Geology.—Rock outcrops are numerous over the hill beside the highway. The rocks have been folded isoclinally into a major anticline (anticlinorium), overturned to the northwest, upon which are impressed lesser synclines and anticlines (fig. 16). Fold axes trend northeast and plunge from 20° to 30° SW. The oldest rocks, a series of thin-bedded argillaceous quartzites, are well exposed in the core of the major anticline. The next younger rock unit is a white limestone very similar to the one being mined in the Janni quarry. It is white to cream white to light gray, medium grained, and moderately well bedded. Its true thickness is estimated to be approximately 40 feet, although at fold crests and troughs the thickness has been greatly increased owing to solid rock flow during folding. The contact between the white limestone and the underlying quartzite is sharp along the fold limbs; however, near fold axes the folding is so intricate and rock flowage has been so intense that the contact is very jagged and indistinct. At such places a zone several feet wide separates the quartzites from the limestone, and within this zone the limestone and micaceous quartzites are complexly interlayered and intimately mixed. These complex structural features are the result of crumpling, slippage, and plastic flow by means of which the limestone was injected, as though liquid, along cleavage surfaces in the quartzite. Overlying the white limestone is a series of phyllites with some thin quartzite interbeds that is, in turn, overlain by a white dolomitic limestone unit 50 feet thick. This unit may be the one that is being worked in the Janni quarry to the southwest. Higher in the stratigraphic section are more quartzites, phyllites, and dark-gray micaceous limestone similar to rocks in the Janni quarry area.

Quality and quantity of limestone.—The quality of the three limestone units of the area has been determined by field inspection and sampling. The gray micaceous limestone unit and the upper white limestone unit were not sampled, because the former is obviously too micaceous and the latter too dolomitic to be classed as high-calcium limestone. The lower white limestone, except in its lowermost few feet where it is in contact with the underlying quartzite, appears to be the purest of the three units. Samples of the lower white limestone were taken by the Hecla Mining Company across the thickened nose of the major fold south of the benchmark (BM) and State Highway 22 (fig. 16) and across the south limb of the fold. Results of their sample analyses are as follows:

Length of sample (feet)	$CaCO_3$ (percent)	MgO (percent)
290	94.8	1.47
280	94.5	1.50
280	88.2	3.94

In the course of the present study four samples (S-180 to S-183) were taken across the lower white limestone (fig. 19).

Analyses of these samples are as follows:

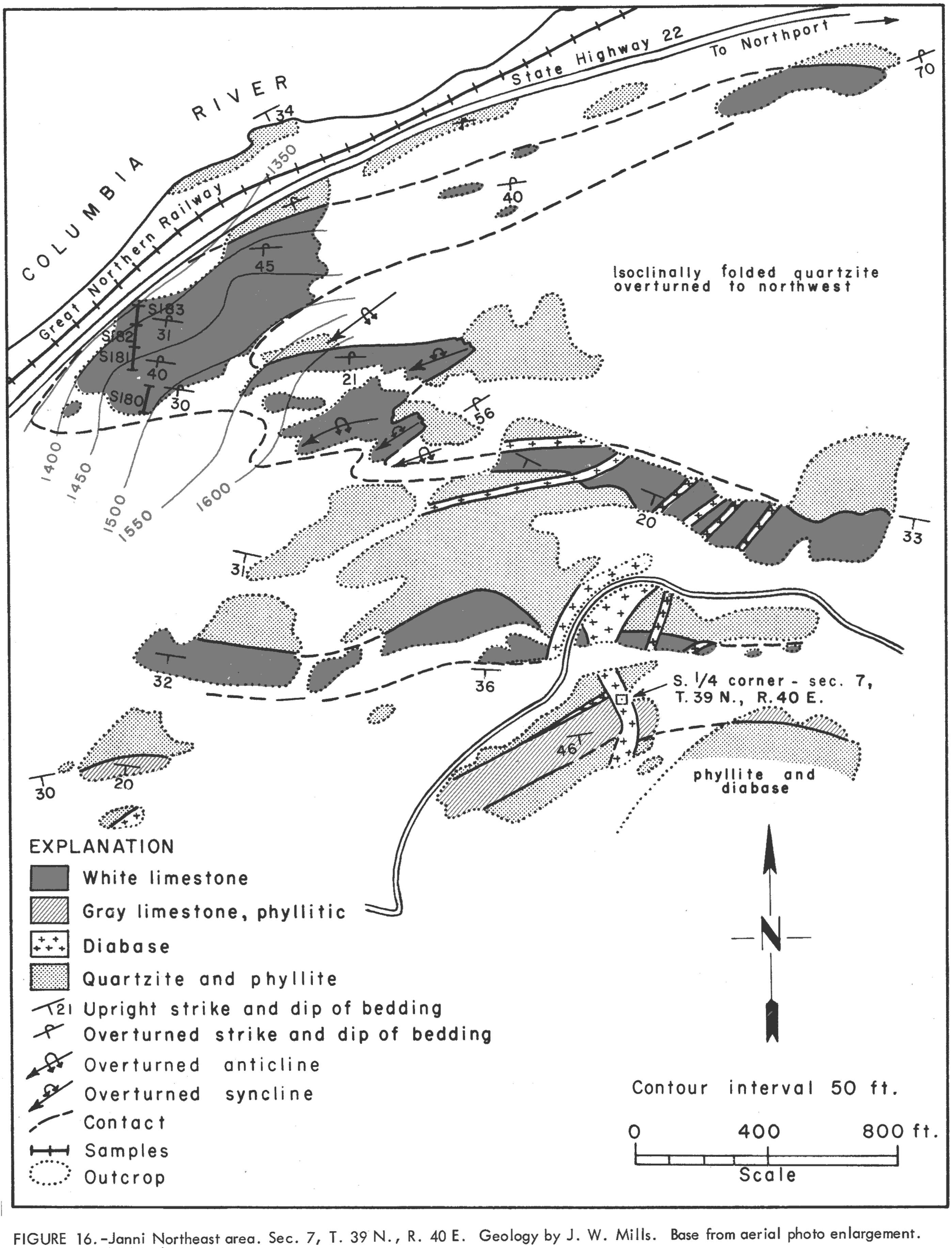

FIGURE 16.–Janni Northeast area. Sec. 7, T. 39 N., R. 40 E. Geology by J. W. Mills. Base from aerial photo enlargement. Topography by altimeter survey.

Sample no.	Length (feet)	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
S-180	75	95.19	1.96	43.00	53.48	0.94	1.37	0.68	0.034
S-181	75	95.19	0.88	42.49	53.48	0.42	2.27	1.04	0.025
S-182	62	94.66	1.23	42.21	53.18	0.59	2.68	1.17	0.032
S-183	49	87.45	2.76	40.11	49.13	1.32	6.89	2.25	0.057

Sample S-183 is too impure for most practical purposes. Samples S-180, S-181, and S-182 have an average $CaCO_3$ content in excess of 95 percent, an MgO content of 0.65 percent, and an average SiO_2 content of approximately 2.10 percent. These three samples are representative of a true thickness of 240 feet of white limestone. It is estimated that the amount of this kind of rock available above the level of the State Highway is at least 3.3 million tons. Considering the fact that small outcrops of the same limestone continue for half a mile to the northeast, it is reasonable to expect the total amount of limestone to be as much as 6 million tons.

The rock meets the chemical specifications for use as a mineral filler and in the manufacture of portland cement and builders' lime.

Situated as it is, this limestone is readily accessible by road, rail, and water. The closeness of the highway is not entirely advantageous, however, because mining operations would have to be planned and carried out so as not to impede or endanger traffic.

Onion Creek Deposit
Sec. 25, T. 39 N., R. 39 E.

Location, accessibility, and ownership.—Limestone crops out in the NE¼SW¼SW¼ sec. 25, T. 39 N., R. 39 E., in the valley of Onion Creek 1 mile due east of the quarries of the Ideal Cement Company and 5 miles in a direction S. 25° W. from Northport. The property, owned by Louis Menegas, of Northport, can be reached easily by driving 2.7 miles up the Onion Creek road from State Highway 22. The outcrops are 125 feet above and 400 feet northeast of the Onion Creek road (fig. 17). The nearest railroad facilities are at Northport.

Geology.—The limestone forms the western extremity of a tongue of dolomitic limestone that is part of a much more extensive area of carbonate rocks to the east. The limestone is white on fresh surfaces and white to light gray on weathered surfaces. It is medium grained and moderately well bedded. The strike of the bedding ranges from N. 55° E. to N. 75° E., and the dip is 35° SE. The minimum stratigraphic thickness of the limestone exposed in the outcrop area is 210 feet. This relatively pure limestone is conformably overlain to the southeast by a very great, but undetermined, thickness of siliceous, dolomitic limestone. This impure limestone is gray to dark gray, medium grained, and thin bedded. It contains abundant nodules and blebs of dolomite that weathers brownish gray, from 4 to 10 percent silica in the form of blebs and stringers, and some disseminated tremolite. Dips are toward the east, and strikes range from northeast to north.

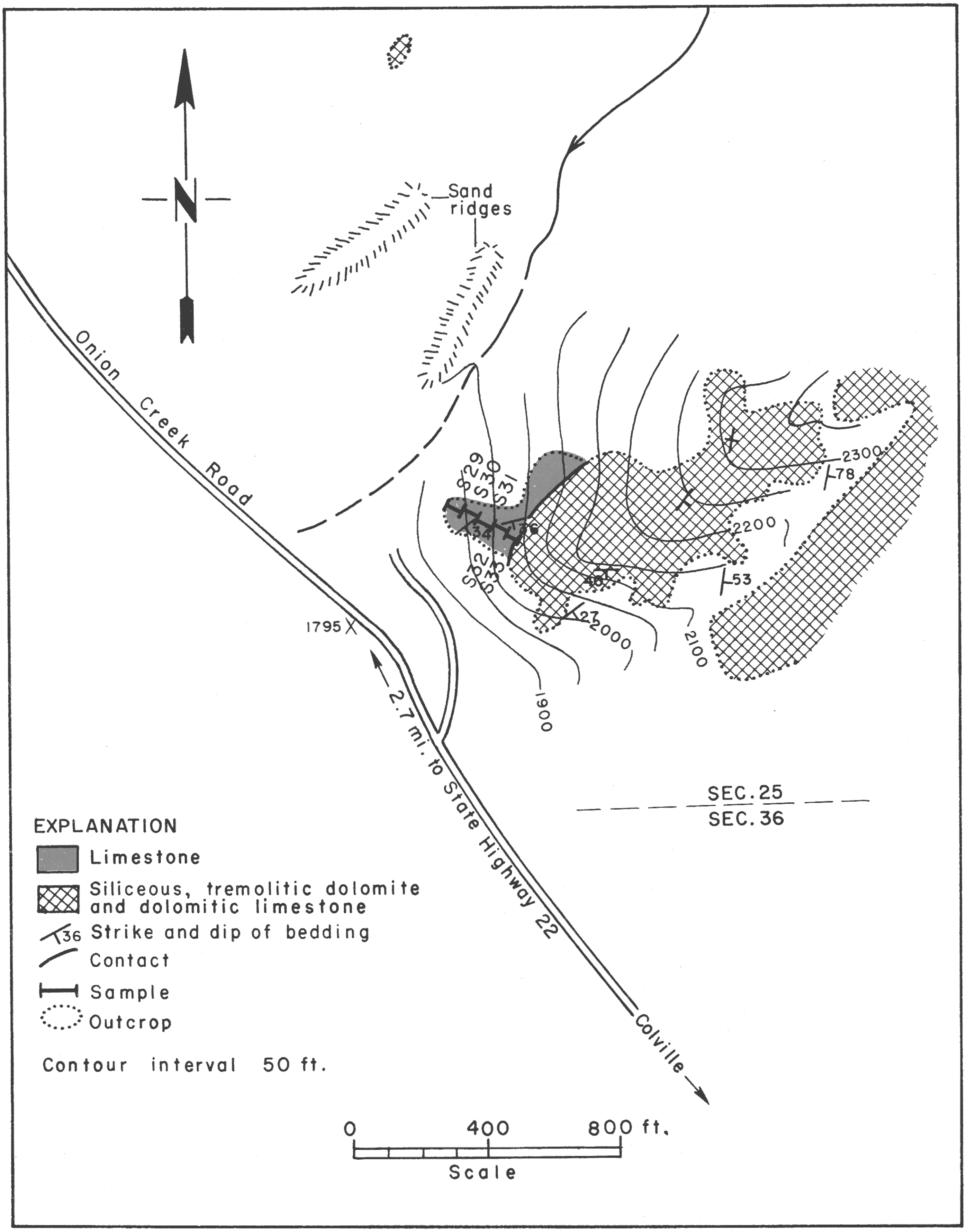

FIGURE 17.-Onion Creek deposit. Sec. 25, T. 39 N., R. 39 E. Geology by J. W. Mills. Base from aerial photo enlargement. Topography by altimeter survey.

Quality and quantity of limestone.—Five samples (S-29 to S-33) were taken in a direction S. 65° E. across the entire extent of the white limestone outcrop. Analyses of these are as follows:

Sample no.	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)
S-29	50	97.37	1.34	43.54	54.70	0.64	0.59	0.31	0.005				
S-30	50	97.29	1.09	43.51	54.66	0.52	0.53	0.35	0.005				
S-31	50	97.49	1.30	43.30	54.77	0.62	0.54	0.29	0.003	220	570	40	45
S-32	50	97.29	1.25	42.73	54.66	0.60	0.70	0.37	0.058				
S-33	38	95.39	1.44	42.03	53.59	0.69	2.56	0.36	0.039				

The unweighted average composition is 54.48 percent CaO, 0.61 percent MgO, 0.98 percent SiO_2, 0.34 percent R_2O_3, and 0.022 percent P_2O_5. All samples have a remarkably low MgO content; all except S-33 contain less than 1 percent SiO_2 and more than 97.5 percent $CaCO_3$. According to the average composition, the limestone meets the specifications for use as chemical lime, metallurgical lime, builders' lime, mineral filler, and in the sugar, pulp and paper, and portland cement industries. It meets all the chemical specifications, except P_2O_5 content, for use in the manufacture of calcium carbide. The amount of such high-calcium limestone available above an altitude of 1,900 feet, and within an area 400 feet long and 300 feet wide, is estimated to be 800,000 tons.

Northport Smelter Quarry
Sec. 33, T. 40 N., R. 40 E.

Location, accessibility, and ownership.—An abandoned quarry in sec. 33, T. 40 N., R. 40 E., is said (Hodge, 1944, p. 53) to have supplied a large tonnage of limestone flux for the former Northport smelter. The quarry is on a strip of land, 80 feet wide, between the Great Northern Railway and State Highway 22A, 0.9 mile east of Northport (fig. 18). The property is now (1960) owned by Mrs. R. J. Evans, of Northport.

Geology.—Limestone is exposed in the quarry and in the nearby railroad and highway rock cuts. It is light gray to gray on fresh surfaces, gray on weathered surfaces, medium grained and thin bedded. There are a few thin interbeds of dolomite. The bedding is well developed and ranges in strike from N. 65° E. to due east; it dips from 64° to 74° S. The true thickness of limestone is approximately 125 feet. At the northeast end of the quarry (fig. 18) the limestone becomes quite dolomitic. The southwest end of the quarry is in limestone only a few feet below the overlying dolomite. Three small mafic dikes were mapped cutting directly across the strike of the carbonate rocks.

Quality of limestone.—Three samples (S-20, S-21, and S-22) were taken near the base of the steep quarry face. The results of the analyses of these are as follows:

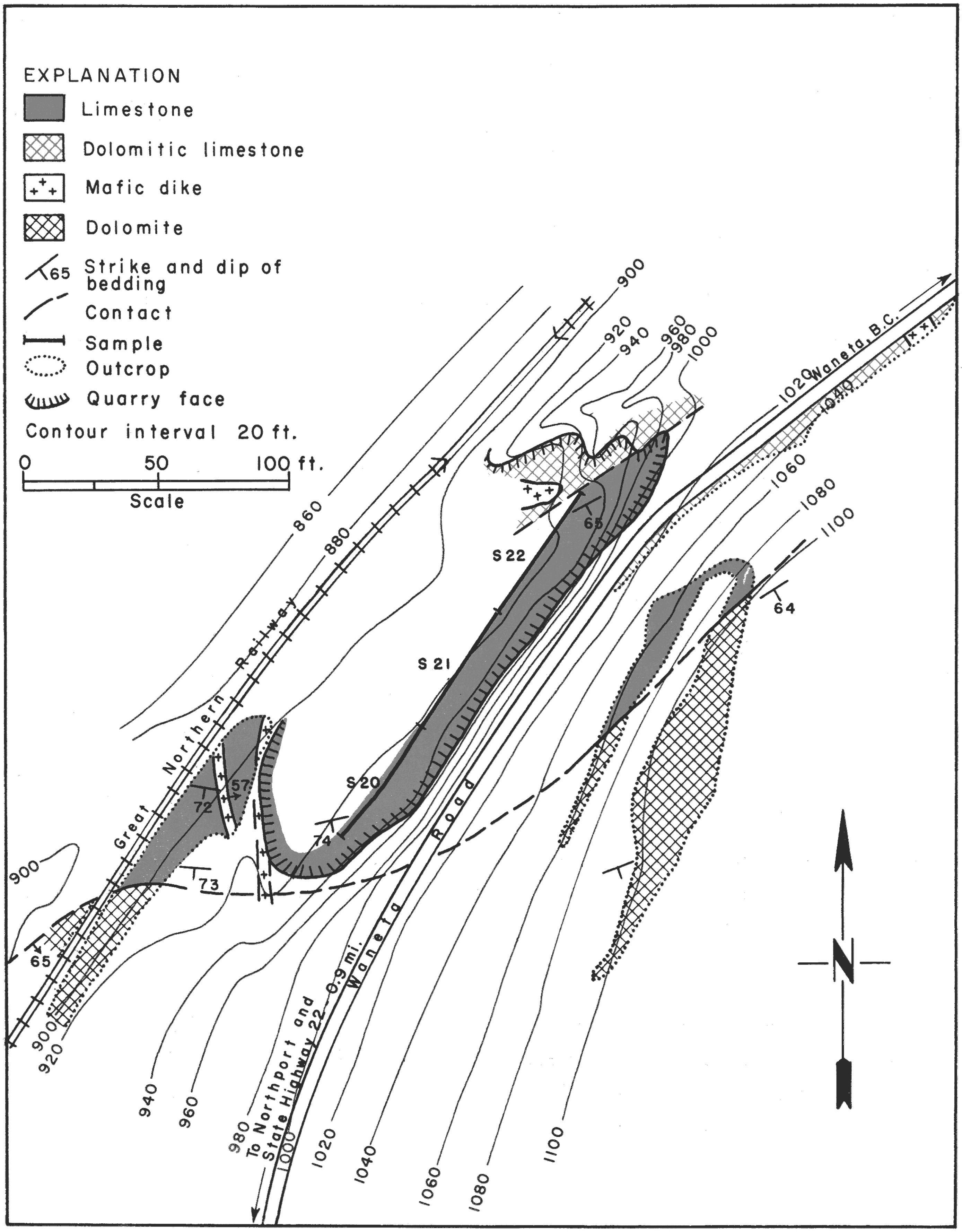

FIGURE 18.-Northport smelter quarry. Sec. 33, T. 40 N., R. 40 E. Geology by C. E. Stearns and C. D. Rau. Base and topography by plane table and alidade survey.

Sample no.	Length (feet)	True thickness (feet)	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
S-20	52	37	93.11	5.18	43.18	52.31	2.48	0.90	0.32	0.035
S-21	52	37	84.85	13.00	43.63	47.67	6.22	1.44	0.31	0.043
S-22	54	39	93.31	5.16	43.40	52.42	2.47	0.69	0.42	0.056

The limestone contains too much magnesia for most uses. Furthermore, the former operators removed all the limestone available below the level of State Highway 22A. Any new development would have to start above the road, where there is considerable overburden and the slopes are steep. It is quite unlikely that this rock will ever have any commercial value.

John Sherve Property
Sec. 8, T. 39 N., R. 40 E.

Location, accessibility, and ownership.—Carbonate rocks crop out on a west-facing hill slope approximately 1 mile south of Northport. The best exposures are in the SE¼NW¼ sec. 8, T. 39 N., R. 40 E., but there are exposures also in the NE¼SW¼ sec. 8, T. 39 N., R. 40 E. Although the deposit sometimes has been referred to as the "Janni Blue Limestone deposit," county records show that the property is owned by John Sherve, of Northport. It is conveniently located within a few hundred feet of State Highway 22 approximately 1.2 miles southwest of Northport and within 1,000 feet of the Great Northern Railway.

Geology.—The limestone is found on the southern three-fourths of a prominent hill 490 feet high, 1,700 feet long, and 800 feet wide (fig. 19). It has been mapped by Weaver (1920) as part of his Northport Formation. The strata are the northward continuations of those mapped and sampled on the Ester Sherve property, 1,000 feet to the south. The northern end of the hill is composed of dolomite. The crest of the hill consists of a slightly dolomitic limestone. The remainder is light-gray to gray, medium-grained, moderately well bedded limestone striking from N. 20° W. to N. 40° W. and dipping approximately 35° W. The true thickness of limestone exposed is about 300 feet. Two small diabase dikes have intruded the carbonate rocks.

Quality and quantity of limestone.—Many years ago a small quarry was started, at the corner of the hill closest to the highway, from which probably 2,000 tons of rock was removed. According to Peter Janni (oral communication) this rock was shipped to a sugar manufacturer. Inspection of the quarry revealed that, except for a very little limestone at the start, most of the quarry operation was in dolomite and dolomitic limestone.

Six chip samples of the limestone near the summit of the hill were taken by the Hecla Mining Company in 1958. These samples were taken around the perimeter of an area 1,200 feet long and 200 feet wide. The approximate location of these samples is shown on figure 19. Because the samples were

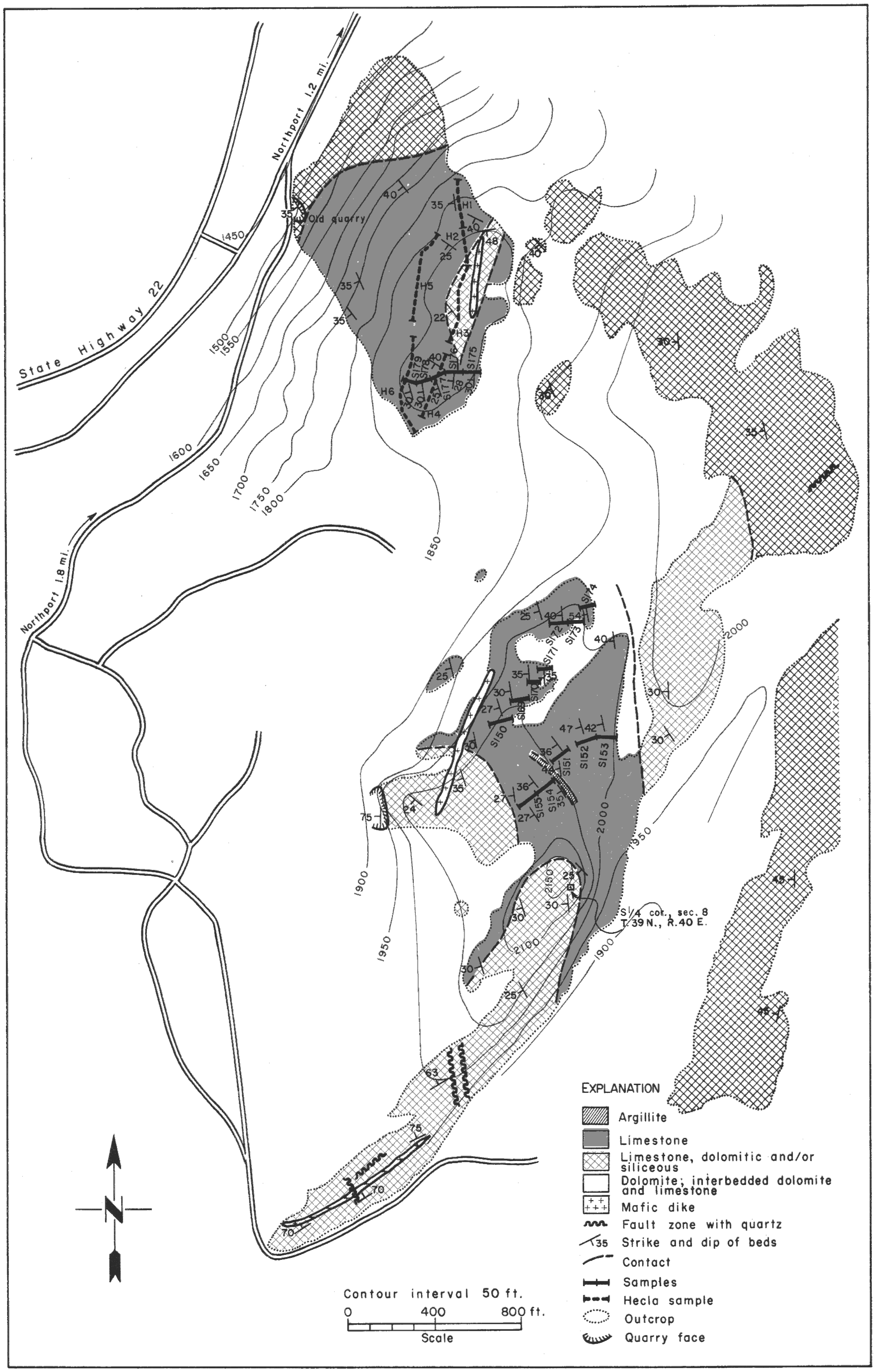

FIGURE 19.–John and Ester Sherve properties. Sec. 8, T. 39 N., R. 40 E. Geology by J. W. Mills, C. E. Stearns, and R. D. Boettcher. Base map from aerial photo enlargement. Topography from altimeter survey.

taken on bearings between N. 26° E. and N. 28° W., it is estimated that they are representative of a true thickness of 200 feet, or two-thirds of the entire thickness of limestone exposed. The samples were analyzed by the Inland Analytical Laboratories of Spokane and reported (written communication) as follows:

Sample no.	CaO	MgO	$CaCO_3$ (calculated)	$MgCO_3$ (calculated)	Length (feet)
1	55.18	0.54	98.47	1.14	230
2	54.84	0.54	97.87	1.14	160
3	54.12	1.40	96.58	2.92	385
4	54.90	0.77	97.97	1.61	335
5	55.08	0.54	98.30	1.13	445
6	54.24	0.64	96.80	1.34	400
Weighted average	54.68	0.77	97.58	1.61	

The analytical results for an equal weighted composite of the six samples are as follows:

CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	P_2O_5
*	*	0.90	0.19	0.18	0.016

(* Not determined)

Five samples (S-175 to S-179, inclusive) were taken across the strike of the bedding near the south end of the outcrop (fig. 19). The total horizontal sample length of 380 feet is representative of a true thickness of 170 feet of limestone. The rock sampled is a light-gray limestone, slightly lighter gray on weathered surfaces, medium grained, and moderately well bedded. It appears to be quite free of impurities of any kind. Analyses of these samples are as follows:

Sample no.	Length (feet)	$CaCO_3$	$MgCO_3$	CaO	MgO	SiO_2	R_2O_3	P_2O_5
S-175	75	98.52	0.56	55.35	0.27	0.39	0.12	0.003
S-176	75	98.52	0.54	55.35	0.26	0.13	0.16	0.003
S-177	75	98.40	0.42	55.28	0.20	0.35	0.17	0.006
S-178	75	97.60	0.71	54.83	0.34	0.69	0.14	0.006
S-179	80	97.72	0.59	54.90	0.28	1.29	0.00	0.012

The unweighted average composition is 55.15 percent CaO, 0.27 percent MgO, 0.57 percent SiO_2, 0.12 percent R_2O_3, and 0.006 percent P_2O_5. The rock is a high-calcium limestone of exceptional purity. Chemically, it meets the specification for all high-calcium limestone uses, with the exception of use in the glass industry.

