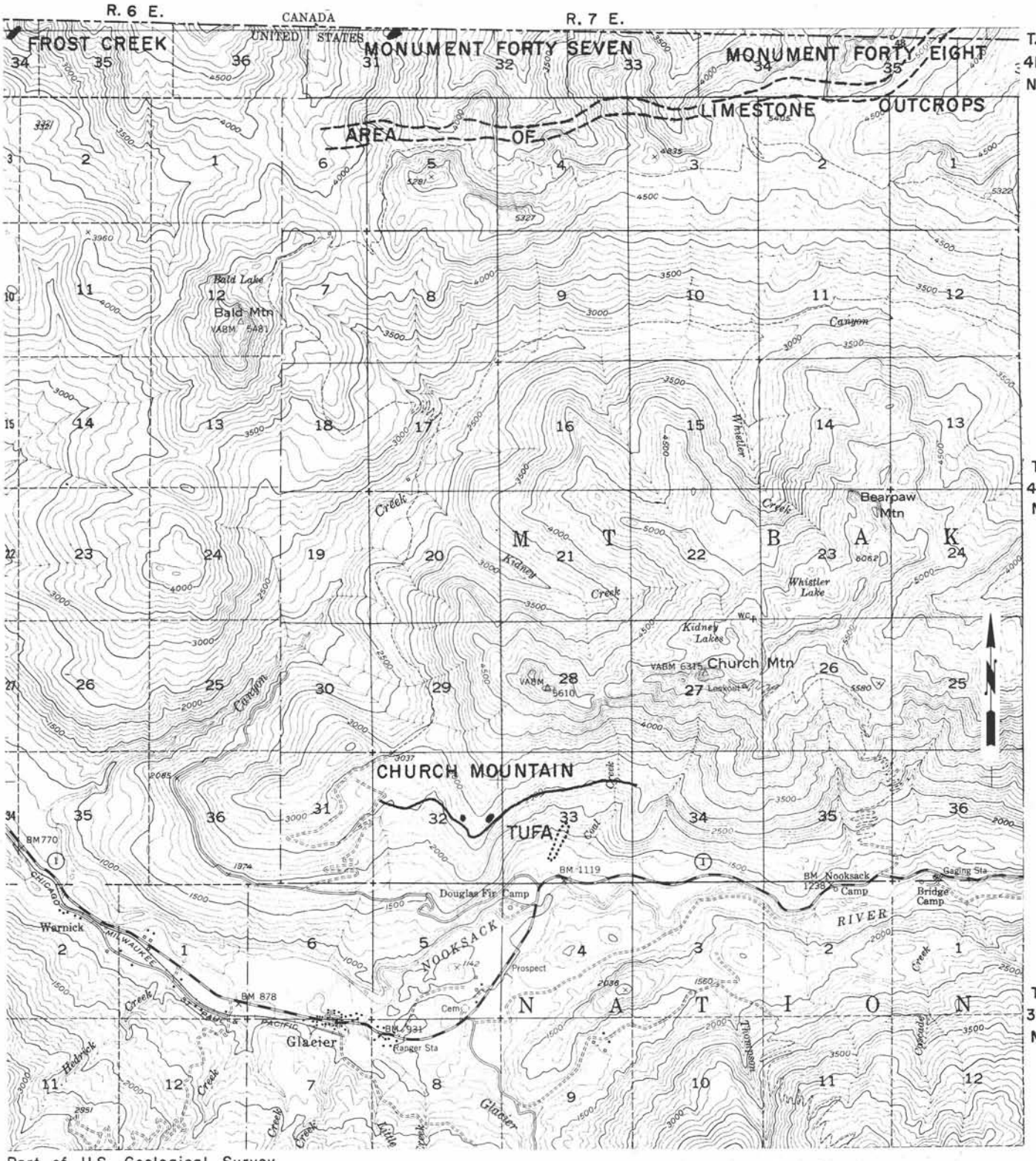
> The apparent stratigraphically lowest unit of the Chilliwack Group to be examined by the writer crops out on Frost Creek, about 200 yards south of the International Boundary and on the adjacent slope of Isar Mountain. It consists of light-gray, buff-weathering, sandy-textured dolomite; massive, medium-gray, brecciated dolomite; and black medium to finely crystalline limestone. The limestone contains what appear to be poorly preserved fusulinids.

He notes further that the limestone underlies volcanic rock.

Quality. — The quality is not known, but in his report Hillhouse indicates that the limestone is dolomitic.

Ownership and development. — The owner is unknown, and there has been no development. The occurrence is difficult of access from the Washington side of the International Boundary.

Reference. — Hillhouse (1956, p. 10).



Part of U.S. Geological Survey map of Mt. Baker quadrangle

1 ½ 0 1 2 3 4 MILES

CONTOUR INTERVAL 100 FEET
DOTTED LINES REPRESENT HALF-INTERVAL CONTOURS
DATUM IS MEAN SEA LEVEL

FIGURE 117. — Limestone deposits along the 49th parallel and in the vicinity of Church Mountain.

Isar Mountain Deposit

Location, size, and accessibility. — The Isar Mountain limestone occurrence is in the NW¼ sec. 35, T. 41 N., R. 6 E., along the International Boundary north of Frost Creek on a northwestern ridge of Isar Mountain. It is at an altitude of approximately 3,800 feet. Its size is unknown, but it is reported as being "small." The deposit can be reached by going up Boulder Creek logging road near Maple Falls and hiking across country for about 3½ miles or by going about 3 miles up Frost Creek from the British Columbia side of the border and climbing up the steep slope to the outcrop. It may be within 1½ miles of a new logging road going up Frost Creek on the British Columbia side of the boundary.

Geology and description. — The occurrence was not visited during this investigation. Hillhouse (1956, p. 10-11) mentions "one small outcrop of limestone on the western slope (Isar Mountain) at approximately the 3,800-foot elevation." He states that the limestone is interbedded in volcanic rocks and describes it thus:

> The apparently interbedded limestone is black, finely crystalline and massive. It is possible that this limestone indicates an infold of older or younger material.

Quality. — Unknown.

Ownership and development. — The owner is unknown, and there has been no development. At present (1962) the area is difficult of access from the Washington side of the border. The deposit is probably too small to be of any economic value.

Reference. — Hillhouse (1956, p. 10-11).

Monument 47 Deposit

Location, size, and accessibility. — The Monument 47 limestone deposit is in the center of the E½ sec. 31, T. 41 N., R. 7 E., on a ridge east of Isar Mountain between two forks of north-flowing Lihumitson Creek. It is near boundary monument No. 47 (United States-Canada), and its size is unknown. It can be reached by driving up Canyon Creek logging road near the town of Glacier for about 6 miles, then up the Bald Mountain branch logging road for about 3 miles. From the end of the road, about 3 miles of trail hiking and then about 1 mile of cross-country hiking would be required to reach the area. The outcrop occurs at an altitude of approximately 3,800 feet.

Geology and description. — The occurrence was not visited during this investigation. Hillhouse (1956, p. 15-16) describes it briefly:

> A dark-gray to black, finely crystalline, thin- to medium-bedded limestone containing fusulinids is exposed on both sides of the ridge east of Isar Mountain. . . . On the west side of the ridge it is exposed about 50 yards south of the boundary at an elevation of approximately 3,800 feet. . . . a large argillite cliff crops out about 50 yards north of the limestone and topographically above it.

The writer examined a sample of this limestone and found it to contain partially recrystallized specimens of a Permian fusulinid, probably Schwagerina.

Quality. — Unknown.

Ownership and development. — The limestone is on lands of the Mount Baker National Forest, and there has been no development. It is too remote and inaccessible at present (1962) to be of any economic value.

Reference. — Hillhouse (1956, p. 15-16).

Monument 48 Deposit

Location, size, and accessibility. — The Monument 48 limestone deposit is in the south part of sec. 34 and S½ sec. 35, T. 41 N., and in the north parts of secs. 2, 3, 4, 5, and 6, T. 40 N., R. 7 E. Its west end is about ½ mile south of the International Boundary. The deposit extends northeastward to and across the boundary. The occurrence ranges in altitude from

about 3,500 to 5,500 feet. Limestone outcrops are reported to extend over an east-west distance of almost 5 miles. The thickness and width are unknown. The west end of the occurrence can be reached by following Canyon Creek logging road north of the town of Glacier for about 6 miles, then following the Bald Mountain branch logging road for about 3 miles and following a trail from Bald Mountain for about 2½ miles, then hiking across country a few hundred feet north to the outcrop area. The limestone is exposed in rough, heavily forested terrain with a few meadow areas on ridge tops.

Geology and description. — Daly (1912) shows a belt of limestone outcrops extending more than 1 mile southwestward from the International Boundary near Monument 48. Peter Misch (oral communication, 1961) has traced a belt of limestone outcrops and sinkholes for about 5 miles southwest and west of Monument 48. The writer has observed, from the Canadian side of the border, a cliff outcrop of limestone about 100 feet high in the northeast corner of sec. 33, but there was not time to approach it for a close examination. Daly mentions the limestone as being 50 feet thick and light gray in color. He collected fossils including Zaphrentis sp., Campophyllum sp., Euomphalus sp., crinoidal fragments, and fucoidal markings.

Quality. — Unknown.

Ownership and development. — The occurrence is on lands of the Mount Baker National Forest, and there has been no development. It is too remote and inaccessible to be of economic value at present (1962) time.

Reference. — Daly (1912, p. 510).

Monument 45 Deposit

Location, size, and accessibility. — The Monument 45 limestone occurrence is in the south-central part of sec. 33, T. 41 N., R. 6 E., about 3,600 feet southwest of Monument 45 on the International Boundary. Its size is unknown, and the best route to the limestone is also unknown. It probably could be reached by going from the Maple Falls-Silver Lake road up 6 miles of washed-out and overgrown logging road to a northwestern ridge of Black Mountain and then hiking across country about 1½ miles to the outcrop. The area is rough and mountainous, and the terrain is heavily forested.

Geology and description. — The limestone is described by Daly (1912, p. 512) as:

> A massive limestone with a fifty-foot interbed of dark-gray shale. . . . It dips under the great volcanic member in apparent conformity. The exposures at this point are too poor to make a section of very great value.

Daly collected the following fossils from this occurrence: "Fusulina elongata" Shumard, Rhombopora sp., Productus? sp. These fossils are similar to those that occur in limestones of Permian age on Black Mountain, to the southwest, and this occurrence is probably a northeasterly extension of that sequence.

Quality. — Unknown.

Ownership and development. — The owner is unknown, and there has been no development. The limestone is too remote and inaccessible to be of economic value at present (1962).

Reference. — Daly (1912, p. 512).

Black Mountain Deposits

Location, size, and accessibility. — The Black Mountain limestone deposits are in the NE¼ and the S½ sec. 4, T. 40 N., R. 6 E., on the northwest side of Black Mountain at altitudes between 3,400 and 4,500 feet. There are seven separate outcrop areas, containing a total of at least 25 million tons of limestone.

The area could be reached at one time by approximately 6 miles of logging road, starting from the Silver Lake road about 3 miles north of Maple Falls. The last 4½ miles of this road is now largely impassable, being overgrown with small trees and brush and in several places partially washed out. The whole area is covered mostly by a dense second growth of trees and brush. Much of it was logged during or shortly after World War II. Some of the higher parts have virgin timber, open meadow and brushy areas, and bare rock cliffs.

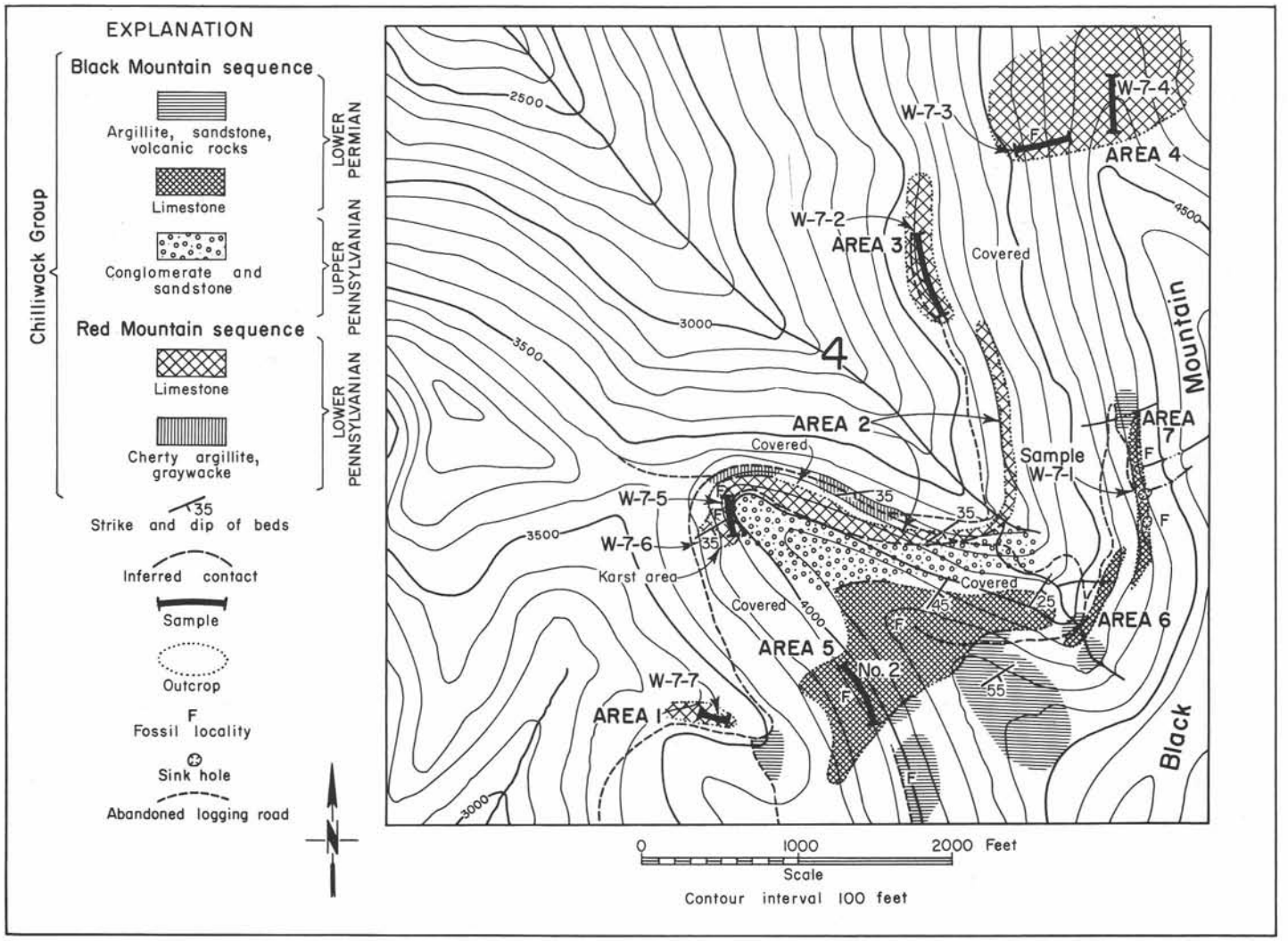


FIGURE 118.—Black Mountain limestone deposits. Sec. 4, T. 40 N., R. 6 E. Geology by W. R. Danner and C. F. McKillop. Base map enlarged from U.S. Geological Survey Van Zandt quadrangle.

Geology and description.—The limestone occurrences of Black Mountain consist of large lenticular bodies interbedded in sedimentary and volcanic rocks of two distinct sequences. The older of these sequences is of probable Early Pennsylvanian age, and the younger is of early to early middle Permian age. Between the two is a unit composed of conglomerate and sandstone that rests with little apparent angularity on the underlying Pennsylvanian sequence.

PENNSYLVANIAN LIMESTONES

It is not certain whether one or more than one limestone bed is present in the Pennsylvanian sequence in this area. It would appear, from the poor exposures, that either there are several limestone lenses at different positions in the sequence or that one limestone unit has been broken into several blocks separated by faults.

No. 1: Outcrop No. 1 is a gray dense-textured limestone in the SE¼SW¼ sec. 4 in a relatively level basin-like area below and on the west side of a northwestward-trending ridge of Black Mountain. The outcrop lies just north of where the logging road divides into a north and a south branch. The limestone forms a low mound, and the outcrop is mostly concealed by vegetation. Its true dimensions are unknown, but it can be traced for a length of at least 200 feet and has a width of 25 feet.

No. 2: Outcrop No. 2 forms a cliff in a small pass on a northwest ridge of Black Mountain in the NE¼SW¼ sec. 4. This cliff is visible from the Silver Lake road, below. The limestone that forms this cliff consists of a bed at least 200 feet thick, but along strike to the east it thins to less than 100 feet in thickness. It is exposed on the north side of the ridge and across a valley for a distance of over 2,500 feet. The strike is about N. 50° E., and the dip is 20°-35° SE. At the northwest end of the limestone outcrop there is a small area of karst topography. Here pinnacles of limestone stick up through a jumble of limestone blocks formed by the collapse of the walls and roofs of underlying solution cavities. The karst area is about 250 feet long east-west and from 50 to 300 feet wide. To the east of the karst area the limestone outcrop forms a nearly vertical cliff 200 feet in height.

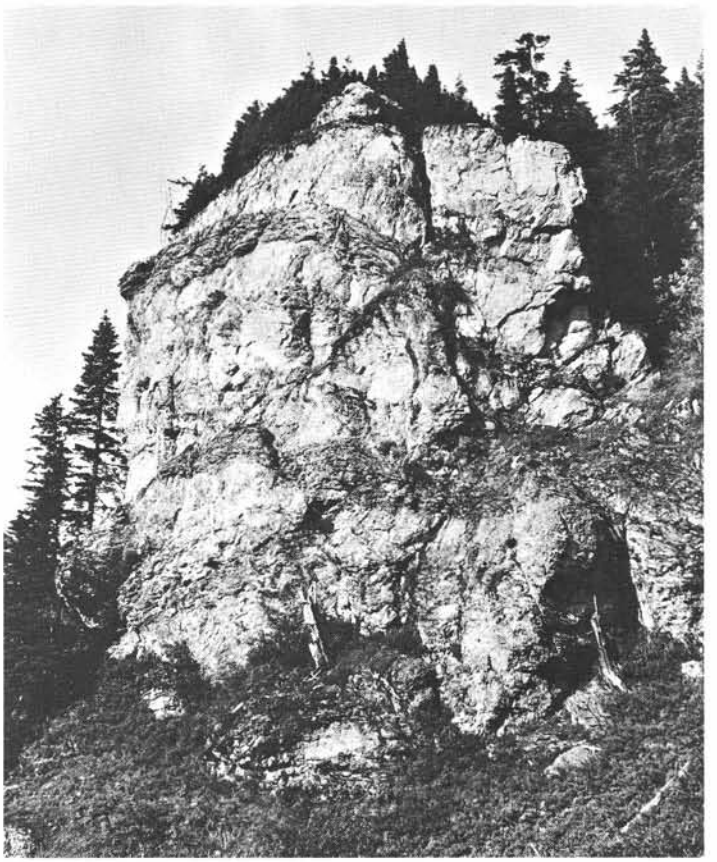


FIGURE 119.—Cliff-forming outcrop of Pennsylvanian age limestone on a northwest ridge of Black Mountain. Pennsylvanian outcrop No. 2. Darker bands with platy jointing richer in magnesium than rest of limestone.

Three thin-bedded units of slabby weathering, sugary textured, brown limestone separated by thick layers of more massive light-gray and dense-textured limestone are exposed on the cliff face. The slabby layers are higher in magnesium than the more massive layers between. Fossils are abundant in parts of the outcrops and include horn and colonial corals, brachiopods, and large crinoid stems. In thin section, calcareous algae, fusulinids, and other foraminifers are visible. The association of Eostafella, Endothyra, Ozawainella, and Tetrataxis is thought to be diagnostic of the Early Pennsylvanian.

Overlying the limestone in the cliff area is a strongly indurated bed of conglomerate made up of pebbles and cobbles as much as a foot in diameter. The pebbles and cobbles are composed mostly of volcanic rocks and chert, but limestone fragments are also common.

The conglomerate dips southeastward and thickens to more than 150 feet down dip. A small fault appears to cut both the conglomerate and underlying limestone to the south, but the displacemnt appears to be only a few feet.

Southeastward across a small valley the limestone becomes thinner and contains interbedded layers of shale. The outcrop belt swings around to the north and forms a small bluff about 150 feet above a branch logging road on the east side of the valley.

Because of the conglomerate overburden, the quarrying possibilities of this limestone are not as good as they might appear from the rather spectacular outcrop. However, it is estimated that more than 2 million tons could be quarried by following the limestone along its strike.

No. 3: The extension of limestone outcrop No. 2 northward into the SW¼NE¼ sec. 4 disappears beneath soil and slope debris above the branch logging road. However, a similar-appearing bed of limestone crops out along the logging road and on the slope above it for a distance of as much as 75 feet. It is light gray in color, dense textured, and contains large fossil crinoid stems. It continues for a distance of about 500 feet along strike.

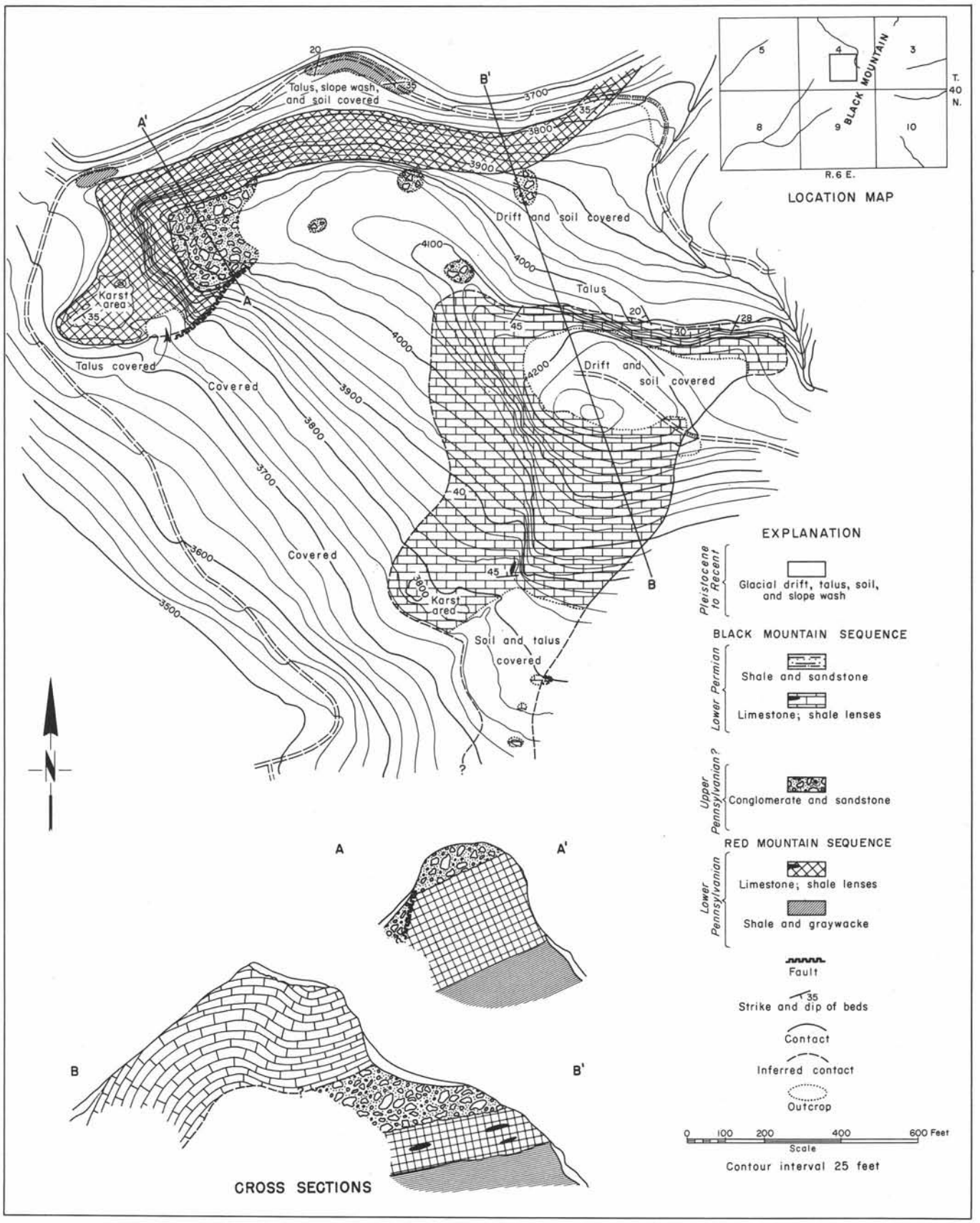


FIGURE 120. — Geologic map and cross sections of part of Black Mountain. S½ sec. 4, T. 40 N., R. 6 E. Geology by W. R. Danner. Compass and tape survey by W. R. Danner, Keifer Fobes, and Richard Schwan, 1955.

No. 4: To the northeast, about 350 feet above the logging road, is a large cliff exposure of massive to well-bedded gray limestone. It is argillaceous and contains numerous small crinoid stems and a few small flattened fossil brachiopods. Parts of the limestone are recrystallized. It crops out vertically for an estimated height of 500 feet up to the top of the ridge and dips gently southeastward into the hillside. It was traced for about 300 feet northward, but may extend for a much greater distance. A minimum of 10 million tons of limestone is exposed.

PERMIAN LIMESTONES

No. 5: The largest of the Permian limestone bodies crops out on the crest and sides of a northwest-trending ridge of Black Mountain southeast and above the Pennsylvanian limestone body No. 2. It is in the SE¼ sec. 4. Limestone is exposed for about 1,200 feet northeast-southwest and has a maximum width of 700 feet, narrowing to about 125 feet at each end. It is exposed vertically for a distance of 525 feet and is underlain by conglomerate and sandstone and is overlain by sandstone, siltstone, and cherty argillite. At the top of the ridge it is partly covered with soil and glacial drift.

FIGURE 121. — Outcrop No. 4, limestone on the northwest side of Black Mountain. View looking north.

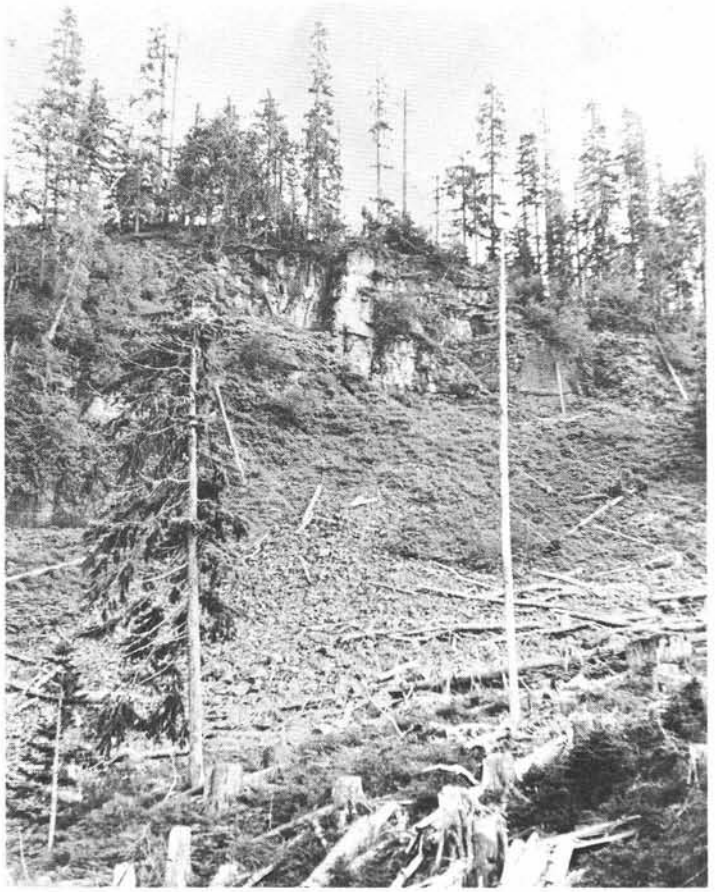


FIGURE 122. — Outcrop No. 5, limestone on the northwest side of Black Mountain. Permian in age. East side of outcrop. View looking southwest.

On the west side of the outcrop area is a cliff exposure with a karst area below it similar to the Pennsylvanian outcrop 800 feet to the north. The east side of the outcrop area is also a cliff and has a talus accumulation of limestone below it.

The Permian limestone is brown to gray in color and dense to sugary in texture. Much of the sugary-textured rock is made up of authigenic dolomite crystals. Black or gray jasperoid in irregular replacement beds is common in the east-side cliffs and also on the west side of the outcrop where it has replaced fossils. One small lens-shaped body of shale was found in the limestone on the western cliff face.

Chemical analyses of Black Mountain limestone

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)
Analyses of samples collected for this report, Mark Adams, analyst														
W 7-1	No. 7 ----------	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	No. 3 ----------	500	86.36	0.83	38.34	48.52	0.40	11.01	1.63	0.018				
W 7-3	No. 4, south side	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	No. 4, top of ridge	300	84.67	11.91	43.74	47.57	5.70	2.72	0.57	0.019	225	500	95	110
W 7-5	No. 2, North cliff base ----------	200	93.61	0.71	41.66	52.59	0.34	4.51	0.91	0.010				
W 7-6	No. 2, karst area	Composite	96.63	0.58	42.84	54.29	0.28	1.90	0.60	0.018				
W 7-7	No. 1 ----------	200	83.96	0.418	37.25	47.17	0.20	14.74	0.47	0.012				
Analyses from other sources														
									Fe_2O_3 / Al_2O_3					
1/	No. 5 ----------	Single specimen	79.31	26.96		44.56	12.90	2.52	0.67 / 1.36					
1/	No. 5 ----------	West side, composite	94.01	10.95		52.82	5.24	6.82	0.83 / 0.55					
									R_2O_3					
2/ 1-7	No. 2 ----------				(Burned to lime)	92.63	0.55	4.88	1.70					
2/ 1A-3A	No. 2 ----------				----- do -----	91.38	0.38	6.52	1.66					
2/ 1B-5B	No. 2 ----------				----- do -----	91.48	0.66	6.36	1.10					
2/	No. 2 ----------				----- do -----	48.90	1.57	45.34	4.20					
2/ 1 and 3DW	No. 5, west side -				----- do -----	92.79	0.51	5.80	1.24					
2/ 2 and 4DW	No. 5, west side -				----- do -----	48.90	1.57	45.34	4.20					
2/ 1, 9, and 11DN	No. 5, north side				----- do -----	63.73	0.40	34.32	1.60					
2/ 3, 5, 6, 10, and 12DN	No. 5, north side				----- do -----	45.14	0.26	53.34	1.00					
2/ 4DN	No. 5, north side				----- do -----	28.26	0.15	70.90	0.88					
2/ 1	No. 5, SW. face, bottom --------				(Not burned)	53.38								
2/ 2	No. 5, SW. face, bottom --------					53.38								
2/ E1	No. 5, SW. face, 2nd ledge ------					54.89								
2/ E2	No. 5, SW. face, 2nd ledge ------					24.22								
2/ E3	No. 5, SW. face, 2nd ledge ------					39.25								
2/ E4	No. 5, SW. face, 2nd ledge ------					48.00								
2/ E5	No. 5, SW. face, 2nd ledge ------					39.48								
2/ E6	No. 5, SW. face, 3rd ledge ------					53.22								
2/ E7	No. 5, SW. face, 3rd ledge ------					53.04								
2/ E8	No. 5, SW. face, 2nd ledge ------					54.22								
2/ E9	No. 5, SW. face, 4th ledge ------					53.76								
2/ E10	No. 5, SW. face, 4th ledge ------					54.96								
2/ E11	No. 5, SW. face, 2nd ledge ------					27.14								
2/ E12	No. 5, SW. face, 2nd ledge ------					53.65								

1/ Northwest Laboratories, T. H. Williams, analyst.
2/ Permanente Cement Company, E. J. Baldwin, analyst.

The limestone is highly fossiliferous in places, and large parts are composed of a fusulinid coquina. Species of Schwagerina and Pseudofusulinella are most abundant. Bryozoans of several different genera are also present. It is estimated that this outcrop contains about 10 million tons of limestone. However, drilling would be required to verify this estimate.

No. 6: A narrow band of limestone crops out to the east of No. 5, on the east side of a topographic basin that is on the northwest side of Black Mountain in the SE¼ sec. 4. It is not well exposed but appears to extend for at least 500 feet north-south. It dips at a low angle into the steep hillside and appears to pinch out to the north and south. The limestone is argillaceous and in places contains numerous small crinoid stems. Near its north end a small stream emerges from underneath the outcrop. The limestone is overlain and underlain by shale and sandstone.

No. 7: About 100 feet above No. 6 is another narrow band of limestone, which can be traced for about 1,000 feet north-south. It appears to be at least 50 feet thick. Although it is crystalline in texture over most of its outcrop, a few brachiopods and fusulinid fossils were found in it. The limestone dips at a low angle into the hillside and forms a small scarp on the steep slope. It gradually declines in altitude along strike to the south, and it appears to pinch out in this direction, as it is not exposed in a streambed a few hundred feet south of the last exposure. The outcrop ends abruptly to the north and may be cut off by faulting. The same bed may reappear again to the south on the west side of Black Mountain, but no limestone outcrop was found along its projected strike. However, boulders of fusulinid- and bryozoan-bearing limestone were found on the slope below.

This limestone bed contains three large sinkholes, two of which have small streams plunging down into them in waterfalls.

No. 8: In about the center of the NW¼ sec. 9, T. 40 N., R. 6 E., is a streambed crossed by the Black Mountain logging road. Numerous boulders and fragments of Permian fusulinid limestone are in the streambed in this vicinity, and the concentration of them indicates the possibility of a limestone body in the vicinity, probably mostly buried by glacial drift.

Quality.—The quality of the limestone in these outcrops is quite variable; samples collected by the writer analyzed from 60 percent to over 96 percent calcium carbonate and were as high as 26.96 percent in magnesium carbonate. Silica in the form of chert or jasperoid and in argillaceous interbeds is also an important impurity.

Ownership and development.—The joint owners of the S½ sec. 4 are W. A. Moore, Bellingham; Mrs. Virginia Lobdell, Mercer Island; Keifer Fobes, Seattle; and the estate of F. D. Fobes. The owner of the NE¼ sec. 4 is unknown. The variable quality and high altitude of this occurrence are unfavorable for its development, despite the large tonnage. Because of heavy snowfall, it is unlikely that quarries could be operated during the winter months. A tramline extending a vertical distance of 3,000 feet would be needed to get the limestone down to the valley floor. A cement plant could probably use the limestone by combining different grades of it from different parts of the outcrop, but under present (1962) conditions the occurrence is uneconomic. There has been no development. A considerable amount of exploration would be required to determine the quality of the limestone at depth and the size of the different bodies.

References.—Private unpublished reports by E. J. Baldwin (1954) and W. R. Danner (1955).

Church Mountain Deposits

Location, size, and accessibility.—The Church Mountain limestone deposits are in the N½SE¼ sec. 32, T. 40 N., R. 7 E., on the south slopes of the west end of Church Mountain ridge, at an estimated altitude of 2,600 feet. The limestone is exposed in three roadcuts on the north side of a logging road. The westernmost outcrop is about 50 feet long north-south, 12 feet wide, and extends vertically for about 20 feet. The middle outcrop is a small limestone pod 2 feet by 3 feet in area. The easternmost outcrop is 300 feet long and separated from another limestone outcrop by 120 feet of siltstone, ribbon chert, and greenstone; the second outcrop is 85 feet long. Both of these outcrops are exposed vertically for about 12 feet.

The occurrences can be reached by logging roads, starting with the Canyon Creek logging road about 2 miles east of the village of Glacier and following it for 2½ miles to an intersection with the west Church Mountain road, following the latter

road for 1.8 miles to a fork, and then following the fork on the right for 1.1 miles to the first outcrop. The limestone outcrops are on a steep hillside, now partly logged. Exposures on the slopes are poor because of soil cover, talus, and vegetation. Where they have been logged, the steep mountain slopes are developing into slide areas.

Geology and description. — The westernmost limestone outcrop is in a roadcut and has soil cover on the east and west sides. The exposure forms a small mound of limestone that can be traced north of the highway for 50 feet to a sinkhole. No extension south of the highway could be found. The limestone is thin bedded, gray in color, and crystalline in texture. It contains partially silicified corals similar to Plagiopora and is considered to be Devonian in age.

The middle outcrop is about 0.2 mile to the east in a roadcut and consists of a small pod of crystalline limestone interbedded in argillite. It also contains poorly preserved, partially silicified specimens of the coral Plagiopora.

The eastern outcrop consists of a bed of limestone about 20 feet thick exposed in a roadcut in a highly folded sequence of siltstone, ribbon chert, and greenstone. At the west end of the outcrop the limestone dips down from the top of the roadcut, forming a small asymmetrical synclinal fold, then rises up in a small anticlinal fold and disappears beneath the roadbed. One hundred and twenty feet to the east a similar bed dips down across the roadcut and disappears in a covered area. The sediments in this roadcut strike about N. 40° E. and dip 15°-50° NW. The limestone is thin bedded, gray in color, and crystalline in texture. No fossils were found in it.

Other small bodies of limestone may exist elsewhere on the slopes of Church Mountain and may be exposed as logging activity continues on the steep hillside.

Quality. — The quality of this limestone is good, but it may contain 2 percent or more of silica.

Chemical analyses of Church Mountain 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
W 12-1	Eastern outcrop -----	20 (thickness)	95.60	0.46	42.69	53.71	0.22	2.43	0.71	0.056
W 12-2	Eastern outcrop -----	385 (length)	96.15	0.52	42.77	54.02	0.25	2.25	0.75	0.009
W 13-1	Western outcrop -----	12 (width)	96.33	0.52	42.85	54.12	0.25	1.72	0.94	0.009

Ownership and development. —The roadcut outcrops of limestone on Church Mountain were staked as claims in 1959. The westernmost was recorded as the Red Bird No. 6 by Oliver Lynn on June 18, 1959, for "lime, uranium, and all other minerals." There was no visible development. Because of their small size, distance from market, and complex folding and faulting, the limestones have no economic value under present (1962) conditions.

Reference. — Peter Misch, unpublished report on regional geology.

Baker Lake Deposit

Location, size, and accessibility. — The Baker Lake limestone occurrence is in the $S\frac{1}{2}$ sec. 34, T. 38 N., R. 9 E., on the mountainside north above Baker Lake. It is best exposed in roadcuts. Other outcrops are reported to be present in the area, but their location is unknown. The limestone examined forms small lenses only a few feet in area. The outcrops can be reached by approximately 22 miles of graveled road north from the town of Concrete.

Geology and description. — The occurrence consists of small lenses of gray, finely crystalline limestone cropping out in roadcuts along the north side of Baker Lake. The largest lens examined was about 10 feet long and 4 feet wide. The limestone is interbedded in a sequence of highly sheared and crumpled slates, phyllites, and indurated coarser clastic rocks cut by quartz veins. Guard (1943, unpublished field notes) describes other outcrops in the vicinity of Baker Lake in the SE¼ sec. 35, T. 38 N., R. 9 E., but all the SE¼ sec. 35 consists of alluvium-covered bottomlands with no outcrops and is now mostly covered by the waters of the impounded Baker Lake. His notes actually appear to describe limestone on the mountainsides southeast of Baker Lake, and the wrong section location is quite likely due to the inadequate and inaccurate maps that were available at the time he visited the area. He reports two outcrops of white crystalline limestone about 1 mile up a logging road east of the former Baker Lake campground (now under water). These bodies are 15 to 30 feet wide, strike N. 15°-25° W. and have a nearly vertical dip. The two beds are about 50 feet apart in a roadcut and are both faulted near the top of the cut. He believes them to be part of the same bed, separated by faulting displacement. He observed other small pods of limestone several hundred feet farther up the hillside, one of which is 6 inches by 2 feet in size; another 3 feet by 5 feet and enclosed in sedimentary rocks; and another, larger body 30 feet across. The limestone is described as being pure white and crystalline in texture. Peter Misch (oral communication, 1962) reports limestone in the vicinity of Silver Creek, in the north part of sec. 10, T. 37 N., R. 9 E., south of Baker Lake.

Quality. —

Chemical analysis of Baker Lake limestone

(Mark Adams, analyst)

Sample no.	Location	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
W 26-1	Composite from roadcuts -----	95.31	0.92	42.33	54.11	0.44	1.42	1.12	0.244

Ownership and development. — The Baker Lake limestone is on lands of the Mount Baker National Forest. There has been no development, and the occurrences are too small and remote to be of economic value. The pure white finely crystalline limestone mentioned by Guard might have some value as terrazzo chips or stucco material.

Reference. — Guard (1943, unpublished field notes).

Ridley Creek Deposit

Location, size, and accessibility. — The Ridley Creek limestone deposit is in unsurveyed land almost midway between the Twin Sisters Mountain and Mount Baker, in central western Whatcom County. The limestone crops out along Ridley Creek, a tributary of the Middle Fork of the Nooksack River, and on the ridge to the southeast known as Sister Divide. It is about 28 miles by road from Bellingham and about 9 miles by trail up the Middle Fork of the Nooksack River and Ridley Creek. At least three limestone outcrop areas are known, the largest of which is 2,200 feet long and about 400 feet in maximum width. The exposures range in altitude from 3,000 to 4,000 feet above sea level.

Geology and description. — The limestone was first reported by Walter Gonnason, who supplied the map illustrated here. Aside from the information appearing on his map, there are no other data available, as the occurrence was discovered after the field work for this bulletin was completed. The limestone strikes northeast-southwest and dips at an angle of about 60° NW. It is reported to contain crinoid fossils, and this, along with the size of the outcrops, indicates that it is probably another body of the Lower Pennsylvanian limestone so commonly present in Whatcom and Skagit counties.

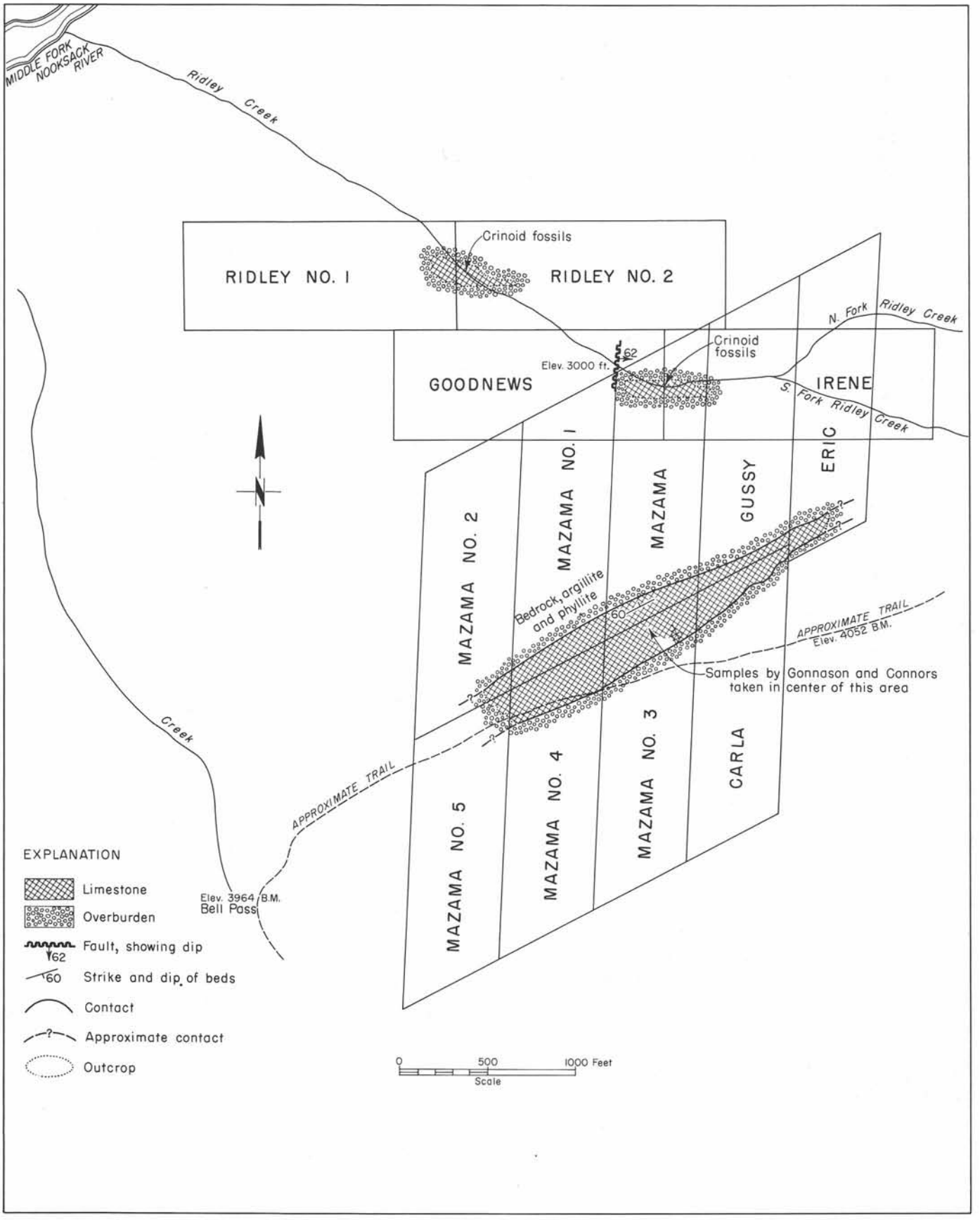


FIGURE 123. — Ridley Creek deposit. Geology by Walter Gonnason.

Quality. — Seven samples from near the center of the largest exposure of the Mazama and the Mazama No. 3 claims showed 0.09 to 0.41 percent SiO_2, 0.09 to 0.25 percent Fe_2O_3, 0.37 to 0.84 percent Al_2O_3, 53.97 to 55.53 percent CaO, 0.03 to 0.90 percent MgO, 42.84 to 43.63 percent ignition loss, 0.00 to 0.01 percent Na_2O, and 0.00 to 0.01 percent K_2O. Analyses of samples from some of the other claims showed the following:

Chemical analyses of Ridley Creek limestone[1/]

Claim	Loss on ignition	CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3	Na_2O	K_2O
Goodnews ----	42.41	49.67	3.23	2.65	0.65	0.94	0.00	0.00
Irene --------	40.94	49.07	2.69	4.48	0.83	1.15	0.00	0.01
Eric ---------	35.14	43.93	0.68	17.72	0.85	1.30	0.02	0.07
Gussy--------	37.63	47.24	0.35	13.59	0.37	0.51	0.00	0.01
Carla --------	37.05	45.85	0.67	14.78	0.53	0.66	0.00	0.02
Mazama No. 2	42.37	52.62	1.15	2.46	0.25	0.54	0.00	0.02

[1/] All analyses were made in 1962 by the Permanente Cement Company.

Ownership and development. — The limestone is owned by Walter Gonnason and the Goodnews Bay Mining Company. There has been no development. The occurrence might be large enough for supplying a cement company, but it is situated in relatively inaccessible country, where there is heavy winter snowfall.

Other Limestones of Whatcom County

It is to be expected that as prospecting is extended into the eastern part of Whatcom County and parts of the area are logged, additional limestone outcrops will be discoverd. During this investigation, limestone outcrops were reported south of Mount Baker on the south side of ridges located to the north and south of the headwaters of Loomis Creek, but because of lack of time these could not be investigated.

Small lenses of dense to finely crystalline textured limestone are interbedded with volcanic rocks and ribbon chert on the eastern side of the south part of Lummi Island. They are thought to be of Mesozoic age.

LIMESTONES OF THE WHATCOM COUNTY-SKAGIT COUNTY BORDER AREA

South of Mount Baker and northwest of the town of Concrete is an area of limestone outcrops on both sides of the Whatcom County-Skagit County border. They are best described as a group rather than as separate occurrences for the two counties. The limestones are believed to occur in a sequence of Pennsylvanian age that is part of the Chilliwack Group. The area is relatively inaccessible, and the geology has not been mapped in detail.

Dock Butte Trail Deposit No. 1

Location, size, and accessibility. — The area of the Dock Butte Trail No. 1 limestone deposit is unsurveyed, but it is believed to be in the $NE\frac{1}{4}NE\frac{1}{4}$ sec. 33 and the $NW\frac{1}{4}NW\frac{1}{4}$ sec. 34, T. 37 N., R. 8 E., almost 1 mile north of the Whatcom County-Skagit County boundary, at an altitude estimated to be between 3,250 and 3,420 feet above sea level. The outcrops lie just south of the Forest Service trail to Blue Lake and Dock Butte Lookout.

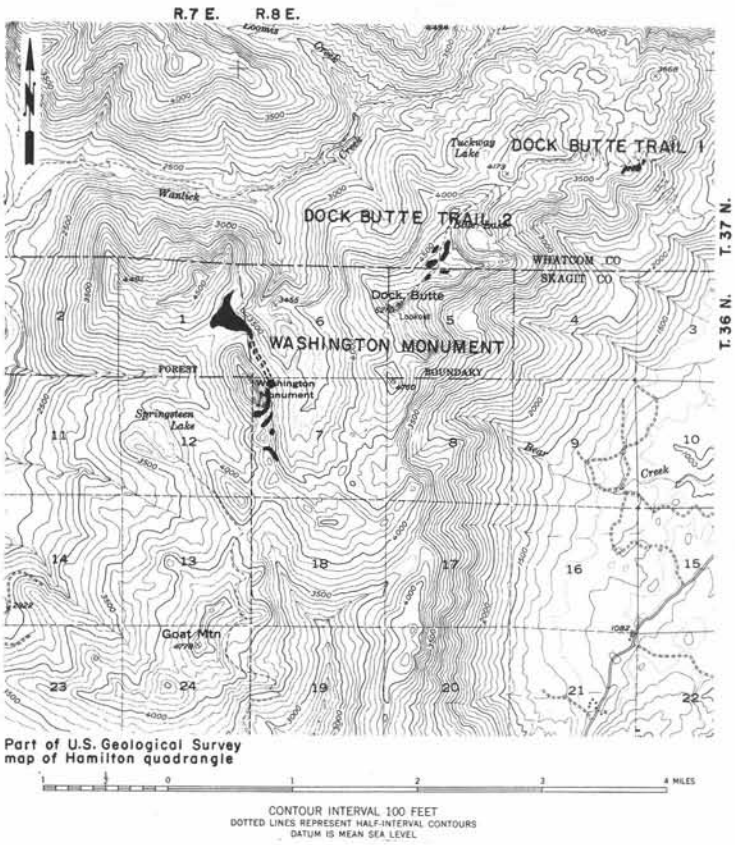


FIGURE 124. — Limestone deposits of the Whatcom County-Skagit County border area.

The occurrence consists of five poorly exposed belts of outcrops and sinkholes exposed over an area 800 feet long east-west and 300 feet wide. Individual outcrops are as much as 30 feet wide, 60 feet long, and 30 feet in vertical exposure.

The area can be reached by about 2 3/4 miles of good but steep trail starting from a narrow logging road about $\frac{1}{4}$ mile west from the Baker Lake road. It is approximately 11 miles from this road junction south to the town of Concrete. The area is covered with relatively open stands of virgin timber and brushy areas of devils club and huckleberry.

Geology and description. — The limestone is so poorly exposed that not much is known about its geology. It is on a gently sloping benchlike area, which has steep slopes down to the south and a more gentle slope down to the north. The topography rises gradually to the west. Five outcrop belts were found striking northeast-southwest. The most westerly of these is composed of four large sinkholes ranging from 30 to 60 feet in width and is as much as 30 feet in depth. Between these, along a strike length of about 260 feet are several smaller sinks. Each of the larger sinks has a small limestone outcrop area on its walls — three have the outcrop on the south side and one has it on the north side. In the most westerly outcrop the limestone has a strike of about N. 30° E. and a dip of 30° NW.

One hundred feet to the southeast is a second outcrop belt extending northeast-southwest about 200 feet. It has a maximum width of 50 feet at its south end across three limestone outcrops.

The third outcrop belt is about 180 feet to the southeast and consists of a limestone knob about 20 feet wide and 60 feet long.

One hundred feet to the east of it is the fourth outcrop belt. It is about 160 feet long and 30 to 50 feet wide. It contains two large outcrop areas as much as 60 feet in length and 30 feet wide. A 25-foot-high cliff of limestone is exposed at the southeast corner of this belt.

One hundred and fifty feet to the east is the fifth outcrop belt. It consists of one major outcrop area about 50 feet long and 20 feet wide, and 140 to 200 feet to the southwest of it are several small outcrops and sinkholes.

The limestone of the Dock Butte Trail No. 1 deposit is light gray on weathered surfaces, dark bluish gray on fresh surfaces, and has a sugary, crystalline texture. The only fossils discovered were a few poorly preserved crinoid stem fragments in the fourth outcrop belt.

Volcanic rocks are exposed in cliffs to the east of the limestone, and thin-bedded contorted shales are exposed in a small streambed to the north.

Quality. — Limestone from this occurrence is relatively high in silica. This composition may be due in part to secondary chert or jasperoid, but it is due partly to the presence of quartz grains deposited originally along with the limestone.

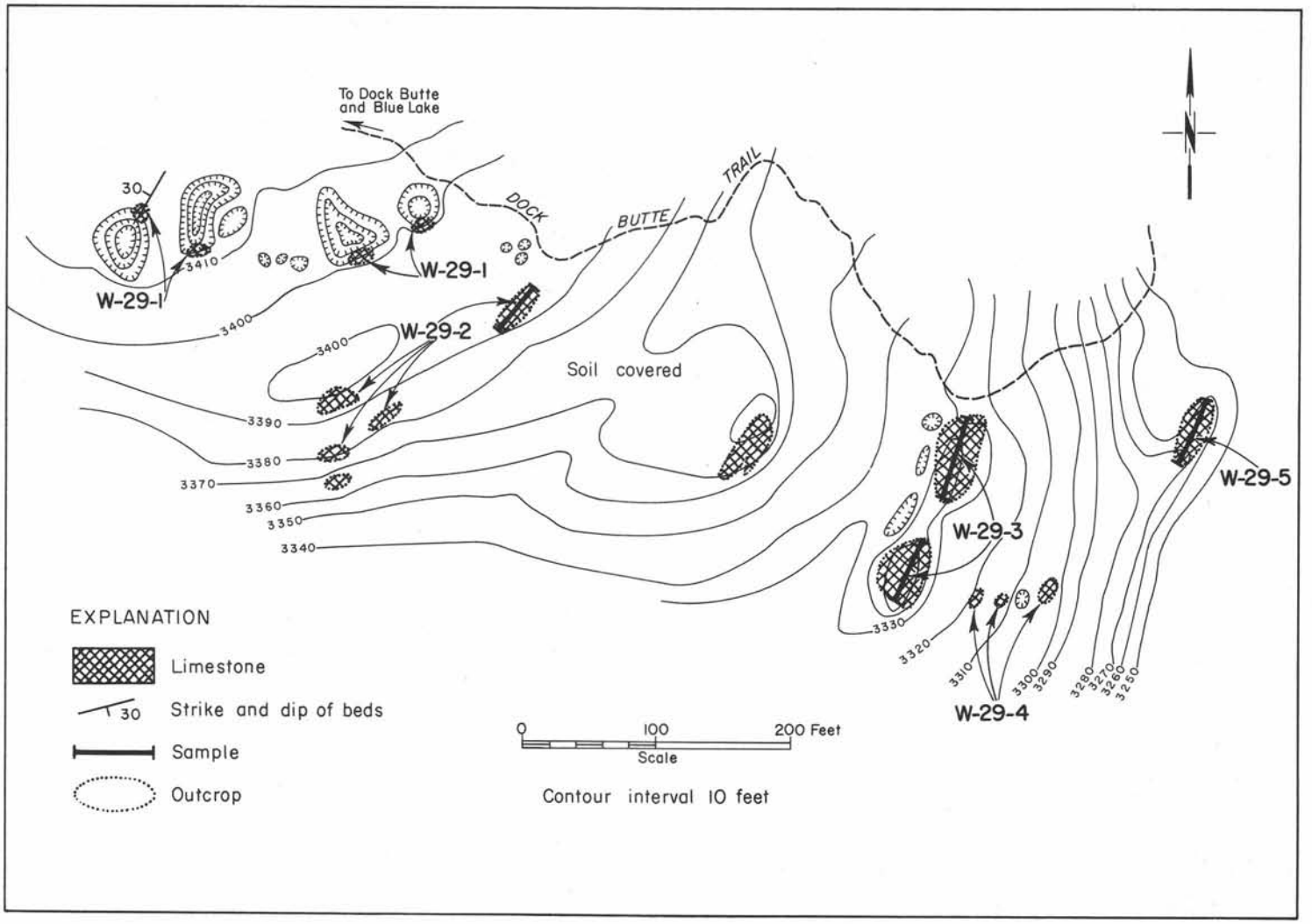


FIGURE 125.—Dock Butte Trail No. 1 deposit. NE¼NE¼ sec. 33 and NW¼NW¼ sec. 34, T. 37 N., R. 8 E. Geology by W. R. Danner, C. L. Smith, E. A. Adams, and C. F. Royse, Jr. Compass and tape survey.

Chemical analyses of Dock Butte Trail No. 1 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)
W 29-1	Sinkholes ----	Composite	89.72	0.62	40.26	50.41	0.30	7.34	0.97	0.026				
W 29-2	Second outcrop	Composite	93.32	0.37	41.71	52.43	0.18	4.10	0.75	0.022				
W 29-3	Fourth outcrop	110	94.92	0.459	42.09	53.33	0.22	3.30	0.67	0.022				
W 29-4	Fifth outcrop, south ------	Composite	94.66	0.37	42.40	53.18	0.18	2.72	0.43	0.014	155	490	170	460
W 29-5	Fifth outcrop, north ------	50	90.65	2.19	41.01	50.93	1.05	5.27	1.35	0.021				

Ownership and development.—The limestone outcrops are on lands of Mount Baker National Forest. There has been no development. The locality has a good quarry site; however, the high altitude and remoteness of the limestone make it of doubtful economic value at present (1962). It needs to be trenched to determine its extent.