The tonnage of high-calcium limestone is difficult to determine for two reasons. First, it is not known what shape and extent the area of slightly dolomitic limestone will have with depth. Second, exposures are small and few on the hillside west of the area sampled by Hecla, so that it is not known what additional valuable limestone may exist there. In order to be conservative, the potential volume of high-calcium limestone is calculated only for the area sampled, omitting consideration of the rock beneath the slightly dolomitized area at the hill crest and the rock downslope from Hecla's samples No. 5 and No. 6. The amount of high-calcium limestone within these limits is approximately 25,000 tons per vertical foot, or 11 million tons to the altitude of State Highway 22.

Ester Sherve Property
Sec. 8, T. 39 N., R. 40 E.

Location, accessibility, and ownership.—One mile due south of Northport there are several bare rock ridges made up of limestone, dolomitic and silicified limestone, and pure dolomite. Most of the purer limestone is in the SE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 8, and the SW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 8, T. 39 N., R. 40 E., on property owned by Ester Sherve, Northport; there are small extensions of the limestone into the NW$\frac{1}{4}$NE$\frac{1}{4}$ sec. 17, and the NE$\frac{1}{4}$NW$\frac{1}{4}$ sec. 17, T. 39 N., R. 40 E. (fig. 19). The area can be reached easily by driving south 1 mile from a point on State Highway 22, 1.2 miles south of the center of Northport. The Great Northern Railway passes through Northport.

Geology.—All outcrops are carbonate rocks of the Metaline Limestone. At the southwest end of the outcrop area (fig. 19) the strata strike northeast and dip 70° NW. About a quarter of a mile to the northeast the strike changes rather abruptly to north and north-northwest; dips here are from 25° to 35° to the west. The western extremities of the outcrop area are intensely fractured, dolomitized, and silicified. The northeast-trending dolomitic limestone ridge, in the NW$\frac{1}{4}$ sec. 17, T. 39 N., R. 40 E. contains numerous white quartz veins and stringers and consequently is much too impure to be of any value. The rocks that lie above and below the pure limestone are gray medium-grained dolomitic limestones containing numerous blebs, nodules, and lenticles of gray dolomite. Toward the east the dolomitic limestone beneath the pure limestone becomes increasingly dolomitic, owing to an increasing number of blebs and masses of dolomite. Some of the masses of relatively pure dolomite are quite irregular in form, but most of them are tabular owing to the selective dolomitization of beds of limestone. The pure limestone crops out for a length of a quarter of a mile along the northwest side of the outcrop area. It is estimated to have a true thickness of 600 feet. Toward the south, in the vicinity of the quarter-section post, the limestone is split into two parts by an intervening dolomitized section.

Quality and quantity of limestone.—The pure limestone is light gray to gray on fresh surfaces, light gray on weathered surfaces, fine to medium grained, and very thin bedded. Samples S-150 to S-155 and S-169 to S-174 were taken across the strike of the strata in the central part of the outcrop area; they represent a true thickness of 450 feet of limestone. The results of the analysis of these samples are as follows:

Sample no.	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)
S-150	100	98.47	0.88	43.71	55.32	0.42	0.21	0.10	0.006				
S-151	100	98.13	0.67	43.68	55.13	0.32	0.37	0.14	0.007				
S-152	100	98.04	1.17	43.82	55.08	0.56	0.25	0.19	0.003	175	360	-30	43
S-153	75	97.06	1.02	43.21	54.53	0.49	1.54	0.21	0.004				
S-154	100	98.52	0.73	43.93	55.35	0.35	0.14	0.20	0.004				
S-155	100	98.74	0.36	43.73	55.47	0.17	0.19	0.10	0.007				
S-169	90	98.52	1.07	43.07	55.35	0.51	0.66	0.19	0.009				
S-170	60	98.67	0.65	43.30	55.43	0.31	0.25	0.19	0.005				
S-171	55	97.72	0.73	42.65	54.90	0.35	1.28	0.15	0.010				
S-172	100	96.53	2.19	42.76	54.23	1.05	0.71	0.31	0.010				
S-173	60	97.72	0.54	43.12	54.90	0.26	1.17	0.00	0.003				
S-174	60	97.72	1.42	43.03	54.90	0.68	0.22	0.20	0.003				

The unweighted average composition is 55.06 percent CaO, 0.46 percent MgO, 0.58 percent SiO_2, 0.16 percent R_2O_3, and 0.006 percent P_2O_5. These high-calcium limestones are remarkable for their high content of $CaCO_3$ (98.01 percent) and their uniformity of chemical composition. It is somewhat surprising to find such a low MgO content (0.46 percent average) in carbonate rocks surrounded by dolomitic limestones and dolomite. The limestone has a composition suitable for all uses (e. g., chemical, metallurgical, calcium carbide manufacture, sugar, pulp and paper) except use in the glass industry. The amount of high-calcium limestone above the base of the outcrop is 5.75 million tons.

Rainey Property

Sec. 18, T. 39 N., R. 40 E.

Location, accessibility, and ownership.—The area lies 2 miles in a direction S. 30° W. from Northport. A good graveled road, leading to Northport, is only a quarter of a mile east of the outcrop area. Most of the limestone is found in the NW¼NE¼ sec. 18, T. 39 N., R. 40 E., and is owned by Stella Trombetta Rainey, of Northport. A small amount extends into the SW¼NE¼ sec. 18, T. 39 N., R. 40 E., owned by R. J. Hilton, in care of J. E. Twaddell, Northport. The nearest railroad facilities are at Northport.

Geology.—The outstanding land form is a rocky hill, in the W½NE¼ sec. 18, that rises about 300 feet above the alluvial flats on either side. From north to south (older to younger) the chief rocks cropping out on the hill are phyllite with some interbedded quartzite, white limestone, gray dolomitic limestone, and light-gray dolomite (fig. 20). These rocks are stratigraphically higher than those in the Janni Northeast area (fig. 16). Strikes and dips vary from place to place because of the presence of minor folds; in general, however, strikes are northeast to east and dips are moderate toward the southeast and south. Diabase sills and dikes of Tertiary (?) age are common in the argillaceous rocks but scarce in the carbonate rocks. The limestone lying between the phyllite and the dolomitic limestone and dolomite is very similar in appearance to the white limestone of the Janni deposits. It is white to

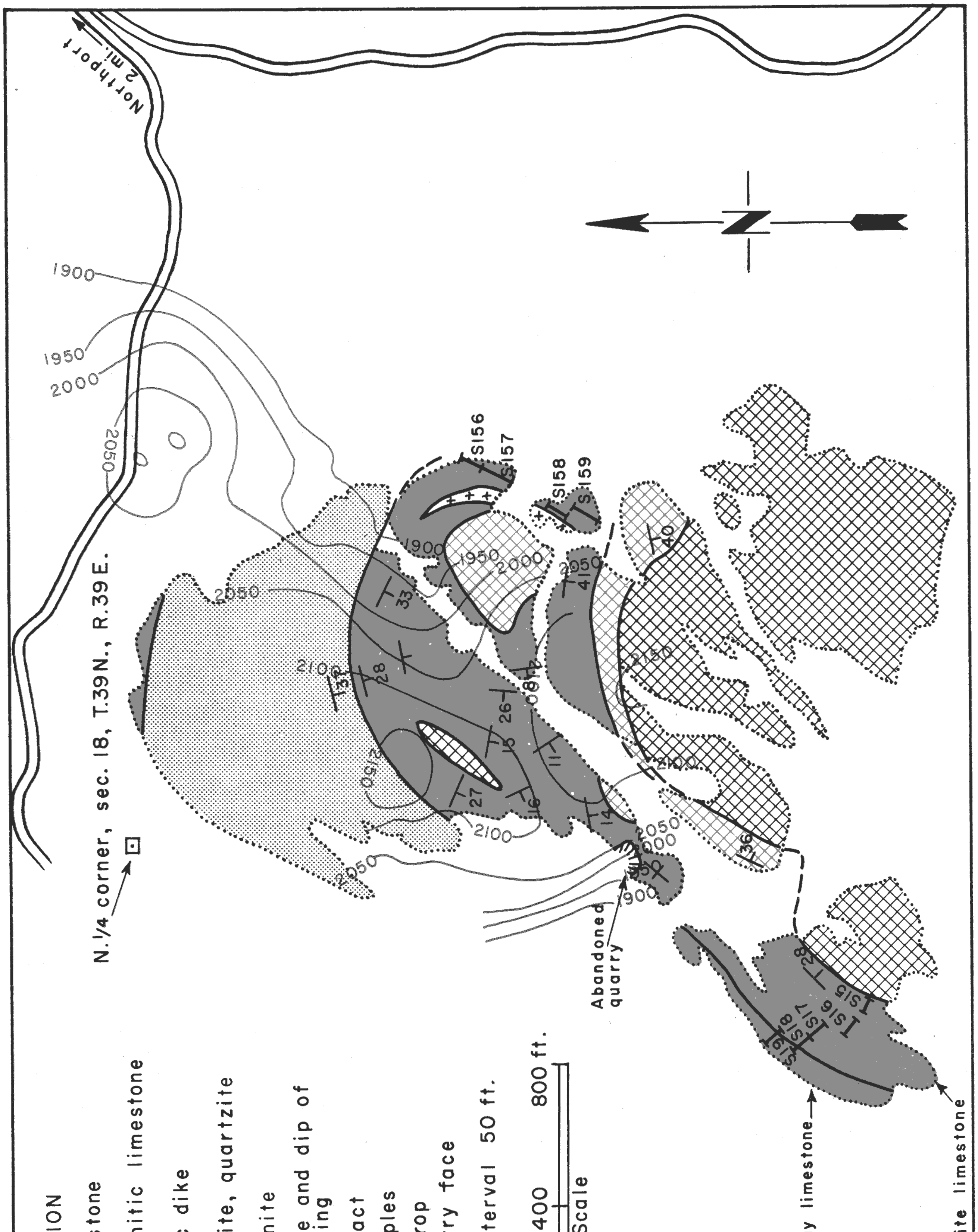

FIGURE 20.—Rainey and Broderius deposits. Sec. 18, T. 39 N., R. 40 E. Geology by J. W. Mills, C. E. Stearns, and R. D. Boettcher. Base from aerial photo enlargement. Topography by altimeter survey.

light gray on fresh surfaces, light gray to pale yellow white on weathered surfaces, medium grained and well bedded. It contains from 1 to 5 percent fine-grained disseminated muscovite, which lends a pronounced sparkle to fresh surfaces in the sunlight. The limestone is in sharp contact with the underlying phyllite and passes gradually, with increasing degrees of dolomitization, into the dolomite above. Bedding attitudes in the limestone (fig. 20) indicate that this unit has been folded into a broad open drag fold on the south limb of a major anticlinal fold, the axis of which lies half a mile to the north, in the area "Janni Northeast."

Quality and quantity of limestone.—Sampling was restricted to the very steep east side of the hill, because on the west side of the hill the slope approximates a dip slope. Sampling was begun at the base of the cliff on the east side of the hill. It was continued in a direction S. 29° W. for 440 (horizontal) feet, including a 125-foot gap where the rock was covered. The total thickness of strata considered to be represented by the four samples S-156 to S-159 is 360 feet. A tabulation of the thickness represented by each sample and their respective analyses follows:

Sample no.	Stratigraphic thickness (feet)	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
S-156	80	98.13	1.05	43.80	55.13	0.50	0.38	0.20	0.007
S-157	80	98.04	0.94	43.85	55.08	0.45	0.24	0.22	0.005
Covered interval	70								
S-158	50	93.63	4.28	43.25	52.60	2.05	1.15	0.76	0.008
S-159	80	93.13	4.18	42.99	52.32	2.00	1.67	0.98	0.007
Total	360								

Samples S-156 and S-157 are of white to very light gray, medium-grained, moderately well bedded limestone. Samples S-158 and S-159 are similar to S-156 and S-157 except that they are finer grained; they weather cream white rather than white to light gray, they contain up to 2 percent of disseminated muscovite, and they are slightly dolomitic.

The sampling shows that there is a stratigraphic thickness of probably 200 feet of high-calcium limestone containing more than 98 percent $CaCO_3$. Above this is a thickness of approximately 160 feet of limestone with a $CaCO_3$ content of slightly more than 93 percent.

The minimum amount of high-calcium limestone available in the immediate vicinity of samples S-156 and S-157 is approximately one-third of a million tons. Assuming that the continuation of these beds for 1,000 feet to the west is of approximately the same grade, then the total amount of high-calcium limestone, above an altitude of 1,950 feet, is 3.5 million tons. This limestone meets the chemical specifications for all high-calcium limestone uses, except use in the glass industry.

Broderius Deposit
Sec. 18, T. 39 N., R. 40 E.

Location, accessibility, and ownership.—The hill on which the limestone is exposed in the SE¼NW¼ sec. 18, T. 39 N., R. 40 E., can be reached by driving southwest from Northport a distance of 3½ miles to the vicinity of the quarter-section post at the northwest corner of the NE¼ sec. 18, then walking south the remaining quarter of a mile (fig. 20). According to county records, the limestone is on the property of J. D. Broderius, of Spokane. The nearest railroad facilities are at Northport.

Geology.—A stratigraphic thickness of 120 feet of light blue-gray medium-grained limestone is well exposed over a length of about 700 feet on the steep northwest side of the hill, from the base of the hill to about 75 feet above the base. Overlying the gray limestone, and extending to the summit of the hill, is a stratigraphic thickness of 225 feet of pale yellow-white, medium-grained, slightly micaceous limestone. The white limestone is the southwestward continuation of the white limestone sampled on the Rainey property. Overlying the white limestone is an undetermined thickness of gray dolomite. The strata strike northeast and dip 28° to the southeast.

Quality and quantity of limestone.—Samples S-15 to S-19 were taken from the top of the white limestone, across the strike, to the lowest exposed part of the gray limestone. The samples are representative of the upper 285 feet of limestone, except for a 40-foot-wide covered interval (37 feet true thickness), between S-15 and S-16, that was not sampled. The analyses of these samples are as follows:

Sample no.	Length (feet)	Stratigraphic thickness (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)
S-15	50	47	94.07	1.65	42.72	52.85	0.79	2.51	1.29	0.007				
Covered	40	37												
S-16	50	47	91.76	1.99	41.87	51.55	0.95	3.87	1.85	0.008				
S-17	50	47	93.98	1.84	42.43	52.80	0.88	2.82	1.27	0.011	220	630	170	30
S-18	50	47	91.97	2.13	41.72	51.67	1.02	3.26	1.42	0.014				
S-19	65	60	94.20	2.45	42.94	52.92	1.17	1.96	0.72	0.009				

The compositions of the gray and white limestones are very similar. The gray limestone is slightly richer in magnesia. The white limestone has a slightly higher content of silica and alumina (R_2O_3), which is attributed to the disseminated small flakes of muscovite present in the white limestone but lacking in the gray. None of the limestone on the hill quite meets the specifications of a high-calcium limestone, but it is sufficiently pure (92.0 to 94.5 percent $CaCO_3$ and low in MgO) to serve for the manufacture of cement.

Makynen Property
Sec. 13, T. 39 N., R. 39 E.

Location, accessibility, and ownership. —The Makynen property is in the SE$\frac{1}{4}$ sec. 13, T. 39 N., R. 39 E., close to the line between Rs. 39 and 40 E. It can be reached by driving east on a narrow graveled road for 0.9 mile from a point on State Highway 22, 3.5 miles southwest of Northport. It is about 3,400 feet due south of the Janni quarry. This property is referred to in earlier literature as the Norton-Ornduff deposit; it is now owned by Helen M. Makynen, Colville. The Great Northern Railway is 0.8 mile west of the property.

Geology. —Limestone crops out on a bare rock hill 2,000 feet long, 600 feet wide, and 400 feet high (fig. 21). The bedding strikes N. 50° E. and dips steeply west to vertical and steeply east. Drag folds in the limestone indicate that the rocks make up part of the locally overturned northwest limb of an anticline plunging at a low angle to the southwest. In plan view, the hill is bisected longitudinally by a gray to dark-gray, fine-grained, moderately well bedded limestone, from 50 to 75 feet thick. Northwest of the gray limestone the hill is composed of a white to yellow-white, medium- to coarse-grained, massive limestone that weathers to a brownish-yellow color. This unit contains a small amount of fine-grained disseminated muscovite and has a true thickness of about 250 feet. To the southeast of the gray limestone is another yellow-white coarse-grained limestone about 300 feet thick. The yellow-white limestones on each side of the gray limestone are a great deal alike, except that the one to the southeast has several percent of disseminated muscovite and a few thin interbeds of muscovite phyllite. To the east the limestones are in fault contact with dolomite that makes up the bulk of the mountain in the adjacent section (sec. 18, T. 39 N., R. 40 E.). The limestones are intruded by two small diabase dikes, as shown in figure 21.

Quality and quantity of limestone. —Three small quarries, now abandoned, were started many years ago about halfway along the northwest side of the hill and at its southwest end. According to Hodge (1938, p. 120), 500 tons of rock was shipped from these quarries to the Rainier Pulp and Paper Company, at Shelton, Washington. Samples of this rock, as shipped, were analyzed by E. W. Lazell and gave the following results (Hodge, 1938, p. 121):

Sample no.	CaO	$CaCO_3$ (calculated)
1	55.32	98.78
2	55.40	98.93
3	55.44	99.00
4	55.34	98.82
5	55.38	98.69

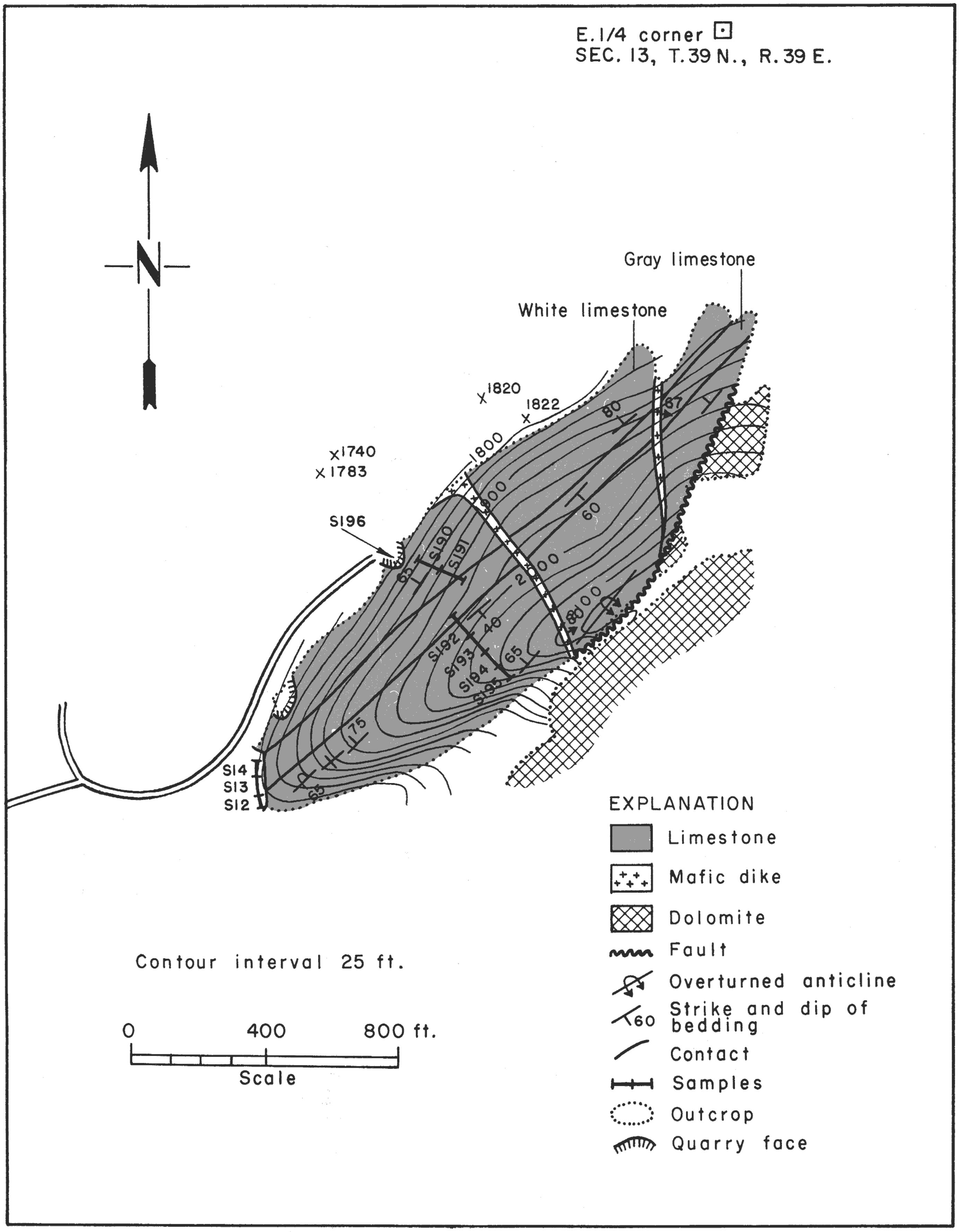

FIGURE 21.–Makynen deposit. Sec. 13, T. 39 N., R. 40 E. Geology by J. W. Mills. Base from aerial photo enlargement. Topography by altimeter survey.

Analyses

Constituents	1*	2**
CaO	54.62	55.05
MgO	0.28	0.06
SiO_2	0.86	0.82
R_2O_3	0.40	1.12
Ignition Loss	43.74	42.30
Total	99.90	99.35

* Gray limestone.
**Sample from cuts on west side (white limestone).

During the present study three samples (S-12, S-13, and S-14) were taken horizontally across the face of the small quarry at the southwest end of the hill; six samples (S-190 to S-195, inclusive) were taken across the strike of the formations about 800 feet northeast of S-13; and one sample, S-196, was composed of chips from 20 limestone boulders broken from the quarry on the west side of the hill (fig. 21).

Sample S-13 is 60 feet long and represents a true thickness of 54 feet of fine-grained gray limestone. Sample S-14 is 50 feet long and represents a true thickness of 45 feet of yellow-white coarse-grained limestone. Sample S-12, 26 feet long, represents a true thickness of 11 feet of yellow-white coarse-grained micaceous limestone. Sampling was not continued farther to the southeast of S-12 because of the greatly increased amount of muscovite in the limestone, both as disseminated flakes and thin phyllite interbeds. Samples S-190 to S-195, inclusive, are estimated to be representative of a true thickness of about 400 feet of limestone.

Sample no.	Length (feet)	True thickness (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)
S-12	26	11	91.39	2.70	42.72	51.34	1.29	2.16	1.39	0.010				
S-13	60	54	93.34	2.97	43.65	52.44	1.42	1.40	0.74	0.004	250	620	-30	180
S-14	50	45	93.09	2.99	43.38	52.30	1.43	1.50	0.79	0.006				
S-190			96.80	1.17	42.91	54.38	0.56	1.33	0.65	0.011				
S-191			93.98	2.63	42.61	52.80	1.26	2.02	0.94	0.004				
S-192	435	400	88.93	1.67	40.02	49.96	0.80	6.00	2.30	0.014				
S-193			93.43	1.57	42.34	52.99	0.74	2.30	0.90	0.006				
S-194			91.19	2.51	41.62	51.23	1.20	4.17	1.56	0.009				
S-195			93.45	1.94	41.98	52.50	0.93	2.54	1.13	0.007				
S-196			96.99	0.96	43.26	54.49	0.46	1.16	0.31	0.017				
Average						52.44	1.01	2.46	1.07	0.009				

The analyses show that the rock is not a high-calcium limestone. However, it is quite suitable for the manufacture of portland cement. The amount of limestone on this hill, above an altitude of 1,775 feet above sea level, is 75 million tons.

Ideal Cement Company Northport Quarries
Secs. 26, 27, and 34, T. 39 N., R. 39 E.

Location, accessibility, and ownership.—The property of the Ideal Cement Company, of Denver, Colorado, is 6 miles due southwest of Northport and about 2 miles east of Marble. The property includes the SW$\frac{1}{4}$ sec. 26, S$\frac{1}{2}$SE$\frac{1}{4}$ sec. 26, N$\frac{1}{2}$NW$\frac{1}{4}$ sec. 35, and part of the SE$\frac{1}{4}$ sec. 27 and NE$\frac{1}{4}$ sec. 34, T. 39 N., R. 39 E. It is served by a spur of the Great Northern Railway and a good graveled road from State Highway 22, 1.4 miles to the west.

Operation.—Current production of approximately 15,000 tons per month is obtained from two of five quarries in the SW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 26, T. 39 N., R. 39 E. The position, shape, area, and altitude of each of the producing quarries, Pit No. 2 and Pit No. 3, are shown on plate 4. Rock is mined by benching; the broken rock is loaded by Marion shovel into 6-ton Dumptor trucks and delivered to the quarry crushing plant. After crushing to minus 2$\frac{1}{2}$-inch size the rock is loaded into railroad gondola cars for shipment to the Ideal Cement Company cement plant at Irvin, Washington, 8 miles east of Spokane. According to Libbey (1957, p. 76), a stockpile of about 50,000 tons of stone is maintained at the quarry site. By drawing on different parts of the stockpile as needed for blending, a uniform kiln feed is maintained. Sixteen men are employed.

Geology.—The plant and quarries are located at the base and northwest side of a prominent hill (pl. 4 and fig. 22). The hill extends from 700 feet southwest of the operating quarries to Onion Creek, 1 mile to the northeast. It has a width of about half a mile and rises from an altitude of 1,800 feet above mean sea level at the plant site to 2,825 feet at the summit. It is composed of carbonate rocks which have been divided into three distinct units in the course of geologic mapping. The three units are distinguished from each other on the basis of color, grain size, layering, and purity.

The lower limestone unit, which has supplied all the production to date, is predominantly gray in color, though light-gray and dark-gray beds may be present in amounts as great as 20 percent each. It is characteristically fine-grained; it is finer grained than either of the other limestone units. Bedding is well developed throughout the unit; thickness of the beds ranges from less than 1 inch to several inches. Locally, it is slightly argillaceous, as in Pit No. 1 and Pit No. 4. Interbeds of dark-gray to black dolomite are common, although their total volume is relatively small. Fine-grained quartz, in small blebs and irregular wormlike forms up to 1 inch long, occurs in the more dolomitic parts of the unit, especially in the outcrops around the top of the south face of Pit No. 2, where it makes up as much as 40 percent of the rock. The total thickness of the lower limestone unit is not known, but it is at least 800 feet.