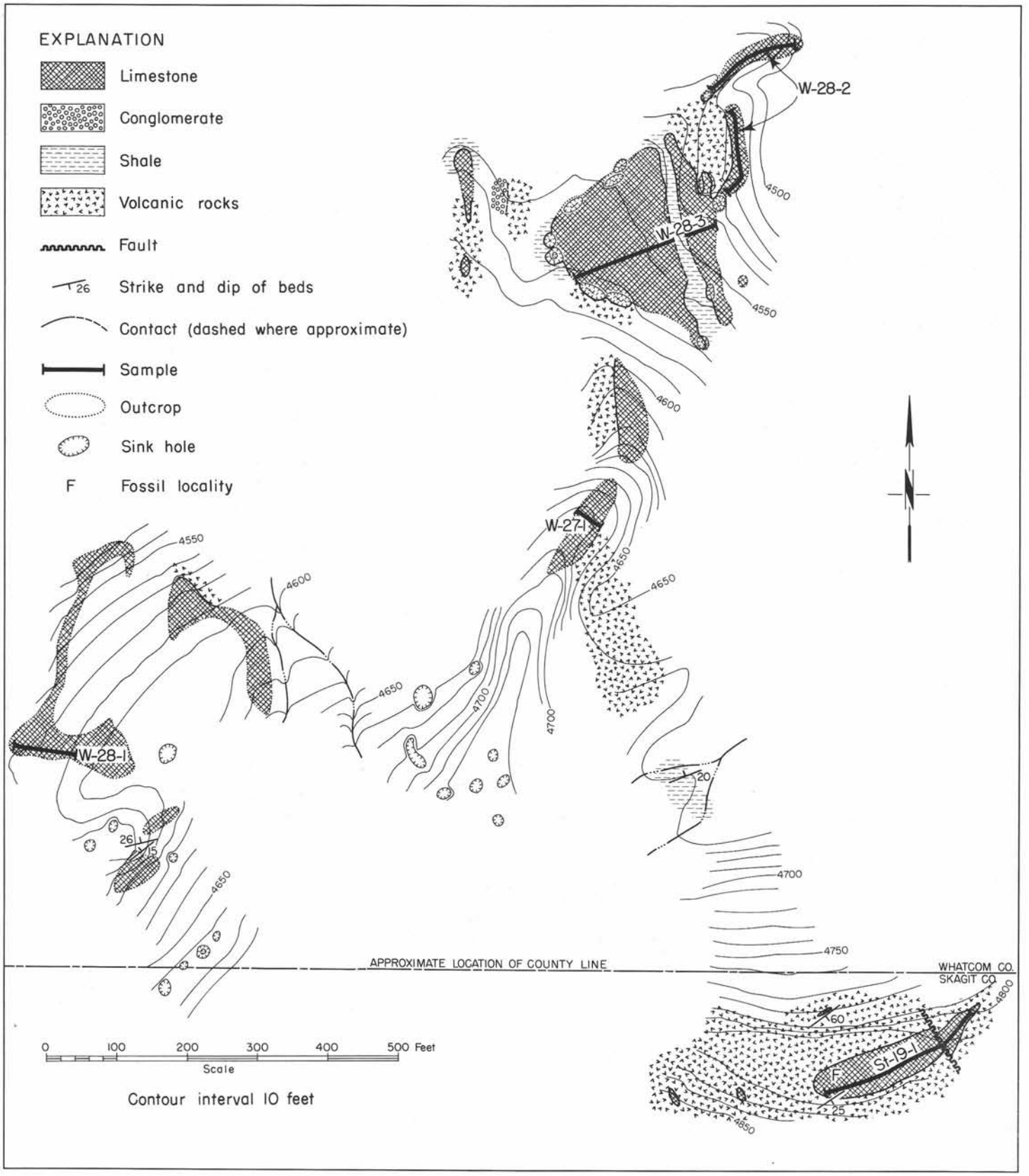


FIGURE 126.—Dock Butte Trail No. 2 deposit. Sec. 32, T. 37 N., R. 8 E., and sec. 5, T. 36 N., R. 8 E. Geology by W. R. Danner, C. L. Smith, E. A. Adams, and C. F. Royse, Jr. Compass and tape survey.

Dock Butte Trail Deposit No. 2

Location, size, and accessibility. — The Dock Butte Trail No. 2 limestone occurrence is in the south-central part and SW¼ sec. 32, T. 37 N., R. 8 E., in Whatcom County, and the north-central part and NW¼ of sec. 5, T. 36 N., R. 8 E., in Skagit County. The outcrops are on the northeast ridge of Dock Butte from about 0.3 to 0.5 of a mile northeast of the abandoned Forest Service lookout and west above Blue Lake. The deposit is at altitudes estimated to be between 4,400 and 4,900 feet above sea level. Numerous lenses and pods of limestone crop out over an area of about ¼ square mile. The largest bodies attain dimensions of about 300 feet in length and have a maximum width of 200 feet.

The area is accessible by 5 miles of steep trail from the Baker Lake road about 11 miles north of the town of Concrete. The trail climbs 3,000 feet from the road to the limestone outcrops. The area consists mostly of gently rolling ridge top and meadow lands dotted with scattered clumps of alpine trees and bushes.

Geology and description. — The deposit consists of numerous limestone lenses and pods interbedded in a sequence of thin-bedded shales and porphyritic basic volcanic rocks. The sequence is highly folded and is broken by faults, most of which appear to be of small displacement. Fifteen distinct bodies of limestone were entirely or partly mapped and range in size from 10 to over 300 feet in length and from 4 to 200 feet in width. There was not time to map the western part of the outcrop area, which contains perhaps an even greater number of limestone bodies.

Numerous sinkholes indicate the presence of many concealed bodies of limestone along the ridge.

The limestone is gray to light gray in color and mostly finely crystalline in texture. Fossils were found only at the southeast part of the area, where a lens of well-bedded limestone contains numerous fragments of large crinoid stems similar to those characteristic of the Chilliwack Group Lower Pennsylvanian sequences in western Washington.

Quality. — Most of the limestone is of high quality.

Chemical analyses of Dock Butte Trail No. 2 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
W 27-1	Central part ----	40	99.30	0.50	42.91	55.79	0.24	0.61	0.25	0.013
W 28-1	West part ------	100	97.59	0.39	43.53	54.83	0.19	0.35	0.30	0.020
W 28-2	Northeast ------	230	97.33	0.39	43.06	54.68	0.19	0.88	0.60	0.019
W 28-3	North ---------	200	97.72	0.31	43.48	54.90	0.15	0.41	0.34	0.025
St 19-1	South ---------	250	96.12	0.54	43.21	54.00	0.26	1.47	0.43	0.013

Ownership and development. — The limestone outcrops are on lands of the Mount Baker National Forest. There has been no development. Although of high quality, individual limestone bodies are too small to be of economic value. In 1960, snow covered the deposit until late July. The deposit is too small and remote to be of economic value under present conditions.

Blue Lake Deposit

Location, size, and accessibility. — The Blue Lake limestone occurrence is in the SW¼ sec. 32, T. 37 N., R. 8 E., in cliffs around the west side of Blue Lake. The size of the deposit is unknown but is believed to be small. The lake is

accessible by about 4½ miles of steep trail from the Baker Lake road 11 miles north of the town of Concrete. The last ½ mile of trail is a branch trail to Blue Lake from the Dock Butte trail. The altitude is between 4,000 and 4,500 feet above sea level.

Geology and description. — The deposit consists of small pods of limestone exposed in cliffs above Blue Lake. The limestone is interbedded with argillite, volcanic breccia, and volcanic flow rocks. It is laminated to thin bedded, is brown, gray, and light pink in color, and is mostly finely crystalline in texture. Some blocks of limestone in talus above the lake attain dimensions of 2 and 3 feet in thickness, whereas others consist of layers of limestone about 1 or 2 inches thick interbedded in argillite. No fossils were seen.

Quality. — The composition of the limestone is unknown, but it appears to be argillaceous and in part dolomitized.

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

Dock Butte Deposit

Location, size, and accessibility. — The Dock Butte limestone occurrence is in the NW¼ sec. 5, T. 36 N., R. 8 E., in Skagit County, on the northwest side of Dock Butte just below the lookout cabin, at an altitude of about 5,000 feet. It consists of several small lenticular beds of limestone less than 25 feet long and 5 feet thick. The area is accessible by approximately 6½ miles of steep trail starting from the highway 11 miles north of the town of Concrete.

Geology and description. — The deposit consists of small lenses of dense-textured brown- to buff-colored argillaceous limestone interbedded with sandstone and argillite. The exposures are on the steep bedrock and alpine meadow slopes of Dock Butte, north and just below the Forest Service lookout cabin. No fossils are visible in the limestone in hand specimen or in thin section. The limestone has an unusual bell-like tone when hit with a hammer. It strikes about N. 35° E. and dips 20° SE. into the mountainside.

Quality. — The limestone is impure and argillaceous.

Chemical analysis of Dock Butte 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
W 28-4	Unknown	Composite	61.85	2.00	27.90	34.75	0.96	28.89	6.48	0.068

Ownership and development. — The limestone outcrops are on lands of the Mount Baker National Forest. The deposit is too small, impure, and remote to be of any economic value.

Washington Monument Deposit

Location, size, and accessibility. — The Washington Monument limestone deposit is in the W½ sec. 7 and SW¼ sec. 6, T. 36 N., R. 8 E., and the E½ sec. 1 and E½ sec. 12, T. 36 N., R. 7 E., on Washington Monument Peak and to the north and south in Skagit County. Outcrops occur at altitudes of 3,800 to 4,400 feet. The deposit consists of one or more beds of limestone, the largest of which is about 300 feet thick and may crop out over a distance of 1¼ miles. The area is difficult of access. It can be reached by hiking 6 miles up the Dock Butte trail from the Baker Lake road 11 miles north by road from the town of Concrete; then by hiking across country without trail 1½ to 3 miles to various parts of the deposit. The area can also

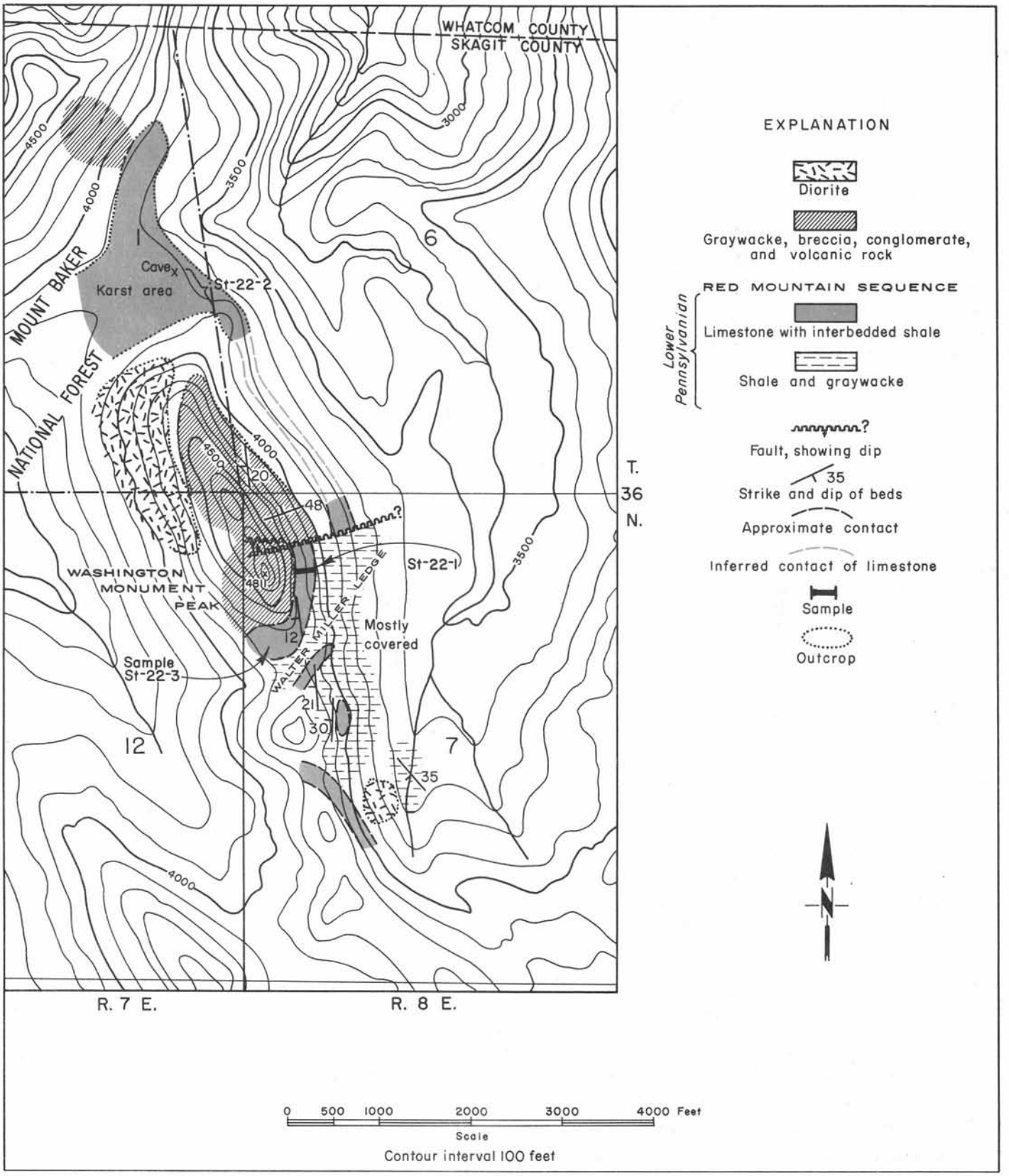


FIGURE 127.—Washington Monument deposit. W½ sec. 7 and SW¼ sec. 6, T. 36 N., R. 8 E.; E½ sec. 1 and E½ sec. 12, T. 36 N., R. 7 E. Geology by W. R. Danner, 1957, and C. L. Smith and C. F. Royse, Jr., 1960. Base map from U.S. Geological Survey Hamilton quadrangle. Reconnaissance mapping incomplete.

FIGURE 128. — Washington Monument deposit. Southern part of the deposit exposed around southern part of Washington Monument Peak. Limestone cliff below forested area. Cliffs of conglomerate and volcanic rocks overlie the limestone. View looking northwest.

be reached via trails from the north and south, which came within 1 or 2 miles of the area, or by hiking 2 to 3 miles without trail over rough terrain from the South Fork of the Nooksack River from a Scott Paper Company logging road.

The area of the deposit is in part meadowland and in part it is covered with stands of virgin timber and dense brush composed of alder, huckleberry, and devils club. Much of the limestone outcrop is on steep slopes.

Geology and description. — Information on the geology of this deposit is far from satisfactory. During the time allotted for its detailed study, heavy rains and fog prevented the accumulation of sufficient data to describe the area satisfactorily.

Stratigraphically, the sedimentary rocks may be divided into three units. The lower unit is composed of graywacke, sandstone, and shale exposed on the lower east slopes of Washington Monument and the ridge to the south. These rocks are calcareous and contain poorly preserved crinoid columnals, bryozoans, and brachiopods. This unit may contain also some interbedded small limestone lenses. Above it is a middle unit consisting of a sequence approximately 300 feet thick containing limestone with shale interbeds. This unit is exposed on the north, east, and south flanks of Washington Monument and, except where covered, forms cliff outcrops. It contains large crinoid columnals, corals, and other fossils, but they are poorly preserved. Above it and making up the third unit, at the top of Washington Monument Peak, is a sequence of graywacke breccia, conglomerate, and volcanic rocks cropping out in great cliffs. The limestone and underlying rocks are thought to be Early Pennsylvanian in age. The overlying sequence may be of the same age or it may be early Permian.

A partial section measured up a streambed on the southeast side of Washington Monument is as follows: (measured by C. L. Smith)

	Ft
Top of section:	
Upper Unit (only lower part measured):	
Conglomeratic feldspathic graywacke	56
Feldspathic graywacke	43
Feldspathic graywacke; contains plant fragments and an 8- to 14-foot bed of crinoidal limestone	21
Middle Unit:	
Magnesian limestone	3½
Calcareous black shale	16
Crinoidal limestone	10
Limestone with black argillite pebbles	5
Black shale	4
Crinoidal limestone	5
Black shale	8
Oölitic crinoidal limestone	10
Oölitic limestone, crystalline matrix	35
Oölitic limestone; shaly to flaggy bedding; dolomite matrix	55
Black clastic limestone	10
Crinoidal limestone	60
Oölitic black limestone	8
Crinoidal limestone	34
Light blue gray crinoidal and cherty limestone	27
Lower Unit:	
Graywacke	12
Calcareous argillite	5
Graywacke	14
Black argillite	1½
Magnesian limestone	2
Black argillite	4
Light-tan graywacke	19
Graywacke, grayish-brown	20
Graywacke conglomerate	8
Black argillite	9
Covered interval	26
Graywacke	6
Dark-green argillite	5
Covered interval	50
Dark blue gray argillite	12
Dark-green and black laminated shale	6
Black banded radiolarian chert	9
Sequence covered	
Base of section	

The main limestone unit forms a bed that crops out on the south side of Washington Monument Peak and then forms a series of cliffs northeastward along the flank of the peak. A nearly vertical north-dipping fault cutting across Washington Monument has dropped the limestone bed about 200 feet lower on its north side. North along strike the limestone outcrop is covered by talus, but reappears again as cliffs at the north end of the peak. Still farther north, it forms a relatively flat area of karst topography with numerous sinkholes and at least one small cave in the saddle between Washington Monument Peak and the next mountain to the north.

To the south, at least three beds of limestone crop out along the crest and east side of the steep ridge south of Washington Monument Peak. Two intrusive bodies of medium-grained diorite crop out in the area, one above the northwest side of the peak and the other to the south on the east side of the ridge south of the peak.

The limestone is oölitic, organoclastic, and crystalline in texture and is massive to thin bedded. The most abundant fossils are large crinoid stems of a type considered diagnostic of an Early Pennsylvanian age in northwestern Washington.

Quality. — The limestone is argillaceous and siliceous, but would be usable as cement rock. Secondary chert or jasperoid is a common impurity.

Chemical analyses of Washington Monument limestone

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)
Analyses of samples collected for this report, Mark Adams, analyst														
St 22-1	East side, stream bed -	290	78.26	1.98	35.86	43.97	0.95	17.65	1.26	0.054	185	490	250	325
St 22-2	North end ---	Composite	74.27	1.19	32.69	41.73	0.57	23.22	2.24	0.060				
St 22-3	South end ---	Composite	95.58	0.39	42.20	53.70	0.19	2.72	0.37	0.010				
Analyses from another source [1]														
1			87.83	4.83				6.34	1.00					
2			93.06	1.70				4.30	0.94					
3			88.12	5.70				4.48	0.76					
4			73.12	22.46				2.94	1.50					
5			93.70	4.26				1.20	0.84					
6			99.00	Trace				0.00	0.50					

[1] Newhall (1917).

Ownership and development. — The W½ sec. 7, T. 36 N., R. 8 E., and the SE¼NE¼ and the SE¼ sec. 12, T. 36 N., R. 7 E., are owned by Mrs. Marie Weibust, and the limestone deposit is known as the "Walter Miller Ledge." The outcrop area in the E½ sec. 1 is on lands of the Mount Baker National Forest. Other owners are unknown.

The deposit is large enough and of a quality that could be used for the manufacture of portland cement if high-grade and low-grade rocks were blended. The best location for a quarry site appears to be in the saddle north of Washington Monument Peak. The remoteness and inaccessibility of the deposit, along with its high altitude and long period of winter snow cover, makes it uneconomical under present (1963) conditions. However, it appears to be one of the largest limestone deposits in western Washington and is a potential source of limestone for cement manufacturing purposes.

A detailed geologic study requiring at least 2 to 3 weeks of ideal field weather would be necessary to determine the extent and amount of limestone in this area of approximately 4 square miles of rough mountainous terrain.

References. — Newhall (1917, private report, unpublished), Danner (1957, private report, unpublished), Smith (1961, unpublished thesis, p. 44-62).

SKAGIT COUNTY

Skagit County lies directly south of Whatcom County and extends for about 90 miles east from the shores of Rosario Strait to the crest of the Cascade Mountains. It is 24 miles wide north-south.

Sedimentary, igneous, and metamorphic rocks ranging in age from Devonian to Oligocene underlie the county in northwest-southeast-trending outcrop belts. Limestone is found in three areas, but only in Paleozoic rocks.

In the extreme southwest, adjacent to the Snohomish County border, are a few small outcrops of limestone in the Trafton sequence of Permian age. They are best exposed along Pilchuck Creek, but none of them is large enough to be of economic value. In the north-central part of the county an outcrop belt of Chilliwack Group rocks about 14 miles wide extends south from the Whatcom County border to beyond the Skagit River and may extend southeastward completely across the county. Limestone bodies of Devonian and Pennsylvanian age are abundant in the Chilliwack sequence, but most of them are exposed in relatively inaccessible mountainous terrain, and only one deposit, near the town of Concrete, has been extensively developed. The Concrete limestone deposit is the largest developed deposit in western Washington, and has been quarried for cement rock since 1907. Except for one small limestone body believed to have been quarried for road metal, no other limestones of Skagit County have had any commercial production.

Devonian limestones within the county vary in composition from high calcium to calcium and argillaceous, and form small reefs or banks and dense-textured lenticular beds. None of them has been quarried, but occurrences on Webber Creek and Presentine Creek might be made reasonably accessible without too much expense, and, although not large enough to supply a cement plant for any great length of time, they do have potential economic value for smaller operations.

The limestones of Pennsylvanian age are siliceous and argillaceous in composition but are suitable for cement rock. Large outcrop areas of them are known in the vicinity of Washington Monument Peak, near the Whatcom County border northwest of Concrete, and on Sutter Mountain, south of Concrete. Their remoteness and location in mountainous terrain have deterred their development and will probably do so for some time in the future.

A third belt of limestone outcrops is north and south of the Skagit River east of the community of Marblemount. These limestones have been metamorphosed into crystalline limestones (Misch, 1952) and are included within the Cascade River Schist (Misch, oral communication, 1954). The age of the schist sequence is unknown. Only one area of limestone outcrop appears to be large enough to be of potential economic value, but its remoteness, mountainous terrain, and relatively high magnesian content have prevented its development. Most of the crystalline limestone is south of the Skagit River (Misch, written communication, 1965).

All the Skagit County limestone deposits are in areas of complicated geologic structure and will require careful and detailed exploration before they can be developed.

Pilchuck Creek Deposits

A considerable amount of limestone float lying in the bed of Pilchuck Creek in southwestern Skagit County is derived from outcrops of Permian sedimentary rocks exposed at several places along the creek.

Two small limestone outcrops are known in the creek just north of the Snohomish County boundary. The first of these is in the SE¼NE¼ sec. 27, T. 33 N., R. 5 E. It consists of two small beds of gray limestone interbedded with cherty argillite, on the north side of the creek. The limestone crops out at the water's edge in two parallel beds 5 to 6 inches thick and separated by cherty argillite. About 2 feet to the north, the limestone beds merge into an outcrop 1½ feet wide that extends beneath alluvium.

The second limestone occurrence is in a 100-foot-high canyon of the creek in the NE¼SW¼ sec. 27, T. 33 N., R. 5 E. The limestone is in thin layers interbedded with black chert and is purple gray in color, dense to finely crystalline in texture, and partly dolomitized. None of the limestone bodies is large enough to be of economic value.

Goat Mountain Deposit

Location, size, and accessibility.—The Goat Mountain limestone occurrence is reported to be at the SW. cor. sec. 24, T. 36 N., R. 7 E. The area was not visited, and the size of the limestone body is unknown. It might be reached

by traveling 5½ to 6 miles of old, unmaintained logging road northwest from Grandy Lake and then by hiking up the mountainside for at least ½ mile.

Geology and description. — This is a reported limestone occurrence that could not be verified during the field season because of fire closure. An occurrence of limestone at this location is considered by the writer to be doubtful.

Quality. — Unknown.

Ownership and development. — The property is owned by the Scott Paper Company. No development has ever been reported.

Reference. — Washington Div. Mines and Geology, files and field notes.

Three Mile Creek Quarry

Location, size, and accessibility. — The Three Mile Creek limestone deposit is in the NE¼ sec. 30, T. 36 N., R. 9 E., at an estimated altitude of 3,000 feet on the mountain slope east of Lake Shannon. The exposed dimensions of the outcrop are about 150 feet northwest-southeast, 125 feet east-west, and 30 feet vertically. The area is accessible by about 9 miles starting from the town of Concrete. The last 4 miles of this road are rough, and in that distance it climbs 2,250 feet. The mountainside is very brushy and was logged within a few years prior to 1963.

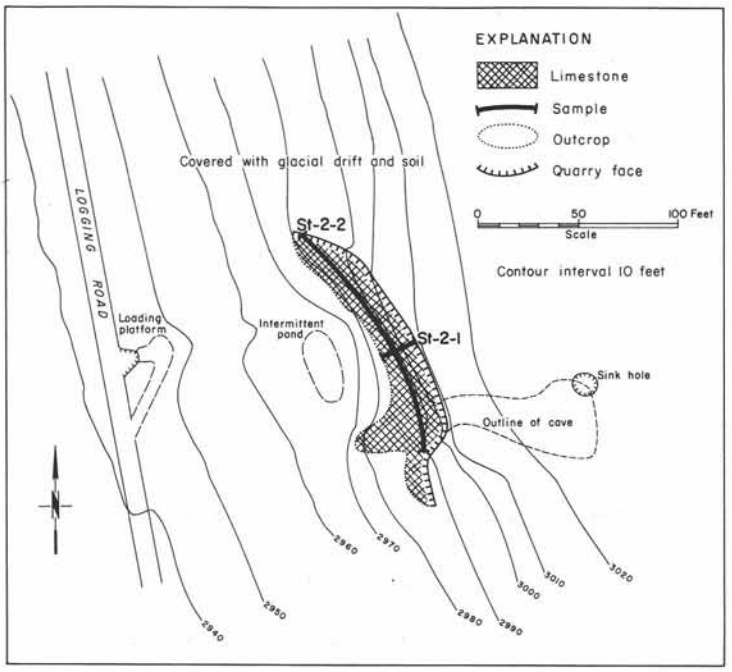


FIGURE 129. — Three Mile Creek deposit. NE¼ sec. 30, T. 36 N., R. 9 E. Geology by W. R. Danner, C. L. Smith, C. F. Royse, Jr., and E. A. Adams. Compass and tape survey.

Geology and description. — The limestone crops out as a small knob on the hillside above and about 100 feet east of a logging road. It is poorly exposed and is surrounded on all sides by glacial drift and soil. The principal outcrop is a worked quarry face about 150 feet long and 50 feet wide. On the southeast end of the face is the entrance to a cave that extends eastward into the hillside for about 75 feet. The cave entrance is about 12 to 15 feet wide and 8 feet high. Inside, the cave is 30 feet wide at its widest point. About 50 feet from the entrance the roof of the cave becomes lower, and one must crawl to go farther. At its northeast side the cave ends in a sinkhole extending down from the surface.

The limestone shows poor bedding, and it strikes northeastward and dips 20°-23° SE. The limestone is light gray in color and mostly finely crystalline in texture. It is cut by calcite veinlets and stylolites. Some parts of the outcrop have been partially dolomitized; where this change has taken place, oölites and fine fragmental crinoid debris are visible on weathered surfaces. One small poorly preserved fossil horn coral was found. Small irregular masses and crystals of authigenic pyrite are visible in a few places. It is thought that the limestone body may be quite a bit larger in size than is indicated by the present limited exposure.

Quality. — The limestone is relatively high in silica and magnesium.

Ownership and development. — The property is owned by the Puget Sound Pulp and Timber Company, which has a gate on the road 4 miles from the outcrop. A small quarry was developed at one time, and the remains of the loading platform on the logging road west of the quarry are still visible. It is though that much of the quarried stone was used for local road surfacing. The limestone is too remote to be of any great economic value at present (1963). It should be drilled and stripped of overburden to determine its size.

Chemical analyses of Three Mile Creek limestone

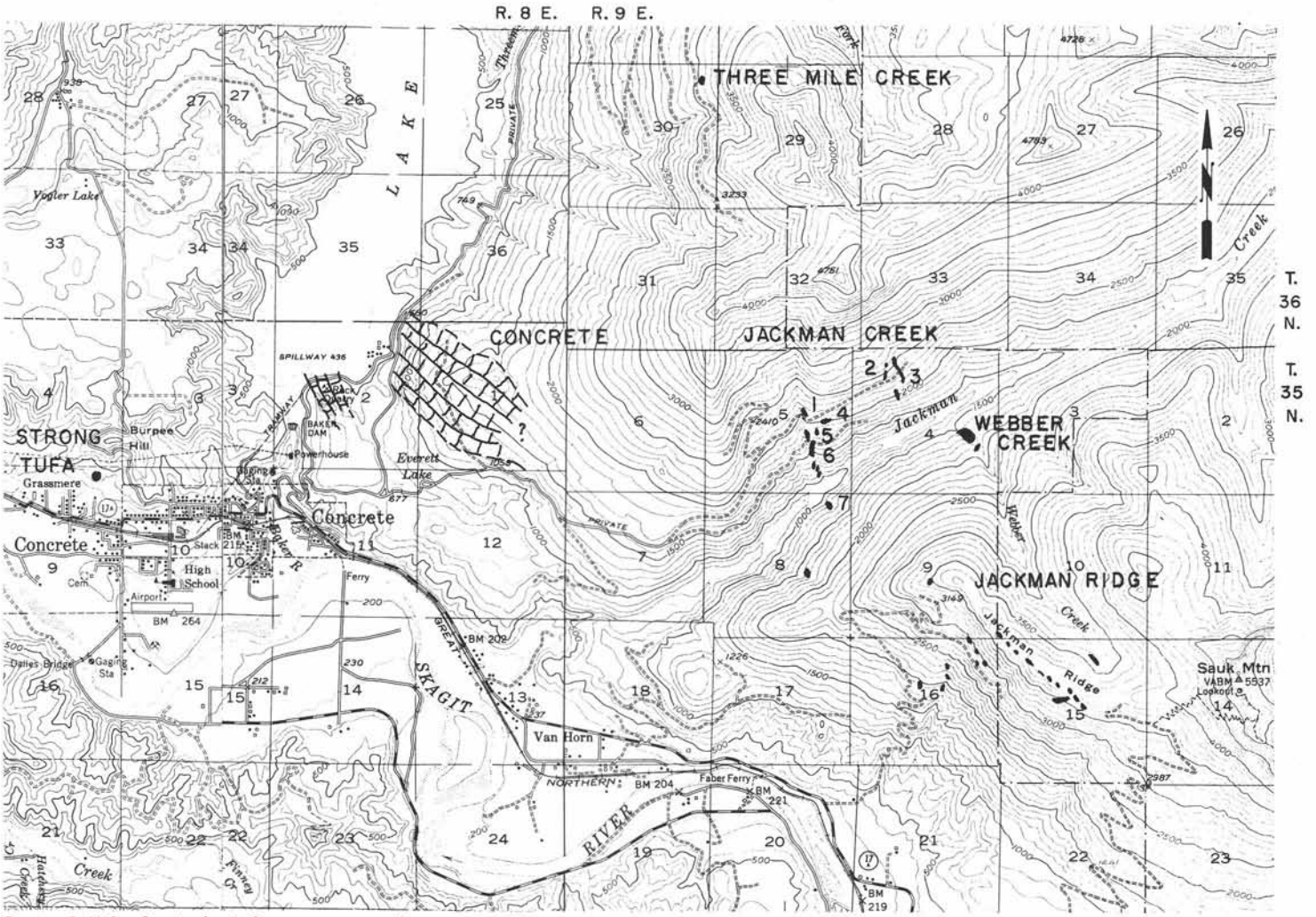
(Mark Adams, analyst)

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)
St 2-1	Width -----	20	92.91	3.84	42.57	52.20	1.84	2.61	0.94	0.019	165	450	250	375
St 2-2	Length ----	120	93.12	3.86	42.49	52.32	1.85	2.63	0.95	0.018				

Reference. — Halliday (1963, p. 69-71).