The middle limestone unit is white to light gray in color. The content of gray and dark-gray beds averages less than 5 percent. Grain size ranges from medium to coarse, generally coarser than either of the other two units. The rock is relatively massive; bedding can be recognized in some outcrops, but it is weakly developed. The middle unit seems to be much the purest of the three units. Weathered

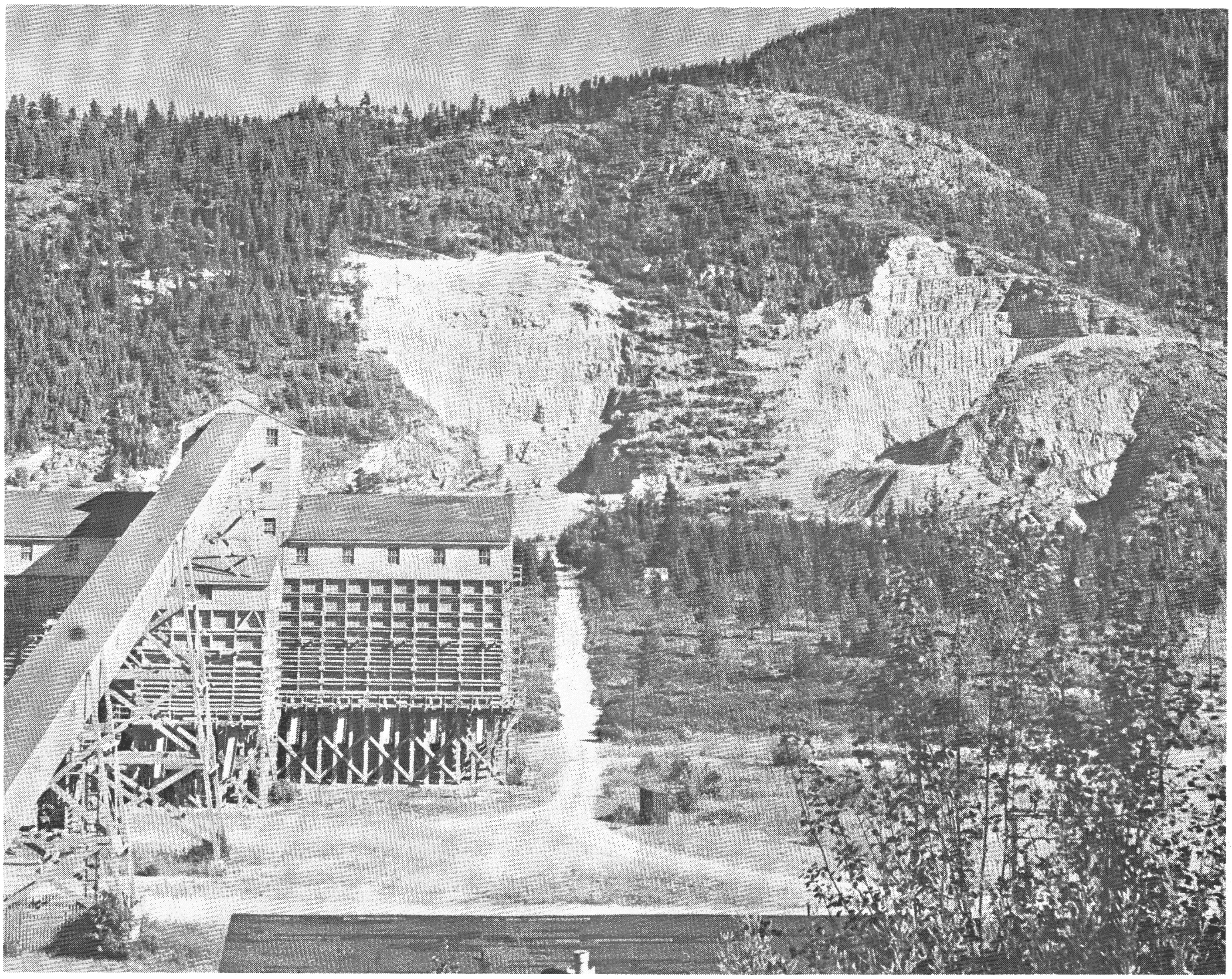

FIGURE 22.—Ideal Cement Company Northport quarries.

surfaces display the smooth rounding and pitted nature typical of higher grade limestones. A few light-gray to white dolomitic limestone interbeds were recognized, but they are scarce as compared to the other two units. Rock cropping out at the northeast end of the hill (pl. 4), presumed to be an extension of the middle unit, is dolomitic limestone and dolomite. The dolomite content increases toward the northeast and is believed to be the product of hydrothermal dolomitization processes possibly related to a zone of structural disturbance in the valley of Onion Creek. The suggestion that the dolomite is not an original constituent of the middle limestone unit, but one that has been added by later mineralizing solutions, is further supported by the fact that the lower limestone unit similarly becomes more dolomitic toward Onion Creek. The small hill 600 feet south of the center of sec. 26 is composed entirely of dolomite and dolomitic limestone believed to be the dolomitized equivalent of the lower unit exposed in the quarries. The true or stratigraphic thickness of the middle limestone unit is estimated to be 750 feet.

The upper limestone unit is well exposed at the summit and on the southeast slopes of the mountain. The color of most of the rock is dark gray to black, though there are some gray and light-gray interbeds, especially toward the base of the unit where it is in contact with the underlying middle limestone unit near the summit of the mountain. The grain size varies from medium to coarse. It is coarser grained than the lower limestone unit and generally finer grained than the middle unit. Bedding is well developed; individual beds range in thickness from a fraction of an inch to several inches. This unit appears to be the least pure of the three. Much of it is siliceous and dolomitic. In a few places, for example at the mountain summit, it contains numerous rosettes of fibrous tremolite up to half an inch in diameter. The true thickness of this upper limestone unit is approximately 200 feet.

Above the upper limestone unit is an unknown thickness of black argillite; it is in a few small outcrops around the southwest end of the mountain and is more abundant on the north slopes of the much larger mountain in the N½ sec. 35 and the NW¼ sec. 34, T. 39 N., R. 39 E. Dikes of mafic igneous rock, from a few inches to several feet in width, cut all the carbonate rocks. They make up an insignificant proportion of the volume of the mountain; nevertheless, their size and distribution must be carefully taken into account in exploration, development, and quarrying, because they can materially reduce the average grade of a given test hole, pit, or quarry. Several such dikes are visible in the quarry walls; none are depicted on plate 4, because they are too small to show clearly on a map of this scale.

The structural geology of the area is simple as compared with that of many other areas of carbonate rock in the Northport region. The three limestone units and the overlying argillite have been folded into two major folds and several smaller ones (pl. 4). A major anticlinal axis passes through Pit No. 2, and a parallel major synclinal axis is toward the southeast side of the mountain approximately 1,800 feet from the anticlinal axis. Between these two fold axes there are at least two lesser anticlinal and synclinal axes. All fold axes have a southwest bearing; they plunge southwest at angles that vary from 20° to 30°.

Many faults, with displacements of several feet, are visible in the quarry walls. It has been mentioned previously (p. 96) that there has been considerable fracturing and addition of silica to the rocks due south of Pit No. 2; the limestones at the northeast end of the hill have been extensively dolomitized. It is quite possible that both the silicification and dolomitization are related to fault zones at both ends of the mountain.

Quality of limestone.—No samples were taken during this study, because the quality of the limestone has already been determined by the operators. Some of the results of exploratory diamond drilling have been generously made available to the author by officers of the Ideal Cement Company and serve very well to indicate the chemical nature of all three limestone units. The average CaO content of the limestone supplied each year to the Irvin cement plant, by the Ideal Cement Company quarries at Northport, is reported (written communication) as follows:

Year	Average CaO (percent)
1959	51.60
1958	51.87
1957	51.01
1956	52.29
1955	53.15
Average	51.98

The average content of MgO in the limestone is less than 1.8 percent, the upper limit that the company will accept for raw (cement) mix.

Exploratory diamond drill hole No. 11 was collared in the upper limestone unit (pl. 4) at an altitude of 2,425 feet above sea level. It was drilled for 346 feet in the direction N. 25° W. at an inclination of -45°. Analyses of core samples from hole No. 11 are as follows:

Footage	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3
0-10	85.14	6.98	39.72	47.83	3.34	8.12	0.77	0.24
10-50	94.95	3.18	42.39	53.34	1.52	2.64	0.22	0.06
50-100	92.31	4.89	42.17	51.86	2.34	3.33	0.28	0.08
100-210	80.83	13.77	41.49	45.41	6.59	6.60	0.16	0.12
210-280	85.97	4.64	39.33	48.30	2.22	9.99	0.26	0.18
280-346	97.58	1.65	42.73	54.82	0.79	1.64	0.39	0.14

The first 280 feet of diamond drill core is not high-quality limestone. In fact, only 40 of the 280 feet is sufficiently free of magnesia to be acceptable for cement-making by Ideal Cement Company standards. On the basis of these analyses and the geologic mapping it is concluded that none of the rock shown as "upper limestone unit" on the geologic map (pl. 4) is of commercial value. The last 66 feet of core from diamond drill hole No. 11 has a low content of MgO and a high content of CaO. Presumably, this rock is the down-dip extension of the middle limestone unit.

Diamond drill hole No. 1 was collared in the middle limestone unit at an altitude of 2,715 feet above the mean sea level; it was drilled for 828 feet in a direction N. 25° W. at an inclination of -45° (pl. 4). Five mafic dikes were intersected in this hole. The first 292 feet of core (excluding the combined dike core length of 35 feet) is from the upper part of the middle limestone unit and qualifies as a high-calcium limestone. The next 468 feet of core, to a hole depth of 760 feet, is from the lower portion of the middle limestone unit; it falls a little short of the high-calcium limestone category, but the rock, on the average, is quite acceptable for cement manufacture. From 760 feet to the bottom of the hole, the carbonate rocks penetrated are those of the lower limestone unit; even if the dike core sections are excluded from consideration, this section of carbonate rocks is too impure to be of any value for most uses. Analyses of the limestone core are as follows:

Footage	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3
0-6.5	97.62	1.78	43.52	54.84	0.85	0.28	0.19	0.08
6.5-10	DIKE ROCK							
10-61	98.38	1.17	43.43	55.27	0.56	0.28	0.63	0.08
61-69	DIKE ROCK							
69-93.5	95.03	1.19	42.34	53.39	0.57	2.55	0.54	0.10
93.5-117	DIKE ROCK							
117-249	94.66	1.40	42.57	53.18	0.67	2.28	0.69	0.16
249-292	96.67	1.19	42.59	54.31	0.57	2.16	0.58	0.08
292-391	91.40	4.37	42.39	51.35	2.09	2.40	1.03	0.04
391-490	93.66	2.93	42.48	52.62	1.40	2.32	0.71	0.10
490-561	89.37	1.94	39.31	50.21	0.93	8.85	0.96	0.04
561-642	98.24	0.61	42.80	55.19	0.29	1.32	0.57	0.12
642-655	74.76	23.89	43.90	42.00	11.43	1.64	1.44	0.49
655-760	96.64	1.59	42.95	54.29	0.76	1.35	0.54	0.16
760-764	74.96	23.41	44.73	42.11	11.20	0.84	0.72	0.45
764-774	DIKE ROCK							
774-787	98.54	0.84	43.14	55.36	0.40	0.65	0.55	0.06
787-792	DIKE ROCK							
792-800	81.17	3.99	37.23	45.60	1.91	12.61	1.00	2.16
800-828	29.99	27.59	14.08	16.85	13.20	36.45	8.95	7.94

Diamond drill holes No. 4 and No. 4A were collared at the same place, at an altitude of 2,210 feet above mean sea level. No. 4 was drilled for 413 feet in a direction N. 25° W., at an inclination of -70°. No. 4A was drilled for 901 feet in a direction S. $20\frac{1}{2}$° E., at an inclination of +15° (pl. 4). Core analytical data from No. 4 drill hole are as follows:

Footage	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3
1-64	80.47	17.45	43.98	45.21	8.35	1.08	0.93	0.28
64-96	98.54	0.73	43.11	55.36	0.35	0.29	0.47	0.16
96-108	76.47	1.19	32.54	42.96	0.57	22.07	1.78	0.26
108-134	93.77	1.90	42.01	52.68	0.91	3.00	0.97	0.22
134-191	89.98	8.51	43.55	50.55	4.07	0.75	0.72	0.08
191-212	95.85	2.53	42.52	53.85	1.21	1.61	1.09	0.24
212-220	DIKE ROCK							
220-264	90.28	7.15	42.93	50.72	3.42	1.88	0.99	0.22
264-309	97.33	1.11	42.59	54.68	0.53	1.57	0.61	0.16
309-351	80.08	13.86	41.68	44.99	6.63	4.68	1.43	0.36
351-413	92.26	2.05	40.57	51.83	0.98	3.76	2.31	0.16

The quality of the limestone cut by this hole varies widely. Three sections qualify as high-calcium limestone (64 to 96 feet, 191 to 212 feet, 264 to 309 feet), and one other section (108 to 134 feet) is suitable for cement manufacture. The average content of CaO for the entire core, excluding the dike, is slightly in excess of 50 percent. This fact, together with the relatively low average content of MgO, shows that the rock is acceptable for cement manufacture but quite unsuitable for high-calcium limestone uses. It is anticipated that the average grade of rock in the immediate vicinity of drill hole

No. 4 would be comparable to that quarried in the south wall of Pit No. 2.

The core analyses for diamond drill hole No. 4A are as follows:

Footage	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3
0-64	99.00	0.71	43.18	55.62	0.34	0.66	0.46	0.10
64-151	98.52	0.69	43.09	55.35	0.33	0.93	0.33	0.06
151-156	91.63	1.27	40.55	51.48	0.61	1.65	1.31	4.27
156-214	95.87	1.48	42.15	53.86	0.71	2.35	0.77	0.24
214-229	74.83	4.24	31.93	42.04	2.03	20.35	3.22	0.61
229-241	72.91	17.39	40.30	40.96	8.32	8.61	0.94	0.49
241-261	93.29	3.03	41.24	52.41	1.45	3.96	1.31	0.20
261-276	76.93	6.48	36.29	43.22	3.10	16.08	0.90	0.30
276-300	94.46	2.45	41.93	53.07	1.17	2.33	1.79	0.22
300-313	DIKE ROCK							
313-430	64.81	3.82	28.53	36.41	1.83	30.60	2.76	0.28
430-441	DIKE ROCK							
441-570	71.08	4.64	32.06	39.93	2.22	25.01	1.10	0.34
570-580	90.39	3.03	38.19	50.78	1.45	9.23	0.35	0.14
580-603	82.49	4.51	37.74	46.34	2.16	12.06	1.43	0.38
603-626	83.86	2.19	37.29	47.11	1.05	14.30	0.74	0.12
626-655	88.34	2.36	39.29	49.63	1.13	9.73	0.67	0.10
655-687	89.04	2.82	39.49	50.02	1.35	8.43	0.94	0.14
687-688	NO SAMPLE							
688-692	92.93	1.19	40.83	52.21	0.57	5.58	0.65	0.26
692-693	DIKE ROCK							
693-708	99.54	1.02	43.32	55.92	0.49	0.33	0.21	0.08
708-710	DIKE ROCK							
710-761	94.38	2.97	41.30	53.02	1.42	3.27	1.10	0.24
761-783	98.40	0.69	43.03	55.28	0.33	0.69	0.81	0.14
783-786	DIKE ROCK							
786-860	96.78	1.27	42.02	54.37	0.61	1.59	0.82	0.14
860-901	95.76	1.84	42.30	53.80	0.88	3.00	0.46	0.04

The only high-calcium limestone core of any great length is that recovered from the first 214 feet of drilling. A shorter length of core, from 710 feet to 783 feet, also is of high-calcium type. The rest of the core contains some rock suitable for cement use, but this rock is bordered by much greater thicknesses of impure limestone of doubtful value, or by worthless dike material. Drill hole 4A is directly beneath the part of the middle limestone unit that is impure (siliceous) in the surface exposure. Apparently the siliceous character of the rock persists with depth. Drill hole No. 1, 475 feet east of drill hole No. 4A, contains much high-calcium limestone and seems to verify the downward continuation of the high-calcium limestone mapped on the surface directly above it. Somewhere between holes No. 1 and No. 4A is the western limit of the high-calcium limestone of the middle limestone unit.

Quantity of limestone.—On the basis of surface mapping and core drilling, it appears that there is a large area underlain by relatively pure limestone. The area is bordered on the south and southwest by the upper limestone unit and the siliceous phase of the middle limestone unit. It is bordered on the east by the dolomitic part of the middle limestone unit. The northwest side is considered arbitrarily as the assumed extension of the surface expression (covered) of the contact between the lower and middle limestone units (pl. 4). Taking into account the dip of the strata and the plunge of the fold axes, it is estimated that there is 125 million tons of limestone between the top of the mountain and the level of the surface plant. This volume of limestone contains in excess of 90 percent $CaCO_3$. A large, but undetermined, amount (one half?) of this is high-calcium limestone, probably suitable for use as a mineral filler, builders' lime, and in the pulp and paper industry.

Other Areas of Northport District

Numerous other areas, reported to contain limestone, were examined. All were found to be entirely dolomite or to be made up of such high proportions of dolomite as to be quite valueless. Following is a list of the areas investigated and property ownership, where established:

Area	Owner
Secs. 4, 9, 16, 17, S$\frac{1}{2}$ sec. 18, and N$\frac{1}{2}$ Sec. 19, T. 39 N., R. 40 E.	not determined
SW$\frac{1}{4}$ sec. 17, T. 39 N., R. 40 E.	J. E. Twaddell, Northport
SE$\frac{1}{4}$ sec. 9, T. 39 N., R. 39 E.	United States
E$\frac{1}{2}$ sec. 3, T. 39 N., R. 39 E.	E. L. Green, Northport
E$\frac{1}{2}$E$\frac{1}{2}$ sec. 16 and W$\frac{1}{2}$W$\frac{1}{2}$ sec. 15, T. 39 N., R. 40 E.	not determined

China Bend District

China Bend Area
NW$\frac{1}{4}$ sec. 12, T. 38 N., R. 38 E.

Location, accessibility, and ownership.—Limestone crops out as a prominent hill in the NW$\frac{1}{4}$ sec. 12, T. 38 N., R. 38 E., on the south side of the Columbia River at China Bend. The outcrop is approximately 1,000 feet south of the Great Northern Railway and State Highway 22, five miles northeast of Bossburg. The hill is about 1,500 feet long and 700 feet wide; its summit is approximately 400 feet above a gravel terrace on its north side and approximately 580 feet above State Highway 22. According to county records, the property belongs to the Boise Cascade Corporation, Spokane.

Geology.—The hill is composed of complexly folded limestone and dolomite intruded by steeply dipping basic igneous rock dikes. It has been mapped as Northport Limestone by Weaver (1920). Like the Northport Limestone near Northport, it is now believed to be correlative with the Metaline Limestone (Park and Cannon, 1943) of Middle Cambrian age. The strike of the limestone bedding over most

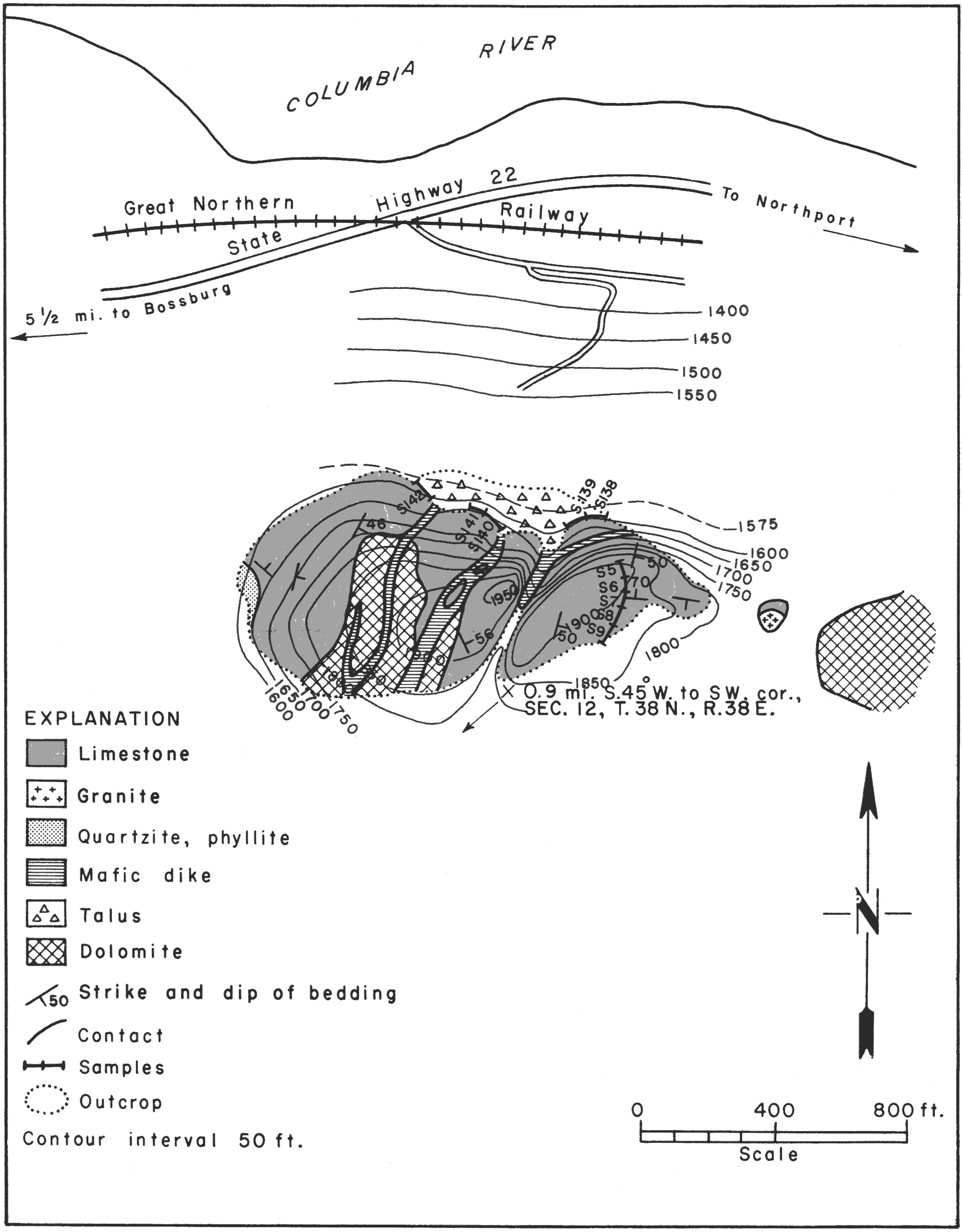

FIGURE 23.—China Bend area. Sec. 12, T. 38 N., R. 38 E. Geology by J. W. Mills. Base from aerial photo enlargement. Topography by altimeter survey.

of the deposit is from a few degrees west to a few degrees east of north; dips are approximately 50° to the east. At the east and west ends of the hill the beds strike almost due east. Where unaffected by dolomitization, the rock is a white to light-gray, medium-grained, thick-bedded limestone. This rock makes up an estimated three-fourths of the volume of the hill. Dolomitization, especially on the south side of the hill, has altered the limestone to a snow-white, medium- to coarse-grained dolomite. Usually the dolomite is in sharp contact with the limestone, but in a few places it continues irregularly into the limestone as small nodules and patches. Tremolite is found in amounts of less than 1 percent in the limestone at the east end of the hill.

Shedd (1903, p. 130 to 131) refers to marble in sec. 12, T. 38 N., R. 38 E., owned by the Florentine Marble Co., "one mile up the river" from Ryan, "a station of the Spokane Falls and Northern Railway, one hundred and eighteen miles from Spokane." He writes of the deposit as follows:

> The marble occurs on the face of a bluff that rises from the Columbia River to an altitude of perhaps 150 to 200 feet but does not extend back from the river to any very great distance . . . The deposits . . . show somewhat of a bedded structure, are fine grained, mostly of a light-gray color and a little harder than most marble.

He reports one analysis, which is reproduced below along with the analyses of samples taken during the present study.

Shedd (1913, p. 153), Hodge (1938, p. 113), and Valentine (1960, p. 7) refer to the same deposit but contribute no new information.

Quality of limestone.—Five samples (S-5 to S-9, inclusive) were taken continuously over a total length of 250 feet near the east end of the hill (fig. 23). Sampling was begun at the top of the steep bluff on the north side of the hill and was continued southward to the south side of the outcrop. Five more samples (S-138 to S-142, inclusive) were taken along the hill face at the head of the talus slope at the north side of the hill. The total sample length is 330 feet. The analyses of these ten samples, together with Shedd's samples, are as follows:

Sample no.	Length (feet)	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
Shedd		96.05	3.34	43.27	53.96	1.60	1.00	none	—
S-5	50	97.06	3.32	43.44	54.53	1.59	0.70	0.41	0.010
S-6	50	91.21	7.62	43.70	51.24	3.65	1.23	0.39	0.016
S-7	50	91.21	7.73	43.64	51.24	3.70	0.43	0.23	0.044
S-8	50	85.07	13.38	43.78	47.79	6.40	0.96	0.13	0.029
S-9	50	83.57	14.00	43.64	46.95	6.70	1.61	0.16	0.004
S-138	70	94.29	4.60	43.62	52.97	2.20	1.01	0.20	0.009
S-139	60	88.96	10.41	44.06	49.98	4.98	0.64	0.30	0.014
S-140	80	83.18	14.69	43.98	46.73	7.03	1.62	0.28	0.004
S-141	40	91.06	8.69	44.18	51.16	4.16	0.75	0.21	0.007
S-142	80	93.27	5.04	43.31	52.40	2.41	1.42	0.15	0.005

The unweighted average of the analyses made during this study shows that the rock contains 50.00 percent CaO, 3.98 percent MgO, 1.04 percent SiO_2, 0.25 percent R_2O_3, and 0.014 percent P_2O_5. The analyses indicate clearly that the rock is not a high-calcium limestone and that it contains too much magnesia for use in the manufacture of portland cement.

Columbia Rock Company Quarry Area
NW¼ sec. 14, T. 38 N., R. 38 E.

Location, accessibility, and ownership.—The operations of the Columbia Rock Company are about 4 miles north-northeast of Bossburg and 3 miles north-northwest of Williams Lake, in the NW¼ sec. 14, T. 38 N., R. 38 E. The deposit is readily accessible from State Highway 22 by 0.5 mile of paved and 0.2 mile of graveled road. The Great Northern Railway is 0.5 mile west of the deposit. The property is owned by Ivan Shovell, of Evans. John Adams, of Evans, leased the deposit and opened a small quarry in March 1958. In August 1959, he had stockpiled 7,000 tons of crushed limestone. Shipments were made to the Inland Empire Paper Company, Spokane, and to the Bunker Hill and Sullivan smelter at Kellogg, Idaho.

Geology.—Weaver (1920) mapped this limestone as Northport Limestone. No other mention is made of the deposit in the literature. The quarry is at about the midpoint on the west side of a bare rock ridge 1,800 feet long, 300 feet wide, and 200 feet high. The ridge trends approximately N. 25° E., parallel to the strike of the rocks composing it (fig. 24). From the crest to the west side of the hill, a horizontal width of 200 feet, the rocks are interbedded light- and dark-gray, medium-grained, thin-bedded limestones. For the most part they appear to be quite pure, but in a few places they contain nodules and lenticles of dolomite as much as 1 inch in diameter. Strikes range from a few degrees west of north to 30° east of north; the average strike is approximately N. 25° E. Normal dips are steep to the west; locally, the beds have been overturned so as to dip to the east. The east side of the ridge has been fractured, dolomitized, silicified, and intruded along the strike by mafic igneous dikes. The fracturing is due to extensive movement along a major fault zone lying between the carbonate rocks of the ridge and a mountain of volcanic rocks (Tertiary) 1,000 feet to the east.