Concrete Deposits

Location, size, and accessibility. — The Concrete limestone bodies are in the central part and NE¼ sec. 2, and the NW¼ and S½ sec. 1, T. 35 N., R. 8 E. They are on the southeast side of Lake Shannon extending from about 3/4 mile to



Part of U.S. Geological Survey maps of Hamilton quadrangle and Lake Shannon quadrangle

1 ½ 0 1 2 3 4 MILES

CONTOUR INTERVAL 100 FEET
DOTTED LINES REPRESENT HALF-INTERVAL CONTOURS
DATUM IS MEAN SEA LEVEL

FIGURE 130. — Limestone deposits of the Concrete area.

1½ miles northeast of the town of Concrete. The occurrence consists of two limestone outcrop belts, one about 1,200 feet wide and at least 1,500 feet long, and a second about 2,500 feet wide and at least 5,500 feet long. The smaller outcrop area lies between altitudes of 500 and 850 feet, and the larger, between altitudes of 500 and 1,700 feet.

The smaller body is accessible by about 1 mile of graveled road from the town of Concrete, and the larger one by 1½ to 2½ miles of rougher graveled road. The town of Concrete is on the Burlington-to-Rockport branch of the Great Northern Railway, a distance of 44 miles from tidewater at Anacortes.

Geology and description. — As no mapping or detailed geological study of this property was permitted by the owners, the information given here is derived from earlier reports by other authors, from the writer's knowledge of the area based on brief visits several years ago, and from the conclusions of other geologists who have visited the quarries in recent years.

The western area of limestone outcrops consists of about 500 to 600 feet of well-bedded limestone. It is underlain on the west by black well-bedded calcareous shales and is overlain to the east by sandstone. The limestone strikes about N. 45° W. and dips approximately 40°-42° NE. The underlying shales strike about N. 22° W. and dip 45° NE., and the overlying sandstone strikes N. 33° W. and dips 43° NE. A steeply dipping fault, apparently of small displacement, is evident near the west end of the quarry.

The limestone is light to dark gray in color and dense to organoclastic and oölitic in texture. Some beds are very argillaceous. Large crinoid columnals are visible on both weathered and fresh surfaces and are similar to those found in other limestones of Pennsylvanian age in northwestern Washington. A few poorly preserved corals and brachiopods have been reported to occur. In thin section, one piece of limestone was seen to contain specimens of the foraminifer Tetrataxis.

The western outcrop area extends north to the shore of Lake Shannon, and disappears to the south under glacial drift and soil. Its total extent is unknown. Vertically, it is exposed for more than 400 feet.

The second, or eastern outcrop area is about 700 feet east of the first and is traceable over an area of about 2,500 feet in maximum width in a northeast-southwest direction and over 5,500 feet in length northwest-southeast. It is not known whether all of this area is underlain by limestone, as the terrain is covered with glacial drift, soil, and dense vegetation.

The limestone is underlain by shale and conglomerate striking about N. 36° E. and dipping 30° SE., and giving an angular relationship to the contact. Misch (1955) shows this contact as a thrust fault and indicates that the underlying sedimentary rocks may belong to the Late Jurassic-Early Cretaceous Nooksack Group. However, similar-appearing sedimentary rocks are known to be present in sequences of Pennsylvanian age elsewhere in western Washington. The overlying rocks are unknown.

FIGURE 131. — Quarry face, western part of the Concrete deposit. Limestone is well bedded and dips eastward. View looking south, July 1960.

The limestone of this eastern outcrop belt appears to be more massive than that of the western area, and over large areas it has been recrystallized. It also contains a large amount of secondary chert. Large crinoid columnals of Early Pennsylvanian type are abundant and indicate a geologic age similar to that of the western limestone outcrop belt. The eastern outcrop area extends northwest to cliffs above Lake Shannon and extends southeast an unknown distance under a cover of glacial drift and soil. A small cave is reported (William R. Halliday, written communication, June 1956) to be present in the S½ sec. 1, T. 35 N., R. 8 E.

Quality. — The quality of this limestone is quite variable, parts of it being argillaceous and parts high in secondary chert. However, there appears to be enough high-calcium limestone to blend with the lower grade material to produce a good grade of cement in the plant at Concrete. In the past, cement produced from this operation has been noted for its high quality.

Concrete plant laboratory report

Weighted Averages - Analysis of Rock from the Concrete, Washington quarry

	1951	1952	1953	1954
SiO_2	12.72	12.42	11.69	12.43
Al_2O_3	1.31	1.14	1.08	1.19
Fe_2O_3	1.15	0.90	0.99	0.63
CaO	46.76	47.27	47.38	47.36
$CaCO_3$ 1/	83.46	84.37	84.56	84.53
MgO	1.07	1.06	1.10	1.04
$MgCO_3$ 2/	2.24	2.22	2.30	2.18
Loss on ignition	36.84	37.00	37.01	36.90
$CaCO_3$ 3/	81.7	81.8	83.1	83.1
Tons Used-Concrete	379,727	320,192	416,588	313,704

1/ Calculated from CaO Content
2/ Calculated from MgO Content
3/ Actual Acid Alkali Determination

Ownership and development. — The first portland cement produced in Washington was made by the Washington Portland Cement Company, at Cement City, east of the Baker River and north of the Skagit River. Work was started on the plant June 1, 1905, and the first cement was made in May 1907. The plant at first had two kilns, each 7½ feet in diameter and 100 feet long, and had a capacity of 900 barrels per day. In the spring of 1911, two additional kilns, each 8 feet in diameter and 125 feet long, were installed. This increased the capacity by 1,600 barrels a day, making the total capacity of the plant 2,500 barrels per day.

The next cement plant that was built in Washington was the Superior Portland Cement Company plant, located at Concrete, just across the Baker River to the west of the Washington plant. When the plant was built in 1906 the town was called Baker, but the name was changed a few years later to Concrete. For several years these two were the only cement plants in operation in the State of Washington.

The limestone deposits northeast of Concrete were first owned and operated by the two companies. The Superior company had a quarry on the eastern outcrop, and the Washington company a quarry on the western outcrop. Both used the

Chemical analyses of Lone Star Cement Company limestone

Sample	Location	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	
Old quarry[1/2/]	Unknown ----------	98.14	0.65				0.80	0.70	
--- Do -----	-------- do --------	92.50	2.30				3.41	1.78	
Operating quarry[3/]								FeO	Al_2O_3
	Average quarry run, 1932			36.12	43.97		13.65	3.88	
--- Do ---	Average quarry run, 1934			36.11	43.34		13.54	3.90	
--- Do ---	Average quarry run, 1935			36.70	46.24		12.68	2.74	
--- Do ---	Selected purer rock	92.59				0.30	3.36	1.74	
--- Do ---	Selected purer rock	98.02				Trace	1.94	0.22	
--- Do ---	Siliceous band, center of quarry ----------			28.97	36.40		28.88	1.68	2.68
--- Do ---	-------- do --------				51.33		40.66	2.37	3.77
[3/]	Unknown -- --------			30.36	36.79		24.83	5.77	
[3/]	-------- do --------			36.92	46.75		11.70	3.84	
								Fe_2O_3	Al_2O_3
[3/]	-------- do --------			33.37	40.74		16.72	3.11	4.69
[3/]	-------- do --------			40.15	50.74		7.34	0.83	0.41
[4/]	Western deposit -----	93.00			52.08	1.08	5.36	1.12	
[4/]	-------- do --------	94.10			52.70	0.91	4.26	1.22	
[4/]	-------- do --------	92.82			51.98	1.10	5.56	0.98	
[4/]	-------- do --------	96.69			54.25	Trace	2.06	1.12	
[4/]	-------- do --------	93.39			52.30	0.92	4.68	1.20	
[4/]	-------- do --------	91.42			51.20	1.16	6.76	0.92	
[4/]	-------- do --------	95.03			53.22	0.62	3.72	1.24	
[4/]	-------- do --------	90.53			50.70	1.04	8.36	0.96	
[4/]	-------- do --------	95.71			53.60	Trace	2.92	1.06	
[4/]	-------- do --------	89.82			50.30	1.22	8.40	0.88	

[1/] Eckel (1913, p. 366). [2/] Hodge (1938, p. 51). [3/] Hodge (1938, p. 52). [4/] Shedd (1913, p. 221).

glory-hole method of quarrying. The eastern quarry was operated from 1909 to 1919, at the end of which time Superior bought out its neighbor and continued in operation only the western quarry. The Superior Portland Cement Company produced cement used in the dams of Seattle City Light on the Skagit River and is reported to have produced well over half of the cement used in the construction of Grand Coulee Dam, on the Columbia River. For a time the company leased a cement plant in Seattle from the Pacific Coast Company and supplied it with limestone both from Concrete and from a quarry at View Cove, Dall Island, Alaska. The Seattle plant was bought and operated for a few years after World War II by Permanente Cement Company, of California, but litigation eventually resulted in ownership by Superior in 1949.

The Lone Star Cement Company, of New York, acquired the Superior company in 1957 and has operated the quarry and plant since that time.

In 1960, development work was being conducted on the eastern limestone outcrop belt and a new quarry site was being opened. This limestone body has the largest reserve of limestone in western Washington—an estimated 500 million tons. In 1943 the Superior company produced about 3,266 tons of limestone per day, but later production figures are unknown. The cement plant is operating now (1963) at about 50 percent of capacity.

References.—Eckel (1913, p. 366), Shedd (1913, p. 72, 220-225), Glover (1936, p. 57-58), Hodge (1938, p. 47-51), Guard (1943, unpublished field notes), Mathews (1947, p. 45-46), Misch (1952, p. 8, 1955, unpublished map), Libbey (1957, p. 86-88), Halliday (1963, p. 66-68).

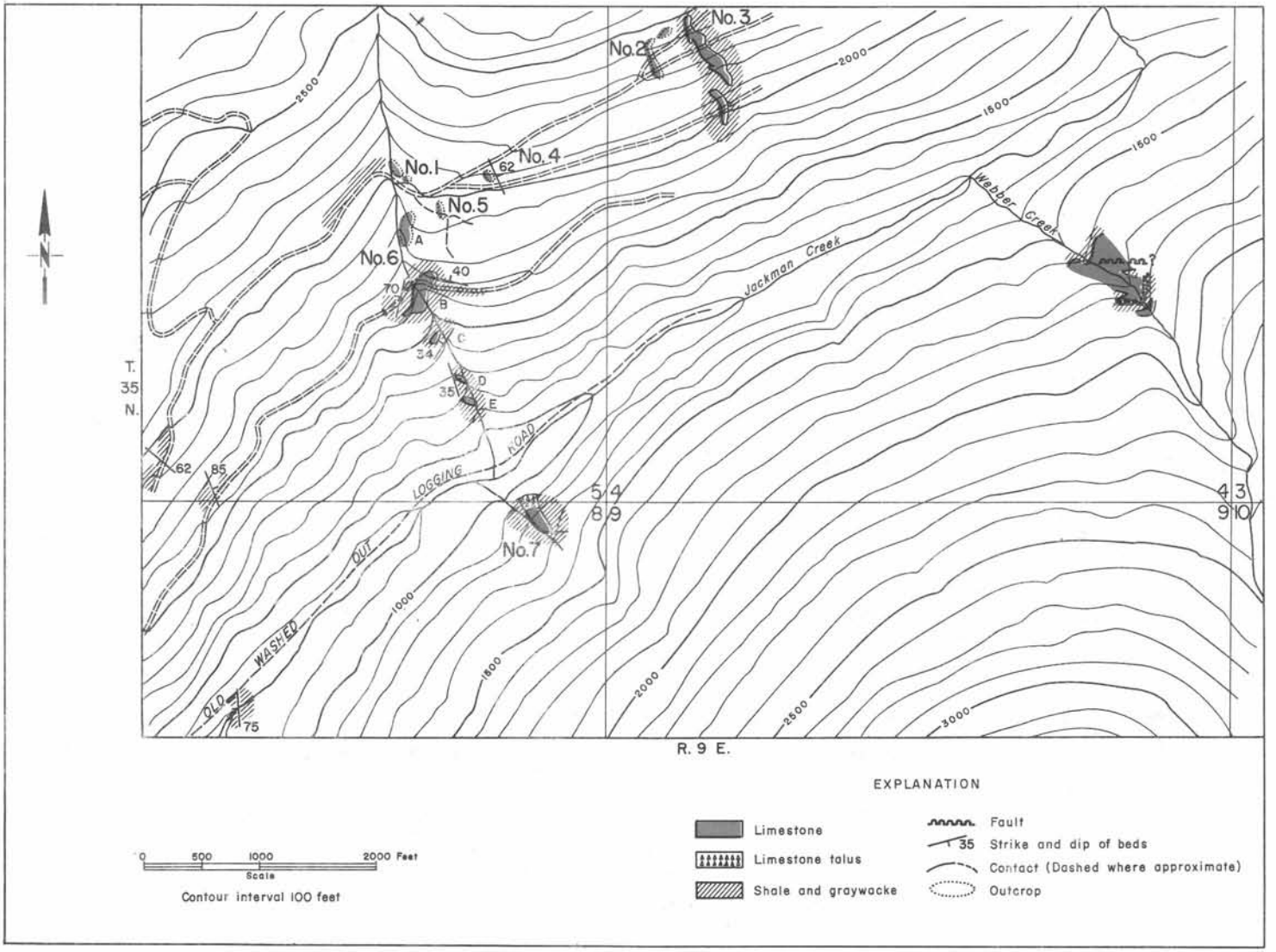


FIGURE 132.—Jackman Creek area limestone deposits. Geology by C. L. Smith and E. A. Adams. Base map from U.S. Geological Survey Lake Shannon quadrangle.

Jackman Creek Deposit No. 1

Location, size, and accessibility.—The Jackman Creek No. 1 limestone deposit is in the SW¼NE¼ sec. 5, T. 35 N., R. 9 E., in a small canyon on the steep north side of Jackman Creek valley. The limestone crops out at altitudes estimated to be between 2,050 and 2,090 feet. The deposit consists of two limestone outcrops, the larger of which is about 100 feet long and 35 to 55 feet wide; the smaller one is about 25 feet long and 15 feet wide. The limestone can be reached by following about 5½ miles of logging road, starting from the town of Concrete and going east and then north up Jackman Creek. In the summer of 1960 this road had a gate across it about 2½ miles from Concrete. The area has been logged recently.

Geology and description.—This limestone is not well exposed but is believed to form a small lenticular body interbedded in a sequence of shale and graywacke. It crops out on the steep walls of a small stream canyon and is partly covered

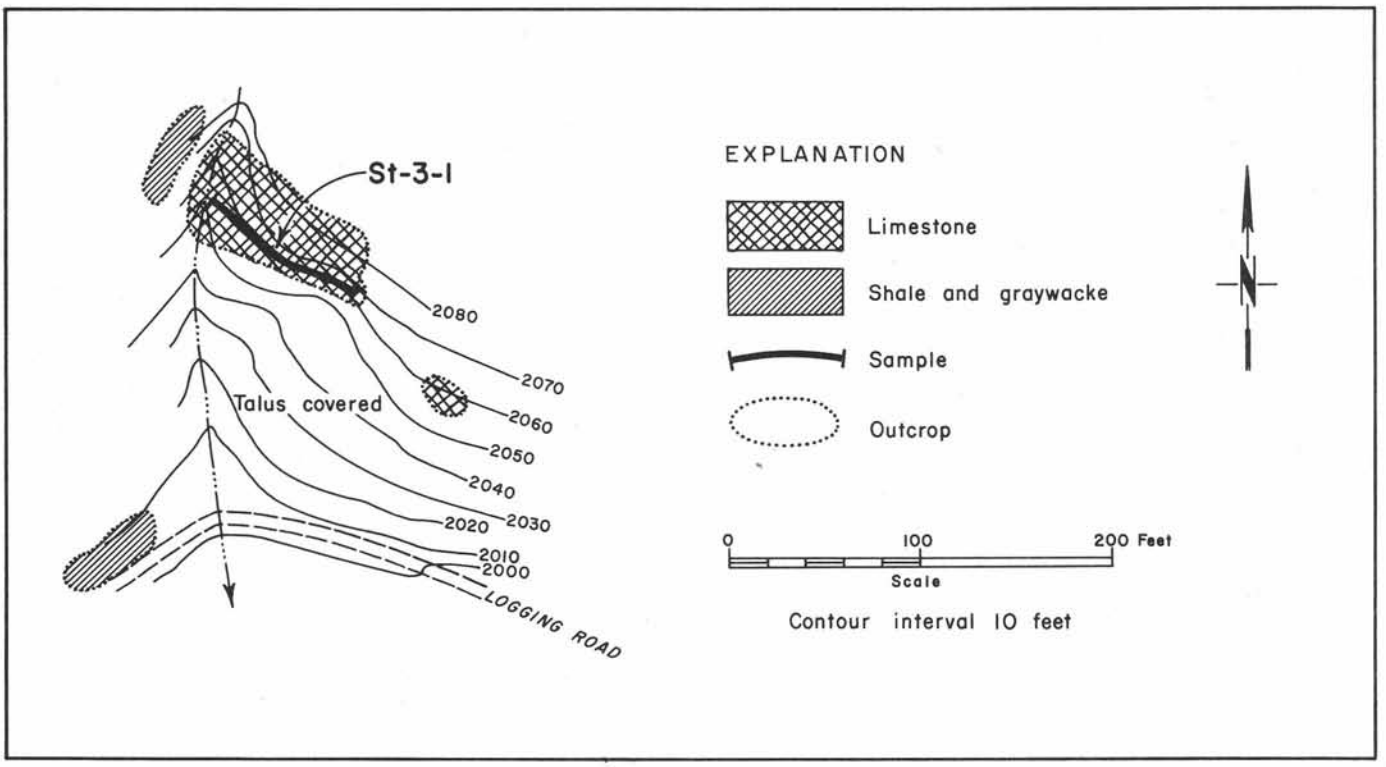


FIGURE 133. — Jackman Creek No. 1 deposit. SW¼NE¼ sec. 5, T. 35 N., R. 9 E. Geology by E. A. Adams and C. L. Smith. Compass and tape survey.

by talus. The limestone is massive, gray in color, and finely crystalline in texture. No fossils were found. The limestone strikes northwest-southeast and appears to dip steeply to the northeast into the hillside.

Quality. — The occurrence consists of a calcium limestone containing variable amounts of argillaceous material and replacement chert.

Chemical analysis of Jackman 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
St 3-1	90	92.56	0.31	40.97	52.00	0.15	6.55	0.42	0.007

Ownership and development. — The limestone is owned by Nettleton Timber Company. There has been no development, and the deposit is believed to be too small to be of economic value. It is overlain by bedrock overburden.

Jackman Creek Deposit No. 2

Location, size, and accessibility. — Jackman Creek No. 2 limestone deposit is a little less than ½ mile northeast of Jackman Creek No. 1 deposit in the NW¼ sec. 4, T. 35 N., R. 9 E., on the steep slopes of the north side of Jackman Creek valley, at altitudes estimated to be between 2,320 and 2,475 feet above sea level. There are two outcrop areas. One is 250 feet long and about 20 feet wide. The other is about 150 feet long and at one end reaches a maximum width of 90 feet.

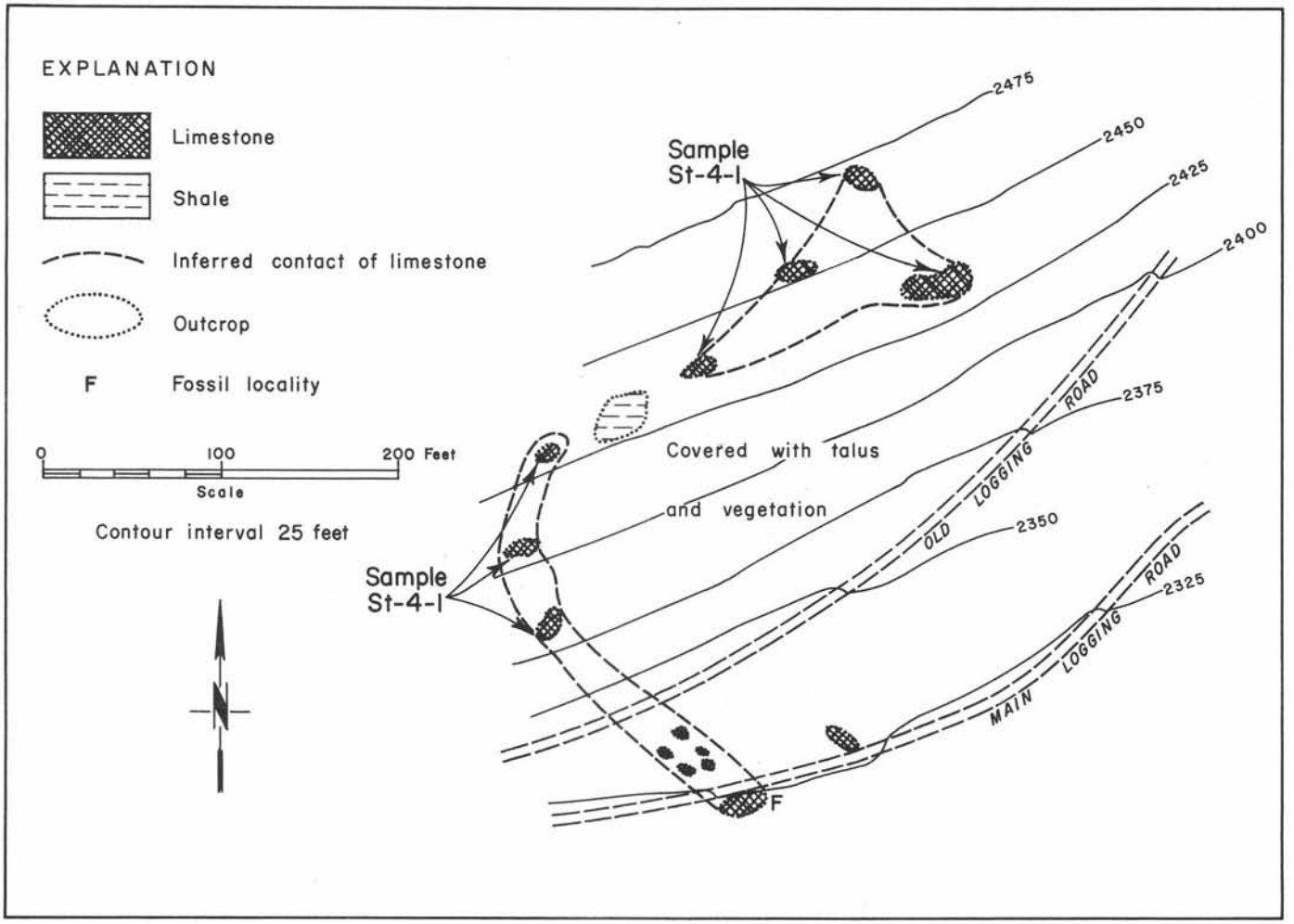


FIGURE 134.—Jackman Creek No. 2 deposit. NW¼ sec. 4, T. 35 N., R. 9 E. Geology by C. L. Smith and E. A. Adams. Compass and tape survey.

The occurrence can be reached by traveling about 6 miles of logging road, starting at the town of Concrete and going east and north up the valley of Jackman Creek. The area has been recently logged.

Geology and description.—Two outcrop areas are exposed on a steep hillside covered with brush, talus, soil, and glacial drift. One outcrop extends 250 feet up the hillside from a main logging road. The most prominent part of the outcrop is a small knob that is at the side of the logging road. The trace up the hillside is marked by numerous boulders of limestone float. The second exposure is triangular in shape and has four knoblike outcrops marking its boundaries.

The limestone is bluish gray to dark gray on fresh surfaces and is finely crystalline in texture. It is not well stratified and appears to be highly deformed. Poorly preserved and partially silicified fossils, including stromatoporoids and the Devonian coral Plagiopora, were found.

Chemical analysis of Jackman Creek No. 2 limestone

(Mark Adams, analyst)

Sample no.	Location	Sample length	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
St 4-1	All outcrops	Composite	94.10	0.44	41.50	52.87	0.21	4.66	0.88	0.007

Quality.—A composite sample for chemical analysis was made from chips taken from all the outcrops and numerous pieces of float. The limestone is partially silicified and contains variable amounts of chert or jasperoid.

Ownership and development.—The limestone is on lands of the Nettleton Timber Company. There has been no development, and the limestone bodies are too small to be of any economic value.

Jackman Creek Deposit No. 3

Location, size, and accessibility.—Jackman Creek No. 3 limestone deposit is in the NW¼ sec. 4, T. 35 N., R. 9 E., on the steep mountainside forming the north side of the valley of Jackman Creek. It lies at altitudes estimated to be between 1,975 and 2,475 feet above sea level. The deposit consists of two outcrops, one of which is 470 feet long and from 10 to 100 feet in width and another, which is 170 feet long and 5 to 30 feet in width. The area can be reached by traveling a little over 6 miles of logging road, starting from the town of Concrete and going east and then north up the valley of Jackman Creek. The area has been logged recently.

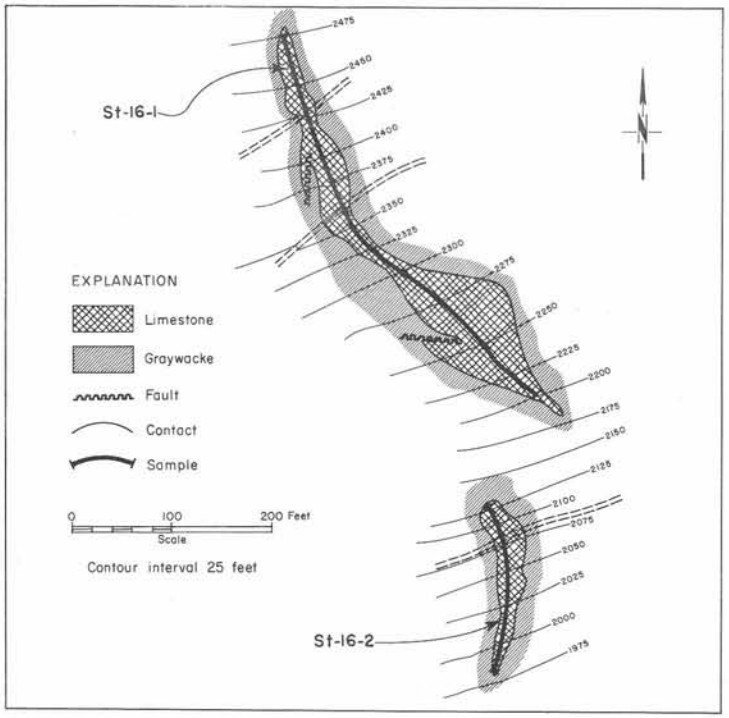


FIGURE 135.—Jackman Creek No. 3 deposit. NW¼ sec. 4, T. 35 N., R. 9 E. Geology by C. L. Smith and E. A. Adams. Compass and tape survey.

Geology and description.—This deposit consists of two lenticular beds of limestone interbedded in a graywacke sequence. The upper and larger limestone bed strikes northwest-southeast down the steep hillside for almost 300 feet vertically. Its dip is unknown. It has sharp contacts with graywacke on all sides, and along its western border two slices of graywacke have penetrated into the limestone by faulting. The thickness is quite variable, reaching as much as 100 feet, but over most of the length is less than 25 feet. The limestone is fine to medium crystalline in texture and contains secondary chert or jasperoid, pyrite, and dolomite. The outcrop surfaces show solution effects, and jointing is prominent.

The smaller limestone outcrop appears also to be a lens-shaped body. It is exposed vertically for about 200 feet and gradually narrows in width along strike from 25 to 5 feet traced down the slope. Its physical appearance is similar to that of the larger outcrop above it.