Quality and quantity of limestone.—Limestone of commercial value is confined to the west side of the ridge. Five samples, S-10, S-11, S-52, S-53, and S-54, were taken across the strike of the limestone, about the middle and toward the ends of the ridge (fig. 24). Analyses of these samples are as follows:

Sample no.	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)
S-10	50	91.19	6.27	43.06	51.23	3.00	0.72	0.60	0.008	235	620	-30	30
S-11	43	96.44	2.51	42.64	54.18	1.20	0.65	0.23	0.011				
S-52	95	97.85	0.79	43.54	54.97	0.38	0.45	0.27	0.006				
S-53	75	98.51	1.17	43.44	55.34	0.56	0.38	0.15	0.018				
S-54	55	98.27	1.59	43.26	55.21	0.76	0.38	0.22	0.008				

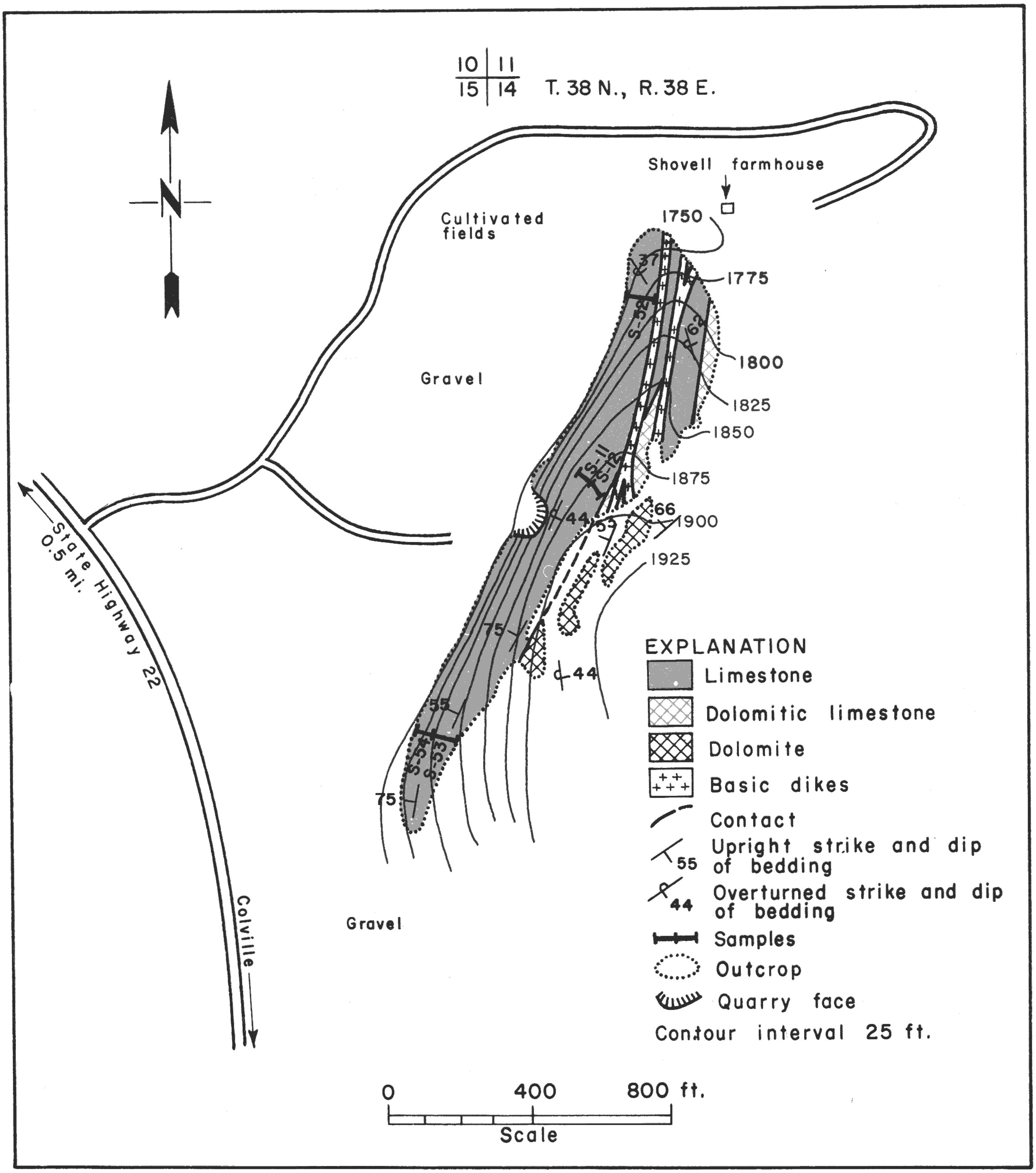

FIGURE 24.—Columbia Rock Company quarry area. Secs. 14 and 15, T. 38 N., R. 38 E. Geology by J. W. Mills. Base map from aerial photo enlargement. Topography from altimeter survey.

Sample S-10 was taken near the dolomite at the ridge crest and has a much higher MgO content (3.0 percent) than the other four samples. Samples S-11, S-52, S-53, and S-54 have an average CaO content of 55.0 percent, that is, a $CaCO_3$ content in excess of 98.5 percent. These four samples are representative of a horizontal width of 150 feet of limestone for the entire length of the ridge. The amount of high-calcium limestone estimated to be available from the level of the alluvium on the west side of the ridge to the ridge crest is 1,280,000 tons.

All samples except S-10 meet the chemical specifications for high-calcium limestone use as chemical, metallurgical, and builders' lime, as a mineral filler, and in the sugar, pulp and paper, and cement industries.

Bossburg District

Bossburg is on the shore of the Columbia River, approximately 15 miles northeast of Kettle Falls on State Highway 22, and approximately 15 miles in a direction N. 24° W. from Colville. It is serviced by a branch of the Great Northern Railway.

Weaver (1920) mapped carbonate rocks, which he called Northport Limestone, on both sides of the Columbia River, from Northport southwest as far as Bossburg. He considers the Northport Limestone to be the equivalent of the Pend Oreille Group of Daly (1912) and thus to be of possible late Paleozoic age. Campbell (1947, p. 600) believes the Northport Limestone in the Northport area to be the equivalent of the Metaline Limestone of Middle Cambrian age (Park and Cannon, 1943) of Pend Oreille County, Washington. Bowman (1950) mapped and described limestones and marbles directly across the Columbia River from Bossburg. He assigns the name Glasgo Marble to these rocks and writes (Bowman, 1950, p. 29):

> The belt of marble appears to be continuous from Glasgo Lake to Northport, except for large areas of alluvial deposits. If the marble is continuous, the Glasgo marble is equivalent to the Metaline limestone and is actually a part of it. In such an event the name Metaline should be applied to the marble near Glasgo Lakes. The writer believes the Glasgo marble very probably is equivalent to the Metaline limestone. However, he prefers to retain a distinctive name for the marble in the Orient area until the area between the east boundary of the Orient area and Northport has been mapped in detail. The Glasgo marble is considered to be probably middle Cambrian.

For the purpose of this report, the name Northport Limestone is retained for those carbonate rocks in Stevens County that are lithologically similar to, and probably the equivalent of, the Metaline Limestone.

With two exceptions, the outcrops of the Northport Limestone between Bossburg and Marble, on both sides of the Columbia River, were found to be composed of interbedded dolomitic limestone and dolomite, or to be essentially pure dolomite. The two exceptions are rather extensive outcrops of relatively pure limestone; one of these is three-quarters of a mile east and the other is three-quarters of a mile north of Bossburg.

Bossburg East Area
Sec. 33, T. 38 N., R. 38 E.

Location, accessbility, and ownership.—Two prominent bare limestone hills are to be found three-quarters of a mile east of Bossburg, in the E½ sec. 33, T. 38 N., R. 38 E., on land owned by Fred and Bill Carrol of Evans. The area is readily accessible from State Highway 22 and the Great Northern Railway at Bossburg.

Geology.—The larger of the two hills (fig. 25 and 26) is approximately 1 mile long and ½ mile wide. Its summit (altitude 2,110 feet above sea level) stands approximately 750 feet above Bossburg and 300 feet higher than the fields to the east of the hill. The smaller hill, a few hundred feet south of the larger hill, is 1,600 feet long and 1,000 feet wide; its summit (altitude 1,965 feet above sea level) is approximately 215 feet above the surrounding fields and 145 feet lower than the summit of the larger hill. Both hills are composed of very well bedded (thin-bedded), medium-grained limestone (fig. 1) that varies in color from white through tones of gray to dark gray. Although the light tones of gray predominate, the presence of the dark-gray rock emphasizes the well-developed layering. Extensions and satellite outcrops to the west of the larger hill have been dolomitized to varying degrees. The dolomite occurs as layers, irregular masses, and nodules, generally darker in color than the limestone, with their longer axes parallel to the bedding of the limestone. The rocks in the east sides of both hills have been extensively dolomitized and silicified. Silica has replaced the carbonate rocks

FIGURE 25.—Large hill of limestone, sec. 33, T. 38 N., R. 38 E., three-quarters of a mile east of Bossburg. View looking north.

to varying degrees, and white quartz stringers and veins are abundant, especially along intensely fractured zones. The eastern extremities of the hills are made up of siliceous limestone breccia and quartz breccia. To the east of the smaller limestone hill, and separated from it by the breccia zone, are outcrops of dark-gray, calcareous argillite.

The structural geology of the larger hill seems to be fairly simple. Practically all the limestone on this hill lies on the east limb of a syncline (fig. 27), the axis of which bears N. 30° E. and plunges at a low angle toward the northeast. The bedding strikes within a few degrees of north over most of the hill. Dips range from 10° to 37°, except close to outcrop margins where faulting may have been responsible for steepening or reversing of the dips. Folds in the limestones of the smaller hill (fig. 26) are much more numerous and more complex than those of the larger hill. Although the strikes of the limestone beds are consistently to the northeast, the dips vary abruptly and widely from flat to steeply inclined, both toward the southeast and northwest. The major structural feature seems to be a syncline, the axis of which bears northeast and lies along the summit of the smaller hill. This major fold is distorted toward the northeast end of the outcrop and it has a number of lesser folds developed along its axis. None of the folds have a discernible plunge. Silicified and brecciated fracture and fault zones, striking from north to northwest and steeply inclined, cut the limestones and dolomitic limestones.

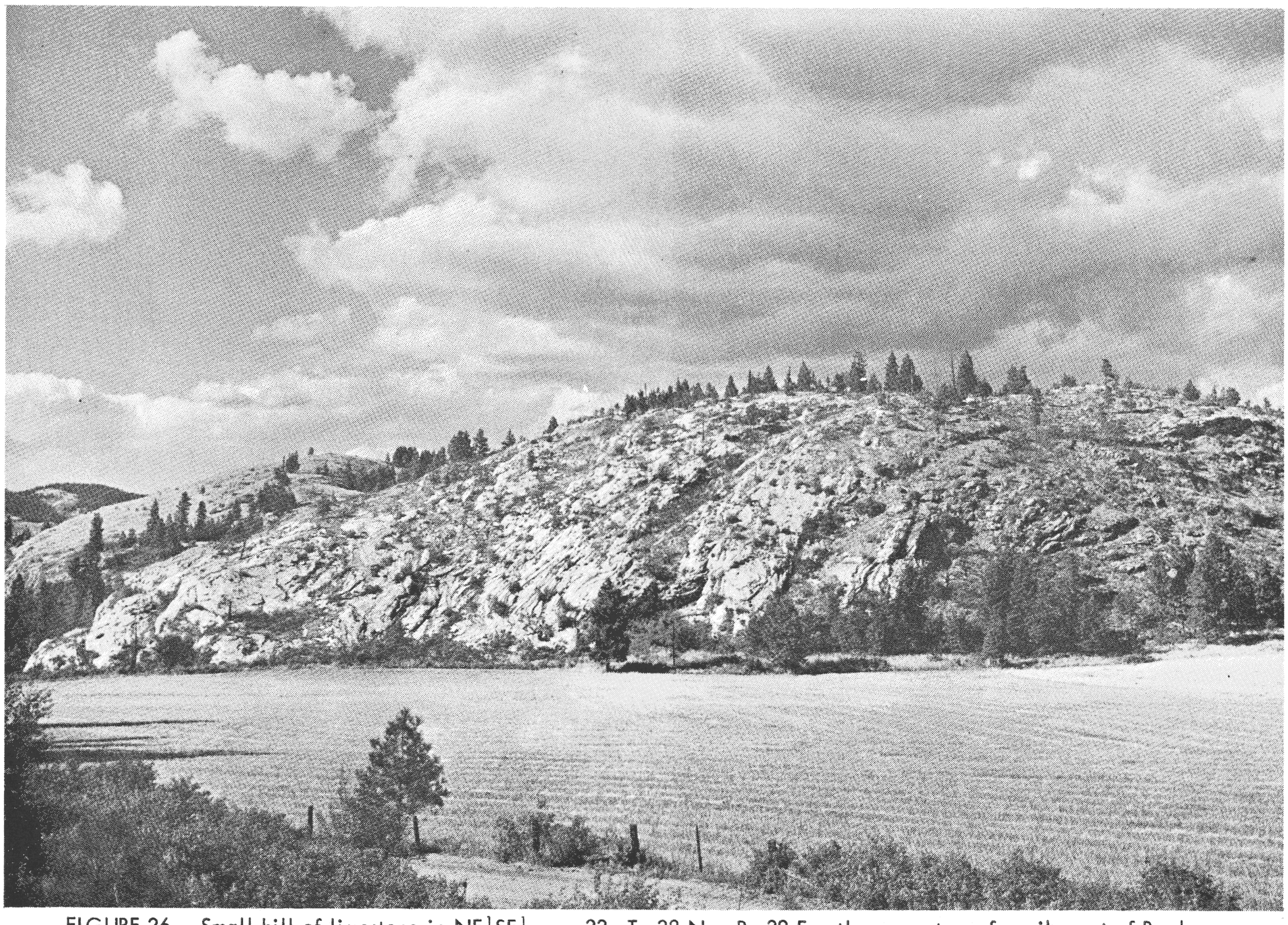

FIGURE 26.—Small hill of limestone in NE¼SE¼ sec. 33, T. 38 N., R. 38 E., three-quarters of a mile east of Bossburg. View looking north.

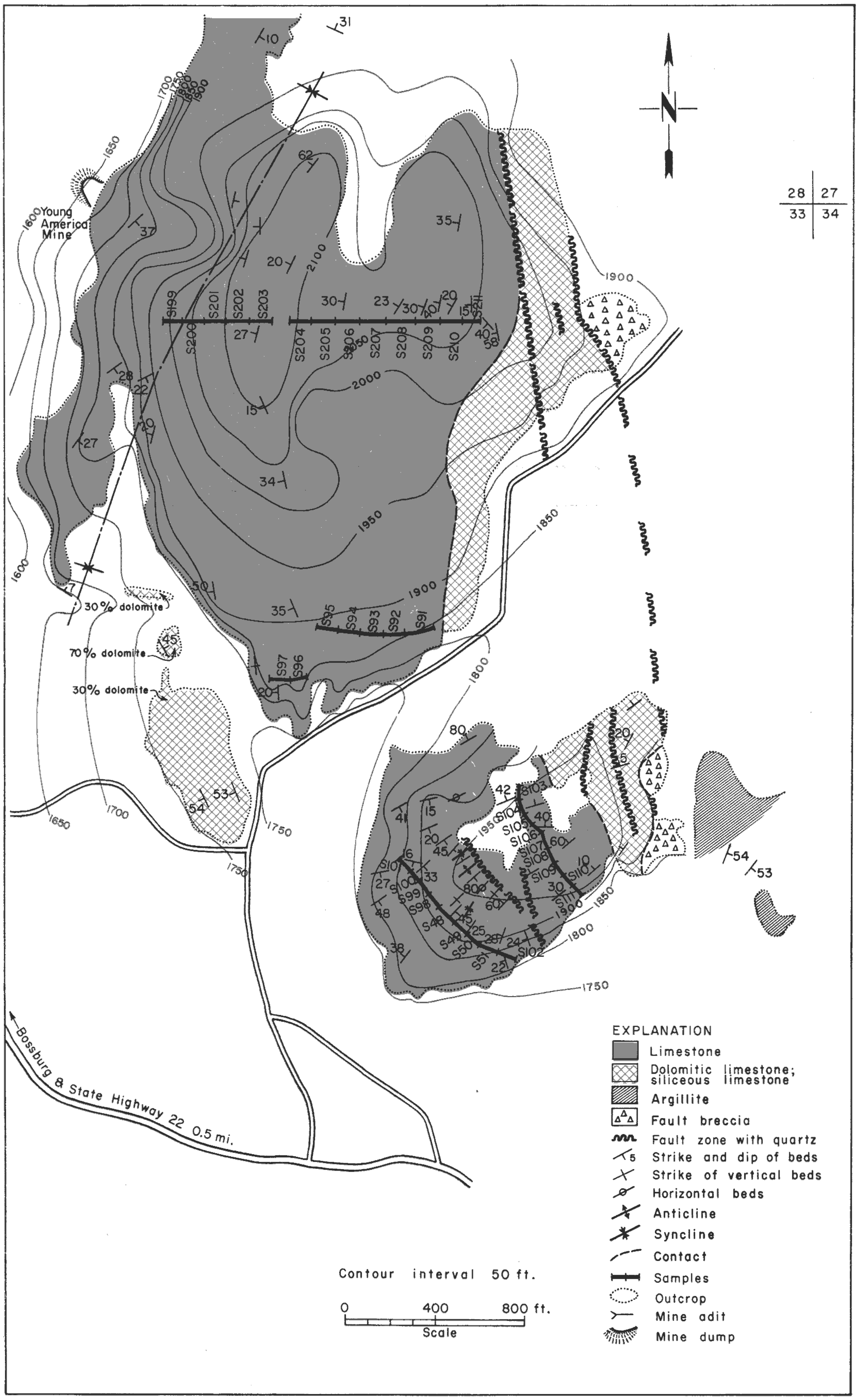

FIGURE 27.—Bossburg East area. Secs. 28 and 33, T. 38 N., R. 38 E. Geology by J. W. Mills. Base from aerial photo enlargement. Topography by altimeter survey.

Such zones are especially numerous and extensive along the east sides of the hills. The largest is at the extreme eastern side of each hill, where quartz-filled fractures and quartz- and silicified limestone-breccia make up a fault zone over 100 feet wide separating the carbonate rocks to the west from the argillaceous rocks to the east.

The stratigraphic thickness of the limestone exposed on the larger hill is estimated to be at least 850 feet. The stratigraphic thickness of the limestone exposed on the smaller hill is much more difficult to estimate because of its structural complexity, but it is of the order of 500 feet.

Quality and quantity of limestone.—Bancroft (1914, p. 62), in his discussion of the geology of the Young America mine (west side of the large hill), reports that "the limestone forms almost vertical cliffs, the tops of which are 400 feet above the Columbia River." He says nothing about the purity of the rocks but writes that they "are massive limestones, showing no pronounced bedding and little or no dynamic metamorphism." The quality of the limestone east of Bossburg is discussed by Shedd (1913, p. 150), and nine analyses reported by him are reproduced here. Shedd gives no indication of the kinds, lengths, or volumes of the samples or of the volume of limestone for which he believes the samples to be representative. The sample locations are given merely as "east side of the Columbia at Bossburg."

Analyses of limestone from east side of Columbia at Bossburg, Stevens County. (Shedd, 1913, p. 150)

A. A. Hammer, analyst

	$CaCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3
I	97.65	42.50	54.86	0.96	0.86	0.26
II	96.48	42.30	54.26	1.15	0.51	0.34
III	96.69	42.54	54.32	0.96	0.65	0.19
IV	95.94	42.00	53.90	1.08	0.78	0.51
V	97.57	42.92	54.64	0.81	0.65	0.31
VI	97.94	43.10	54.85	Tr.	0.51	0.45
VII	95.80	42.68	53.65	1.46	1.13	0.26
VIII	97.71	43.00	54.16	1.06	0.96	0.20
IX	94.94	43.16	53.16	0.96	1.41	0.41

Hodge (1938, p. 112, 113) summarizes some of the descriptive material given by Shedd (1913) and reports one analysis of "limestone near Bossburg." This analysis is identical to Shedd's analysis IV, above, and presumably was taken from Shedd's report.

In the course of the present study 2 rows of samples, consisting of 9 samples each, were taken across the strike of the limestone (fig. 27) on the small hill. The results of the analysis of these are as follows:

Sample no.	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)
S-101	60	95.92	1.50	43.03	53.89	0.72	1.83	0.18	0.020				
S-100	75	95.78	2.34	43.46	53.81	1.12	0.87	0.12	0.020				
S-99	75	96.30	1.82	43.16	54.10	0.87	1.41	0.12	0.017				
S-98	75	97.94	0.82	43.64	55.02	0.39	0.70	0.10	0.010				
S-48	75	97.88	0.56	43.62	54.99	0.27	0.83	0.20	0.017				
S-49	75	98.79	0.44	43.14	55.50	0.21	0.72	0.20	0.010				
S-50	75	98.59	0.63	43.57	55.39	0.30	0.42	0.17	0.013				
S-51	70	98.54	0.65	43.41	55.36	0.31	0.64	0.17	0.009				
S-102	80	97.60	0.69	43.21	54.83	0.33	0.96	0.16	0.016				
S-103	60	87.84	0.50	38.56	49.35	0.24	11.40	0.34	0.051				
S-104	60	98.04	0.63	43.49	55.08	0.30	0.58	0.13	0.017				
S-105	60	98.18	0.71	43.57	55.16	0.34	0.72	0.19	0.031				
S-106	60	97.94	0.71	43.52	55.02	0.34	0.42	0.12	0.041				
S-107	60	97.86	0.65	43.35	54.98	0.31	0.81	0.18	0.011				
S-108	60	97.29	0.38	43.08	54.66	0.18	1.54	0.19	0.014				
S-109	60	98.70	0.36	43.60	55.45	0.17	0.26	0.13	0.007	125	300	-30	14
S-110	60	97.44	0.56	43.20	54.74	0.27	1.31	0.14	0.016				
S-111	50	98.47	0.50	43.54	55.32	0.24	0.58	0.13	0.016				

The analyses show that the rock is a high-calcium limestone containing (unweighted average) 54.59 percent CaO, 0.38 percent MgO, 1.44 percent SiO_2, 0.16 percent R_2O_3, 0.020 percent P_2O_5, and 97.17 percent $CaCO_3$. Omitting sample S-103, the rock contains (unweighted average) 54.90 percent CaO, 0.38 percent MgO, 0.86 percent SiO_2, 0.15 percent R_2O_3, 0.017 percent P_2O_5, and 97.72 percent $CaCO_3$. The composition meets the chemical specifications for use as a mineral filler, ceramic whiting, builders' lime, and in the sugar, pulp and paper, and cement industries.

The amount of limestone in the (smaller) hill, above the level of the surrounding fields (1,750 feet above sea level), is 13,750,000 tons. The deposit is close to excellent transportation facilities and well suited topographically for quarrying.

Twenty samples were taken across the larger hill, 7 at the south end (S-91 to S-97, inclusive) and 13 across the highest part of the hill (S-199 to S-211, inclusive). The locations of these samples are show in figure 27. Samples S-199 to S-211 are representative of a true thickness of 850 feet of limestone. The results of their analysis are as follows:

Sample no.	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)
S-91	130	96.96	1.53	43.35	54.47	0.73	1.60	0.15	0.011				
S-92	100	97.12	1.55	43.52	54.56	0.74	1.14	0.26	0.035				
S-93	100	95.27	2.78	43.73	53.52	1.33	1.14	0.20	0.047	135	490	-30	14
S-94	100	96.23	1.42	43.15	54.06	0.68	2.12	0.19	0.030				
S-95	100	96.00	2.72	43.71	53.93	1.30	0.97	0.25	0.050				
S-96	100	95.39	3.01	43.79	53.59	1.44	1.02	0.15	0.015				
S-97	110	96.69	1.76	42.62	53.04	0.90	3.05	0.13	0.026				

Sample no.	Length (feet)	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
S-199	100	92.13	3.95	41.43	51.76	1.89	3.61	0.32	0.022
S-200	100	92.40	3.22	42.20	51.91	1.54	3.05	0.29	0.028
S-201	100	94.39	3.36	42.75	53.03	1.61	1.53	0.16	0.020
S-202	100	91.19	6.71	42.76	51.23	3.21	2.37	0.03	0.027
S-203	100	96.80	2.30	43.16	54.38	1.10	0.50	0.12	0.021
S-204	100	82.41	15.19	43.61	46.30	7.27	1.87	0.35	0.033
S-205	100	89.32	8.72	42.94	50.18	4.17	2.06	0.29	0.038
S-206	100	94.52	4.56	43.49	53.10	2.18	1.01	0.00	0.021
S-207	100	96.12	2.82	43.12	54.00	1.35	0.72	0.14	0.025
S-208	100	93.25	4.97	42.99	52.39	2.38	0.75	0.39	0.021
S-209	100	97.33	1.84	43.38	54.68	0.88	0.67	0.03	0.014
S-210	100	96.12	1.30	42.35	54.00	0.62	2.31	0.03	0.013
S-211	85	93.98	3.05	42.50	52.80	1.46	2.21	0.11	0.010

The analyses show that the rock is not a high-calcium limestone. The (unweighted) average of the analyses is 52.84 percent CaO, 1.84 percent MgO, 1.63 percent SiO_2, 0.18 percent R_2O_3, 0.025 percent P_2O_5, and 94.05 percent $CaCO_3$. The rock is well suited to the manufacture of portland cement.

Tonnage figures were calculated for a block of ground 2,500 feet long and 1,400 feet wide. The base of the block was taken as the elevation 1,850 feet above sea level. The amount of limestone in this block is 46 million tons.

Bossburg North Area
Sec. 25, T. 38 N., R. 37 E.

Location, accessibility, and ownership.—A cliff of limestone 100 feet high is found three-quarters of a mile north of Bossburg, on the west side of the Columbia River, in the NE$\frac{1}{4}$ sec. 25, T. 38 N., R. 37 E. The limestone is on property owned by Clarence Hansen and Frank Rettinger of Kettle Falls, and Paul Rettinger of Manzanita, Oregon. The limestone cliff parallels the road along the west shore of the Columbia River for a distance of 2,000 feet (fig. 28). The area is reached from Kettle Falls by driving west 7 miles on U.S. Highway 395 to the bridge across the mouth of the Kettle River, thence along a good graveled road on the west side of the Columbia River a distance of 11 miles. The cliff is 400 feet west of the road, directly across the river from Bossburg. The nearest railroad facilities (Great Northern Railway) are 11 miles south, at the mouth of the Kettle River.

Geology.—The limestone exposed in the cliff and along the north shore, across the Columbia River from Bossburg, is in the lower part of the stratigraphic column and the southwest extremity of an area of carbonate rocks that Bowman (1950) has mapped as Glasgo Marble. He reports (1950, p. 27, 28)

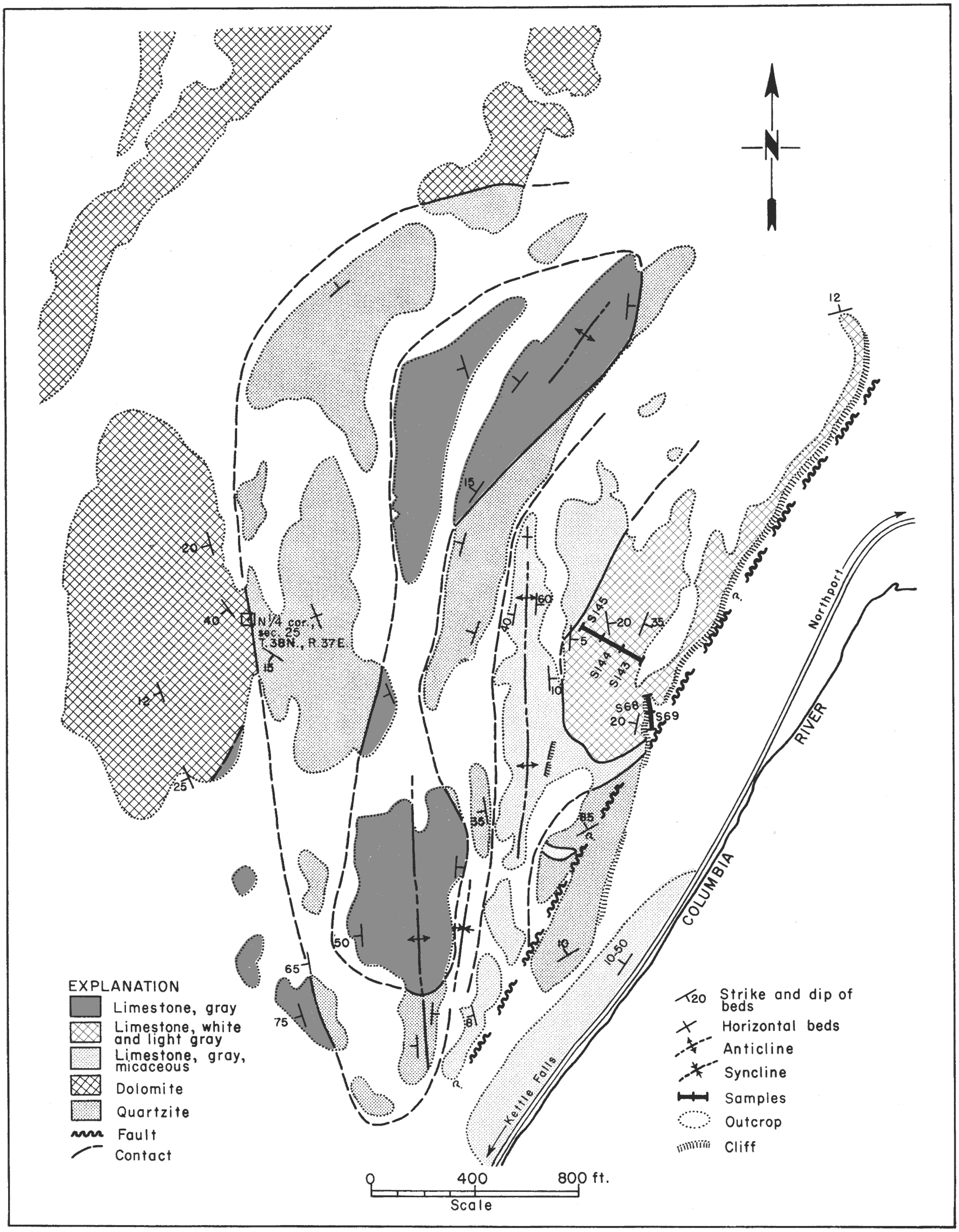

FIGURE 28.—Bossburg North area. Sec. 25, T. 38 N., R. 37 E. Geology by J. W. Mills, C. E. Stearns, and R. D. Boettcher. Base map from aerial photo enlargement.

a minimum thickness of 1,750 feet of the Glasgo Marble in the area southeast of Glasgo Lakes, and of 2,300 feet on the north bank of the Columbia River. The base of the Glasgo Marble is not exposed in Bowman's map area, and the formation is overlain conformably by the Kelly Hill Phyllite (Ordovician?), according to Bowman (1950, p. 24, 30). The lithologic character of the Glasgo Marble is described by Bowman (1950, p. 24) as follows:

> In general the Glasgo marble is gray to white; the colors are in distinct bands which range in thickness from 2 mm. to 1 cm. The bands are portions of larger layers 2 or 3 inches to about 4 feet thick. The grain size ranges from 0.1 to 3 mm. Both large and small grains are present in most specimens; the larger grains are concentrated in the white bands and the smaller grains are concentrated in the gray bands.

He also reports the presence, in the Glasgo Marble, of dolomitic marble containing abundant radiating aggregates of dolomite crystals, and subordinate amounts of quartz-tremolite marble, fine-grained quartzite, and andalusite schist.

The limestone exposed in the cliff (fig. 28) is the lowermost unit in a series of five metamorphosed sedimentary rock units. It is white to light gray in color, medium grained, and thin bedded. The true thickness of the exposed portion of this limestone is estimated to be 120 feet. It is overlain by gray to dark-gray, medium-grained, thin-bedded micaceous limestone, quartzite, and a great thickness of carbonate rocks consisting of gray dolomitic limestone in the lower part and white dolomite in the upper part. Outcrops of the white dolomite (Glasgo Marble) of the uppermost unit are large and numerous throughout secs. 13, 23, and 24, T. 38 N., R. 37 E., and secs. 18 and 19, T. 38 N., R. 38 E.

The principal structural feature of the area is an anticline, the axis of which trends north throughout the central part and northeast in the northern part of the map area. Dips on either side of the axial region of the fold are moderate and they tend to become steeper away from the axis. Two smaller folds have axes that parallel and lie east of the major fold axis. Intense crumpling of the thin quartzite beds, reversals in dip of the limestone beds, and the pronounced linear character of the limestone cliff lead to the conclusion that the base of the cliff marks the position of a fault striking N. 30° E. The dip and displacement of the fault are unknown.

Quality and quantity of limestone.—The purest limestone in this area is the white to light-gray limestone exposed for 2,000 feet along the cliff west of the Columbia River and for a map width of 500 feet up the hill (west) from the cliff. Its strike varies from north to a few degrees east of north and its dip varies from 5° to 35° to the east throughout most of the outcrop area. Along the cliff face the white limestone dips to the west. Because the slope of the hillside and the dip of the beds are very nearly equal, only a thin section (about 30 feet) of this lower unit is exposed west of the cliff. An additional 90 feet of true thickness is exposed in the cliff face.

The white limestone was examined and diamond drilled by the Ideal Cement Company in 1955. They report (written communication, 1959) that "practically all of the material exceeded the 1.80 percent MgO limit" for cement use. Further, they report that "the deeper material was found to be steeply dipping and the stratigraphy was cut at a small angle . . . even the best appearing deposits may not be satisfactory in this dolomitic terrain."

For the purpose of this report, two 50-foot samples (S-68 and S-69) were taken vertically down the cliff face (fig. 28). Three more samples (S-143, S-144, and S-145) were taken horizontally over a total sample length of 310 feet, almost directly across the strike of the bedding west of the cliff face. These five samples represent a total vertical thickness of 272 feet and a minimum stratigraphic thickness of 120 feet of limestone. The analyses of the samples are as follows:

Sample no.	Length (feet)	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
S-68	50 V.	90.44	2.30	40.94	50.81	1.10	5.11	2.04	0.133
S-69	50 V.	85.23	8.97	41.90	47.88	4.29	3.84	1.66	0.150
S-143	110 H.	94.11	2.05	42.47	52.87	0.98	2.47	0.85	0.083
S-144	100 H.	90.12	6.23	42.69	50.63	2.98	2.62	0.75	0.050
S-145	100 H.	88.11	8.36	42.73	49.50	4.00	2.63	0.88	0.061

V.-Vertical
H.-Horizontal

From these analyses and the findings of the Ideal Cement Company, it is concluded that the limestone is not a high-calcium limestone and because of its high MgO content it is unsatisfactory for the manufacture of portland cement.

Bossburg Vicinity

Shedd (1913, p. 149) records three analyses of limestone "taken about two miles north of Bossburg on the west side of the Columbia River." He states further that "number one and two are from section 13, township 38 north, range 37 east, while number three is from section 18, township 38 north, range 38 east." The analyses of these samples are reported by Shedd (1913, p. 149) as follows:

Sample no.	Loss on Ignition	CaO	MgO	SiO_2	Fe_2O_3	FeO	Al_2O_3
1	—	31.56	18.56	2.49	0.49	Tr	0.49
2	—	54.95	0.54	0.13	—	—	—
3	43.26	54.48	0.79	0.98	—	—	0.36

Sample 1 is not limestone, but dolomite. Samples 2 and 3 are high-calcium limestone. The writer traversed the sections from which these samples were taken and found the rock to be almost entirely dolomite. In a few places relatively pure thin beds of limestone were found interbedded with the dolomite. It was probably from one of these that Shedd obtained his samples. It is not believed that any sizeable volume of high-calcium limestone is to be found in these sections.

Valentine (1960, p. 57) lists a property in the SE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 28, T. 38 N., R. 38 E., approximately 1$\frac{1}{2}$ miles northeast of Bossburg, on which high-grade limestone is reported to occur. According to

Valentine (1960, p. 57) this limestone deposit "was recently under development by John Thomson of Colville." The property was not examined during this study.

Evans District

Evans, formerly the side of the limestone-quarrying and lime-making operations of the U.S. Gypsum Company, is on State Highway 22 and the Great Northern Railway approximately 11 miles north of Kettle Falls and 4 miles south of Bossburg.

U.S. Gypsum Company Upper Quarry
Sec. 10, T. 37 N., R. 38 E.

Location, accessibility, and ownership.—The Upper Quarry is in the SW$\frac{1}{4}$ sec. 10, T. 37 N., R. 38 E., approximately 2,000 feet northeast of Evans and 350 feet above State Highway 22. It is now (1960) owned by the Boise Cascade Corporation, of Spokane.

Operation.—The property was first developed by the Evans family in 1912; it was acquired by the U.S. Gypsum Company in 1936. It was abandoned in 1953 because the company could not produce a lime of sufficiently low phosphorus and silica content to compete in West Coast markets with the high-grade lime shipped in from the Midwest. According to records of the U.S. Gypsum Company (written communication), a total of 2,600,000 tons of stone has been quarried since the inception of operations.

When the quarry was operating, according to Hodge (1938, p. 110), the broken quarry rock was hand sorted and 6- to 10-inch pieces of stone were trammed to loading bins at the quarry site. From the bins the rock was carried 2,600 feet by aerial tramway to a bin about 100 feet from the kilns, then trammed to the kilns. Approximately 300 tons of rock a day was broken at the quarry, and from this about 150 tons was sent to the kilns, which were on a spur of the Great Northern Railway. The plant, which was dismantled after the shutdown in 1953, consisted of eight vertical kilns with a capacity of approximately 100 tons per day of burned lime.

The Upper Quarry is L-shaped (fig. 29). Its two largest faces are about 800 and 500 feet long and 170 feet high. The main floor of the quarry is at an altitude of 1,700 feet above mean sea level. A smaller quarry, approximately 150 feet square and of unknown depth, is in the floor of the main quarry. This smaller quarry is now (1961) full of water.

Geology.—The limestone of the Upper Quarry is exposed only in the quarry (fig. 30) and its immediate vicinity. According to Hodge (1938, p. 108), the surrounding overburden is as much as 25 feet thick; according to the U.S. Gypsum Company records, the gravel overburden is as much as 100 feet thick. The limestone is mapped as "undifferentiated limestone" by Weaver (1920). Its age and relations to other rocks in the area are as little known now (1960) as in 1920. The rock exposed in the Upper

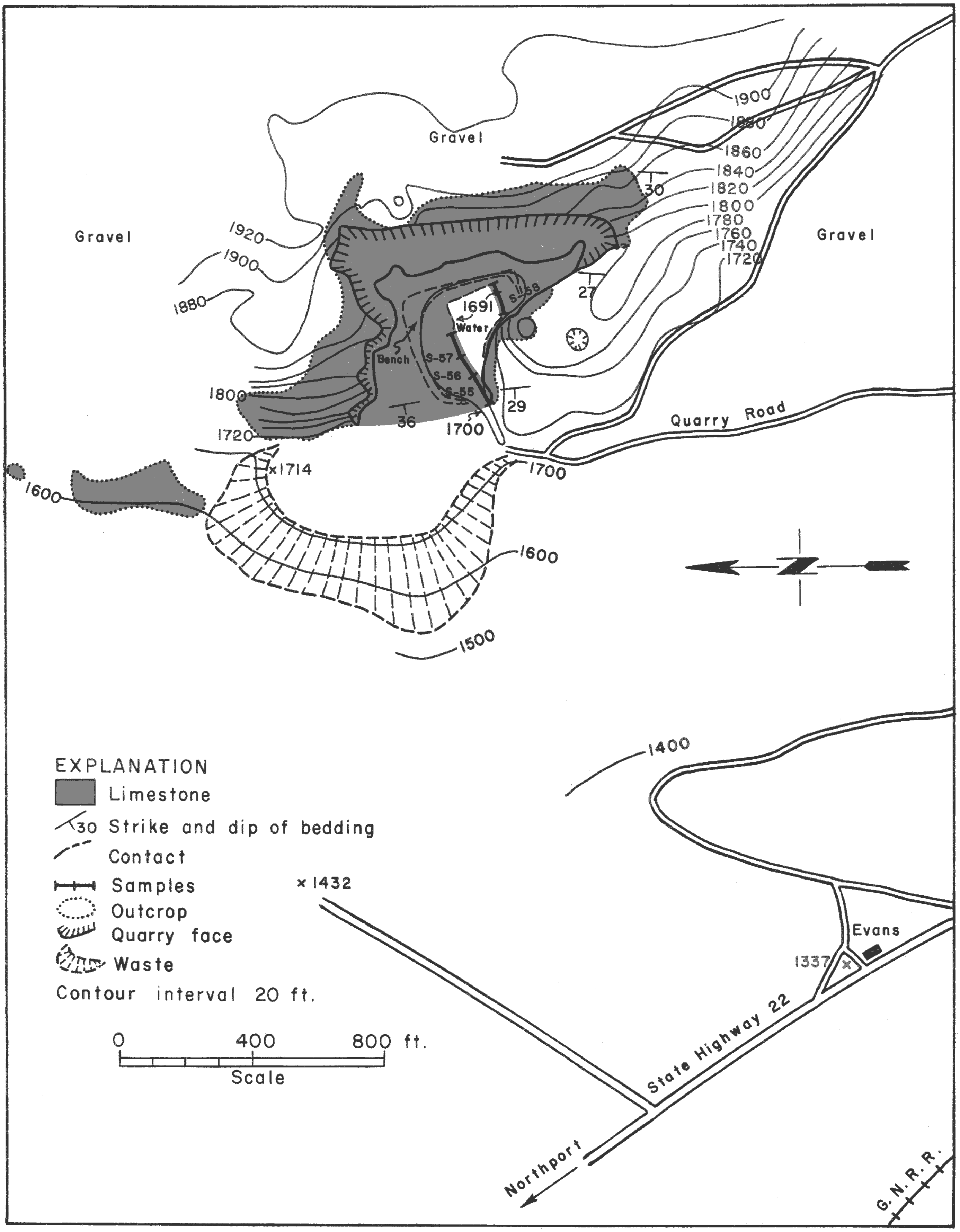

FIGURE 29.—U.S. Gypsum Company upper quarry, Evans. Sec. 10, T. 37 N., R. 38 E. Geology by J. W. Mills, C. E. Stearns, C. D. Rau. Base from aerial photo enlargement. Topography by plane table and alidade survey.

Quarry is a light-gray to gray, fine- to medium-grained, very well bedded limestone. Beds range in thickness from several inches to 3 or 4 feet. They strike uniformly N. 13° W. and dip from 28° to 36° W. The rock appears to be very pure, though some areas of silicified rock were seen in the east face of the quarry.

Quality of limestone. —According to Hodge (1938, p. 111), typical analyses of the (hand-sorted) stone sent to the kilns are as follows:

Loss on Ignition	Insol.	CaO	MgO	SiO_2	R_2O_3
42.40	0.38	55.54	0.56	0.42	0.17
—	—	55.10	0.36	0.96	0.20

According to F. C. Appleyard, Manager of Mines, U.S. Gypsum Company (written communication), there was a wide variation in analyses from one part of the quarry face to another, but a typical

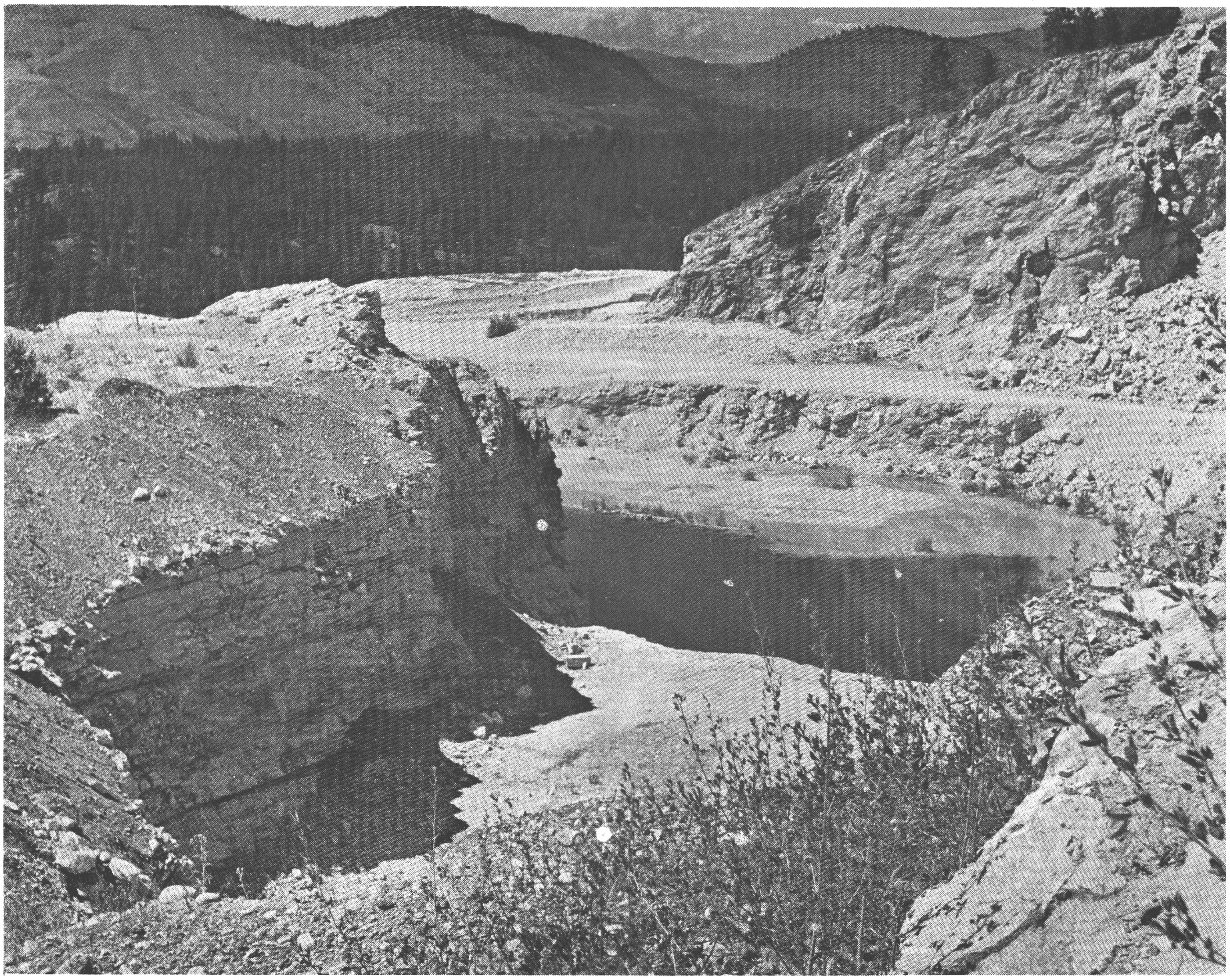

FIGURE 30.—U. S. Gypsum Company upper quarry, Evans. View looking west.

analysis of this limestone is: 94.00 to 97.00 percent $CaCO_3$, 0.75 to 1.75 percent MgO, 1.50 to 3.50 percent SiO_2, and 0.005 to 0.050 percent P_2O_5. Presumably, these analyses are of unsorted quarry-run rock. Appleyard reports further that "silicification is very irregular but widespread, and it was only by thorough hand sorting that a low silica lime could be produced."

Sampling (present study) was limited to the rock exposed around the lip of the smaller quarry, because the main quarry walls are too precipitous and loose for safe working. Four samples (S-55 to S-58, inclusive) were taken horizontally across the strike of the limestone for a total length of 350 feet. They represent the upper 200 feet (stratigraphic thickness) of the entire 250 feet (stratigraphic thickness) of limestone exposed in the quarries.

Sample no.	Length (feet)	Stratigraphic thickness (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)
S-55	100	57	98.72	0.77	43.29	55.46	0.37	0.91	0.11	0.008	190	840	-30	45
S-56	75	43	98.79	0.59	42.82	55.50	0.28	1.29	0.27	0.022				
S-57	75	43	99.04	0.73	43.19	55.64	0.35	0.53	0.20	0.017				
S-58	100	57	97.19	0.98	42.90	54.60	0.47	1.44	0.51	0.011				

The unweighted average composition is 55.30 percent CaO, 0.36 percent MgO, 1.00 percent SiO_2, 0.27 percent R_2O_3, and 0.015 percent P_2O_5. These analyses show that the limestone exposed in the main (upper) quarry floor is high-calcium limestone. Three of the samples (S-55 to S-57) have an average $CaCO_3$ content in excess of 99 percent. The samples have a CaO content approximately equal to that reported by Hodge for the hand-sorted rock, and slightly less than the CaO content reported by company officials for quarry-run rock. Sample S-58, representing a lower part of the rock section, is less pure than the other three. This suggests that the lowest part of the section exposed, the 50 feet (true thickness) not sampled, is less pure than the upper part and may account for the generally lower grade of the quarry-run rock. The composition of the rock is suitable for its use as ceramic whiting, builder's lime, mineral filler, and in the sugar, pulp and paper, and cement industries. The P_2O_5 content is a little too high for the limestone to be used for making calcium carbide, chemical lime, or metallurgical lime.

Quantity of limestone.—Assuming that the limestone in the upper part of the rock section maintains its high grade for 400 feet north and south of the present quarry walls, it is estimated that there is 1¼ million tons of limestone above the main quarry floor. The amount of similar rock below the main quarry floor, over a length of 1,200 feet and a width of 400 feet, is estimated to be 40,000 tons per vertical foot. Assuming the smaller quarry has an average depth of 50 feet, the amount of limestone below the main quarry floor, to a depth of 50 feet, is estimated to be 1,880,000 tons. The total quantity of high-calcium limestone available in the upper part of the rock section, from the surface to an altitude of 1,650 feet above sea level, is estimated to be about 3 million tons.

U.S. Gypsum Company Lower Quarry
Sec. 16, T. 37 N., R. 38 E.

Location, accessibility, and ownership.—Limestone is well exposed in the area between the Great Northern Railway and State Highway 22 for a quarter of a mile south from Evans (fig. 31), in the NE¼NE¼ sec. 16, T. 37 N., R. 38 E. The Lower Quarry, now (1961) abandoned and filled with water, marks the site of limestone-quarrying operations that preceded those of the Upper Quarry. The property is now owned by Edward Rasmusson, of Evans.

Geology.—Low, narrow, north-trending ridges are composed of white to light-gray fine-grained thin- to medium-bedded limestone. The rock appears to be quite pure except for the presence of very thin stringers and nodules of quartz in amounts up to 1.5 percent. Bedding in the limestone strikes northward and dips from 25° to 30° to the west.

Assuming that the large areas of alluvium between the outcrops are underlain by limestone, the stratigraphic thickness of the limestone extending from the Lower Quarry to State Highway 22 is approximately 350 feet.

Quality and quantity of limestone.—Shedd (1913, p. 147) reports analyses of two samples from this area as follows:

Loss on Ignition	CaO	MgO	SiO_2	R_2O_3
43.28	55.10	0.36	0.96	0.20
43.64	54.21	Trace	1.15	Trace

Two samples (S-136 and S-137) were taken in a direction N. 57° W., each 80 feet long, for a total horizontal length of 160 feet. They represent a stratigraphic thickness of 66 feet.

Sample no.	Length (feet)	Strati-graphic thickness (feet)	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
S-136	80	33	97.88	0.56	43.49	54.99	0.27	0.73	0.24	0.003
Covered	10	4								
S-137	70	29	97.60	0.56	43.17	54.83	0.27	1.56	0.12	0.022

The average composition is 54.91 percent CaO, 0.27 percent MgO, 1.14 percent SiO_2, 0.18 percent R_2O_3, and 0.012 percent P_2O_5.

The rock sampled is a high-calcium limestone, containing more than 97 percent $CaCO_3$. It is very much like the rock exposed in the Upper Quarry, though slightly lower in grade. It is suitable (in composition) for use as mineral filler, builders' lime, ceramic whiting, and in the manufacture of pulp and paper. It meets the chemical specifications for use in making calcium carbide, except that the the P_2O_5 content (average, 0.012 percent) is slightly higher than the specified amount (0.01 percent).

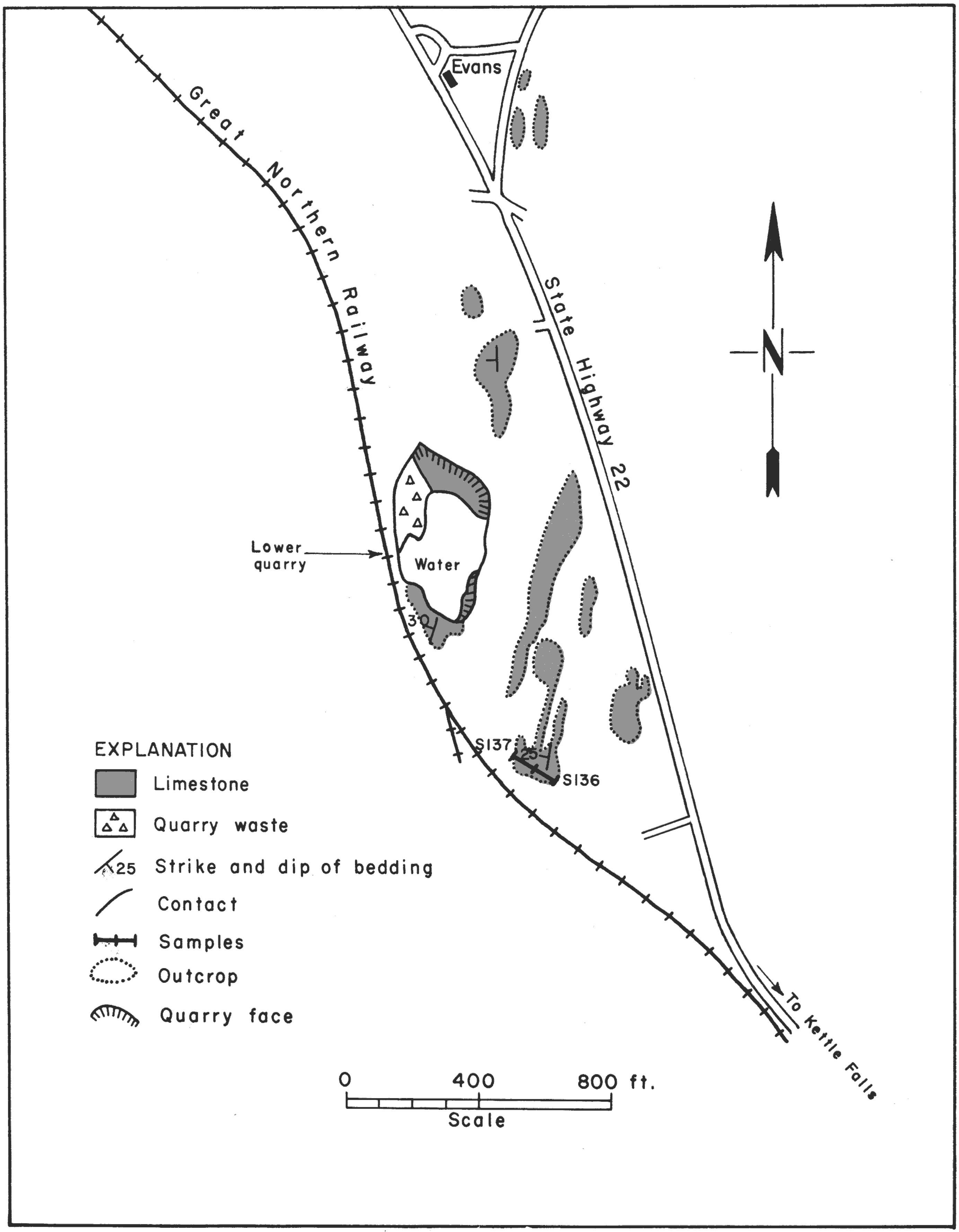

FIGURE 31.—U.S. Gypsum Company lower quarry, Evans. Sec. 16, T. 37 N., R. 38 E. Geology by J. W. Mills. Base from aerial photo enlargement.

Because sampling was confined to only about a fifth of the probable total thickness of limestone, estimates of the volume of such high-calcium limestone available here must be considered as merely suggestive. Disregarding the amount of relief and thickness of overburden, each of which is only a few feet, the amount of limestone available between the old quarry and the highway is about 20,000 tons per vertical foot, or 1 million tons to a depth of 50 feet.

Ideal Cement Company Quarry Area
Sec. 15, T. 37 N., R. 38 E.