Quality.—An analysis of chip samples taken along the strike of the limestone indicates that it is a high-calcium limestone having a variable amount of silica of replacement origin.

Chemical analyses of Jackman Creek No. 3 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
St 16-1	Upper -------	460	96.06	0.39	40.97	53.97	0.19	3.35	0.98	0.013
St 16-2	Lower -------	170	98.02	0.48	41.93	55.07	0.23	2.01	0.31	0.005

Ownership and development. — The property is owned by the Nettleton Timber Company. There has been no development. The limestone is high in calcium, but the deposit is small. Its narrow width and great vertical extent up the steep slope would make quarrying difficult.

Jackman Creek Deposit No. 4

Location, size, and accessibility. — Jackman Creek No. 4 deposit is in the NE¼ sec. 5, T. 35 N., R. 9 E., about 1,000 feet east of Jackman Creek No. 1 deposit. It is at an altitude of about 2,100 feet and is exposed in and above a roadcut on a lower spur road off the main Jackman Creek logging road. It consists of a bed of limestone 3 to 4 feet thick overlain by 5 feet of shale, which in turn is overlain by 8 to 10 feet of limestone. The limestone sequence is exposed for 150 feet up the hillside. The area is accessible by about 5 3/4 miles of logging road from the town of Concrete.

Geology and description. — The deposit consists of a lenticular bed of limestone exposed for a length of at least 150 feet and a width of as much as 14 feet. It contains an interbedded lens(?) of shale approximately 5 feet thick, but whether the shale body persists through the entire limestone body is not known. The limestone outcrop is exposed to a depth of 7 feet in a roadcut, and it strikes N. 25° W. and dips 62° NE. The limestone is light gray on weathered surfaces and dark gray on fresh surfaces. It is thin bedded to massive and is finely crystalline in texture. Poorly preserved crinoid columnals and corals are present and are similar to the fossils found in other limestone of Devonian age in the vicinity.

Quality. — Chip samples were collected along strike, and their analysis indicates a high-calcium limestone containing variable amounts of silica in the form of replacement chert or jasperoid.

Chemical analysis of Jackman Creek No. 4 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
St 5-1	Along strike	150	97.36	0.397	42.98	54.70	0.19	1.30	0.40	0.005

Ownership and development. — The limestone is on land owned by the Nettleton Timber Company. There has been no development, and the limestone body is too small to be of economic value.

Jackman Creek Deposit No. 5

Location, size, and accessibility. — Jackman Creek No. 5 limestone deposit is on a small spur logging road in the N½SE¼ sec. 5, T. 35 N., R. 9 E. It is about 110 feet in length, 20 feet in maximum width, and has a vertical exposure of about 50 feet. It is accessible by 5 3/4 miles of logging road from the town of Concrete and is reached by a rough spur road going down the slope from just east of Jackman Creek No. 1 deposit.

Geology and description. — The deposit consists of a small lenticular body of finely crystalline limestone exposed in, below, and above a logging road. The limestone ranges in width from 2 to 20 feet.

Chemical analysis of Jackman Creek No. 5 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
St 16-3	105	96.36	0.50	41.60	54.14	0.24	2.99	0.72	0.010

Quality. — The limestone is high in calcium and contains variable amounts of silica in the form of secondary chert or jasperoid.

Ownership and development. — The property is owned by the Nettleton Timber Company. There has been no development, and the limestone body is too small to be of any economic value.

Jackman Creek Deposit No. 6

Location, size, and accessibility. — Jackman Creek No. 6 limestone deposit is in the SE¼ sec. 5, T. 35 N., R. 9 E., in a small steep-walled canyon on the northeast side of the valley of Jackman Creek. It consists of five separate outcrops, the largest of which is about 120 feet long, 50 feet wide, and is exposed vertically for about 120 feet. The area can be reached by traveling about 5½ miles east on a logging road from the town of Concrete and then by climbing down the steep canyon for a distance of almost ½ mile from the most northerly to the most southerly outcrop, a vertical distance of about 800 feet. The area has been logged recently.

Geology and description. — The outcrops of limestone form a series of cliffs in the walls of a stream canyon. They appear to be part of a group of small lenses or tectonically developed pods of limestone, all probably belonging to the same stratigraphic zone. Outcrop A parallels the east side of the creek and forms a cliff 120 feet high above it. Outcrop B is exposed on both sides of the creek and in a logging road. It consists of well-bedded limestone and trends approximately parallel to the stream along the creekbed. It ranges from 40 to 100 feet in thickness and dips steeply to the west. Outcrop C is best exposed on the east side of the creek and is about 60 feet in length. It is underlain by a limestone pebble conglomerate and graywacke. Outcrops D and E are small well-bedded limestone bodies less than 50 feet in length and 20 feet in thickness. They are underlain and overlain by graywacke. The limestone is dense in texture.

Quality. — Chip samples taken from the various outcrops are composed of high-calcium limestone containing variable amounts of silica in the form of secondary chert or jasperoid.

Chemical analyses of Jackman Creek No. 6 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
St 6-1	Outcrop B	120	95.49	0.02	42.11	53.65	0.01	3.82	0.29	0.007
St 16-4	All outcrops	Composite	96.97	0.188	42.30	55.00	0.17	1.93	0.30	0.006

Ownership and development. — The limestone is on lands owned by the Nettleton Timber Company. The deposit is too small and broken up to be of economic value. It would be difficult to quarry on the steep hillside, and the limestone is overlain by bedrock overburden.

Jackman Creek Deposit No. 7 (Bear Creek, Jackson Creek, Little Sauk Association Placer Mining Claim)

Location, size, and accessibility. — Jackman Creek No. 7 limestone deposit is in the NE¼NE¼ sec. 8, T. 35 N., R. 9 E., on the south side of the Jackman Creek valley about 500 to 600 feet from the creek. It is about 50 to 75 feet in thickness and over 350 feet long. It can be reached by traveling about 2½ miles on a logging road leading to the NE¼ sec. 12, T. 35 N., R. 8 E., and by hiking from that point a little over 2 miles on an abandoned and washed-out logging road down to

the floor of Jackman Creek valley and then climbing up the south side of the valley about 250 feet in altitude to the outcrop. The area is covered with virgin timber and thick masses of vine maple and devils club.

Geology and description. — Massive limestone crops out as a cliff 20 to 40 feet high on the south side of the Jackman Creek valley and south for several feet up the east bank of a small tributary stream. The limestone strikes northwest-southeast and dips vertically or steeply to the northeast. It is underlain in the streambed by shale and graywacke, and to the east it is overlain by massive to thick-bedded graywacke and volcanic rocks. Talus of large limestone blocks lies on the hillside below the outcrop. The limestone is gray in color and finely crystalline in texture.

Quality. — The limestone is variable in quality and has a high silica content, caused locally by masses of replacement chert or jasperoid.

Chemical analyses of Jackman Creek No. 7 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										
St 14-1	Talus -----	Composite	97.18	0.12	41.91	54.60	0.06	2.83	0.32	0.008
St 14-2	North face	100	89.60	0.75	38.99	50.34	0.36	9.03	0.92	0.007
Analyses from another source										
1/	Unknown ---				42.91	53.89		1.60	Fe_2O_3 0.56, Al_2O_3 0.16	
1/	----- do ---		94.40					2.80	Fe_2O_3 0.98, Al_2O_3 0.28	
1/	----- do ---		97.65					1.58	Al_2O_3 0.46	

1/ Hodge (1938, p. 55).

Ownership and development. — The owner of the property is unknown, and there has been no development. This limestone has possibilities for a small operation; however, it needs to be explored in greater detail.

Reference. — Hodge (1938, p. 54-55).

Webber Creek Deposit

Location, size, and accessibility. — The Webber Creek limestone deposit is in the N½SE¼ sec. 4, T. 35 N., R. 9 E., in the canyon of Webber Creek at an altitude of 1,600 feet and above. The size is unknown, but the main outcrop, traceable up the canyon for about 700 feet, is at least 200 feet wide and is exposed vertically for over 200 feet. This occurrence is not easily accessible but can be approached by traveling about 2½ miles on a logging road from the town of Concrete to the eastern edge of sec. 12, T. 35 N., R. 8 E., and by hiking from this point down an abandoned and washed-out lower spur logging road to Jackman Creek and up along the creek for a total distance of about 3 miles, then by hiking up the creekbed for about ½ mile to the mouth of Webber Creek and climbing up Webber Creek canyon approximately 800 feet to the outcrop. The limestone is on the steep south side of Jackman Creek valley, in an area covered with virgin forest and thick brushy areas of devils club and vine maple. The walls of Webber Creek canyon consist mostly of bedrock.

Geology and description. — Field time was available for only a brief reconnaissance investigation of this area, so details of the geology are unknown. The deposit appears to consist of a faulted and folded mass of limestone in shale and graywacke. The main outcrop is exposed in the canyon of Webber Creek and forms cliffs as much as 200 feet in height along that stream. It contains sliver-like masses of graywacke interbedded or faulted into it. Its contacts downstream and upstream appear in part to be conformable and in part to be fault surfaces. Ten feet upstream from the main outcrop is a 60-foot bed

Chemical analyses of Webber 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)
St 15-1	Southern bed ---	60	96.97	0.64	42.23	54.48	0.31	2.63	0.19	0.003				
St 15-2	Northern bed, south part -----	300	97.93	0.29	42.53	55.02	0.14	1.96	0.33	0.008	150	490	100	350
St 15-3	Northern bed, north part -----	400	98.73	0.33	42.75	55.47	0.16	0.89	0.20	0.008				

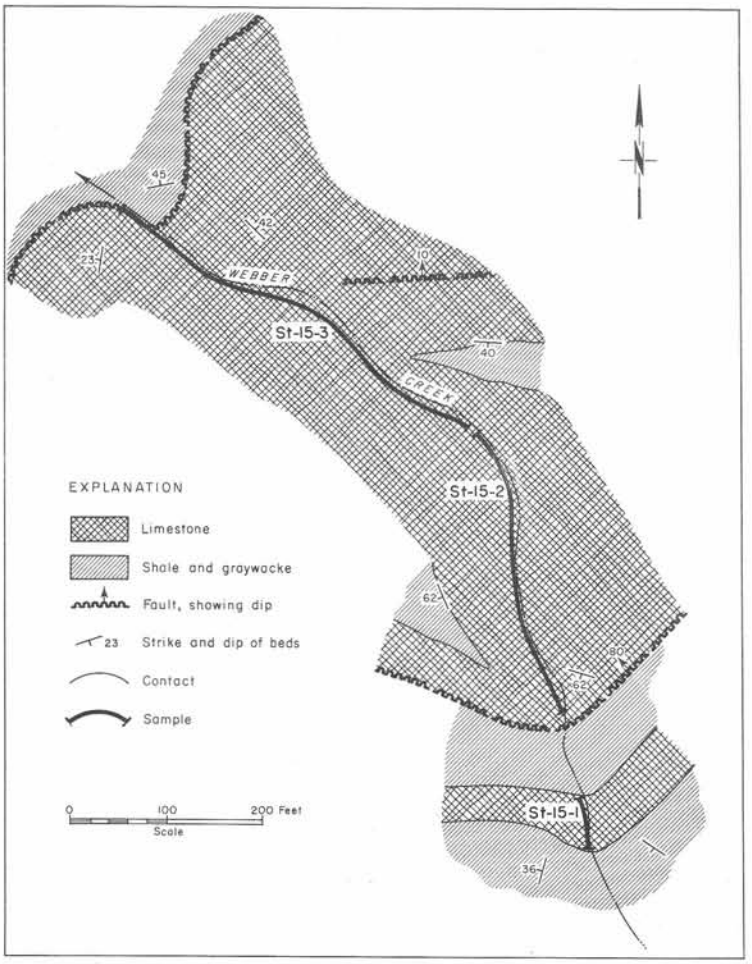


FIGURE 136. — Webber Creek deposit. SE¼ sec. 4, T. 35 N., R. 9 E. Geology by C. L. Smith and E. A. Adams. Compass and tape survey.

of limestone striking almost east-west across the canyon. Graywacke and shale beds between the two limestone bodies and farther upstream are crumpled and faulted.

The limestone is massive to thin bedded, bluish gray to dark gray in color, and mostly crystalline in texture. Poorly preserved and partially silicified corals and stromatoporoids of Devonian (?) age occur in several layers of the limestone. Also, there are beds of fossiliferous limestone conglomerate. Secondary chert and pyrite are present as impurities. The surface of the outcrop shows extensive solution activity, especially along joints.

Quality. — Chip samples from outcrops of this limestone are high in calcium and have variable amounts of silica, orginating as seconday chert or jasperoid.

Ownership and development. — The owner of this occurrence is unknown, and there has been no development. The good quality and apparent large size indicate that this limestone has economic value. However, it should be explored in detail, as it has a complicated structure. To make the limestone accessible, about 5 miles of road would have to be constructed up Jackman Creek valley from Van Horn, on State Highway 17-A, east of the town of Concrete.

References. — Shedd (1913, p. 225-226), Hodge (1938, p. 54-55).

Other Limestones of the Jackman Creek Area

Shedd (1913) and Popoff (1948) report limestone outcrops in secs. 4, 5, 8, and 9, T. 35 N., R. 9 E., up Jackman Creek, and also in secs. 35 and 36, T. 36 N., R. 9 E. Some of these are described in the preceding pages of this report, but undoubtedly there are other outcrops in the area, and when the Jackman Creek valley is logged they will be uncovered

and become reasonably accessible. Peter Misch (oral communication, 1962) reports a limestone outcrop in the E½SE¼ sec. 32, T. 36 N., R. 9 E., and another in sec. 15 in the same township.

Chemical analyses of some of these limestones are given by Shedd (1913), but the exact locations of the samples analyzed are unknown.

Chemical analyses of other Jackman Creek area limestone [1/]

Sample no.	Location	$CaCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3
1	Secs. 4, 5, 8, 9, T. 35 N., R. 9 E. --	98.07	42.67	54.92	Trace	1.94	0.22
2	Secs. 35 and 36, T. 36 N., R. 9 E. --	92.59	42.61	51.85	0.30	3.36	1.78

1/ Shedd (1913, p. 226).

Jackman Ridge Deposits

Location, size, and accessibility. — The Jackman Ridge deposits are in the S½ sec. 9, N½ and SE¼ sec. 16, SW¼ sec. 10, and N½ sec. 15, T. 35 N., R. 10 E., on the south slopes of Jackman Ridge between altitudes of 1,400 and 4,000 feet. The actual size of the limestone bodies is not known for certain, but it is thought that there may be beds of limestone nearly 4,000 feet in length and as much as 200 feet in width. However, the poor exposures and difficult terrain have so far prevented an accurate determination of their size.

The occurrences are accessible by two logging roads, one of which starts from State Highway 17-A four miles east of the town of Concrete; the other starts from the same highway about 7 miles east of Concrete. The western road can be followed up the mountainside about 3 miles to a point from which the limestone outcrop can be reached on foot over the hillside, mostly without trail. The eastern road can be followed up about 5 miles to the Paystreak outcrop, and other limestone outcrops can be reached on foot without trail or by following old trails and roads. Most of the hillside is steep, and there are many small canyons and cliffs. Parts of the hill have been logged, but there are still large areas covered with virgin timber.

Geology and description. — Very little is known about the geology of this limestone area. In general, Jackman Ridge is composed of a sequence of highly folded and faulted shales, graywackes, ribbon cherts, and andesitic volcanic rocks containing interbedded lenticular bodies of limestone. Popoff (1948, p. 6) states:

> All of the limestone deposits . . . . are geologically similar. Apparently they are remnants of several limestone beds that have been squeezed, stretched, broken, displaced, and otherwise distorted by folding, faulting, and metamorphism.

The writer considers that this interpretation is probably correct.

The limestone is mostly massive to well bedded, finely to coarsely crystalline in texture, and light gray to dark gray in color. Black, finely crystalline argillaceous limestone is also present. Fossils, including crinoid debris, corals, and bryozoans have been reported from various outcrops, but the only fossils seen by the writer were poorly preserved, medium-sized crinoid columnals. The age of the sequence is unknown, but the similarity of this limestone to that in Jackman Creek tends to indicate that it might be of Devonian age.

Dikes of volcanic rocks have been found cutting the limestone in various places, but they are not abundant.

A considerable amount of folding is apparent in the limestone and associated rocks. Some limestone bodies dip northeastward into the mountainside, whereas others dip southwestward, usually at angles steeper than the slope angle.

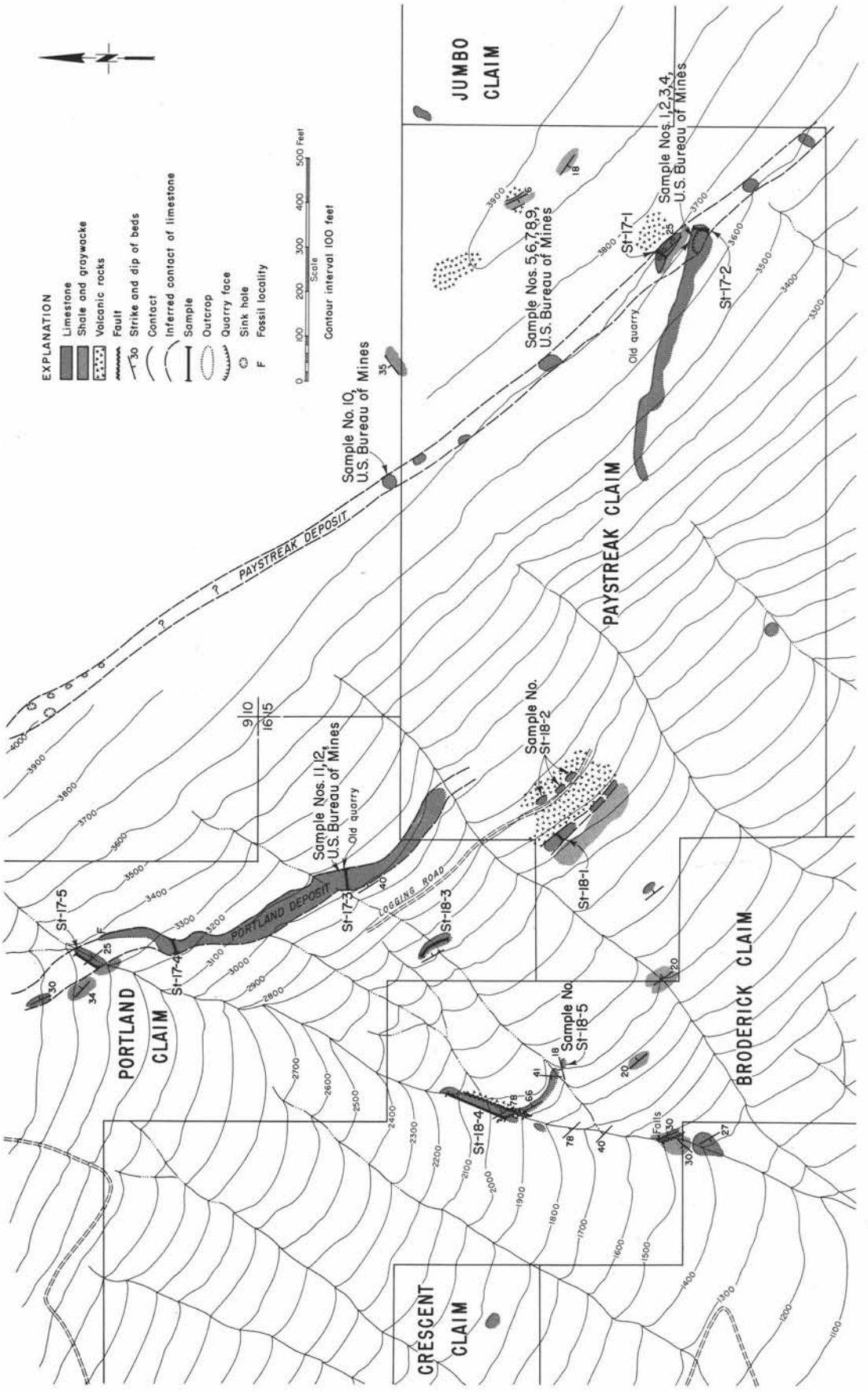


FIGURE 137.—Jackman Ridge deposits. Secs. 9, 10, 15, and 16, T. 35 N., R. 9 E. Reconnaissance map compiled from maps and notes of G. Jamme, 1923, C. C. Popoff, 1948, A. K. Guard and W. A. G. Bennett, 1943, 1945, and C. L. Smith and E. A. Adams, 1960.

Description of individual limestone bodies. — The various outcrops are described according to the claims in which they are situated. It is probable that additional limestone outcrops will be found when more detailed geological investigations of the area are made and when vegetation is removed by logging operations.

PAYSTREAK CLAIM

The Paystreak claim lies south and southeast of the corner common to secs. 9, 10, 15, and 16, T. 35 N., R. 10 E. Both Jamme (1923) and Popoff (1948) show the Paystreak deposit as consisting of a northwest-trending belt of discontinuous limestone outcrops. Popoff states (p. 7):

> The deposit was traced N. 30° W., from outcrop to outcrop for about 4,000 feet and throughout a vertical range of 400 feet. The width of limestone that is exposed on the steep slope ranges from 0 to 270 feet, but, unfortunately, no complete section of the limestone is exposed. Contact with the footwall (?) schist has been established in but one place.
>
> The best outcrop is in the upper part of an old, irregular quarry near the trail. Four samples from different parts of the quarry have proved the high-calcium grade of the limestone. A band of schist about 13 feet wide, trending N. 60° E., is exposed in this quarry. The schist [actually phyllitic slate (Misch, written communication, 1965)] probably is a "window" exposing the footwall of the limestone body. The lower part of the quarry is covered with large blocks of limestone, none of which appears to be in place.
>
> Less than 500 feet northwest of the quarry, on outcrop No. 2, a limestone outcrop not less than 100 feet wide is exposed. Part of the outcrop is weathered and stained by hydrous iron oxide to a depth of several feet. Correspondingly, the weathered limestone has a higher content of silica and iron oxide than has the usually clean limestone in the quarry.
>
> Northwesterly from outcrop No. 2 to outcrop No. 3, the limestone crops out as small isolated spots. Outcrop No. 3 is about 15 feet high and at least 25 feet wide.
>
> The most northwesterly outcrop (No. 4) is more than 1,000 feet northwest from outcrop No. 3. Between No. 3 and No. 4, only a few small outcrops and erosion cavities near the projected position of the footwall are evidences of a continuous bed.
>
> It is believed that the Paystreak bed dips southwesterly at 40° to 45°. If such is the case, the strike of the bed is N. 40° W., and the possible true thickness is 50 to 100 feet. If, on the other hand, the dip is steeper, is vertical, or is opposite the slope, the thickness of the body will be much greater.

Field work by Guard and Bennett in 1943 and 1945 indicated that another body of limestone extends westward from near the southeast end of the Paystreak outcrop belt. This limestone body is more than 1,000 feet long and is 100 or more feet in width.

The limestone of the Paystreak deposit is overlain and underlain by a sequence of andesite flows, graywacke, and shale. However, most of the contacts with these rocks are concealed. The limestone is medium crystalline in texture and light gray, dark gray, or brownish gray in color. Some parts of it contain fossils visible on weathered surfaces. Most of these are poorly preserved and consist of crinoid columnals, bryozoans, corals, and stromatoporoids. The geologic age is believed to be Devonian, but the fossils are not well enough preserved for specific identification.

The limestone is mostly massive, and little of it shows good bedding. However, jointing is prominent. Residues of limonite and carbonaceous material are common where the limestone has been weathered. Dikes of andesite intrude the limestone, but they are not abundant.

One small outcrop of limestone is reported to occur in the southeast part of the claim, and at least two small and discontinuous belts of limestone outcrops occur at its western edge. One of these outcrops forms a cliff that is 80 to 100 feet high at its western limit and about 15 feet high a short distance to the east. The outcrop band is exposed discontinuously for about 350 feet and appears to thin and pinch out eastward. It is underlain by shale and overlain by andesite. The limestone is massive, light gray in color, and crystalline in texture.

About 150 feet above the main Paystreak limestone outcrop is a second limestone bed. It appears to be underlain and overlain by volcanic rocks and is about 20 feet thick, but it is not well exposed. The best outcrops are along an abandoned logging road. The limestone contains interbedded small layers of shale and volcanic rocks.

About 400 feet to the southwest is another small bed of dark-gray argillaceous limestone between 2 and 3 feet in thickness and traceable for about 20 feet. It strikes northwest-southeast and dips northeastward into the mountainside.

Quality. — The limestone of the Paystreak claim is, in general, a good grade of calcium limestone, but it contains small shaly interbeds and a few volcanic dikes.

Chemical analyses of Paystreak 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
St 17-1	Sec. 15-----	50	96.97	0.188	42.10	54.48	0.09	2.28	0.79	0.018
St 17-2	---- do ----	50	97.52	0.188	42.08	54.79	0.09	2.04	0.48	0.006
St 18-1	Sec. 16 Stratigraphic section ----	50	97.59	0.27	42.15	54.83	0.13	2.27	0.30	0.003
St 18-2	Strike ------	250	90.81	2.69	39.74	51.02	0.48	7.56	1.16	0.008

Chemical analyses of Paystreak limestone[1/]

Sample no.	Length, feet	Percent, dry basis									Remarks
		Loss on ignition	CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3	P	S	Free C	
Old Quarry:											
1 ----------	10 vertical	43.2	55.7	0.1	0.6	0.1	0.1	0.006	0.001		Unstained.
2 ----------	10.0 vertical	43.1	55.8	0.0	0.5	0.1	0.1	0.005	0.001		Do.
3 ----------	17.0 vertical	43.2	55.6	0.0	0.9	0.1	0.2	0.003	0.000		Do.
4 ----------	12.0 inclined	43.4	55.7	0.0	0.7	0.1	0.3	0.005	0.000		Do.
Weighted average, samples 1-4 -----	49.0	43.2	55.7	0.0	0.7	0.1	0.2	0.005	0.000	0.04	
Outcrop No. 2:											
5 ----------	16.0 horizontal	43.2	55.6	0.0	1.0	0.1	0.2	0.005	0.000		Unstained.
6 ----------	17.5 horizontal	42.5	54.9	0.0	2.1	0.2	0.3	0.009	0.001		Do.
Weighted average, samples 5-6 -----	33.5	42.8	55.2	0.0	1.6	0.15	0.25	0.007	0.001	0.04	
7 ----------	16.0 inclined	42.2	53.5	0.3	2.3	0.4	0.8	0.012	0.008		Stained and contaminated
8 ----------	14.0 inclined	42.2	53.5	0.3	2.8	0.3	0.4	0.010	0.010		near surface.
9 ----------	21.0 inclined	42.7	54.5	0.3	1.4	0.2	0.3	0.005	0.001		Do.
Weighted average, samples 7-9 -----	51.0	42.4	53.9	0.3	2.1	0.3	0.5	0.009	0.006	0.03	
Outcrop No. 3:											
10 ----------	24.0 vertical	43.0	54.9	0.2	1.1	0.1	0.1	0.005	0.000		
Weighted average, samples 1-10 ----		42.8	54.9	0.13	1.4	0.17	0.3	0.006	0.002	0.036	

[1/] Popoff (1948, p. 12).

PORTLAND CLAIM

The Portland claim is northwest of the Paystreak claim in the NE¼ sec. 16 and SE¼ sec. 9, T. 35 N., R. 10 E. The main outcrop belt is about 1,000 feet or more to the southwest of the northern supposed extension of the Paystreak outcrop belt. Popoff (1948, p. 8) describes the geology as follows:

> Although the writer examined only part of the deposit, he traced it throughout a strike length of about 400 feet and throughout a vertical range of 150 to 200 feet. Previous investigators report that it has been traced, without interruptions, throughout a strike length of nearly 4,000 feet and throughout a vertical range of 800 feet.
>
> The best exposure, about 40 feet wide and from a few feet to 15 feet high, is near the old trail. At this place the contact with the black slates and calcareous shales of the footwall is exposed.
>
> The true strike is N. 40° W., and the dip is about 40° southwest. The horizontal thickness of limestone exposed is about 40 feet. The total horizontal thickness of the bed probably is about 50 feet.
>
> The samples taken from this outcrop contained considerably more silica than the samples taken from the Paystreak deposit. A comparison may not be entirely fair, however, because the Portland deposit was exposed for sampling only near the footwall. The hanging-wall sections may contain less silica.

In the northern outcrops this limestone is about 150 feet wide. It is thin bedded and contains interbedded calcareous shales. The strike is N. 45° W., and the dip is 25°-30° N. Small crinoid columnals are common fossils in the outcrops. The limestone is underlain by crumpled shales. In the southern part of the Portland claim is another limestone outcrop, about 150 feet long and 50 feet wide, exposed in a small canyon. It may be a northwesterly extension of the outcrops in the western part of the claim.

Quality. — The limestone is of variable compositon.

Chemical analyses of Portland 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
St 17-3	Sec. 16------	100	98.25	0.125	42.53	55.20	0.06	1.59	0.22	0.004
St 17-4	Sec. 9------	60	91.49	1.40	40.22	51.40	0.67	6.86	0.62	0.008
St 17-5	Sec. 9------	150	59.16	2.69	28.15	33.24	1.29	32.92	4.62	0.018
St 18-3	South Portland claim, talus -	150	71.39	1.15	31.30	40.11	0.55	25.05	3.44	0.015

Chemical analyses of Portland limestone[1/]

Sample no.	Length, feet	Percent, dry basis									Remarks
		Loss on ignition	CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3	P	S	Free C	
11 ----------	12.5 vertical	40.6	51.5	0.4	5.3	0.6	0.9	0.011	0.035	0.04	Includes two thin seams of shales.
12 ----------	1.0 vertical	32.5	[2/]41.0		19.9	1.6	3.1	-	-		Footwall sections carbonaceous limestone.

[1/] Popoff (1948, p. 12).

[2/] Calculated.

BRODERICK CLAIM

The Broderick claim is southwest of the Portland claim and west of the Paystreak claim, mostly in the E½ sec. 16, T. 35 N., R. 10 E. It contains one main limestone outcrop area, which is exposed in two stream canyons and on the ridge between. The limestone crops out for almost 400 feet in the stream canyons, but is broken by faults and intruded by dikes of volcanic rock. It is dense to finely crystalline in texture, has good bedding, and contains poorly preserved corals, bryozoans, and small crinoid columnals. It strikes northwestward and dips from 40° to 80° into the hillside.

A smaller limestone body lies to the east along strike. Its outcrop is about 25 feet long and 10 feet wide. It is crystalline in texture and contains a few poorly preserved fossils.

Quality.—The limestone contains a variable amount of silica.

Chemical analyses of Broderick 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
St 18-4	Sec. 16	300	89.56	0.89	38.75	50.32	0.43	9.04	1.27	0.005
St 18-5	Sec. 16	25	92.82	0.52	40.16	52.15	0.25	6.29	0.99	0.005

CRESCENT CLAIM

The Crescent claim lies to the west and northwest of the Broderick claim. It contains one limestone outcrop in its southeast part, in sec. 16, T. 35 N., R. 10 E., and one in its northwest part, in the SE¼ sec. 8. This latter outcrop was not visited. The outcrop in the southeast part of the claim consists of dense, dark-gray to black argillaceous limestone. It forms several small resistant knobs in a small patch of timber.

OTHER LIMESTONE OUTCROPS ON JACKMAN RIDGE

Southwest of the Broderick claim is another small limestone outcrop. It consists of an exposure about 100 feet long in a creekbed. The limestone is covered with glacial drift and soil on both banks. It is argillaceous, thin bedded, and strikes N. 30°-40° W. and dips to the southwest. It is somewhat contorted and locally dips to the north. North of it, shales and graywackes are exposed in the stream canyon and contain some thin interbeds of limestone.

Quality.—Most of the limestone of these Jackman Ridge deposits contains a considerable amount of silica as an impurity, mainly as argillaceous material. This would not deter its use for cement rock.

Ownership and development.—The Paystreak, Portland, and Broderick claims are owned by the Meiklejohn and Brown Company, of Seattle. The north part of the Paystreak is on lands of the Mount Baker National Forest. At one time small quarries were started on the Paystreak and Portland limestone outcrops, but, as far as is known, no rock was shipped from them. These deposits appear to contain millions of tons of limestone, but, because of the poor exposure and the folded and faulted nature of the rocks in the area, the deposits would have to be studied very carefully before any major attempt at development were undertaken. Not enough information is available at present to evaluate their commercial possibilities, but the high altitudes (above 3,000 feet) of the larger outcrops and the heavy snow cover during the winter months would be disadvantageous.

Popoff (1948, p. 5) describes the old workings as follows:

> A number of old, shallow pits, trenches, and cuts are caved and overgrown with vegetation, but a few old prospecting quarries on outcrops are partly preserved. All, or nearly all, of this work was done more than 25 years

ago. The largest and most impressive quarry is on the Paystreak deposit. An adit was driven in the upper part of the outcrop, and several tons of dynamite were blasted. Numerous blocks of limestone dislodged by the blast cover the slope and give an erroneous impression of the thickness and true structure of the deposit.

References. — Shedd (1913, p. 227-228), Jamme (1923, private unpublished report), Hodge (1938, p. 54-56), Guard and Bennett (1943-1945, unpublished field notes), Popoff (1948, p. 1-14).

Sauk Mountain Deposit (Jumbo Associated Group Claim)
(Roosevelt Association of Placer Claims)

Location, size, and accessibility. — The Jumbo associated group limestone claim is in the headwaters of Webber Creek, on the west side of Sauk Mountain in the NE¼ sec. 15, T. 35 N., R. 9 E., and the Roosevelt claims are in the NE¼SW¼ sec. 14, T. 35 N., R. 9 E., on the south side of Sauk Mountain. The area was not visited by the writer, but Guard (1943) reports one outcrop of limestone in the Jumbo claim as much as 100 feet wide projecting 30 feet above snow, and another outcrop of limestone to the west beyond the claim line. He reports a limestone body about 30 feet thick exposed for a length of 65 feet on the Roosevelt claims.

The claims can be reached by the Sauk Mountain Lookout road, 5½ to 6 miles in length, and then by foot travel to the limestone outcrops. The Roosevelt claims are above 4,000 feet in altitude, and the Jumbo, between 3,500 and 4,000 feet in altitude.

Geology and description. — Limestone on the Jumbo claim is described as being light-gray to bluish gray in color and finely crystalline in texture. An outcrop west beyond the claim line consists of a vertical cliff 36 feet high and about 93 feet long, trending N. 30° E. Jointing or bedding strikes N. 73° E. and dips 73° SE. A low limestone cliff about 90 feet west of the high cliff is underlain by graywacke.

Bluish-gray limestone crops out on the south slope of Sauk Mountain, on the Roosevelt claim. Exploratory work done at one time uncovered a 50- by 90-foot area of limestone. A shale bed within the limestone has a strike of N. 42° W. and a dip of 45° NE. The limestone outcrop extends N. 30° W. for 65 feet, but beyond this point it is covered with soil and glacial till. Overburden is as much as 20 feet thick and appears to thicken rapidly along strike.

Quality. — Unknown.

Ownership and development. — The Jumbo claim group was located on Sept. 10, 1909, and surveyed as a patented claim July 7, 1917, by James L. McPherson, as Mineral Survey No. 1116. It was owned by Geoge B. Woodruff and others, but was later inherited by Mrs. W. Soren, of Hamilton, Wash. The Roosevelt claims were owned by William Soren, of Hamilton, Wash. (1945). Exploratory stripping has been done on the property, but no commercial production is known.

References. — Guard and Bennett (1943-45, unpublished field notes).

North Rockport Deposit

Location, size, and accessibility. — The North Rockport limestone deposit is in the SE¼ sec. 23 and NE¼ sec. 26, T. 35 N., R. 9 E., on the west side of Presentine (Graves) Creek, a tributary of the Skagit River, between altitudes of 1,050 and 1,700 feet above sea level. The deposit has been traced for 950 feet along its length. It has a width of 45 to 100 feet and a vertical range of 60 to 600 feet. The area can be reached by following the Skagit Lookout road north from State Highway 17A for 1 mile, starting at a point about 7 miles east of the town of Concrete, then by following on foot an old logging road for about 1½ miles to the boundary of the Mount Baker National Forest and following a faint brushed-out section-line trail east a few hundred feet to Presentine Creek and the limestone outcrop. An alternate approach would be to hike north up Presentine Creek for about 1 mile from the place where the creek crosses State Highway 17A just north of the town of Rockport.

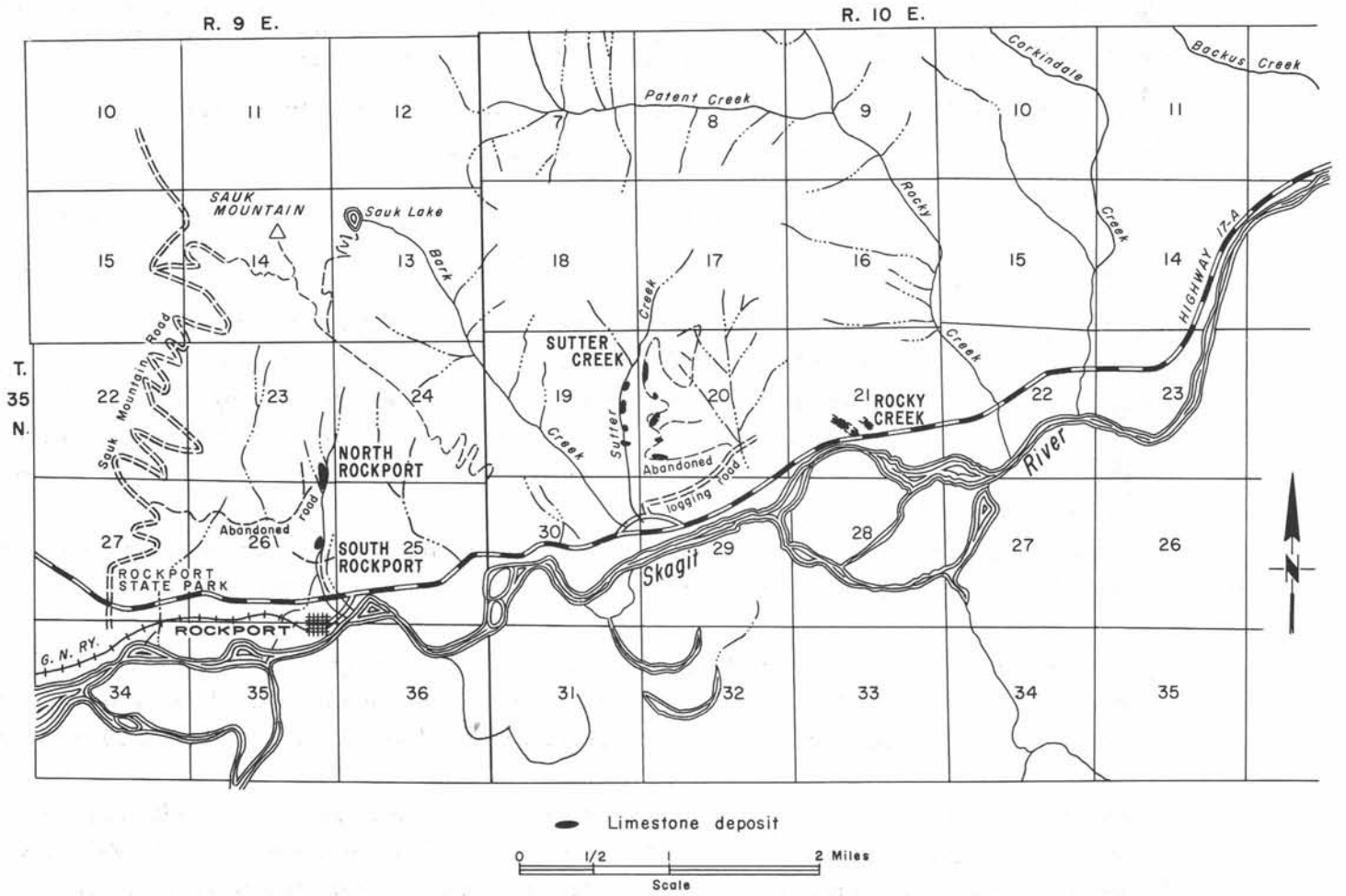


FIGURE 138. — Index map of limestone deposits, Rockport area. Base map by U.S. Forest Service, 1956.

Geology and description. — Limestone is exposed on the steep west bank of Presentine Creek, extending in a northwesterly direction from the creekbed on the south up along the top of a small ridge. The limestone body appears to be lenticular in shape and thins and pinches out to the south. It is covered to the north, but Popoff (1948, p. 9) suggests that it probably extends farther north. His suggestion is based on the fact that a narrow overburden-covered ridge continues N. 45° W. along approximately the same direction as the strike of the limestone. Exposures of limestone are not continuous along the ridge, but are separated from each other by narrow depressions covered with overburden. Outcrops on the steep slope down to the streambed are separated by talus and slide debris. Popoff suggests the possibility that the narrow depressions across the ridge may be the result of differential erosion along cross faults.

The limestone is massive to poorly bedded, and its structure is not readily apparent. At the south end, shale interbeds strike about N. 45° W. and dip 65° SE. An outcrop near the center of the deposit strikes N. 80° W. and dips from steeply south to vertical. There is some suggestion that a fault forms part of the western contact at this place.

No definite contact of limestone with bedrock was found along the western side of the deposit, but fragments of shale are plentiful in the soil. Good exposures of shale occur on the east bank of Presentine Creek, and they contain thin interbedded lenses of argillaceous limestone, some of which weathers to a reddish-orange color. It appears that either there is a fault underlying and parallel in attitude with the upper part of these shales, or part of the east bank of the creek is a landslide block.

South of the limestone, intensely sheared chert, cherty shale, calcareous shale, and amygdaloidal greenstone are exposed, dipping steeply to the southwest.

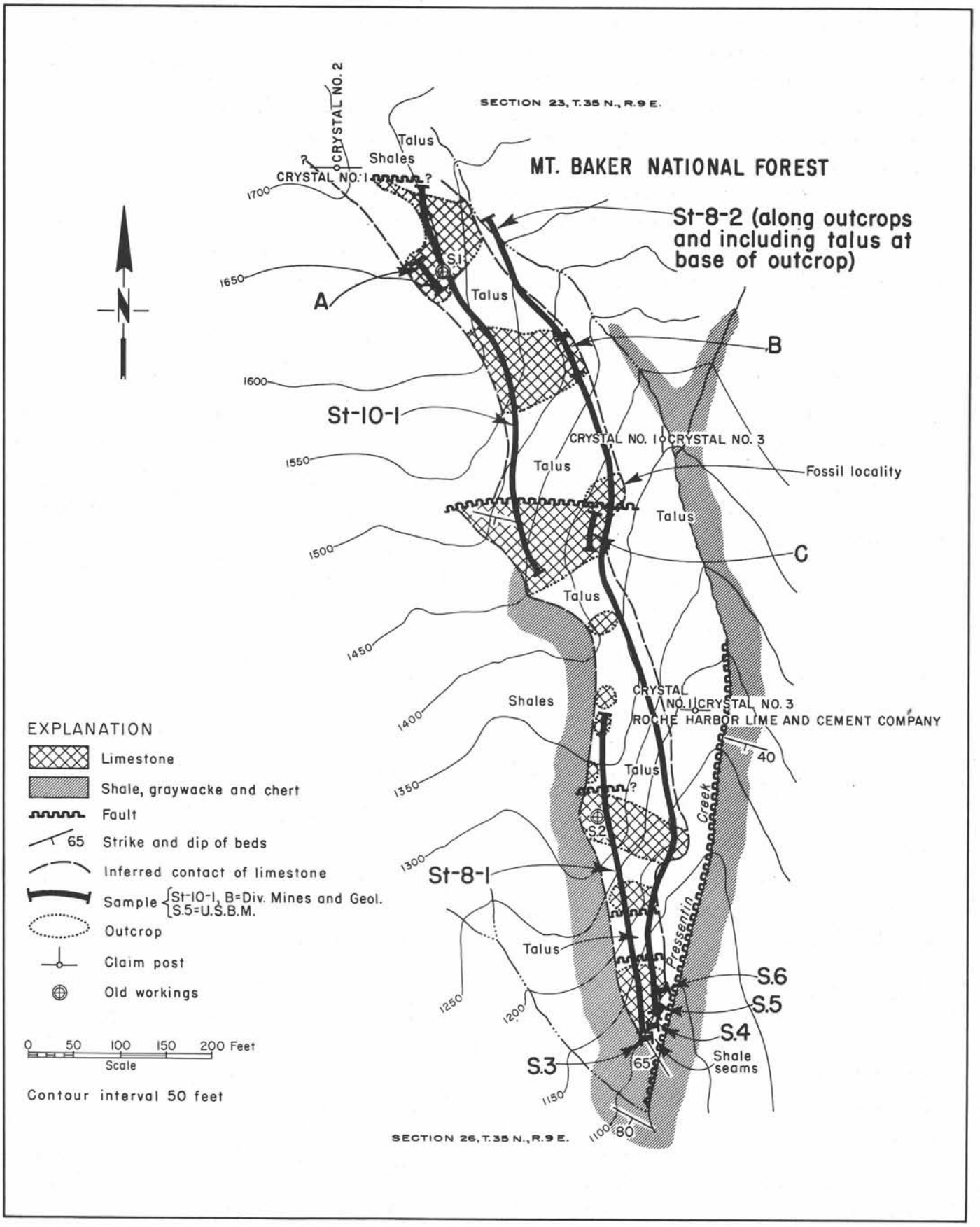


FIGURE 139. — North Rockport deposit. Secs. 23 and 26, T. 35 N., R. 9 E. Geology by C. C. Popoff, 1948, modified slightly by W. R. Danner, 1960. Base map from U.S. Bureau of Mines Report of Investigations No. 4355, 1948.

The limestone along the western side of the deposit appears to be more pure than in other areas and is light to dark gray in color and finely crystalline in texture. It is massive to laminated. Toward the east side of the deposit the limestone tends to be argillaceous, and this is particularly true of the northern end. Interbeds of black calcareous shale are common.

Some of the more argillaceous beds contain numerous poorly preserved and partially recrystallized brachiopods, which resemble the Silurian and Devonian genus Atrypa. Insoluble residues of this limestone contain well-preserved scolecodonts of several different types. One form closely resembles the genus Oenonites.

The folding and faulting are so severe in this area that no accurate tonnage estimate could be made on the basis of the present limestone exposures. The deposit should be drilled to determine its depth.

Quality. — The limestone is siliceous and argillaceous in places, but otherwise mostly of good quality. The silica appears to be sedimentation impurity and not replacement or secondary silica in the form of chert or jasperoid.

Chemical analyses of North Rockport limestone

Sample no.	Location	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
1/ St 8-1	Ridge, along strike ------	350	96.44	0.29	41.69	54.18	0.14	4.22	0.65	0.005
1/ St 8-2	Along stream -	750	96.04	0.37	42.31	53.96	0.18	2.80	0.39	0.005
1/ St 10-1	North claim -	350	95.51	0.56	42.48	53.66	0.27	2.74	0.73	0.003
2/					43.50	54.95	Trace	0.78	0.72	
3/		40	98.3					1.59		
3/		50	94.3					4.97		
3/		40	95.2					4.40		

1/ Samples collected for this report, Mark Adams, analyst. 2/ Shedd (1913, p. 230). 3/ Unpublished private report.

Chemical analyses of North Rockport limestone 1/

Sample no.	Sample length (feet)	Percent, dry basis									Remarks
		Loss on ignition	CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3	P	S	Free C	
North outcrop:											
1 ----------	40.0 horizontal	43.1	55.5	0.1	1.0	0.1	0.0	0.001	0.011		Near hanging wall.
Outcrop near old shaft:											
2 ----------	14.0 horizontal	43.1	55.1	0.0	1.1	0.1	0.1	0.004	0.010		Do.
South outcrop:											
2/ 3 ----------	13.2 horizontal	43.0	55.1	0.1	1.4	0.1	0.1	0.002	0.004		Do.
4 ----------	11.8 horizontal	43.4	55.3	0.1	0.6	0.1	0.0	0.002	0.003		Next to sample 3.
5 ----------	9.0 horizontal	43.4	55.1	0.1	0.6	0.1	0.0	0.002	0.013		Next to sample 4.
2/ 6 ----------	10.0 horizontal	43.3	55.5	0.1	0.7	0.1	0.0	0.002	0.005		Next to sample 5.
Weighted average, samples 4-6 --------	44.0	43.3	55.2	0.1	0.9	0.1	0.0	0.002	0.006	0.03	
Weighted average, samples 1-6 --------		43.2	55.3	0.1	1.0	0.1	0.0	0.002	0.008		
Near station B D:											
3/ 7 ----------	9.0	37.1	46.8	0.6	9.8	1.5	3.4	0.004	0.005		Near footwall.
8 ----------	8.0	39.3	50.4	0.2	9.4	0.3	0.5	0.003	0.016	0.07	Do.

1/ Popoff (1948, p. 13). 2/ Excluding seam of shales less than 1 foot in thickness. 3/ Thin seams of shales included.

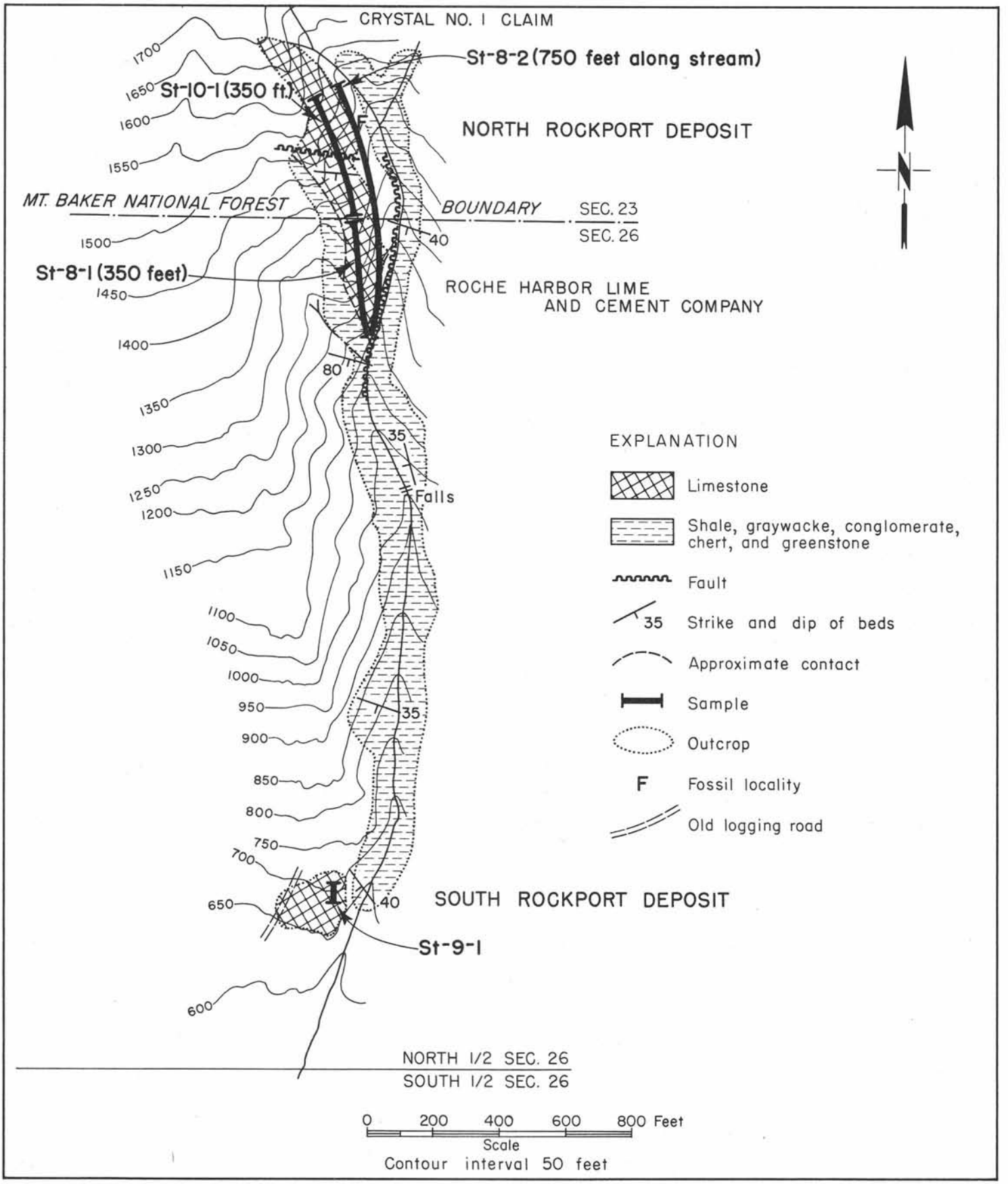


FIGURE 140. — North and South Rockport deposits. SE¼ sec. 23 and NE¼ sec. 26, T. 35 N., R. 9 E. Geology by C. C. Popoff, 1948, modified slightly by W. R. Danner, C. L. Smith, E. A. Adams, and C. F. Royse, Jr., 1960. Base map from U.S. Bureau of Mines transit survey, Report of Investigations No. 4355, 1948.

Ownership and development. — The northern part of the area, in sec. 23, comprising Crystal claims No. 1, No. 2, and No. 3, was owned (1948) by V. J. Granfors, C. M. Farrer, and A. O. Stensrud, of Seattle, However, only the Crystal No. 1 claim contains limestone outcrops. The southern part of the limestone body, in the NE¼ sec. 26, is owned by the Roche Harbor Lime and Cement Company, Roche Harbor, Wash. There has been no development.

Though not of high-quality chemical grade, this limestone would be usable for cement or agricultural stone. Its low elevation and nearness to the highway and railroad at Rockport make it the most economic of the deposits east of Concrete. It does not appear large enough to support a cement plant, and before being developed for any purpose it should be drilled thoroughly to determine the possible tonnage. Estimates of the quantity of limestone present range from 100,000 to 800,000 tons.

References. — Shedd (1913, p. 229-230), Hodge (1938, p. 57-58), Popoff (1948, p. 9).

South Rockport Deposit

Location, size, and accessibility. — The South Rockport limestone deposit is on the west side of Presentine Creek, in the SE¼NE¼ sec. 26, T. 35 N., R. 9 E., at an altitude of between 650 and 750 feet above sea level. It lies about halfway between the North Rockport deposit and the town of Rockport.

Outcrops of limestone occur over an area about 200 feet north-south and about 215 feet east-west. The vertical height is about 60 to 70 feet.

The deposit can be reached by hiking north about 1,500 feet up an old logging road along the east side of Presentine Creek from State Highway 17A and then going up the creekbed to the deposit. It is in an area of dense second-growth trees and brush.

Geology and description. — The limestone is poorly exposed and is overgrown with a dense cover of brush. It appears to strike northwestward, but no definite attitude could be ascertained. Shales underlie and overlie it. The underlying shales exposed about 60 to 80 feet below the limestone strike approximately N. 35° W. and dip 40° SW. Popoff (1948, p. 10) estimated the true thickness of the limestone to be between 25 and 30 feet. The limestone is gray in color and finely crystalline in texture. It is similar in appearance to that of the North Rockport deposit.

Quality. — The limestone is generally of good quality, but is siliceous in places.

Chemical analyses of South Rockport limestone

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/ St 9-1	Ridge west of creek -----	100	97.65	0.29	42.76	54.86	0.14	1.59	0.39	0.001	
1/ St 9-2		Composite	94.99	0.37	41.85	53.36	0.18	3.18	0.82	0.008	
2/ 9	Middle part--	10 (vertical)			42.7	54.7	0.1	1.8	3/ 0.3	0.003	0.003

1/ Samples collected for this report, Mark Adams, analyst.
2/ Popoff (1948, p. 13).
3/ Fe_2O_3=0.2, Al_2O_3=0.1.

Ownership and development. — The deposit is owned by the Roche Harbor Lime and Cement Company, Roche Harbor, Wash. There has been no development. The deposit should be drilled to determine its thickness, and it needs stripping and trenching to determine its size, as its nearness to the highway gives it an economic advantage over other deposits in the area.

Reference. — Popoff (1948, p. 9-10).

Sutter Creek Deposit

Location, size, and accessibility. — The Sutter Creek limestone outcrops are in the bed of Sutter Creek and on both sides of the canyon walls above it in the E½ sec. 19 and W½ sec. 20, T. 35 N., R. 10 E., between altitudes of 400 and 1,500 feet. The deposit consists of beds of argillaceous limestone or calcareous shale 50 feet or more in thickness and traceable for as much as 1,000 feet.

The deposit can be reached by hiking up an abandoned logging road on the east side of Presentine Creek; the road is steep and in places washed out. Limestone is found in scattered outcrops along the road for approximately 2 miles. Outcrops in the creekbed can be reached by climbing down canyon walls from the logging road above or, with difficulty, climbing up the creekbed and scaling waterfalls at periods of low water.

Geology and description. — The limestone beds are in a thick sequence of thin-bedded shales and graywackes. In the lower part of Sutter Creek are some areas of greenstone, and to the northeast some of the shales have been converted into phyllites. The limestone itself contains interbeds of black shale as much as 4 inches thick. Calcite veinlets are common and are crenulated in some places. The limestone is dark gray to gray in color and massive to well bedded to laminated. It is mostly dense textured, but parts are finely crystalline. In thin section, much of the limestone is seen to be dense textured and to have numerous small recrystallized spheres that appear to have been fossils, possibly foraminifers or radiolarians. These have been squeezed and distorted. Some of the limestone is oölitic, and the oölites commonly exhibit compression. A few poorly preserved foraminifers were observed in thin sections of the oölitic limestone.

The rocks of the Sutter Creek area have been intensely deformed and are cut by numerous faults. Rocks exposed in the canyon walls dip gently north, but in the northern part of the deposit they dip gently to the south. On the steep mountain

Chemical analyses of Sutter 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
St 11-1	Highest outcrop on road -----	50	66.98	0.96	29.82	37.63	0.46	31.07	1.29	0.66
St 11-2		25	82.69	0.87	37.47	46.46	0.42	13.35	1.85	0.073
St 11-3		25	89.30	0.94	39.31	50.17	0.45	8.39	0.86	0.056
St 11-4	Roadbed ------	15	87.94	0.56	39.51	49.41	0.27	9.43	0.87	0.055
St 11-5	Second switch-back, upper exposure ----	60	85.13	1.00	37.94	47.83	0.48	11.90	1.77	0.065
St 11-6	Second switch-back, lower exposure ----	100	87.55	0.92	38.95	49.19	0.44	10.04	1.35	0.090
St 11-7	Creekbed -----	94	83.96	5.18	39.48	47.17	2.48	8.91	2.01	0.106
St 11-8	Creekbed -----	174	83.10	0.87	37.23	46.69	0.42	13.37	1.90	0.057
St 11-9	Creekbed -----	Single sample, high grade	98.13	0.188	43.41	55.13	0.09	0.55	0.42	0.003
1/	NE¼SE¼ sec. 19 -----				25.4	32.0	0.6	39.9	2/ 1.5	

1/ Popoff (1948, p. 10).