Location, accessibility, and ownership.—Five abandoned limestone quarries approximately a mile south of Evans, formerly owned by the Spokane Portland Cement Company, are now (1961) the property of the Ideal Cement Company. They lie east of the Great Northern Railway and State Highway 22 in the $S\frac{1}{2}$ sec. 15, T. 37 N., R. 38 E. (fig. 32).

According to Hodge (1938, p. 104), quarrying first began adjacent to State Highway 22. This quarry was abandoned in 1928 and mining was begun at the larger quarry 1,000 feet east of the highway. At the time of writing of Hodge's report the larger quarry was 300 feet long and its face was 200 feet high. The normal rate of production was from 100,000 to 120,000 tons per year (Hodge, 1938, p. 105). The rock was used chiefly for the manufacture of portland cement; some was sold as a flux for the Bunker Hill and Sullivan smelter and some was sold to the Camas (Washington) paper mill; ground rock was sold for chicken grits and for dusting (fire protection) in the Roslyn (Washington) coal mines.

Geology.—Limestone crops out in the form of a broad open S from the roadside quarry, at an altitude of 1,370 feet above mean sea level, to the east and southeast up to an altitude of 1,970 feet (fig. 33). The carbonate rock exposed in and around the four largest quarries is a fine-grained siliceous well-bedded limestone made up of alternating light-gray, gray, and dark-gray thin beds. It is intimately fractured, and these fractures are healed with white calcite and quartz. Quartz is found as small lumps and irregular blebs disseminated through the rock as well as in seams, joints, and on fault surfaces. The stratigraphic thickness of the well-bedded limestone is about 300 feet.

Above and below the well-bedded limestone is gray to dark-gray, brown-weathering argillite, with intercalated pods and rudely tabular masses of limestone. This limestone has a gray to dark-gray color and fine grain size. The silica impurities and calcite-filled fractures are similar to those found in the well-bedded limestone. Unlike the latter, the limestone pods and masses intercalated with the argillite are quite massive; bedding is seldom to be seen, but when visible it is weakly developed and the beds are as much as 2 feet thick. The small quarry in the southeast part of the map area (fig. 32) is in limestone of this kind.

The age of sedimentary rocks is assumed to be Permian. This assumption is based upon the similarity in the lithology of these rocks with that of the limestone and argillite in the Kettle Falls area that the writer has determined to be Permian in age.

Intrusive into the sedimentary rocks are numerous small sills, dikes, and irregular masses of (Tertiary?) diabase and porphyritic andesite.

The limestones and argillites have been folded so that they now have steep dips. An anticlinal axis passes between the two western quarries and a synclinal axis through the large quarry at the ridge crest. Both axes trend and plunge south.

Numerous slickensided surfaces and zones of brecciation in the limestone testify to the faulting to which the rock has been subjected. There does not appear to be any particular pattern to the faults. Some fault surfaces are coated with coarse crystals of calcite as much as 2 inches in diameter. The limestones are generally more silicified in the areas where faults are more numerous, but the silicification is not confined to areas of faulting. The presence of the fault, shown on the geologic map to be striking N. 20° E. in the eastern part of the map area, is postulated on the basis of (1) the discordant strikes and dips on the opposite sides of a depression in which the fault is believed to lie and (2) on the lack of continuity of map formations in the two blocks separated by the fault. The dip and displacement on the fault are not known.

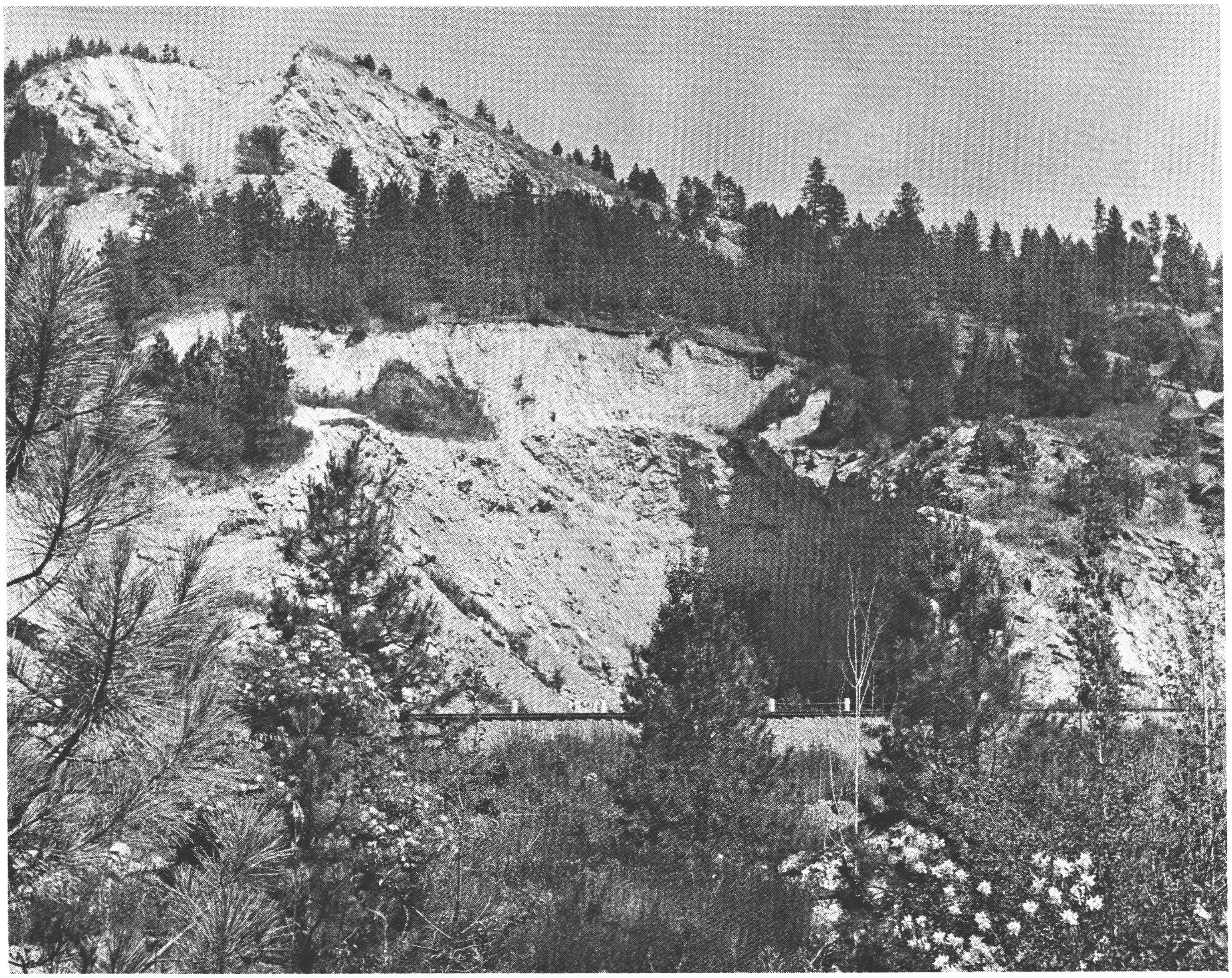

FIGURE 32.—Ideal Cement Company quarries, Evans. View looking northeast. Great Northern Railway, State Highway 22, and roadside quarry in foreground; main upper quarry in background.

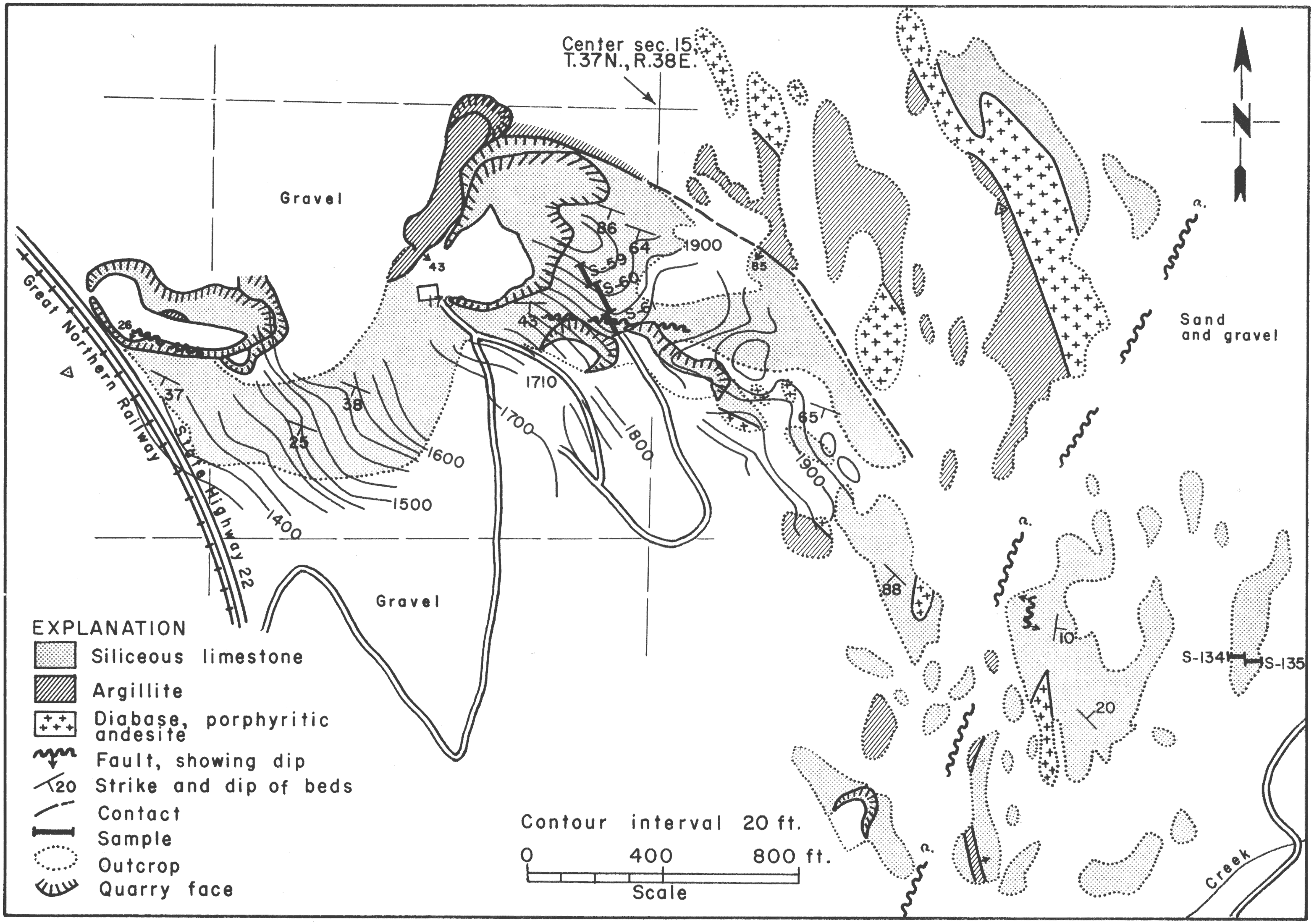

FIGURE 33.—Ideal Cement Company quarry area, Evans. Sec. 15, T. 37 N., R. 38 E. Geology by J. W. Mills. Base from aerial photo enlargement. Topography by Ideal Cement Company.

Quality of limestone.—The limestone mined in 1938 had an average content of 96 percent $CaCO_3$ (Hodge, 1938, p. 106). Hodge reports that four lots shipped to the Bunker Hill and Sullivan smelter had the following composition:

Lot	CaO	Insoluble (SiO_2)	Iron (Fe_2O_3)
1	51.3	4.2	0.5
2	52.5	3.4	0.4
3	50.9	5.3	0.3
4	51.8	4.8	0.5

The field examination clearly indicates that the limestone that remains is of no better quality than the rock that was quarried. Two areas were chosen for sampling, one near the largest quarry at the hill summit and the other at the east side of the map area. The three samples (S-59 to S-61) from near the large quarry are from the thin-bedded and well-bedded limestones and are representative of the limestone available in the vicinity of the principal quarries. The analyses of the three samples are as follows:

Sample no.	Length (feet)	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
S-59	75	77.20	1.02	34.11	43.37	0.49	21.52	0.70	0.047
S-60	75	71.34	0.56	31.64	40.08	0.27	27.16	0.95	0.030
S-61	95	86.01	0.63	38.33	48.32	0.30	2.35	0.85	0.025

Two samples (S-134 and S-135) were taken of the massive limestone; they are representative of the massive limestone found throughout the southeast quarter of the map area. Their analyses are:

Sample no.	Length (feet)	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
S-134	50	86.45	0.50	38.50	48.57	0.24	11.71	0.94	0.026
S-135	50	86.90	0.56	39.10	48.82	0.27	10.84	0.70	0.024

Neither the thin-bedded limestone nor the massive limestone qualifies as a high-calcium limestone. The rock is unsuitable for the manufacture of portland cement without costly additions of high-calcium limestone and alumina.

Brooks Property
Sec. 22, T. 37 N., R. 38 E.

Location, accessibility, and ownership.—Limestone is exposed on the face of a rock cliff 200 feet high, about 1½ miles southeast of Evans. It can be readily seen from State Highway 22 and the Great

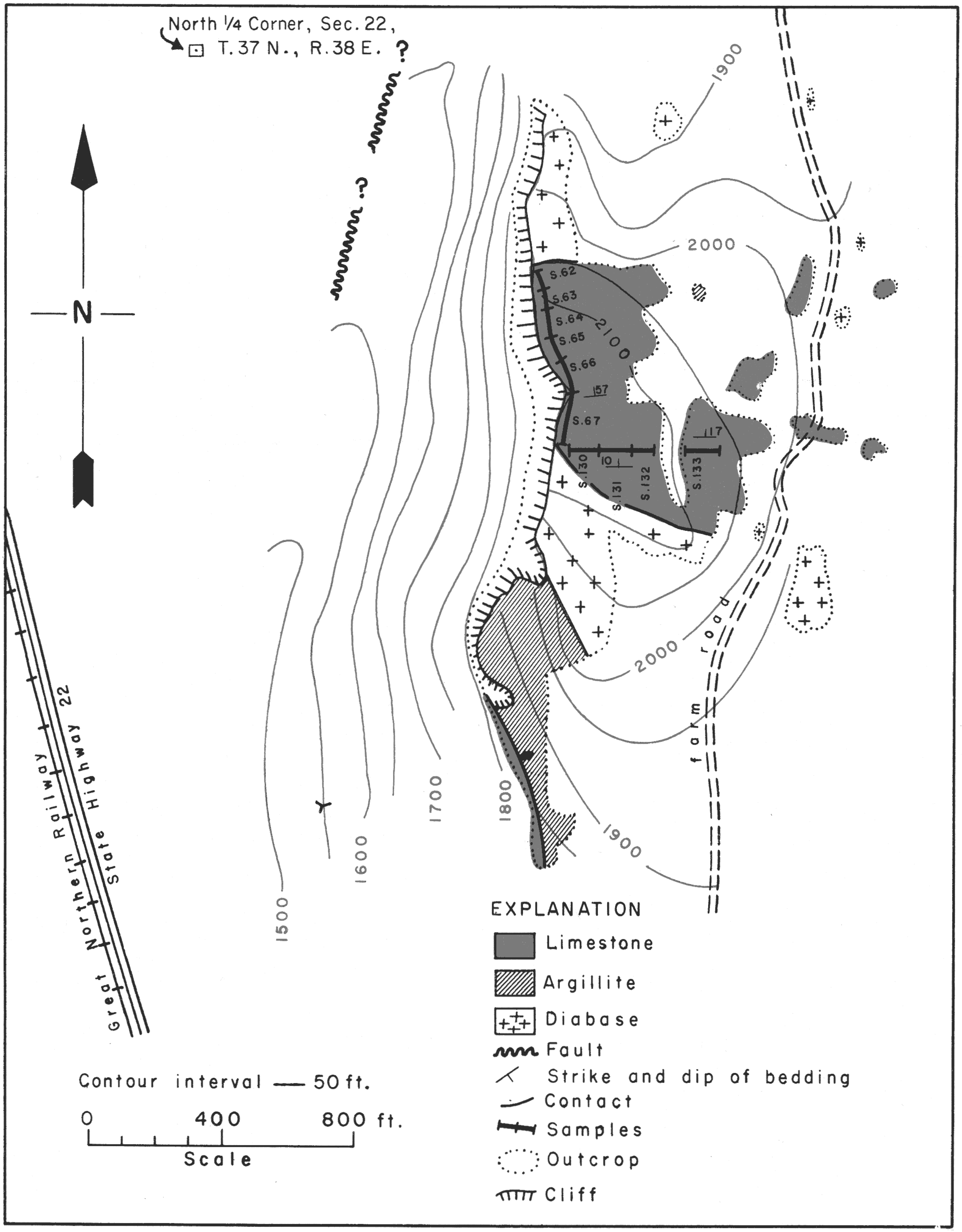

FIGURE 34.—Brooks property. Sec. 22, T. 37 N., R. 38 E. Geology by J. W. Mills. Base from aerial photo enlargement. Topography by altimeter survey.

Northern Railway 1,600 feet west of the cliff (fig. 34). The portion of the limestone in the NE¼NE¼ sec. 22, T. 37 N., R. 38 E., is on the property of Carl and Wilbur Brooks, of Evans. The portion of the limestone, including the cliff face, in the NW¼NE¼ sec. 22, T. 37 N., R. 38 E., is on United States land.

Geology.—The nearly vertical cliff is along the west side of a hill approximately ½ mile long and ¼ mile wide. The summit of the hill is at an altitude of 2,110 feet above mean sea level and approximately 800 feet above State Highway 22. Limestone is exposed in the cliff face over an area 200 feet high and 500 feet long. On the top of the hill the limestone is exposed almost continuously over an area of 3,500 square feet, with smaller outcrops extending as much as 1,000 feet east of the cliff (fig. 34). It is light-gray to gray, very fine grained, massive limestone, which weathers to a light-gray or white color. Gray calcite oval-, circular-, or rod-shaped bodies up to one-tenth of an inch in their greatest dimension make up as much as 50 percent of the rock. They contrast with the slightly lighter gray to white matrix, so that the rock appears to have a coarse texture. No structure could be seen in these gray calcite bodies, and their origin is unknown. It is possible that they are fragments of fossil crinoid stems. Quartz, as thin stringers and blebs replacing limestone, was found here and there in amounts up to 3 percent. The limestone is quite massive. Jointing, probably along weakly developed bedding planes, strikes due east and varies in dip from 10° to 57° to the north.

The limestone is in contact to the north and south with very steeply dipping intrusive masses of diabase. The diabase does not seem to have introduced any impurities or to have caused any recrystallization of the limestone. Gray to brownish-gray argillite is exposed in a small outcrop northeast of extensive outcrops of limestone. Similar argillite is exposed over a large part of the south end of the hill. It is underlain, on the west side of the hill, by a thin layer of gray limestone.

A few poorly preserved gastropods up to 1½ inches in diameter were found in sample S-65. The lithology of the main limestone body, including the presence of crinoid (?) fragments, is very similar to the fusulinid-bearing limestone masses north of Kettle Falls, which have been recognized to be Permian in age (McLaughlin and Simons, 1951). The brown-weathering argillite is similar lithologically to the argillite of the Kettle Falls area, which the writer (Mills and Davis, 1962) has determined to be Permian in age. On the basis of this rather slim evidence, it is concluded that the limestone of the Brooks property is Permian in age. The diabase intrusions are lithologically identical to those found elsewhere in northern Stevens County and are believed to be Tertiary in age.

Quality and quantity of limestone.—Because bedding could not be recognized, two sets of samples of the limestone were taken at right angles to each other (fig. 34). Insofar as there is truth in the assumption that the jointing is parallel to the bedding, the samples S-62 to S-67, inclusive, are more representative of the main mass of the limestone than samples S-130 to S-133, inclusive. The analyses of these samples are as follows:

Sample no.	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)
S-62	60	98.52	0.46	43.53	55.35	0.22	0.60	0.27	0.036				
S-63	60	98.36	0.79	43.46	55.26	0.38	0.42	0.27	0.021				
S-64	80	98.52	0.59	43.69	55.35	0.28	0.36	0.29	0.013	225	600	-30	15
S-65	80	96.65	0.75	43.02	54.30	0.36	1.71	0.24	0.012				
S-66	100	96.87	1.02	43.08	54.42	0.49	1.34	0.29	0.043				
S-67	150	98.68	0.73	43.57	55.44	0.35	0.35	0.25	0.026				
S-130	77	97.54	0.69	43.24	54.80	0.33	1.16	0.15	0.013				
S-131	100	97.72	0.65	43.20	54.90	0.31	1.17	0.15	0.015				
S-132	65	95.62	0.54	42.36	53.72	0.26	2.97	0.30	0.012				
S-133	100	95.87	0.56	42.64	53.86	0.27	2.76	0.25	0.016				

The unweighted average of these analyses is 54.74 percent CaO (97.44 percent $CaCO_3$), 0.32 percent MgO, 1.28 percent SiO_2, 0.25 percent R_2O_3, and 0.021 percent P_2O_5. Samples S-62 to S-67, inclusive, are representative of a total horizontal length of 530 feet; samples S-130 to S-133, inclusive, are believed to be representative of a total horizontal length (including covered intervals) of 430 feet. The analyses show the limestone to be rich in CaO and lacking in MgO; that is, a high-calcium limestone of exceptional purity. It has a composition that meets the chemical specifications for use as mineral filler, ceramic whiting, builders' lime, and in the pulp and paper industry. The SiO_2 content may be a little too high for use in the sugar industry. The P_2O_5 content is about twice as high as is permitted in the manufacture of chemical and metallurgical lime.

The composite of samples S-62 through S-66 showed 225 ppm Na_2O, 600 ppm K_2O, less than 30 ppm TiO_2, and 15 ppm S. Samples S-63 and S-65 analyzed separately showed 225 and 225 ppm Na_2O, 570 and 550 ppm K_2O, 50 and less than 30 ppm TiO_2, and 60 and 75 ppm S, respectively.

The amount of limestone containing more than 97.4 percent $CaCO_3$ and less than one-third of 1 percent MgO is estimated to be 22,500 tons per vertical foot. This would amount to $2\frac{1}{4}$ million tons to a depth of 100 feet, or $4\frac{1}{2}$ million tons between the surface and the top of the talus slope to the west of the cliff face.

Orient-Kelly Hill District

The Orient-Kelly Hill district, as defined here, is the area lying between the Kettle River and the Columbia River, including all of T. 39 N., R. 37 E.; the eastern two-thirds of T. 38 N., R. 37 E; and the NE$\frac{1}{4}$ T. 37 N., R. 37 E. The southern border of the area is 6 miles north and the northern border is 21 miles north of Kettle Falls. U.S. Highway 395 and the Great Northern Railway follow the Kettle River valley in the west side of the area. State Highway 22 and the Great Northern Railway are on the east bank of the Columbia River to the east. From U.S. Highway 395, the area is reached by crossing bridges over the Kettle River at its mouth, at Napoleon, and at Orient.

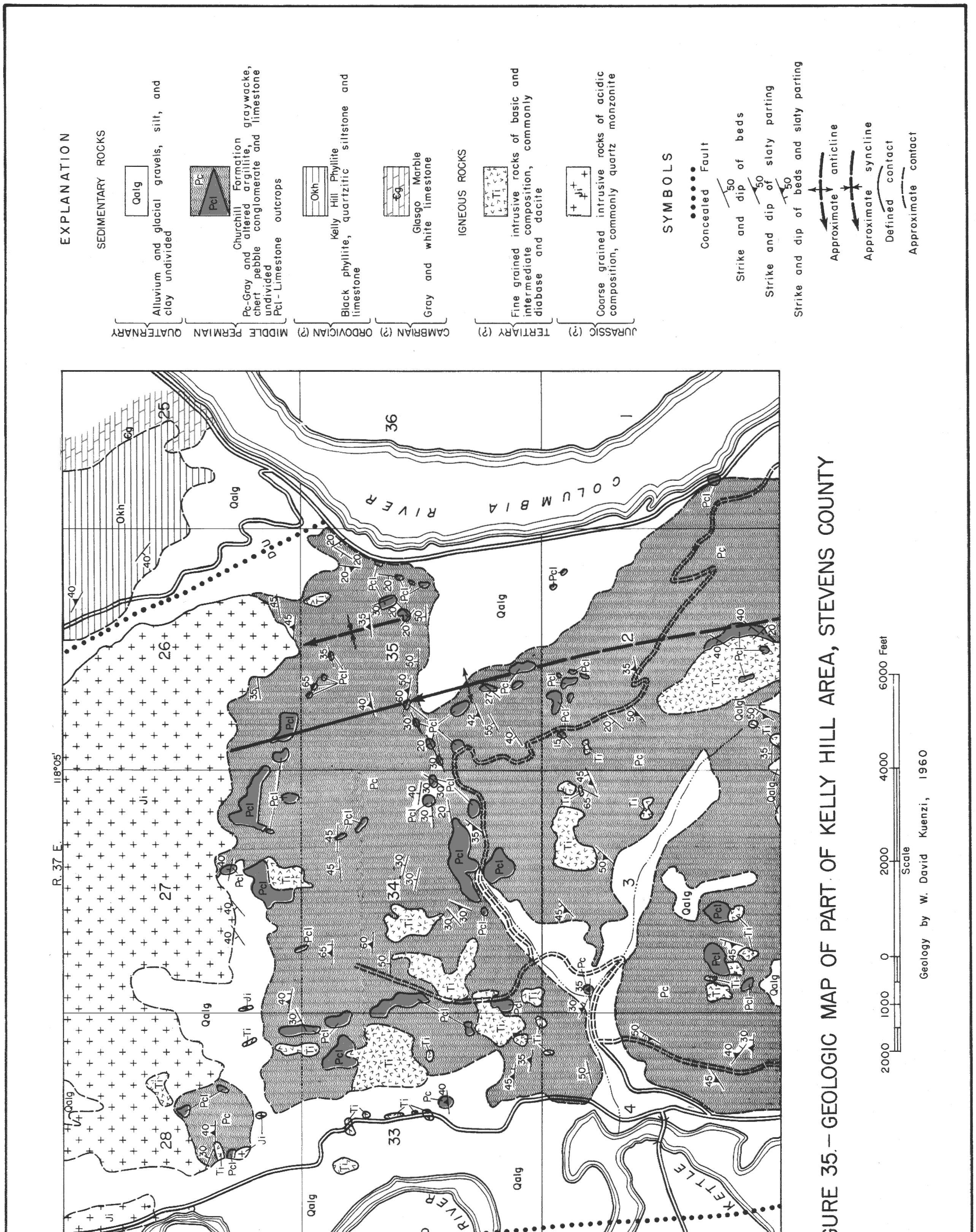

FIGURE 35.—GEOLOGIC MAP OF PART OF KELLY HILL AREA, STEVENS COUNTY

The geology of the Orient area, including the north half of the Orient-Kelly Hill district, has been described by Bowman (1950). The geology of the south half of the Orient-Kelly Hill district was mapped by Kuenzi in 1959. His report is in preparation (Kuenzi, 1961, written communication); he has made his geologic map (fig. 35) available to the writer, together with a few notes on the distribution and character of the limestone in the area.

According to Bowman (1950), the oldest rocks in the area are metamorphic rocks of the Boulder Creek Formation of Precambrian age. They consist of quartzite, dolomite and calcite marble, lime-silicate gneiss, sillimanite schist, sillimanite gneiss, and amphibolite. Unconformably overlying these is a series of three formations of Paleozoic age. The oldest is the Glasgo Marble of Cambrian age (minimum thickness 2,300 feet); it is composed of limestone, dolomite, and andalusite schist. The next younger formation is the Kelly Hill Phyllite, of Ordovician (?) age (minimum thickness 8,500 feet). The youngest formation is the Churchill Formation, of Permian age (minimum thickness 7,400 feet). Unconformably overlying the rocks of Paleozoic age is a thickness of at least 6,700 feet of sedimentary clastic rocks (augite, graywacke, and conglomerate) and volcanic rocks (augite, andesite, latite, and agglomerate), of Middle Jurassic (?) age. Unconformably overlying all the older rocks is a series of volcanic rocks of Tertiary age, at least 6,500 feet thick. Intrusive into the metamorphic, sedimentary, and the older volcanic rocks are dikes, sills, and stocks of granite, granodiorite, monzonite, and mafic intrusive rocks of Mesozoic and Tertiary age. Folding is intense in most of the rocks of Precambrian and Paleozoic age, moderate in the rocks of Jurassic age, and mild in the rocks of Tertiary age. Numerous high-angle faults of Tertiary age divide the area into a patchwork of smaller areas. Most of the faults strike north or east, although some strike northeast or northwest.

Limestones.—Carbonate rocks are found in the Boulder Creek Formation, the Glasgo Marble, the Kelly Hill Phyllite, and the Churchill Formation. The limestones in the Boulder Creek Formation are dolomitic and very impure, owing to the large content of contact metamorphic silicates. The Boulder Creek Formation does not crop out in the Orient-Kelly Hill district, but it crops out 3 miles west of the area in sec. 3, T. 39 N., R. 36 E. This occurrence is in Ferry County. The limestone of the Glasgo Marble is described on page 115 (Bossburg North area), and page 133 (Barstow area). The limestone of the Kelly Hill Phyllite occurs as rather thin dolomitic beds, generally less than 50 feet thick, interbedded with the phyllite. Limestone masses, some of which are very large, are found within the Churchill Formation and are discussed in detail in the following paragraphs.

Geology and quality of the limestones of the Churchill Formation.—The Churchill Formation is composed of the following marine rocks, in the order of their abundance: argillite, graywacke, conglomerate, quartzite, and limestone (Bowman, 1950, p. 39). On the ridge (Kelly Hill) between the Kettle and Columbia Rivers, the thickness of the formation is at least 4,000 feet. Bowman (1950, p. 48) establishes the age of the formation as Middle and (or) Late Permian. He suggests that the formation may be correlative with the Chilliwack Series (Daly, 1912) and the Cache Creek Group (Dawson, 1895) of British Columbia, and with the Anarchist Series (Waters and Krauskopf, 1941) of the Okanogan

Valley, Washington. Rocks of similar kind and age are found at Kettle Falls (Mills and Davis, 1962) a few miles to the south, and in Republic district (Muessig and Quinlan, 1959) in Ferry County, to the west.

Bowman (1950, p. 45) describes the limestone of the Churchill Formation as light to dark gray in color, fine grained, and massive to thin bedded. Dark-gray chert lenses are common in some limestone outcrops. In his discussion of the occurrences, he writes (Bowman, 1950, p. 45), "highly folded limestone beds of the Churchill formation crop out along the precipitous southeastward-facing scarp north of Larson School." On the map accompanying his report, this limestone outcrop is shown to extend for a length of 1.6 miles (from the NE$\frac{1}{4}$ sec. 4, T. 38 N., R. 37 E., to the NE$\frac{1}{4}$ sec. 34, T. 39 N., R. 37 E.), and a width of approximately 400 feet. No description is given of the lithology of the limestone in this deposit. He writes further (Bowman, 1950, p. 44) that "the most extensive exposures of limestone in the Churchill formation appear west of the Kettle River, south of Barstow School." On the geologic map accompanying his report, these exposures are shown to be in the W$\frac{1}{2}$ sec. 32, W$\frac{1}{2}$ sec. 31, E$\frac{1}{2}$ sec. 30, and the NE$\frac{1}{4}$ sec. 29, T. 38 N., R. 37 E., in Ferry County. The exposures are within the Barstow area, not the Orient-Kelly Hill area, as defined in this paper. However, they are discussed here because their geologic setting and lithology are similar to those of other limestone exposures of the Churchill Formation. Further reference is made to them on pages 134 and 178 of this report. The limestone is intruded by a stock of monzonite of Tertiary age. Bowman (1950, p. 44) describes this limestone as medium gray, fine grained, oolitic, and massive, commonly with elongate lenses of gray chert. Its thickness is at least 100 feet; a more precise estimate is not possible owing to intense folding, faulting, and intrusion by monzonite.

Kuenzi (1961, written communication) reports that the limestone exposed on Kelly Hill occurs as scattered outcrops surrounded by black argillite and graywacke. Some of the outcrops (fig. 35) are elongate masses, as much as 500 feet wide and 1,700 feet long, of gray to dark-gray, very fine to medium-grained massive limestone. Calcite veins are very common; nodular black chert, argillaceous materials, and detrital quartz grains are present also. Fossils, particularly fusulinids and bryozoa, are locally very abundant. Other outcrops (fig. 35) are composed of gray to dark-gray, fine- to medium-grained, well-bedded limestone. Individual outcrops are generally small, seldom exceeding 30 feet in lateral extent and 50 feet in stratigraphic thickness, although one bedded deposit, in sec. 2, T. 37 N., R. 37 E., has a length of 800 feet and a stratigraphic thickness of 125 feet. The limestone contains a few detrital quartz grains and argillaceous impurities; fossils, particularly pelecypods, are abundant in some outcrops.

Limestone in the SW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 2, T. 37 N., R. 37 E., is said by Kuenzi (1961, written communication) to be fairly pure; however, the amount of limestone is probably less than 400,000 tons. Limestone cropping out between the NE$\frac{1}{4}$ sec. 4, T. 38 N., R. 37 E. and the NE$\frac{1}{4}$ sec. 34, T. 39 N., R. 37 E., is mentioned by Bowman (1950, p. 45); however, he says nothing about the nature of amount of impurities.

In conclusion, the limestone of the Churchill Formation, with the possible exceptions of the two occurrences just referred to, are too impure (containing chert nodules, chert lenses, argillaceous impurities, clastic and hydrothermal quartz) and too small (generally much less than 1,000,000 tons) to be of any value for most purposes.

Barstow Area

Location and accessibility.—As defined here, the Barstow area is that area within 2 miles of Barstow, a town on U.S. Highway 395 about 15 miles north of Kettle Falls. Barstow is on the west bank of the Kettle River and it is serviced by the Great Northern Railway, U.S. Highway 395, and lesser graveled roads.

Geology.—Weaver (1920) mapped "undifferentiated limestone" on Little Marble Mountain in sec. 17, T. 38 N., R. 37 E. According to Bowman (1950), the outcrops in the area consist of the Glasgo Marble (Middle Cambrian in age), the Cascade Granodiorite (Early Cretaceous?), and the Hodgson Creek Monzonite (Tertiary). For a discussion of the age, correlatives, and character of the Glasgo Marble, the reader is referred to the section BOSSBURG NORTH in this report. The carbonate rock around Barstow is regarded by Bowman (1950) as the faulted extension of the Glasgo Marble cropping out around Glasgo Lakes 4 miles to the east. The intervening area is made up of alluvium and Kelly Hill Phyllite (Ordovician). Bowman's map shows the Barstow area carbonate rock to be bordered on all four sides by large steeply dipping faults. The marble west of the Kettle River is intruded by the Hodgson Creek Monzonite. The combination of folding, faulting, and intrusion has resulted in a considerable amount of deformation of the sedimentary rocks, so that strikes and dips are varied.

The largest single area of exposed Glasgo Marble is on Little Marble Mountain in the central part of sec. 17, T. 38 N., R. 37 E. The summit of the mountain (altitude 2,148 feet above sea level) is about 0.8 mile north of Barstow (altitude 1,402 feet).

The part of Little Marble Mountain lying in the N$\frac{1}{2}$ sec. 17 is composed of white to brownish-white, fine-grained, massive to moderately well bedded dolomite. The rock is cut by numerous white quartz stringers, up to a sixteenth of an inch across, that stand out in relief on the gray-weathered surface. The part of the mountain lying in the S$\frac{1}{2}$ sec. 17 is similar to that described above but includes dolomitic limestone in addition to the dolomite. Strikes range from due east to N. 55° E., and dips are from 20° to 35° to the south. Bowman (1950, p. 27) has calculated the minimum true thickness of the Glasgo Marble in the vicinity of Little Marble Mountain as 3,400 feet.

Quality of limestone.—From the description of the "limestone" given above, it is apparent that the rock is either dolomite or dolomitic limestone; the presence of numerous quartz stringers and some tremolite contribute to the silica content. Four samples (S-146 to S-149) were taken as follows:

Sample no.	Location	Bearing	Length (feet)
S-146	Along quarry face on west side of mountain in SW¼NW¼ sec. 17	S. 5° E.	100
S-147	North of summit; NE¼NW¼ sec. 17	N. 80° E.	80
S-148	Summit south; about on east-west quarter section line.	S. 80° E.	100
S-149	South slope; NE¼SW¼ sec. 17	N. 80° E.	80

Analyses of these samples are as follows:

Sample no.	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
S-146	55.09	45.06	46.97	30.95	21.56	0.69	0.49	0.037
S-147	54.24	44.64	46.63	30.47	21.36	1.84	0.50	0.005
S-148	56.69	41.21	45.72	31.85	19.72	0.70	0.74	0.018
S-149	64.81	34.13	45.93	36.41	16.33	1.09	0.38	0.009

The analyses bear out the field observation that the rocks at the northern end of the hill are essentially dolomite and those toward the south end are highly dolomitized limestone. No tonnage estimates were made, because the rock is obviously of no value for cement manufacture or for any use requiring high-calcium limestone.

Smaller outcrops of Glasgo Marble occur to the north of Little Marble Mountain, in the NW¼ sec. 17, the NE¼ sec. 18, and the SW¼ sec. 8, T. 38 N., R. 37 E. On the west side of the Kettle River, in Ferry County, similar rocks crop out in the W½ sec. 19 and the SE¼NE¼ sec. 19, T. 38 N., R. 37 E., around the margin of the Hodgson Creek Monzonite intrusive. All these outcrops are quite similar to those on Little Marble Mountain. They were not sampled.

Limestone of the Churchill Formation of Permian age (Bowman, 1950, p. 45) crops out approximately 2 miles south of Barstow, in secs. 29 to 32, T. 38 N., R. 37 E., in Ferry County. This limestone is referred to on page 178 and is discussed on pages 131 and 132 of this report.

Kettle Falls North District

Kettle Falls (formerly Meyers Falls) is on U.S. Highway 395 approximately 89 miles north of Spokane and 9 miles northwest of Colville. The town is in the valley of the Colville River 2 miles northeast of its confluence with the Columbia River. The altitude of the valley floor at Kettle Falls is 1,625 feet above mean sea level. The town and the surrounding area is served by U.S. Highway 395, the Great Northern Railway, and the Columbia River (Lake Roosevelt) 2 miles to the west.

Kettle Falls North district is an area of approximately 20 square miles (fig. 36) bounded on the north and west by the Columbia River and on the south by U.S. Highway 395. The eastern boundary is considered arbitrarily to be a north-south line 3½ miles east of Kettle Falls. Most of the area falls within the U.S. Geological Survey Marcus Quadrangle (1:125,000), but the eastern portion overlaps the Colville and Echo Valley quadrangles (1:24,000) by approximately two-thirds of a mile.

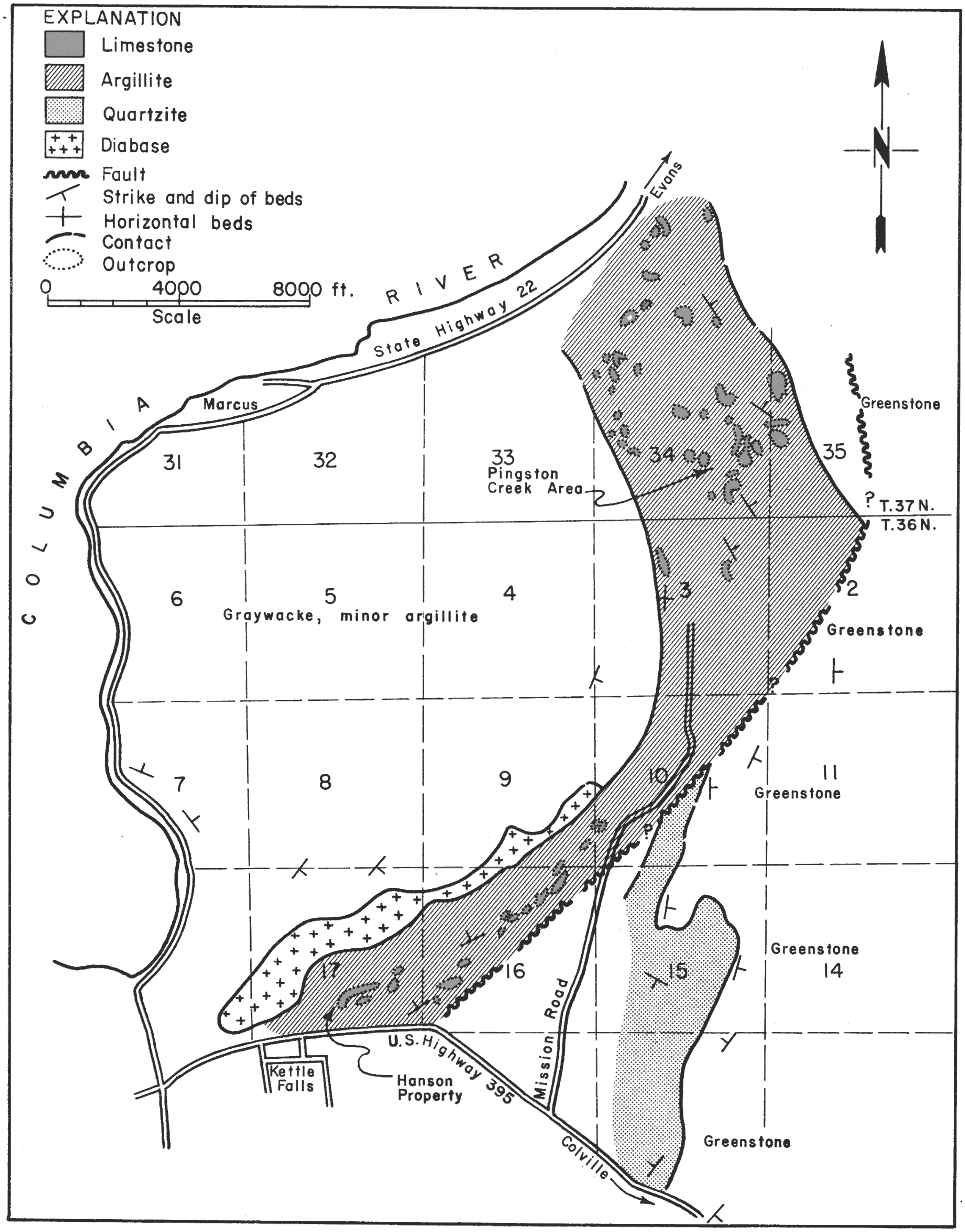

FIGURE 36.—Kettle Falls North district. T. 36 N., R. 38 E., and T. 37 N., R. 38 E. Geology by J. W. Mills. Base map from aerial photos.

Weaver (1920) shows the area to be underlain by the Mission Argillite and undifferentiated limestone of Paleozoic age, intruded by diabase and granite porphyry of Tertiary age. He describes (1920, p. 73) the Mission Argillite in part as follows:

> The formation comprises banded and massive argillites, calcareous argillites, quartz-mica schists, and narrow intercalated bands of quartzite and limestone. Argillites and quartz-mica schists predominate as constituents of the formation. In places the argillites are only very slightly metamorphosed and are in composition not far removed from indurated clay-shales. They grade into as well as alternate with black, slaty, carbonaceous argillites. In some places they become very calcareous and approach in composition argillaceous limestones. Bands of pure white limestone varying in thickness from two to over one hundred feet occur interbedded with the argillites. In places these limestone bands are so persistent that they can be traced for several miles and have been mapped as undifferentiated limestones but are to be regarded as constituent parts of the Mission argillite formation.

The author became interested in the area while teaching a Washington State University geology field camp at Kettle Falls in 1957. Mapping was begun as a part of the geology field camp program in 1957, and further work was done in 1958 and 1959. The following remarks are based upon this preliminary work and will require revision when more geologic mapping, currently (1961) underway, is completed.

The Mission Argillite of the Kettle Falls North district is composed of five mappable units. The western half of the area (fig. 36) is underlain by a great thickness of coarse clastic rocks, principally graywacke and chert pebble conglomerate. Bordering the coarse clastic rocks on the east is a band of dark-gray to black argillite, apparently lying conformably beneath the graywacke. To the east of the black argillite is an arcuate belt of brown-weathering argillite and siltstone, containing at least 40 distinctive intercalated pods, lenses, and large irregular masses of limestone. This belt is from 3,000 to 6,000 feet wide. Its exact relation to the black argillite is as yet unknown because of the complexity of the folding and faulting, the intrusion of diabase along the critical zone of contact of the two units, and insufficient mapping. To the east of the argillite-limestone belt is a great thickness of greenstone and associated smaller amounts of quartzite. Rocks mapped as greenstone include more or less schistose and calcareous amygdaloidal, pillowed, and some massive basic lavas and pyroclastic rocks. An unusual feature is the presence of discontinuous small pods and lenses of impure siliceous limestone within the greenstone. Only a few of these limestone areas are more than a few tens of feet long and a few feet wide, though some are as much as 200 feet long. Bedding in the limestone is weak to absent, and all of the rock is much too siliceous to be of any value. Similar calcareous greenstone is found in the Republic District (Muessig and Quinlan, 1959), and the Heidegger Hill, The Splitoff, and Hunters Creek areas described in this report. The relationship between greenstone and the quartzite and the argillite-limestone belt to the west is not known definitely. There is some evidence to support the idea that the greenstone and quartzite are separated from the argillite-limestone belt by a major fault zone (fig. 36). All the metasedimentary and metavolcanic rocks of the Kettle Falls North district are complexly folded, faulted, and intruded by diabase (Tertiary?) and minor amounts of what Weaver (1920) calls granite porphyry (Tertiary?).

Limestone of the argillite-limestone belt. —Although limestone masses occur in the greenstone belt, they are much too small and too siliceous to be of any value. The argillite-limestone belt, however, has many limestone masses that are several hundred feet long and of exceptional purity, as well as its share of small siliceous limestone bodies. Exploration for high-calcium limestone in the Kettle Falls North district can be confined to the argillite-limestone belt.

The limestone masses are more resistant to weathering than the enclosing argillite, so that many of them stand out as prominent hills and ridges. One such mass of limestone, $\frac{1}{2}$ mile northeast of Kettle Falls, is approximately $\frac{1}{4}$ mile long and 100 feet wide. More commonly, especially toward the north end of the belt, the larger masses are approximately 800 feet long and 600 to 700 feet wide. The majority of them have one side that is very steep to vertical or overhanging, and as much as 75 feet high (fig. 37). Their contacts with the enclosing argillite are usually covered by alluvium, although in many places the covered interval is only a few feet wide, indicating that the change from limestone to argillite is an abrupt one. Toward the ends of some of the limestone masses there is interfingering of limestone and argillite. Unlike the Metaline Limestone and other limestone of northern Stevens County, the Kettle Falls limestone is almost totally lacking in bedding. The rock is usually massive and apparently quite structureless, except for a slight development of weak parallel jointing

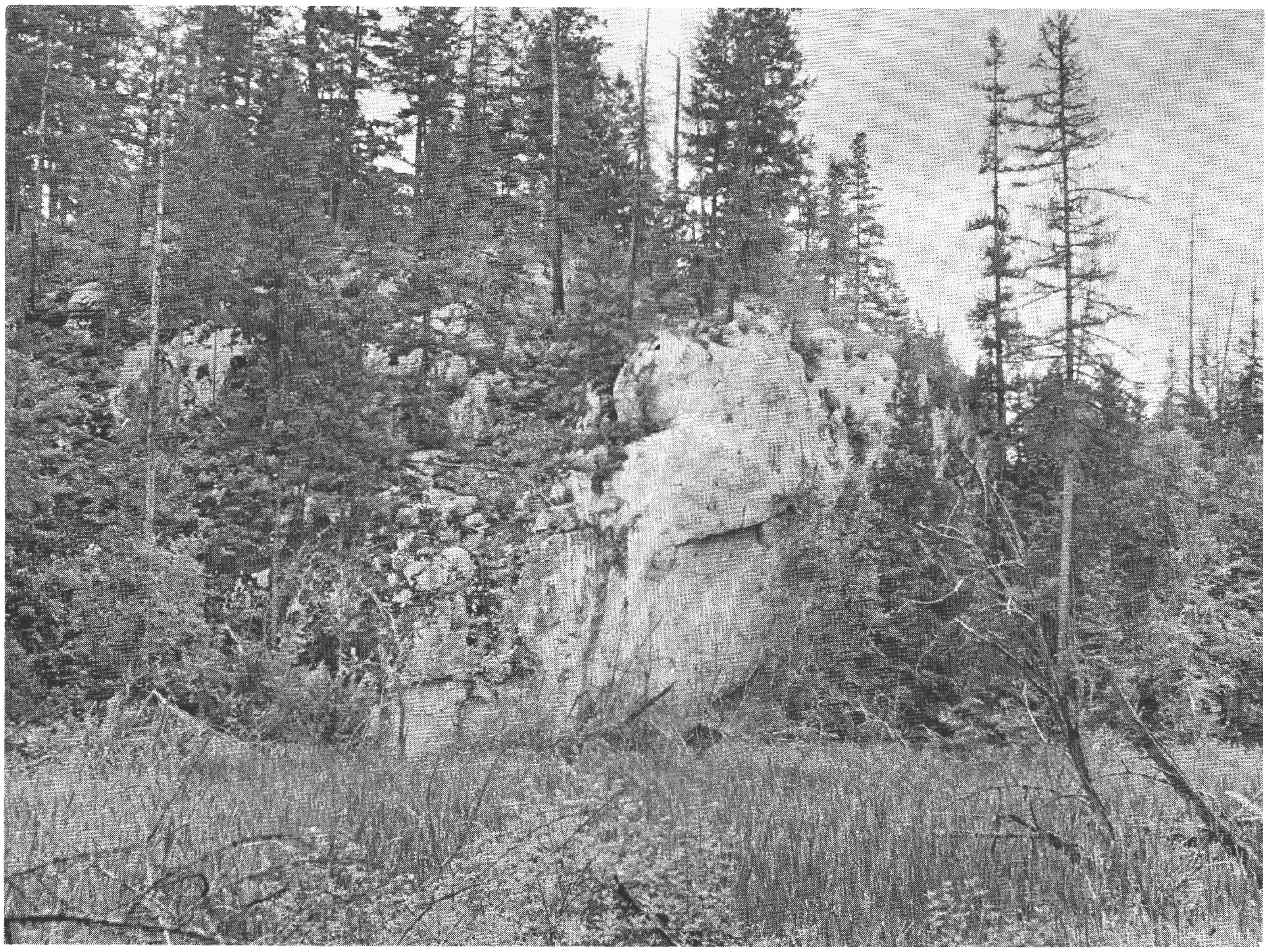

FIGURE 37.—Steep west side of Pingston Creek North reef (limestone). View looking southeast.

in some outcrops. It is light gray to gray on fresh and weathered surfaces, fine to medium grained, and approximately equigranular. In thin section, much of it appears as a fossil "hash" composed almost entirely of small fragments of fossils, especially crinoids, bryozoa, and fusulinids. Excellently preserved fusulinids are found in abundance in some of the limestone. Furthermore, fairly well preserved bryozoa, gastropods, and tetracorals have been collected from the limestone; brachiopods, gastropods, pelecypods and plant fragments have been collected from the enclosing argillite. The abundance and kinds of fossils, the lack of stratification, and the shape and distribution of these limestone masses lead to the conclusion that they are bioherms.

The age of the rocks of the argillite-limestone belt is Permian. This conclusion is based upon past and present (incomplete) studies of fossil collections from both the argillite and the limestone reefs. Fossil foraminifera from limestone near the south end of the belt have been identified (McLaughlin and Simons, 1951) as the fusulinid Parafusulina dunbari. The author has collected other fusulinid genera, bryozoa, gastropods, and tetracorals from the limestones, and brachiopods from the brown-weathering argillites and siltstones of this belt 4½ miles northeast of Kettle Falls. These fossils are being studied and will be described in a later publication. The brachiopod collection contains a number of the same genera (and species?) reported by Cooper (1957) from the Coyote Butte Formation (Permian) of central Oregon. Dixon (1958) collected gastropods, pelecypods, scaphopods, and brachiopods from the argillite half a mile northeast of Kettle Falls. He favored a "lower or middle Permian age for the argillite at this locality," although some of the genera had a range from lower Carboniferous to Triassic. The best information gained to date indicates that the age of the rocks of the argillite-limestone belt is middle to late Permian.

Only three limestone masses were found to be sufficient both in size and purity to be of interest. These are north of Pingston Creek and are discussed in the following section.

Pingston Creek Area
Secs. 34 and 35, T. 37 N., R. 38 E.

Location, accessibility, and ownership.—Pingston Creek drains Rigley Lake, which lies in the north-central part of sec. 2, T. 36 N., R. 38 E., approximately ½ mile west of the summit of Echo Mountain. The creek runs almost due west for 5 miles, to where it empties into the Columbia River, 1 mile south of Marcus and 3½ miles north of Kettle Falls. The limestone bioherms are from 3/4 mile to 1-1/2 miles north of Pingston Creek, in secs. 34 and 35, T. 37 N., R. 38 E. They can be reached by driving east from State Highway 22, at the mouth of Pingston Creek, up the Pingston Creek valley a distance of 4 miles to the Mission road junction. From there a narrow graveled road extends almost due north for a distance of 2 miles through the E½ sec. 34. The closest railroad facilities are at Kettle Falls and at the mouth of Pingston Creek.

Three separate limestone reefs (bioherms) were studied. The south reef is in the SE¼SE¼ sec. 34, T. 37 N., R. 38 E., on property owned by Leonard Fuhrman of Kettle Falls. The middle reef, a quarter of a mile farther north, is in the NE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 34, T. 37 N., R. 38 E., on property owned by A. C. McDonald of Hot Springs, Montana. The north reef is in the NW$\frac{1}{4}$NW$\frac{1}{4}$ sec. 35, T. 37 N., R. 38 E., on State land.

Geology.—All three reefs and the adjacent smaller limestone masses are within the Kettle Falls North argillite-limestone belt (fig. 36) and hence are enclosed by brown-weathering argillite and siltstone. Bedding in the argillite strikes northwestward and dips gently to steeply to the northeast. Fossils in the argillite and in the limestone indicate a Permian age for both rocks. Intrusive into the sedimentary rocks are diabase dikes of widely different sizes, shapes, and attitudes. Some of the limestone bodies were considered to be of sufficient size and purity to merit study and sampling. They are composed of white to light-gray, fine- to medium-grained, massive fossiliferous limestone.