2/ Fe_2O_3= 0.7, Al_2O_3= 0.8.

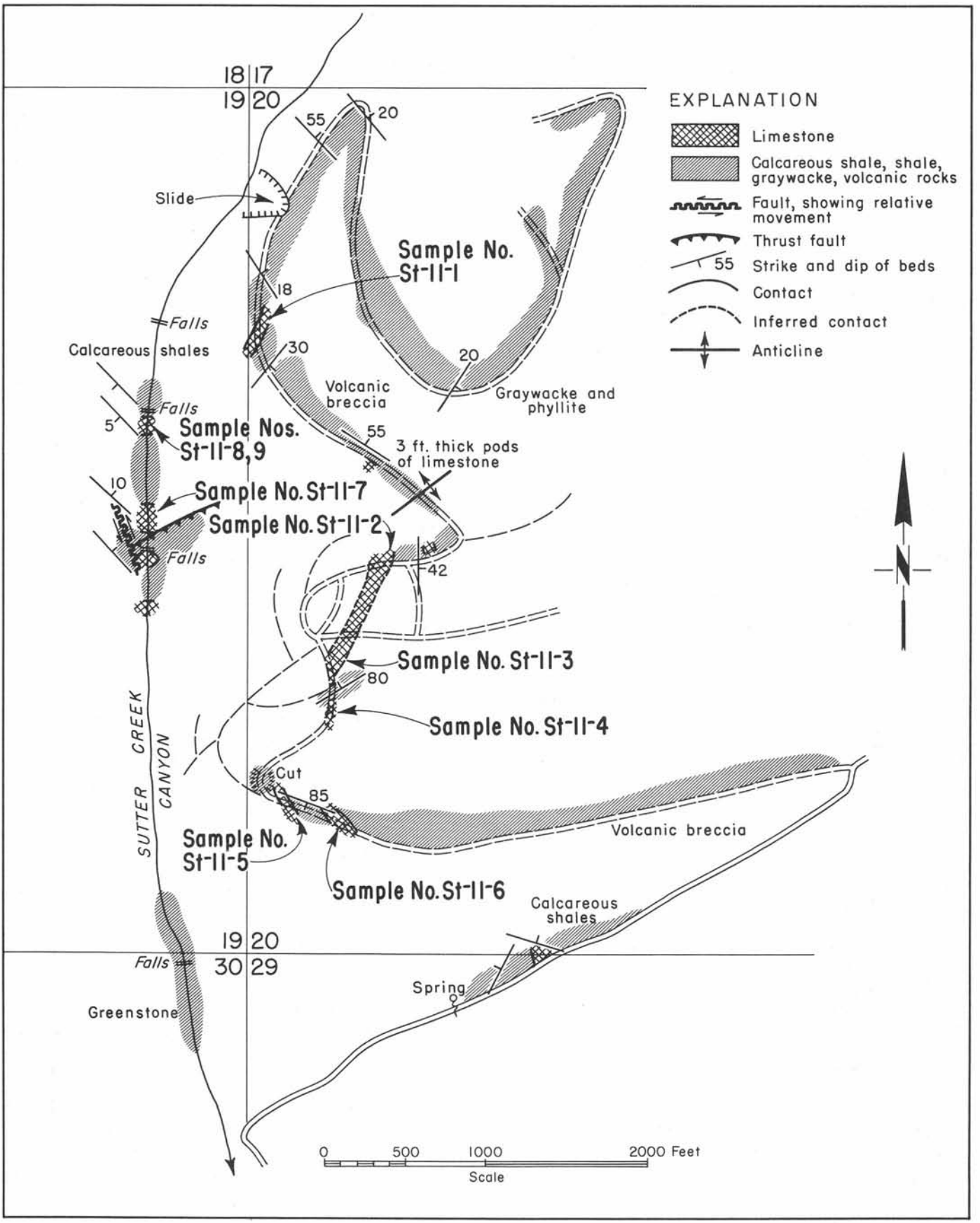


FIGURE 141. — Reconnaissance geologic map of the Sutter Creek deposits. E½ sec. 19 and W½ sec. 20, T. 35 N., R. 10 E. Geology by W. R. Danner, C. L. Smith, E. A. Adams, and C. F. Royse, Jr. In part compass and tape survey.

slope to the east the limestone beds appear to be folded into anticlines and synclines. Here some of the roadcuts are parallel to the limestone bedding planes, and although the exposures look like large masses of limestone, they are only slabs less than 25 feet thick. Limestone beds cropping out in roadcuts range from about 3 to 20 feet in thickness. Some limestone units contain up to 50 percent interbedded shale. A texture much like that of petrified wood is exhibited on weathered surfaces by many of the limestones, but its origin is unknown. Water seeping through the rock sequence along Sutter Creek has deposited coatings of tufa on the canyon walls.

Quality. — Most of the limestone appears in hand specimen to be argillaceous and impure. The shale interbeds and argillaceous nature of the rock are reflected in its high silica content when chemically analyzed. No secondary chert is visible, and magnesia in most samples is less than 0.5 percent.

Ownership and development. — The limestone-bearing area is owned by Edward Presentine, of Rockport. He describes the deposit as consisting of cement rock. There has been no development, and the limestone is not pure enough for uses other than for cement. Quarrying in Sutter Creek canyon would be extremely difficult because of the steep walls and the overburden. The folding of the limestone-bearing sequence would make selective quarrying of the beds higher in calcium very difficult. Limestone outcrops are scattered over an area of almost 1 square mile, but it is doubtful that this deposit is of economic value under present conditions.

Reference. — Popoff (1948, p. 10).

Rocky Creek Deposit

Location, size, and accessibility. — The Rocky Creek limestone deposit is in the S½ sec. 21, T. 35 N., R. 10 E., on the mountainside north of the Skagit River. It consists of at least two argillaceous limestone beds ranging from 5 to 25 feet in thickness. Isolated outcrops indicate an extension of at least 900 feet along strike. The deposit can be reached by following Highway 17A to a location 4 miles east of Rockport, or 12½ miles east of Concrete. One limestone bed is exposed in a highway cut, and the second approximately 300 feet to the east in an abandoned railroad cut about 40 feet above the highway. Dense second-growth trees cover the deposit. The lowest outcrop is at an altitude of 300 feet above sea level.

Geology and description. — The deposit consists of two or more internally folded argillaceous limestone beds in a sequence of volcanic rocks, thin-bedded shales, and chert. One bed is exposed for a distance of 30 feet in a highway cut, and is underlain by shales and volcanic rocks and overlain by volcanic rocks. It is thin bedded and appears to be more pure than that in other outcrops. This limestone is dark blue gray in color and dense to crystalline in texture. It could not be traced north of the roadcut and is either covered by glacial drift and soil or faulted out.

The second bed is about 40 feet above the first and 300 feet east along the grade of the City of Seattle Skagit Railroad Line. It consists of as much as 25 feet of limestone and calcareous shales, and can be traced about 300 feet to the northwest, for a vertical distance of about 200 feet. It is more shaly in the lower part and is underlain and overlain by volcanic rocks. There is about a 6-foot thickness of true limestone; the rest is calcareous shale. The limestone is blue gray in color and dense in texture. Its extension toward the roadcut below is covered by volcanic rock debris dumped on the hillside from the railroad grade above.

In three intermittent streambeds to the northwest, similar limestone is exposed with a maximum thickness of 5 feet. Shales underlie and overlie it. The limestone is mostly very thin bedded, but individual beds may be 3 inches or more in thickness. Interbeds of calcareous shale are common. Much of the limestone is folded into small, tight chevron folds; commonly there are as many as four folds in a 5-inch thickness

No fossils were seen, and the age is unknown. The hillside above is covered with dense second-growth vegetation and glacial drift, so that most of the bedrock is obscured. It is not known how far along strike the limestone may extend.

Quality. — The limestone is siliceous and argillaceous and has some magnesium-rich layers.

Ownership and development. — The owner is unknown, and there has been no development. The limestone is too impure and the bed is too thin to be of any economic value, but indications are that in the vicinity there may be larger areas of low-grade limestone that might be usable for cement rock, especially if blended with high-calcium limestone.

Chemical analyses of Rocky 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
St 12-1	Roadcut --------	30	89.24	0.56	39.60	50.14	0.48	8.78	0.90	0.090
St 12-2	North of railroad grade -	40	62.35	6.33	30.23	35.03	3.03	30.71	1.53	0.021
St 12-3	Along strike, east bed ------	80	68.19	1.19	25.74	38.31	0.57	38.34	3.17	0.102
St 12-4	Composite of three creekbeds		60.19	1.02	27.22	33.82	0.49	36.43	1.55	0.049

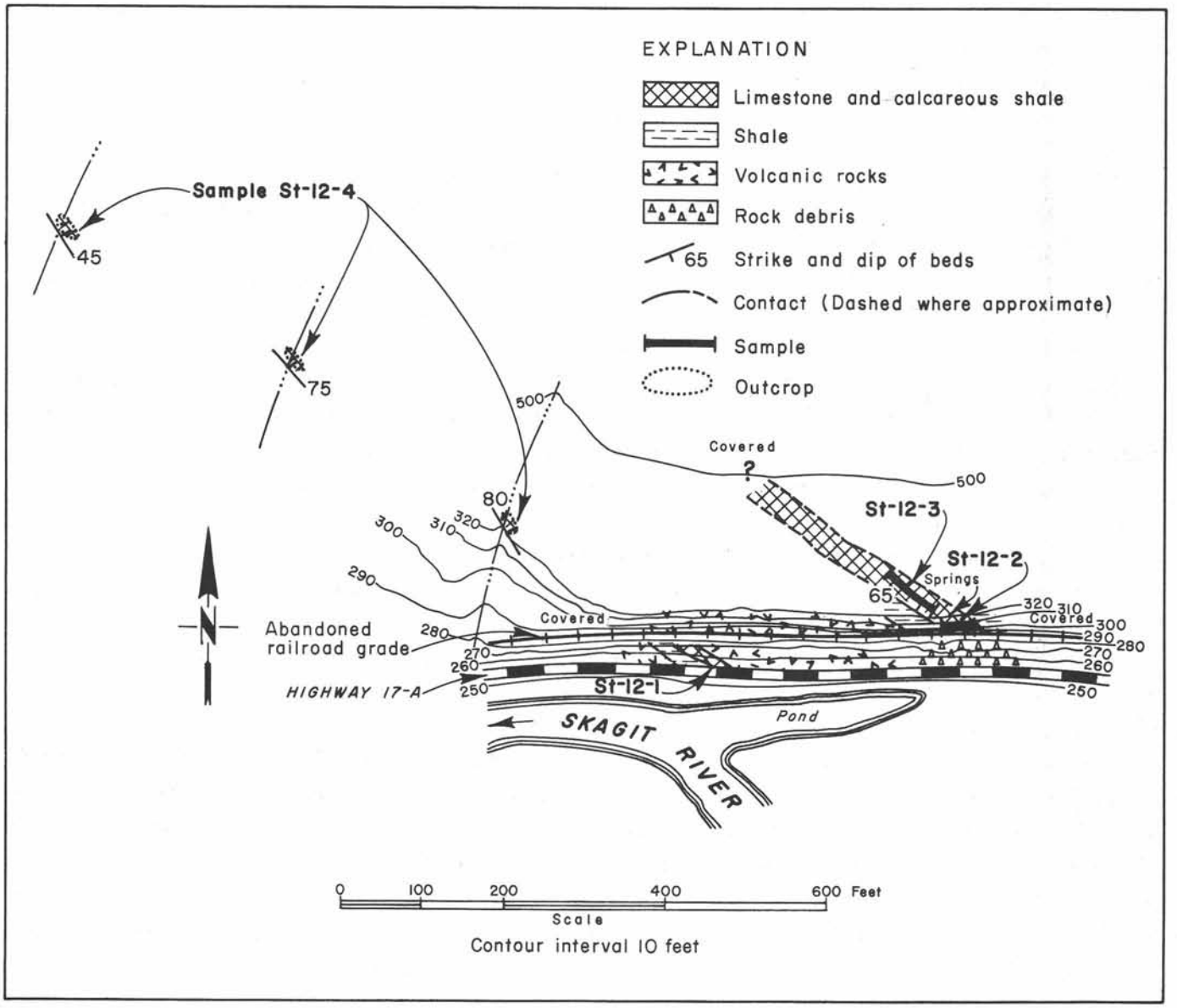


FIGURE 142. — Reconnaissance geologic map of the Rocky Creek deposit. S½ sec. 21, T. 35 N., R. 9 E. Geology by W. R. Danner, C. L. Smith, E. A. Adams, and C. F. Royse, Jr. In part compass and tape survey.

Marble Creek Deposit

Location, size, and accessibility. — The Marble Creek deposit is in the E½ sec. 3 and W½ sec. 2, T. 35 N., R. 12 E., on both sides of the valley of Marble Creek, a major tributary of the Cascade River. The area is mountainous, and outcrops

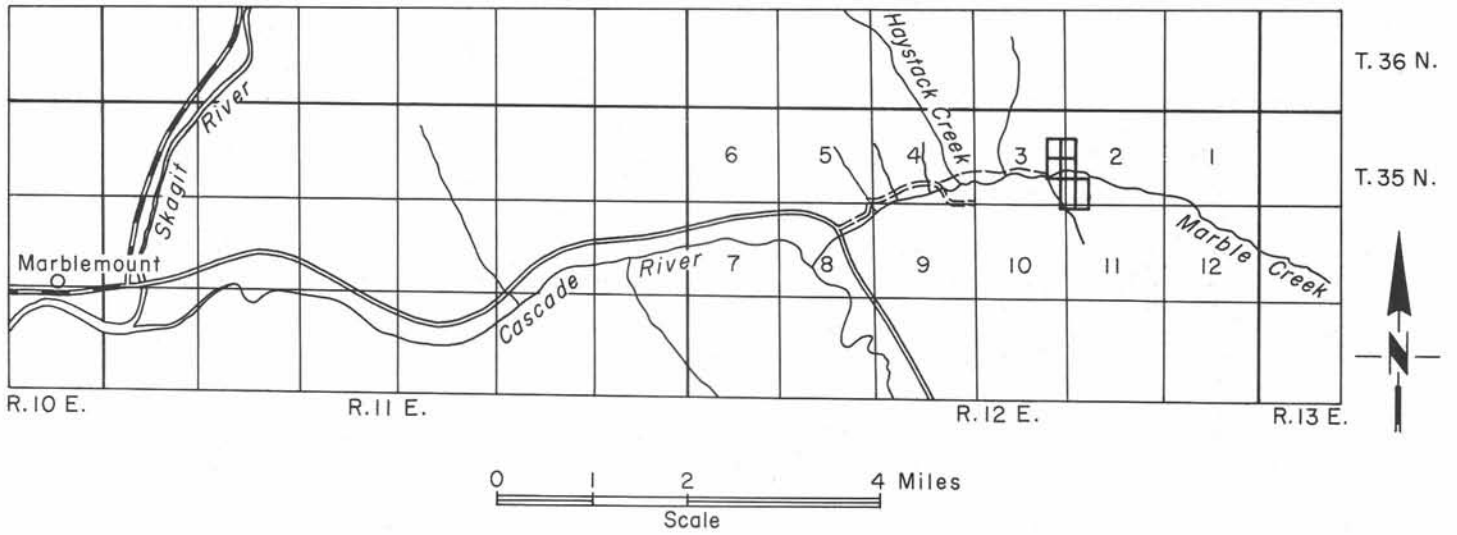


FIGURE 143. — Index map showing approximate location of the Marble Creek deposit.

on the south side of the valley are from 225 to 375 feet above the creek. Of the five outcrop belts reported to occur at this locality, only two were examined. One of these has an exposed width of 52 feet but is partly covered with slide debris and is reported to be approximately 90 feet wide. It was traced about 100 feet along strike and probably extends much farther. It is exposed vertically for over 100 feet. The deposit is difficult of access at present, but can be reached by driving 8.1 miles on a good graveled road from the town of Marblemount to Marble Creek, then up a logging road 2½ miles on the north side of Marble Creek to Haystack Creek, and then by hiking a little over 1 mile of poor trail. In July 1960 only the first 0.9 mile of the logging road was passable. Beyond this part the road was washed out in three places. The trail was partly covered by a pond formed by the blocking of Marble Creek by flood debris of Haystack Creek. Parts of the trail that were not flooded were heavily overgrown and were covered with windfalls. The trail disappears about 1 mile upstream.

The outcrops on the south side of the deposit were reached by following a rough and recently brushed-out trail and by crossing Marble Creek three times on log jams or fallen trees. The original trails to the outcrops are now heavily overgrown and are no longer visible.

Geology and description. — Only two limestone outcrops were examined by the writer. Several days of field exploration would be required to find and brush out trails through the dense vegetation to the other outcrops. The deposit consists of at least three outcrop belts of crystalline limestone striking northwestward on the south side of Marble Creek, and two limestone outcrop belts reported to strike northeastward on the north side of the creek. The southern limestones dip steeply to the southwest and are interbedded with medium-grade schists of the Cascade River Schist. Lower down Marble Creek are exposures of granitic rocks formerly classified as Skagit Gneiss (Misch, 1955), but now assigned to the Marble Creek trondjhemitic orthogneiss (Misch, written communication, 1965).

Outcrop No. 1 is well exposed in a cliff containing a waterfall above a small creekbed. The limestone is underlain by schist and at its base contains interbeds of schist. The upper part is mostly concealed by talus and slide debris. A thin dikelike body as much as 1½ feet in width cuts the western part of the limestone. The limestone is medium to coarsely crystalline in texture and is beautifully banded with alternating blue and white layers that are highly contorted and bent in part into chevron folds. The unit as a whole strikes between north-south and N. 35° W., and dips 80° W. to vertical.

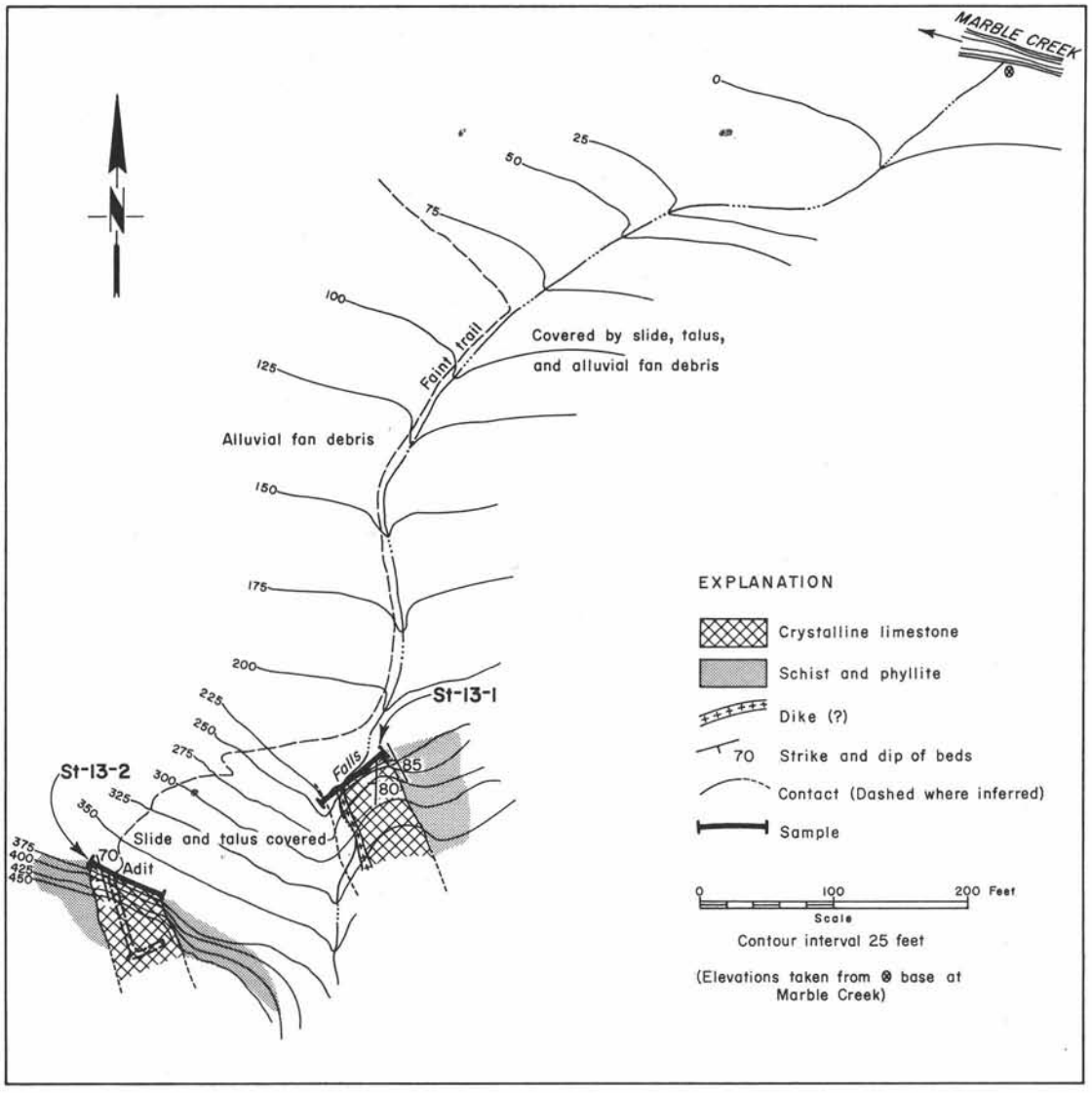


FIGURE 144.—North part of the Crescent No. 1 claim, Marble Creek deposit. Geology by W. R. Danner, C. L. Smith, E. A. Adams, and C. F. Royse, Jr. Compass and tape survey.

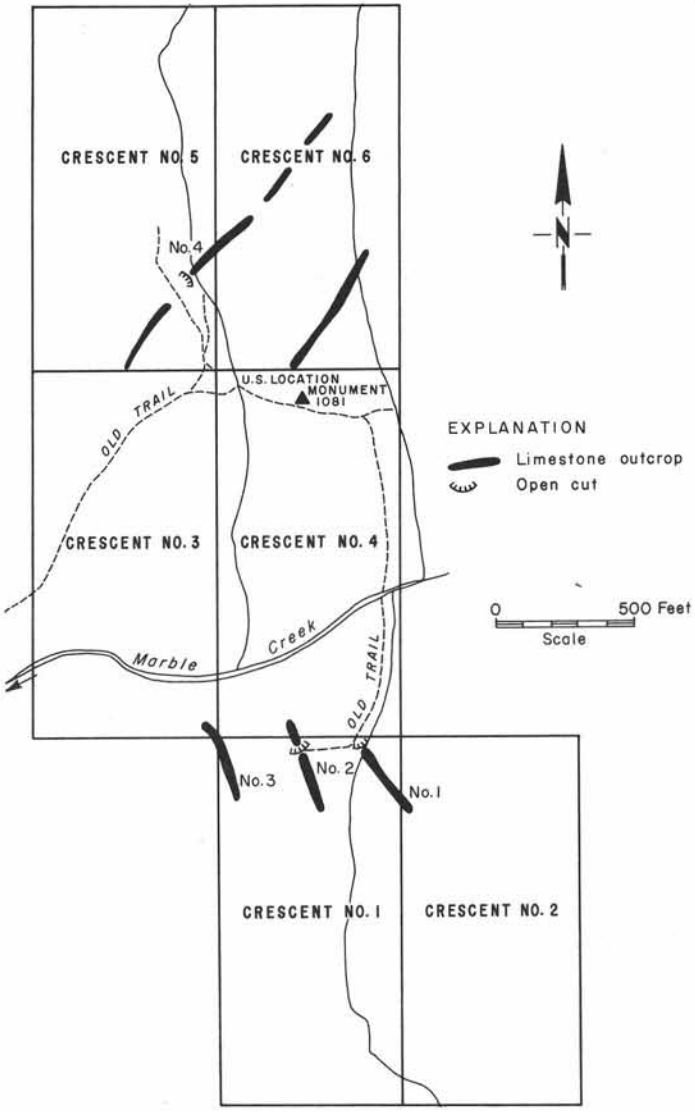


FIGURE 145.—Marble Creek deposits, Crescent claims. E½ sec. 3 and W½ sec. 2, T. 35 N., R. 12 E. From Survey 1081 by S. A. Newman (date unknown).

Outcrop No. 2 is about 130 feet southwest of No. 1 and about 150 feet higher. It is 40 feet wide and is underlain by schist and overlain by fine-grained but medium-grade schist. The limestone strikes N. 15° W. and dips 70° SW. It is similar in appearance to the limestone of outcrop No. 1. The limestone is exposed on a very steep slope and extends an unknown distance up the mountainside. A third limestone body was seen to the southwest of outcrop No. 2, but was not visited. It appears to be smaller than the other two outcrops.

Small bands of crystalline limestone have been reported on the ridge tops to the north (Little Devils Peak) and south of Marble Creek (Peter Misch, oral communication, 1962) and farther south (Tabor, 1958, p. 31). Tabor reports limestone beds 30 to 50 feet thick, but gives no specific location.

Quality. — This limestone has a relatively high magnesium content, and therefore would be unsuitable for cement or chemical use.

Chemical analyses of Marble 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)
St 13-1	No. 1	50	89.28	9.86	43.91	50.16	4.72	1.06	0.31	0.064	125	380	150	125
St 13-2	No. 2	50	88.82	10.11	43.41	49.90	4.84	1.25	0.96	0.200				

Ownership and development. — The Marble Creek deposit is owned by the Crescent Marble Company, George Kerr, President; E. V. Presentine, of Rockport, Vice President. At one time open cuts and crosscuts were made on several of the limestone outcrops. In limestone outcrop No. 2 there is a 60-foot adit extending southward parallel with the limestone strike. At its south end a branch extends east for about 27 feet. The adit is about 4 feet wide and 6 feet high, and the walls are inclined approximately parallel with the dip of the limestone.

This deposit appears large enough to be economically workable, if the beds maintain their width along strike. Outcrop No. 1 appears to be the best. Outcrops No. 2 and No. 3, on the south side of the valley, extend back into cliff faces and would be difficult to quarry very far into the mountainside. Two outcrops on the north side of the valley were not examined. Factors against the deposit are its relatively high magnesium oxide content, remoteness from potential markets, and location in mountainous terrain. A great amount of clearing of vegetation and much trail construction would be required to make the deposit more accessible, in order to properly assess its economic value. The colorful banding of this rock might make it an attractive decorative stone, if it can be polished well. A private report gives an estimate of 5,000,000 tons of limestone in the property.

References. — Glover (1936, p. 58), Northern Pacific Railway Co. (1941, unpublished notes, p. 14), Tabor (1958, p. 31), Phoenix, C. E. (unpublished private report, date unknown), Newman, S. A. (unpublished map, date unknown).

Sutter Mountain Deposit

Location, size, and accessibility. — The Sutter Mountain limestone deposit is in the E½ sec. 32, T. 35 N., R. 9 E., along the Finney Creek logging road just east of Miller Creek. The southern part of the deposit consists of at least three limestone outcrops, the largest of which is 45 feet long and 15 feet wide and is exposed over a strike distance of 700 feet. The northern part of the deposit is an outcrop area over 1,350 feet in length north-south; it may reach 250 feet or more in width and is exposed vertically for at least 125 feet.

The area is accessible via the Finney Creek logging road, the northern outcrop being about 1.8 miles from the junction of the logging road with the Concrete-Darrington highway on the south side of the Skagit River. The southern limestone outcrops are between 2 and 2½ miles up the road from the junction.

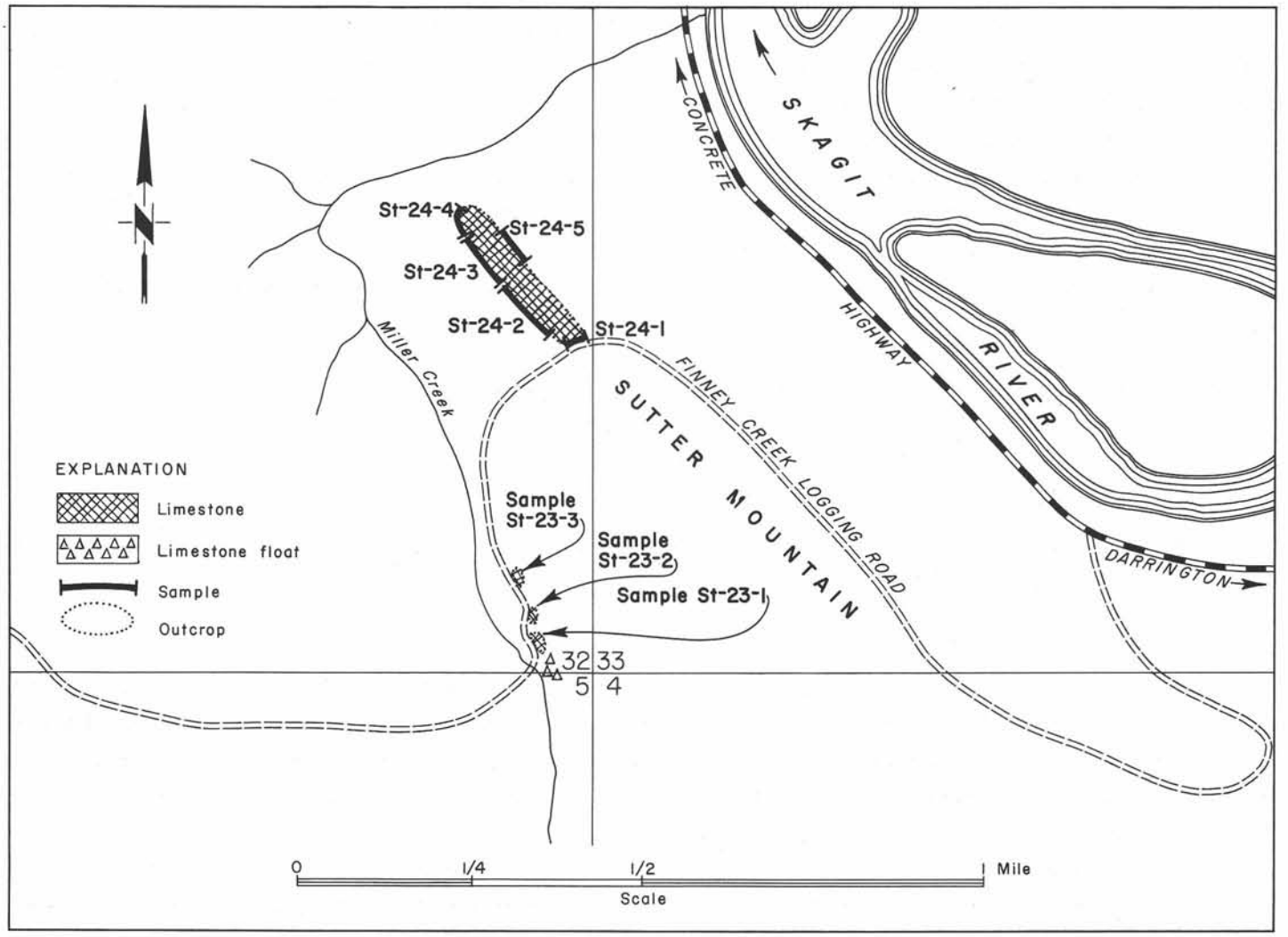


FIGURE 146. — Sutter Mountain limestone deposits. E½ sec. 32, T. 35 N., R. 9 E. Geology by C. L. Smith and C. F. Royse, Jr. Base map by U.S. Forest Service.

Geology and description of the southern outcrops. — The southern outcrops are exposed in roadcuts on the east side of the logging road. The southernmost is 8 feet thick and is overlain by subgraywacke and underlain by calcareous shale. The limestone is exposed for 32 feet along the road and has a vertical height of 12 feet; it strikes N. 80° W. and dips 55° SW. It is medium crystalline in texture and appears to be partially dolomitized. Carbonaceous residues are common on the bedding planes. Another exposure, 100 feet to the north, is about 30 feet long and 12 feet wide and is of a similar type. Just below it is a 10-foot bed of limestone. A third limestone outcrop, 200 feet farther north, is 45 feet long and 15 feet wide. It contains small fossil fragments consisting mostly of crinoid debris. Blocks of crinoidal limestone float were found in two places over a distance of 1,000 feet to the southeast.

Geology and description of the northern outcrops. — The largest limestone outcrop area in the northern part of the deposit is exposed along the road for a distance of 52 feet and is exposed vertically for about 23 feet. In appearance, the limestone closely resembles that of the southern outcrops, but it is broken up into a jumble of blocks. The ridge to the northwest is bordered by limestone cliffs for a distance of over 1,350 feet. Exposures are scarce along the ridge crest, but there are a few and also several sinkholes. It is probable that a large tonnage of limestone is present here, but no indication of the structure of the limestone could be seen. No fossils were found, but it is quite likely that the limestone at Sutter Mountain is a continuation to the southeast of the Pennsylvanian age limestone of the Concrete deposit.

Quality. — This limestone is quite variable in composition; some parts are high in magnesia and silica.

Chemical analyses of Sutter Mountain 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)
St 23-1		32	77.78	7.23	37.86	43.70	3.46	12.64	2.11	0.045				
St 23-2		30	75.59	0.75	33.76	42.47	0.36	21.74	1.62	0.017				
St 23-3		45	78.26	1.90	34.30	41.72	0.91	18.31	4.74	0.038				
St 24-1	Roadcut	52	94.12	0.73	41.87	52.88	0.35	3.69	0.74	0.007				
St 24-2		500	98.91	0.81	42.83	55.57	0.39	1.08	0.36	0.017	175	490	180	195
St 24-3		400	97.71	0.48	42.24	54.89	0.23	2.36	0.29	0.021				
St 24-4		250	87.22	1.81	38.68	49.00	0.87	10.64	0.73	0.018				
St 24-5		300	90.97	1.40	39.78	51.11	0.67	8.03	0.60	0.010				

Ownership and development. — The owner is unknown, and there has been no development as far as is known. The area needs to be studied in greater detail, particularly the northern part of the deposit.

Reference. — Vance, J. A. (1958, unpublished field notes).

Sauk River Bridge Deposit

Location, size, and accessibility. — The Sauk River Bridge deposit is in the SW¼NE¼ sec. 30, T. 34 N., R. 10 E., in a roadcut on the west side of the Darrington to Concrete road just southwest of the bridge over the Sauk River. Calcareous rocks from 3 to 20 feet in thickness are exposed for about 200 feet along the road.

The deposit can be reached by following the main road north from Darrington about 12 miles to the Sauk River Bridge.

Geology and description. — The deposit is exposed in a roadcut in highly sheared and faulted sedimentary rocks. Calcareous rocks of two types are exposed. One type consists of a bed about 4 feet thick of light-colored fissile thin-bedded calcareous shale, and underlying it is a 5- to 20-foot-thick dark fine-grained carbonaceous massive calcareous shale.

Quality. — The rock is too impure to be considered a limestone.

Chemical analyses of Sauk River Bridge calcareous shale

(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
St 25-1	100	14.94	1.88	7.45	8.39	0.90	75.58	7.03	0.175
St 25-2	100	26.53	1.33	13.33	14.91	0.64	63.89	6.41	0.200

Ownership and development. — The owner is unknown, and there has been no development.

Suiattle River Bridge Deposit

Location, size, and accessibility. — The Suiattle River Bridge deposit is in the NW¼ sec. 11, T. 33 N., R. 11 E., in a roadcut on the west side of the Darrington road at the bridge over Suiattle River. As the deposit was not visited, the size is unknown. The deposit, about 12.3 miles northeast of the town of Darrington, is accessible by the Darrington-Suiattle River road.

Geology and description. — The deposit is reported to consist of limestone intercalated with calcareous sandstone and shale, and striking about N. 61° W. and dipping 48° NE. It is exposed in a 510-foot-long roadcut. It is overlain to the north by serpentine and underlain to the south by shale. The calcareous sediments consist of thin beds of chloritized green impure limestone, black argillaceous limestone, and calcareous shale. The entire sequence is cut by numerous vertical faults and brecciated zones. Shale cropping out to the south is intensely folded.

Quality. — Unknown.

Ownership and development. — The owner is unknown, and there has been no development. The rock is probably too impure to be of economic value as limestone.

Reference. — Guard, A. K. (1943, unpublished field notes).

Damnation Creek Deposit

Location, size, and accessibility. — The Damnation Creek limestone deposit is reported to be in the SE¼ sec. 10, T. 36 N., R. 11 E., about 8 miles north of the town of Marblemount and 300 to 400 feet up the hill west of the old City of Seattle Electric Railroad, near the center of sec. 10. The deposit was not visited during the course of this survey, but it has been described as consisting of at least two small beds of limestone, one of which is about 1 foot thick and the other 2 feet thick. The deposit can be reached by driving 8 miles on a paved road north from Marblemount and then climbing up the hillside.

Geology and description. — (From notes of A. K. Guard) Limestone occurs in siliceous schist and is bedded with alternating bands of dark-gray to black limestone and white to gray limestone ranging from ½ inch to 2 inches in thickness. The strike is N. 6°-10° E., and the dip is 58°-73° W. A section east to west is as follows:

	Ft
Quartzite and siliceous schist	
Calcareous schist	
Limestone	1
Calcareous green schist	3
Limestone	2

About 100 feet farther up the gully in which the previous section is exposed, the 2-foot bed of limestone has increased to 3 feet in thickness and the 1-foot bed to 15 inches. The limestone is exposed for hundreds of feet up over the mountainside. In no place does it attain any considerable thickness.

Quality. — Unknown.

Ownership and development. — In 1943 the deposit was owned by J. W. Collins, of Van Horn, Wash. There has been no development. The deposit is too small to be of any economic value. It is probably a continuation along strike of the Marble Creek limestone beds to the southeast.

Reference. — Guard, A. K. (1943, unpublished field notes).

Other Limestone Deposits of Skagit County

Joseph Vance (oral communication, Dec. 1962) reports limestone outcrops in the following localities north of Darrington, in Skagit County:

(1) An outcrop of impure clastic limestone averaging 15 feet in thickness is exposed along the Suiattle River road north of Darrington about 1 mile or more south of the bridge, in about the NE¼NW¼ sec. 15, T. 33 N., R. 10 E.

(2) A limestone outcrop about 8 feet thick is exposed on a logging road up the hillside in about the NE¼NE¼ sec. 15, T. 33 N., R. 10 E.

SNOHOMISH COUNTY

Snohomish County lies south of Skagit County and is 60 to 65 miles long. It extends from the shores of Puget Sound on the west to the crest of the Cascade Mountains on the east, and is 36 miles wide north-south. The western part of the county is underlain by Pleistocene glacial, interglacial, and alluvial deposits and Eocene and Oligocene sedimentary and volcanic rocks. The central and eastern parts of the county contain extensions of the belts of Mesozoic and Paleozoic igneous, sedimentary, and metamorphic rocks trending northwest-southeast from Skagit County. Limestone deposits occur in six areas of Snohomish County in Mesozoic and Paleozoic rocks.

In the western part of the county is a belt of middle and upper Permian sedimentary and volcanic rocks informally known as the Trafton sequence. It extends southeast for 25 miles, from Pilchuck Creek at the Skagit County boundary on the north to the Pilchuck River, south of Mount Pilchuck, on the south. Many small high-calcium limestone lenses occur in this belt, and six of them have been quarried. Two of them are still being quarried, mainly for agricultural stone. Only one undeveloped deposit, near south Twin Lake, appears to be large enough to be of potential value as a small producer of pulp rock or of agricultural stone.

In southern Snohomish County, near the towns of Gold Bar and Sultan, are a group of dense, oölitic, and cherty limestone deposits in rocks of supposed Late Jurassic or Early Cretaceous age. Because of their ease of accessibility, two of the deposits have been quarried and used mainly for agricultural stone. Other deposits of the group could be exploited for the same purpose in the future, but none are large enough for a major operation.

A third area of limestone outcrops is in the north-central part of the county, east of the town of Darrington, on an extension of the Chilliwack Group rocks south from Skagit County. Several limestone bodies have been found, but most of them are in relatively inaccessible mountainous terrain. They are siliceous and argillaceous in composition and are believed to belong to the division of the Chilliwack Group that is of Pennsylvanian age. None of them have been quarried, and none are believed to be large enough or pure enough to be of economic value under present conditions.

Southwest of the town of Darrington, on Whitehorse Mountain, is a fourth group of limestone bodies. They contain several million tons but are at high altitudes and are of variable composition, having a relatively high magnesium content in some places. Their geologic age is unknown, and in texture and composition they do not resemble any of the other limestone deposits of western Washington. They have been prospected to a limited extent but have never been developed into a commercial operation.

A fifth area of limestone outcrops occurs in the northeastern part of the county, just west of Glacier Peak, in a belt of crystalline metamorphic rocks. Beds of crystalline limestone extending for several thousand feet are known, but their remoteness, inaccessibility, and location in mountainous terrain of a high relief and heavy snowfall make them of little economic value. All the limestone beds contain layers of schist, and they are cut by numerous dikes of volcanic rock, aplite, and pegmatite.

A sixth group of limestone outcrops is in a sequence of graywackes, slates, phyllites, and ribbon cherts believed to be of Mesozoic age, lying north and south of the South Fork Stillaguamish River between Canyon Creek and Silverton. No limestone beds are known in surface outcrop to be more than a few feet thick, and all are in heavily forested mountainous country difficult of access.

Rock Creek Deposit

Location, size, and accessibility.—The Rock Creek limestone deposit is in the NW¼ sec. 6, T. 32 N., R. 6 E., on the steep east bank of Rock Creek on the south slope of Bald Mountain, just south of the Skagit-Snohomish County boundary. It is accessible by about 5½ to 6 miles of good black-topped and graveled road from the community of Bryant, about 3½ miles north of the town of Arlington, and then by nearly 2 miles of steep and rough bulldozed logging road. It is at an altitude of about 1,700 feet in steep mountainous terrain covered with dense second-growth trees and brush.

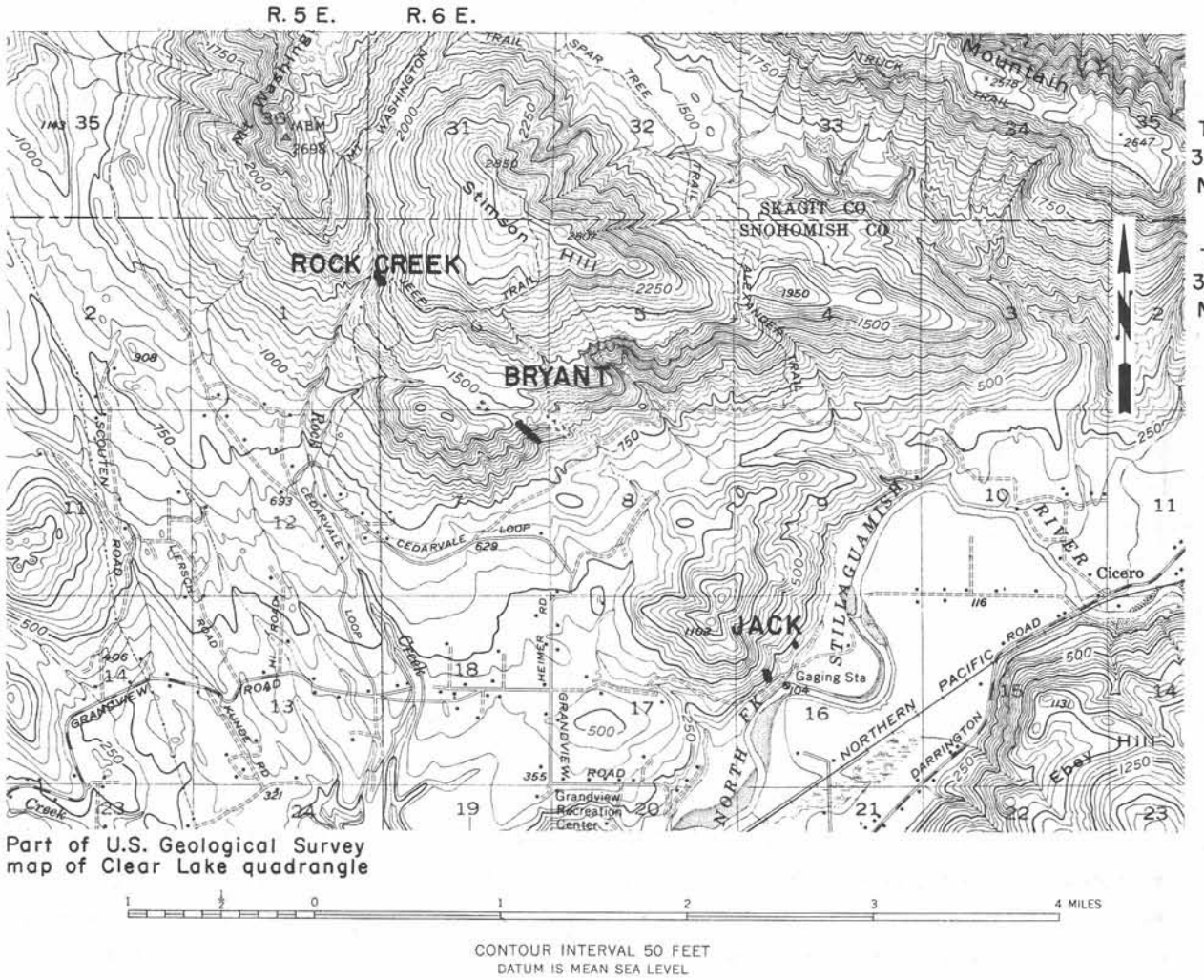


FIGURE 147. — Index map showing limestone deposits of the Bryant area, Snohomish County.

In 1954 limestone was exposed in a small quarry in an outcrop about 50 feet long, 20 feet wide, and 50 feet high.

Geology and description. — The Rock Creek deposit is a small lenticular body of limestone exposed on a steep hillside above a stream. The limestone strikes N. 50°-60° W. and dips vertically, or nearly so. It thickens and thins along strike but averages 20 feet in width. It is interbedded with ribbon chert and argillite of probable Permian age, although no fossils were found. At the top of the quarry the limestone is overlain by 1 foot or more of glacial drift and soil. A strike fault borders the deposit on its north side. The limestone is dark bluish gray to black in color and finely crystalline in texture. It is cut by many calcite veinlets.

Quality. — The limestone is high in calcium.

Chemical analysis of Rock Creek limestone

Sample	CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3	P	S
1/	55.3	0.4	0.4	0.1	0.1	0.044	0.003

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

Ownership and development. — The limestone outcrop was examined and sampled by the U.S. Bureau of Mines in 1946. By 1954 a small quarry had been developed on the deposit and limestone was removed for use as agricultural stone. The occurrence is on State land, and in 1946 it was leased to J. A. Jack. Later (1958?) it was leased to the Western Lime Company, of Mount Vernon, Wash. This company ceased operations on the property during the summer of 1960.

References. — Popoff (1949a, p. 7), Danner (1957, p. 203).

Bryant Deposit

Location, size, and accessibility. — The Bryant deposit is in the NE¼ sec. 7, T. 32 N., R. 6 E., on the south side of an eastern spur of Bald Mountain, at an altitude of between 1,000 and 1,450 feet. The deposit consists of a narrow lenticular bed of limestone between 25 and 35 feet in thickness and about 650 feet long. The area is accessible by about 6 miles of road from the small community of Bryant, which is about 3½ miles north of the town of Arlington. Bryant is on the Northern Pacific Railway and is 20 miles from Everett and 65 miles from Seattle. From the graveled road below the deposit the outcrops can be reached by climbing a steep abandoned and overgrown logging grade extending north about ¼ mile from the Cicero-Bryant road. In 1955 the ruins of a house stood in the woods on the south side of the road opposite the start of the route to the deposit.

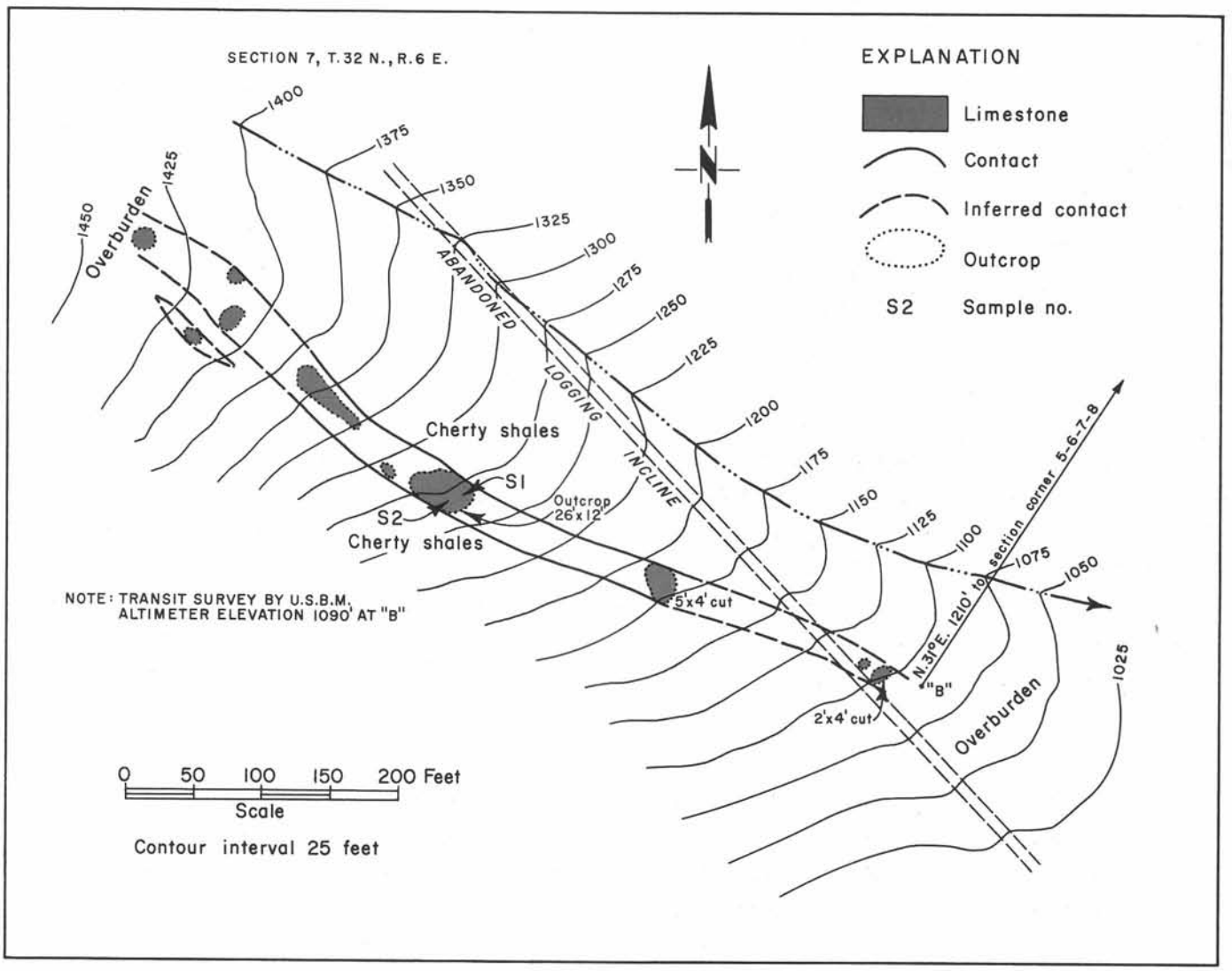


FIGURE 148. — Bryant deposit. NE¼ sec. 7, T. 32 N., R. 6 E. Geology by C. C. Popoff, 1949. Reprinted from U.S. Bureau of Mines Report of Investigations No. 4393. Transit survey.

The area is mountainous and has a dense cover of second-growth trees and brush.

Geology and description. — The deposit consists of an aligned series of discontinuous outcrops extending northwestward up the steep hillside almost to the top of the hill, a distance of about 650 feet. It is not known whether the limestone forms a continuous bed or a series of lenses. The outcrops show a maximum thickness of between 25 and 35 feet but narrow in places to less than 10 feet. The limestone strikes approximately N. 55° W., and it dips steeply to the northeast. The contacts to the east and west are with a sequence of argillites and ribbon cherts. Although no fossils have been found, the limestone is thought to be Permian in age because of its similarity in appearance and alignment along strike with the fossiliferous Permian limestones to the southwest in the Twin Lakes area.

The limestone is gray in color and dense to finely crystalline in texture. It is cut by numerous calcite veinlets.

Quality. — The limestone is high in calcium.

Chemical analyses of Bryant limestone

Sample no.	Location	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3		P	S
1/ 1			97.96		43.57	54.87	1.13	0.39	0.26			
1/ 2			98.48		43.53	55.18	0.97	0.26	0.16			
2/ 3			97.77			54.66	0.15	1.23	0.29			
3/ S1	Center of deposit ---	13			43.2	55.1	0.7	0.7	Fe_2O_3 0.2	Al_2O_3 0.0	0.059	0.004
3/ S2	Center of deposit ---	10			43.4	55.2	0.6	0.6	0.1	0.0	0.041	0.004

1/ Analyses by Utah-Idaho Sugar Company, Toppenish, Wash.
2/ Analysis by Sound View Pulp Company.
3/ Analyses by U.S. Bureau of Mines, Popoff (1949a, p. 7).

Ownership and development. — The deposit was mapped and sampled by the U.S. Bureau of Mines in 1946. When the property was examined by the writer in 1954, several outcrops had been blasted but there had been no quarrying. The outcrop is on State-owned land, and at the time of the Bureau of Mines examination was leased by John D. Eads, of Arlington, and F. G. Schults, of Everett, and subleased to Silica Products, Inc., Tacoma, Wash. It was later leased to the Western Lime Company, of Mount Vernon, Wash. (1958?), and the limestone was used for agricultural stone. The latter company is reported to have put a tunnel into the outcrop. Limestone is hauled by truck to an 80-ton plant at the intersection of Highway 99 and the Bryant-Stanwood road.

Reference. — Popoff (1949a, p. 6).

Jack Quarry

Location, size, and accessibility. — The Jack limestone deposit is in the $SW\frac{1}{4}NE\frac{1}{4}NW\frac{1}{4}$ sec. 16, T. 32 N., R. 6 E., about $6\frac{1}{2}$ miles by road east of the community of Bryant, which is about 4 miles north of the town of Arlington. The deposit is on a cliff above the North Fork of the Stillaguamish River at an altitude of 150 feet. It has been quarried for several years, and is now abandoned and considered to be exhuasted.

Geology and description. — The deposit consists of a faulted, irregularly shaped body of finely crystalline, dark-gray to bluish-gray limestone. Only remnants of the original limestone body are exposed in the quarry walls; the main exposure is about 50 feet wide and has a steeply dipping fault and shear zone bisecting it approximately parallel with its strike.

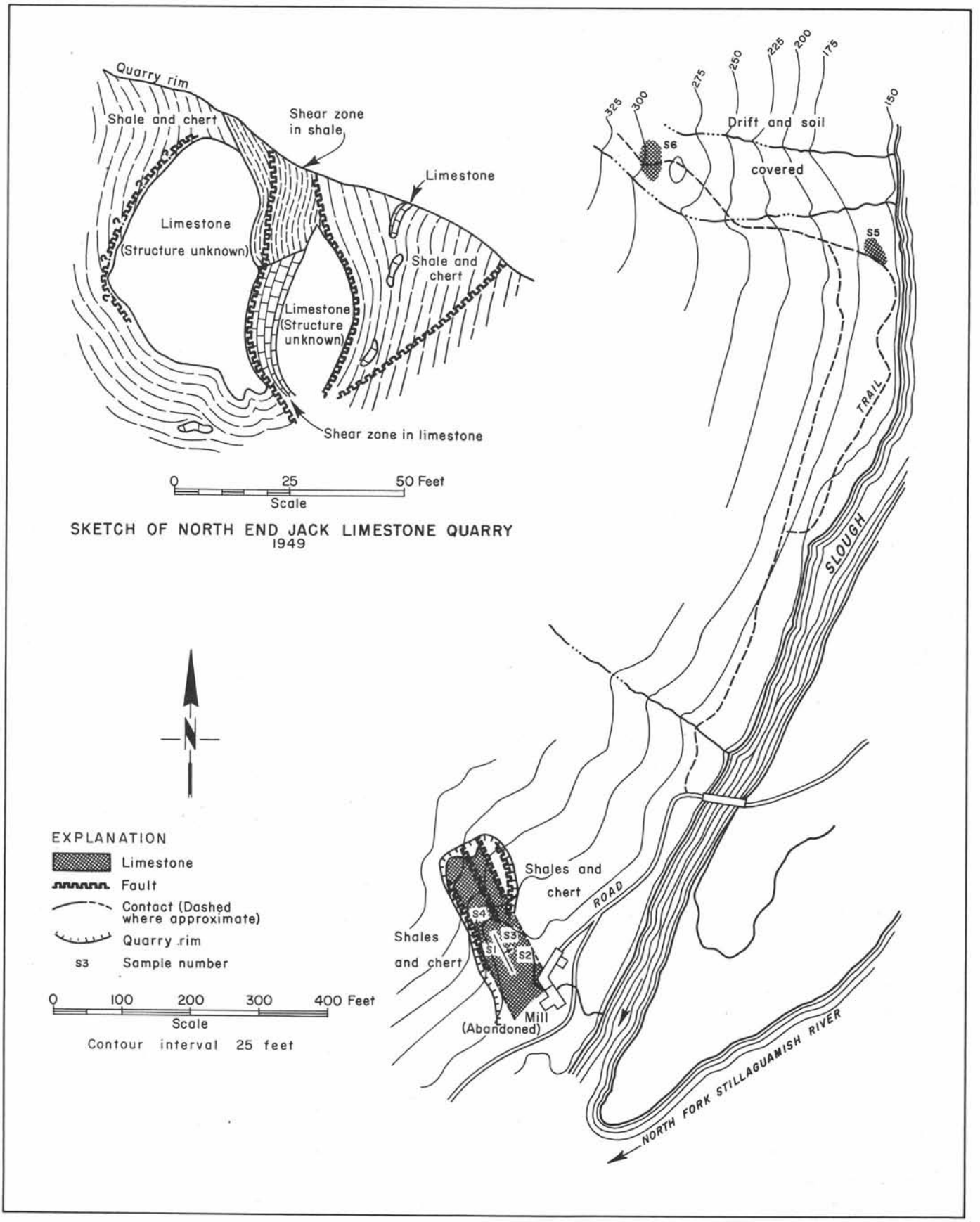


FIGURE 149. — Jack deposit. SW¼NE¼NW¼ sec. 16, T. 32 N., R. 6 E. Geology by C. C. Popoff, 1949, modified by W. R. Danner. Base map reprinted from U.S. Bureau of Mines Report of Investigations No. 4393. Sketch of north end of Jack limestone quarry, by W. R. Danner, 1949.