Quality and quantity of limestone.—The south reef (fig. 38) forms a prominent ridge approximately 800 feet long and 200 feet wide, with a vertical face 75 feet high on its west side. Six samples (S-38 to S-43, inclusive) were taken in a northeast direction, for a total length of 335 feet, along the foot of the steep west face. The middle reef (fig. 38) is approximately 800 feet long and 400 feet wide, with a vertical face 50 feet high on its east side. Four samples (S-81 to S-84, inclusive) were taken northeastward across this reef for a total sample length of 265 feet. The north reef (fig. 39) crops out over a length of 800 feet and a width of 700 feet. It has a vertical to overhanging face, 50 feet high, on its west side (fig. 37). Six discontinuous samples (S-44 to S-47, S-79, and S-80) were taken in an easterly direction across the exposed parts of the reef for a total sample length of 315 feet. These samples are representative of a width of 650 feet, including the parts of the reef that are covered by a thin soil mantle. Another set of six continuous samples, (S-85 to S-90, inclusive) was taken in a southeasterly direction, along the top of the west face, for a total length of 480 feet. The analyses of the samples taken of the three reefs are as follows:

Sample no.	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)
SOUTH REEF													
S-38	50	97.01	0.79	43.00	54.50	0.38	1.12	0.56	0.030				
S-39	50	97.06	0.82	43.19	54.53	0.39	1.47	0.54	0.050				
S-40	60	97.37	0.73	42.78	54.70	0.35	1.40	0.49	0.020				
S-41	50	96.73	0.79	42.63	54.34	0.38	1.50	0.55	0.020	225	560	40	40
S-42	50	97.24	0.61	42.73	54.63	0.29	1.74	0.56	0.040				
S-43	75	97.21	0.63	42.56	54.61	0.30	1.80	0.60	0.030				
MIDDLE REEF													
S-81	75	97.86	0.44	42.12	54.98	0.21	2.79	0.29	0.019				
S-82	70	97.86	0.56	43.08	54.98	0.27	1.10	0.42	0.029				
S-83	70	98.56	0.48	43.39	55.37	0.23	0.32	0.16	0.028				
S-84	50	98.38	0.61	43.15	55.27	0.29	0.63	0.22	0.028				
NORTH REEF													
S-44	50	96.85	0.50	43.51	54.41	0.24	1.18	0.34	0.023				
S-45	50	96.00	0.59	43.26	53.93	0.28	1.59	0.46	0.034				
S-46	70	96.12	0.50	43.02	54.00	0.24	2.31	0.49	0.027	220	560	-30	470
S-47	15	96.55	0.48	43.18	54.24	0.23	2.09	0.37	0.028				
S-79	55	98.11	0.52	43.64	55.12	0.25	0.76	0.19	0.012				
S-80	75	97.72	0.82	43.06	54.90	0.39	1.22	0.30	0.012				
S-85	80	98.51	0.52	43.28	55.34	0.25	0.49	0.27	0.019				
S-86	80	98.18	0.48	43.16	55.16	0.23	0.79	0.18	0.017				
S-87	80	97.99	0.54	42.98	55.05	0.26	1.05	0.22	0.017				
S-88	80	97.49	0.65	42.75	54.77	0.31	1.58	0.15	0.022				
S-89	80	97.65	0.50	43.28	54.86	0.24	1.37	0.28	0.025				
S-90	80	98.27	0.40	43.66	55.21	0.19	0.80	0.21	0.020				

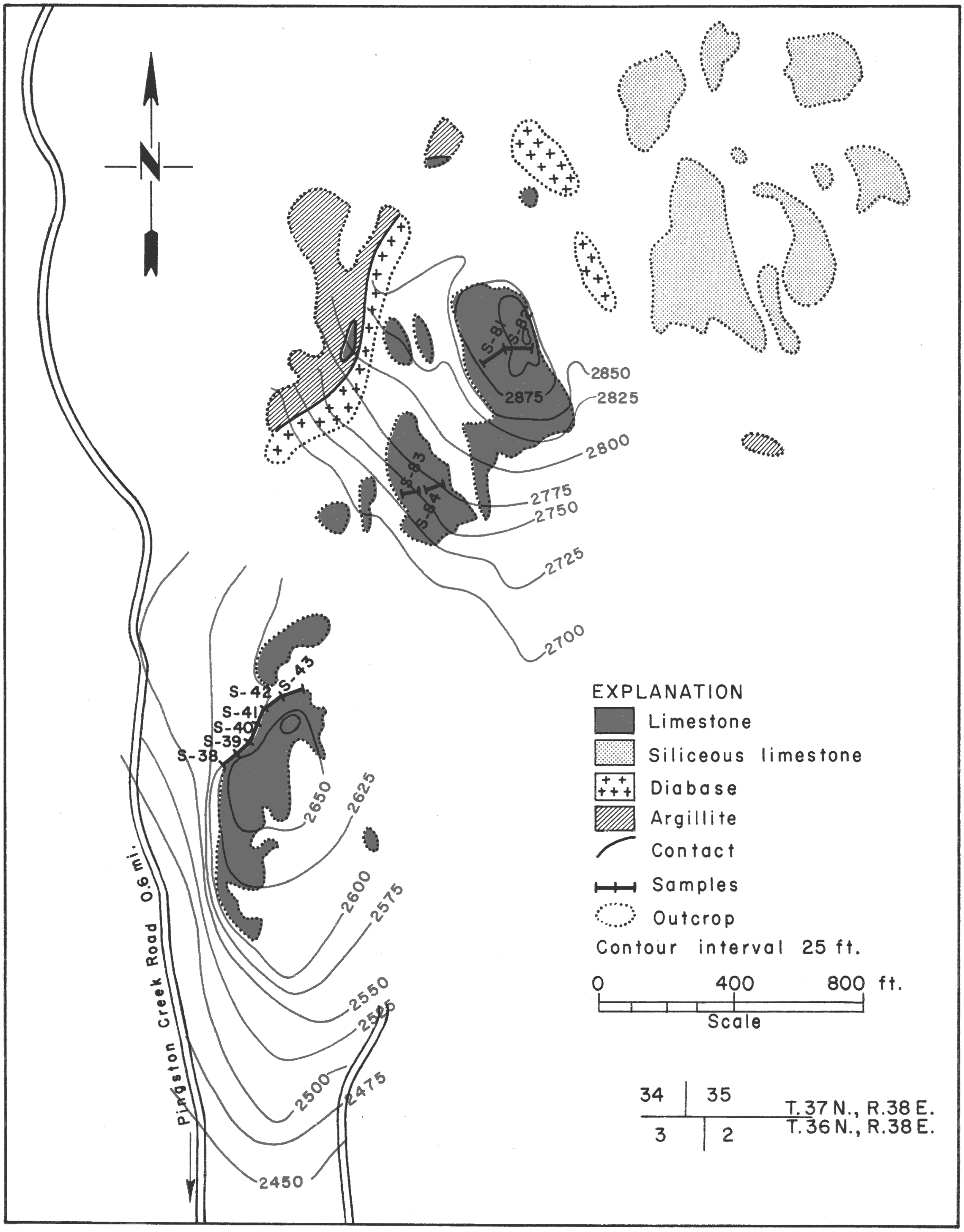

FIGURE 38.— Pingston Creek South and middle reefs. Secs. 34 and 35, T. 37 N., R. 38 E. Geology by J. W. Mills. Base map from aerial photo enlargement. Topography from altimeter survey.

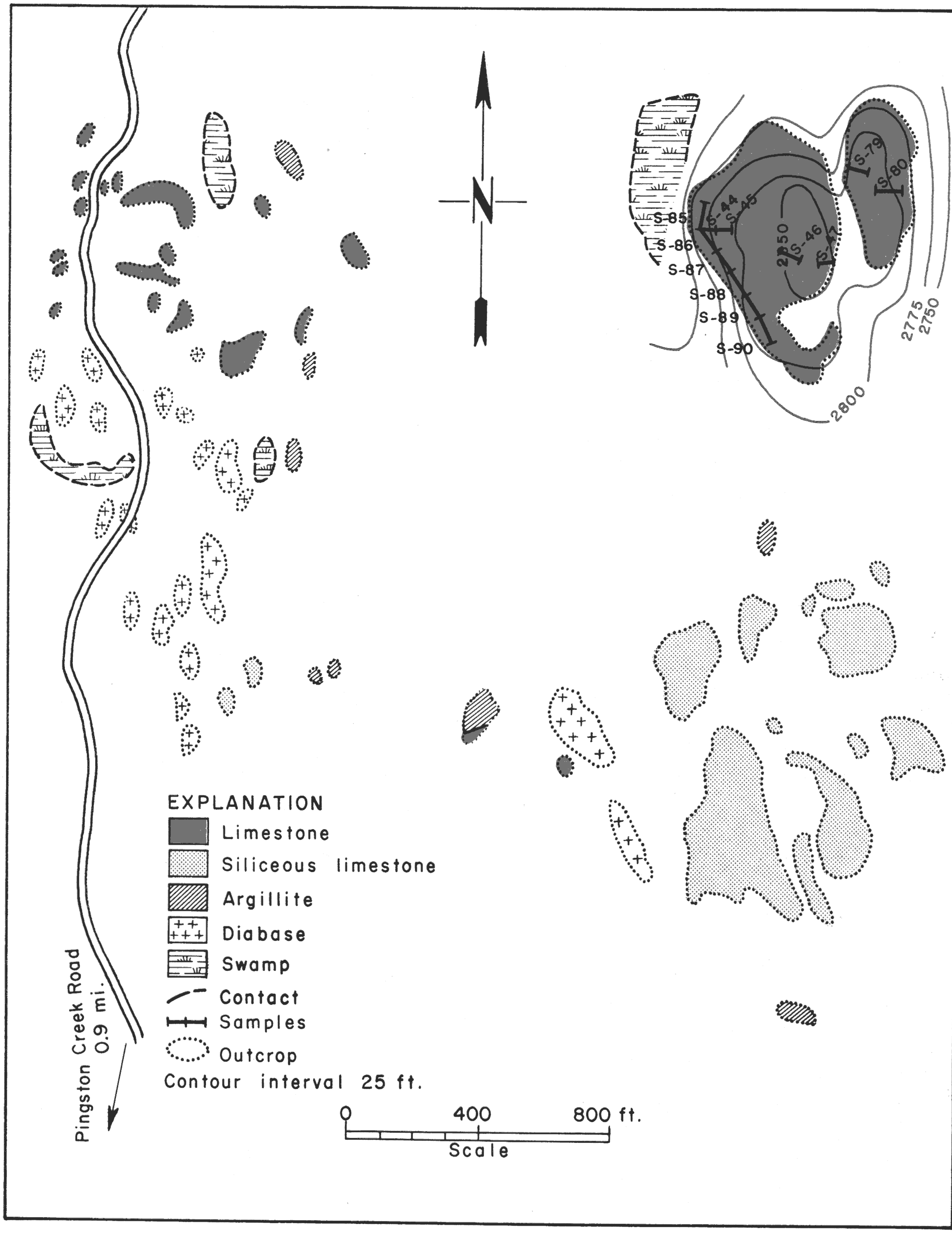

FIGURE 39.—Pingston Creek North reef. Secs. 34 and 35, T. 37 N., R. 38 E. Geology by J. W. Mills. Base map from aerial photo enlargement. Topography from altimeter survey.

The unweighted average of the analyses of the samples (S-38 to S-43) of the south reef is 54.55 percent CaO, 0.35 percent MgO, 1.50 percent SiO_2, 0.55 percent R_2O_3, and 0.032 percent P_2O_5. The unweighted average composition of the middle reef (S-81 to S-84) is 55.15 percent CaO, 0.25 percent MgO, 1.21 percent SiO_2, 0.27 percent R_2O_3, and 0.026 percent P_2O_5. The unweighted average composition of the north reef is 54.76 percent CaO, 0.26 percent MgO, 1.28 percent SiO_2, 0.29 percent R_2O_3, and 0.021 percent P_2O_5.

The analyses show the limestone of each reef to be high-calcium limestone. The CaO content ranges from 54.00 to 55.37 percent. The average content of $CaCO_3$ is 97.58 percent. The maximum content of MgO is 0.39 percent, and of R_2O_3 is 0.56 percent. The principal impurity is silica, which ranges from 0.32 to 2.79 percent.

Each of the reefs, though some distance from the Great Northern Railway and State Highway 22 along the Columbia River, can be reached easily by auto. The reefs have little or no overburden and they stand out boldly enough from the surrounding argillite that quarry operations could be begun with a minimum of preparation. The amount of limestone available in each reef to the depth of the base of its vertical face is:

South reef	1,900,000	tons
Middle reef	3,250,000	"
North reef	2,450,000	"
Total	7,600,000	tons

The composition of the reef limestone meets the chemical specifications for use as ceramic whiting, mineral filler, builders' lime, and for use in the manufacture of pulp, paper, and portland cement.

In the event that quarrying of the limestone should ever be considered, it should be pointed out that careful sampling of some of the smaller limestone masses near the large reefs would undoubtedly result in outlining a considerable additional tonnage of limestone of like grade.

Hanson Property
SE¼ sec. 17, T. 36 N., R. 38 E.

Location, accessibility, and ownership.—Limestone crops out a quarter of a mile north of the town limits of Kettle Falls and 700 feet north of U.S. Highway 395 and the Great Northern Railway. The property belongs to the Clem Hanson Estate, in care of Sarah Hanson, of Colville.

Geology.—The limestone sampled is the southern end of a prominent steep-sided ridge over 1,500 feet long and as much as 100 feet wide. The ridge is one of the many fusulinid-bearing limestone reefs of the argillite-limestone map unit (fig. 36). It is surrounded by brown-weathering argillite. Dixon's fossil collection locality (Dixon, 1958, p. 1) is about 500 feet to the northwest of the south end of this reef.

Quality of limestone.—The limestone is gray on fresh and weathered surfaces, medium grained and massive. It contains numerous irregular stringers and blebs of pale yellow weathering silicified and dolomitic limestone. Some of these are up to 5 inches across and several feet long. They become more numerous toward the steep south end and southeast side of the outcrop. Four samples were taken from northwest to southeast across the crest of the ridge. The analyses of these samples are as follows:

Sample no.	Length (feet)	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
S-1	20	87.22	2.51	41.83	49.00	1.20	4.60	1.46	0.032
S-2	20	80.10	2.51	38.84	45.00	1.20	11.10	1.44	0.038
S-3	20	86.33	2.93	42.06	48.50	1.40	4.40	1.09	0.043
S-4	8	78.32	2.09	37.75	44.00	1.00	14.15	1.06	0.033

The sampling and the field studies show the rock to be much too impure to be of any value for most uses.

Kettle Falls South District

The town of Kettle Falls is in the valley of the Colville River 10 miles northwest of Colville on U.S. Highway 395. It is 1 mile east of the junction of State Highway 22 and U.S. Highway 395 and 2½ miles east of the Columbia River. It is serviced by the Great Northern Railway. The area Kettle Falls South begins at the mouth of the Colville River, where it empties into the Columbia River 2½ miles south of Kettle Falls, and extends southwest for 3 miles parallel to the Columbia River and east of State Highway 22. The area has many good graveled roads in addition to the State Highway. The principal outcrop areas are on the western slopes of Mingo Mountain.

Mingo Mountain Area

Location and accessibility.—Mingo Mountain area is in sec. 36, T. 36 N., R. 37 E.; secs. 1, 2, 11, and 12, T. 35 N., R. 37 E.; and secs. 5 and 6, T. 36 N., R. 38 E., approximately 3 miles south of Kettle Falls. State Highway 22 is in the west part of the area (fig. 40).

Geology.—Weaver (1920) shows the area to be underlain by Colville Quartzite and Mission Argillite. The writer and students of a Washington State University geology field camp mapped (1957) the area geologically (fig. 40). Four distinct units were recognized. The oldest is a quartzite that forms the crest of Mingo Mountain. Overlying the quartzite conformably is phyllite followed by a thick section of argillaceous limestone with minor amounts of dolomite. The youngest sedimentary rock is a black argillite that overlies the argillaceous limestone unit conformably. The thickness of these was not determined. The four units, quartzite, phyllite, limestone, and argillite, are believed to be

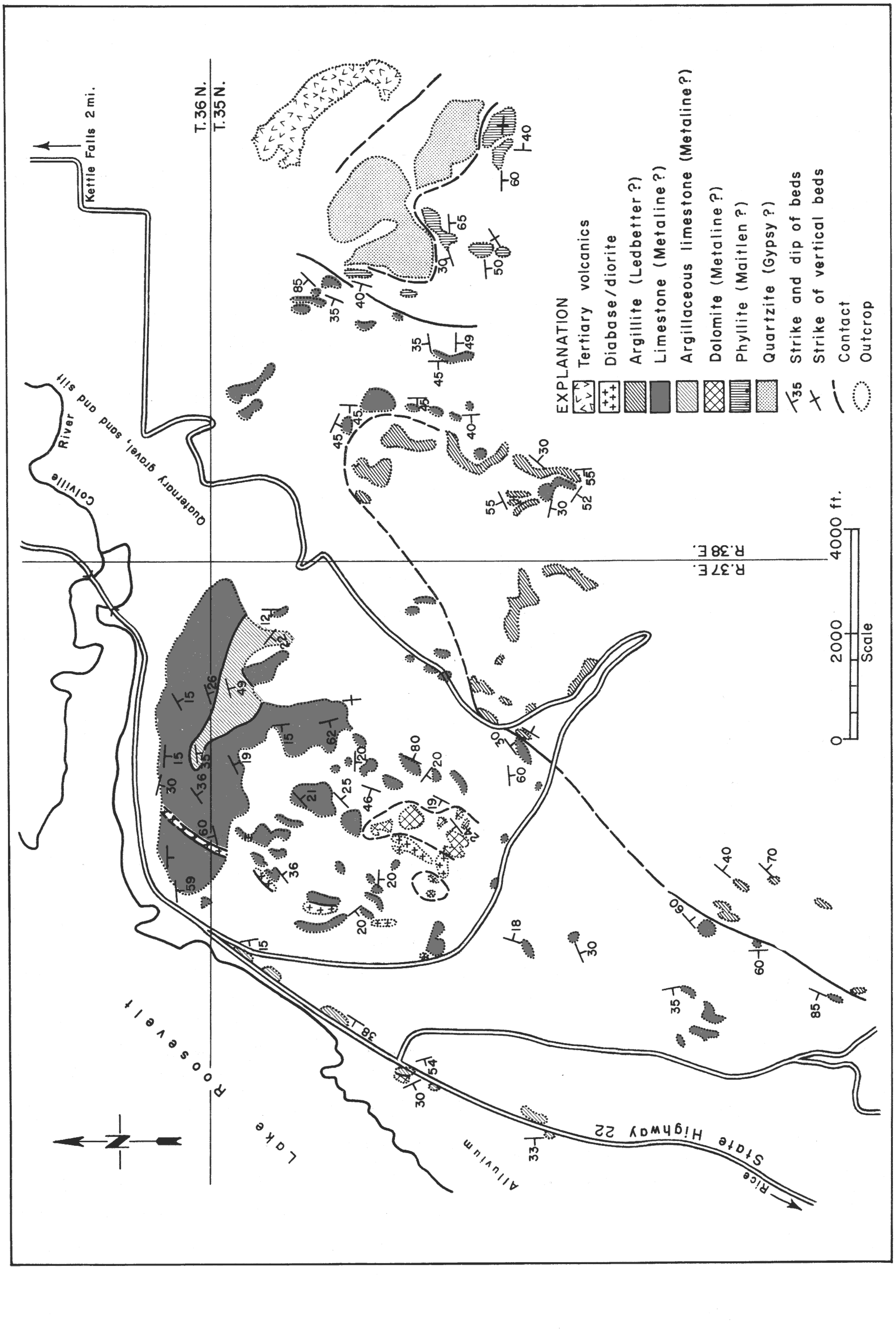

FIGURE 40.—Mingo Mountain area. T. 35 N., Rs. 37 and 38 E., and T. 36 N., R. 37 E. Geology by R. Raper, J. Eke, E. Hanson, C. Gladish, P. Collins, and J. W. Mills Base map from aerial photos.

correlatives of the Gypsy Quartzite, Maitlen Phyllite, Metaline Limestone, and Ledbetter Slate, respectively, mapped by Park and Cannon (1943) in the Metaline district, Washington. The correlation is based entirely on similarity in lithology and rock succession. If this correlation is correct, then the three older units are Cambrian and the argillite is Ordovician in age. The entire assemblage has been folded into a syncline plunging about 40° to the southwest. There is some evidence to indicate that a large part of the limestone section has been omitted by faulting in a north-south direction through the center of sec. 6, T. 35 N., R. 38 E. The sedimentary rocks have been intruded by dikes and stocks of diabase and diorite. To the northeast, volcanic rocks (Tertiary) overlie the older rocks unconformably.

The limestone (Metaline ?) forms a prominent hill in the S$\frac{1}{2}$ sec. 36, T. 36 N., R. 37 E. and sec. 1, T. 35 N., R. 37 E. and occurs in scattered outcrops toward the southwest.

Quality of limestone.—The limestone unit is composed principally of dark-gray fine-grained well-bedded argillaceous limestone interbedded with dolomitic limestone, calcareous argillite and dolomite. No high-calcium limestone is present and no limestone suitable for cement manufacture was found. No samples were taken.

Shedd (1913, p. 142) reports that "about two miles south of Kettle Falls [this is old Kettle Falls, now inundated] . . . limestone occurs and lime was burned here at one time. . . . The deposits occur in low rounded knolls which rise only a few feet above the road and not far from the river." Shedd's two analyses of this rock indicate a CaO content in excess of 54 percent. According to Valentine (1960, p. 51), this high-grade limestone "is now covered by water."

The Ideal Cement Company studied the limestones 4 miles southwest of Kettle Falls, in sec. 2, T. 35 N., R. 37 E., and found them to be "too magnesian and much too siliceous" (1959, written communication).

Heidegger Hill District

The area referred to as Peaceful Valley by Shedd (1913, p. 143) and as Heidegger Hill by Cole (1959) extends south from the southeastern corner of T. 35 N., R. 37 E., to Pleasant Valley. It borders the east side of the Columbia River and State Highway 22 from 7 to 13 miles south of Kettle Falls. The east boundary is the line between Rs. 37 E. and 38 E. Access can be gained easily by the Columbia River, State Highway 22, and good graveled county roads, such as Thorpe road and Childers road. The nearest railroad is the Great Northern Railway at Kettle Falls.

Weaver (1920, p. 68) shows the bedrock on the east side of the area, along the crest of the Huckleberry Mountains, to be quartzite that he calls the Colville Quartzite. "Approximately parallel to the Columbia River and about two miles west of the belt which lies along the Huckleberry Mountains is a second belt of the same quartzite ranging from two-thirds of a mile to over two miles in width. Between these two quartzite belts is a long narrow belt of Mission argillite." (Weaver, 1920, p. 69.) He believes (p. 73) that the "Mission argillite lying between the two belts of Colville quartzite is involved in a closely folded syncline which has not been overturned." Weaver considers the age of these metasedimentary rocks to be Cambrian (?) to Carboniferous (?). He describes the lithology (1920, p. 73) of the Mission Argillite as follows:

> The formation comprises banded and massive argillites, calcareous argillites, quartz-mica schists, and narrow intercalated bands of quartzite and limestone. Argillites and quartz-mica schists predominate as constituents of the formation. In places the argillites are only very slightly metamorphosed and are in composition not far removed from indurated clay-shales. They grade into as well as alternate with black, slaty, carbonaceous argillites. In some places they become very calcareous and approach in composition argillaceous limestones. Bands of pure white limestone varying in thickness from two to over one hundred feet occur interbedded with the argillites. In places these limestone bands are so persistent that they can be traced for several miles but are to be regarded as constituent parts of the Mission argillite formation.

Cole (1959) recognizes at least five distinct and conformable (?) mappable units in the area. Plate 5 is a slightly modified version of Cole's map. On the east side of the area is quartzite corresponding to Weaver's eastern belt of Colville Quartzite. To the west of the quartzite is a north-south belt of phyllite overlain by argillite. Above the argillite is a greenstone-limestone unit overlain in turn by graywacke. The graywacke corresponds to Weaver's western Colville Quartzite belt. Cole's combined phyllite, argillite, and greenstone-limestone units are part of Weaver's Mission Argillite. All five units make up the western limb of a faulted synclinorium on which are superimposed two lesser synclines and anticlines (pl. 5) overturned to the west and plunging 30° to the south.

Cole (1959, p. 5) writes that "the phyllite is possibly equivalent to the Maitlen Phyllite named by Park and Cannon (1943, p. 15) in the Metaline area." The inference is that Cole's quartzite (Weaver's eastern belt of Colville Quartzite) may be correlated with the Gypsy Quartzite (Park and Cannon, 1943, p. 13), because Cole reports that "the phyllite probably grades into the underlying quartzite." There are no rocks similar to the Metaline Limestone overlying the phyllite, which leads Cole to suggest that "the limestone is apparently missing due to faulting." If Cole's interpretations are correct, then the phyllite and the quartzite units are Cambrian in age.

The argillite overlying the phyllite is composed of "dark-gray and black slates and phyllites . . . thin-bedded limestones and quartzite lenses" (Cole, 1959, p. 5). In his discussion of the age of the argillite unit, Cole (p. 6) writes:

> This argillite is probably equivalent to the Ordovician Ledbetter Slate of Park and Cannon. The author visited a road cut containing graptolites which is located along the extended strike of the formation and is two and a half miles south of the area. The slate containing the fossils can be traced northward into the map area.

The greenstone-limestone unit is composed of schistose meta-andesites, meta-basalts, and limestone pods of various sizes. Cole (1959, p. 6) describes the metamorphosed volcanic rocks as,

> . . . predominantly a fine-grained green to brown chlorite schist. The greenstone is everywhere shot full of calcite veins which are so numerous as to make the formation highly calcareous throughout. In several places [there are] metacrysts of amphibole as pseudomorphs of pyroxene, and albite laths occur in the green rock.

The limestone lenses are the rocks of principal interest in this report. Cole (1959, p. 7) writes about these as follows:

> Within the greenstones there occur what are apparently discrete pods of limestone. The limestones are generally medium-grained, light to dark gray on the fresh surface, and weather to a light gray. They are siliceous and dolomitic and have numerous small calcite veins. The dolomite occurs as parallel stringers usually less than half an inch thick; less often it is in rounded masses which reach a diameter of a few feet. Where it occurs as stringers, the yellowish-brown dolomite, because of a greater resistance to erosion, stands up as ridges on the weathered limestone surfaces. The dolomite is unquestionably secondary in origin.
>
> The limestone pods are isolated bodies in the greenstones and vary from a few feet to several thousand feet in size. The larger pods occur as ridges with sharp white cliffs; a spectacular example of this is the Splitoff, located in section 33, T. 35 N., R. 37 E., which has an impressive white cliff along its west side. All of the larger pods are closely jointed and fractured, but any evidence of bedding is completely missing. The larger limestones crop out in the lower half of the formation, but the smaller bodies are distributed throughout the greenstone terrain. No fossils were found in the limestone even though an intensive search was made.

Cole's greenstone-limestone unit is lithologically identical to greenstones (fig. 36) north of Kettle Falls. No definite age can be assigned to these rocks, but they are considered tentatively to be Permian in age. A discussion of the geology of the area north of Kettle Falls is to be found on pages 134 to 138 of this report.

The graywacke unit, corresponding to Weaver's western Colville Quartzite belt, is described by Cole (1959, p. 8) as follows:

> Graywacke.—Coarse clastic rock interbedded with brown and black slates. Dark-gray to black, poorly sorted, with subangular to subrounded quartz grains. Mainly quartz (over 90%) and lithic fragments with a matrix of clay and sericite, and hematite staining in some places. The coarse-grained graywacke alternates with beds of black and brown siliceous argillite or slate. The graywacke bedding is usually two to three feet thick and is separated by beds of argillite inches in thickness.
>
> The graywacke is conglomeratic in places, especially near the lower contact of the formation. A crude graded bedding is present in the individual sandstone and slate combinations.

The age of the graywacke is unknown. It is younger than the Permian (?) greenstone-limestone unit.

The only limestone occurrences of large size are those on the Splitoff, Heidegger Hill, and Thorpe road.

The Splitoff Deposit

Sec. 33, T. 35 N., R. 37 E.

Location, accessibility, and ownership.—A prominent steep hill, known as The Splitoff, is in the SW$\frac{1}{4}$NE$\frac{1}{4}$ sec. 33, T. 35 N., R. 37 E., 1,000 feet due east of State Highway 22, 10$\frac{1}{2}$ miles south of Kettle Falls. The ground rises sharply from State Highway 22 (altitude 1,400 feet) to the sharp crest of The Splitoff, the summit of which has an altitude of 2,112 feet above mean sea level (fig. 41). One-third of a mile to the southwest is a second, smaller hill. Both hills are on property owned by Irvin Mollenberg, of Kettle Falls. The closest railroad facilities are at Kettle Falls.

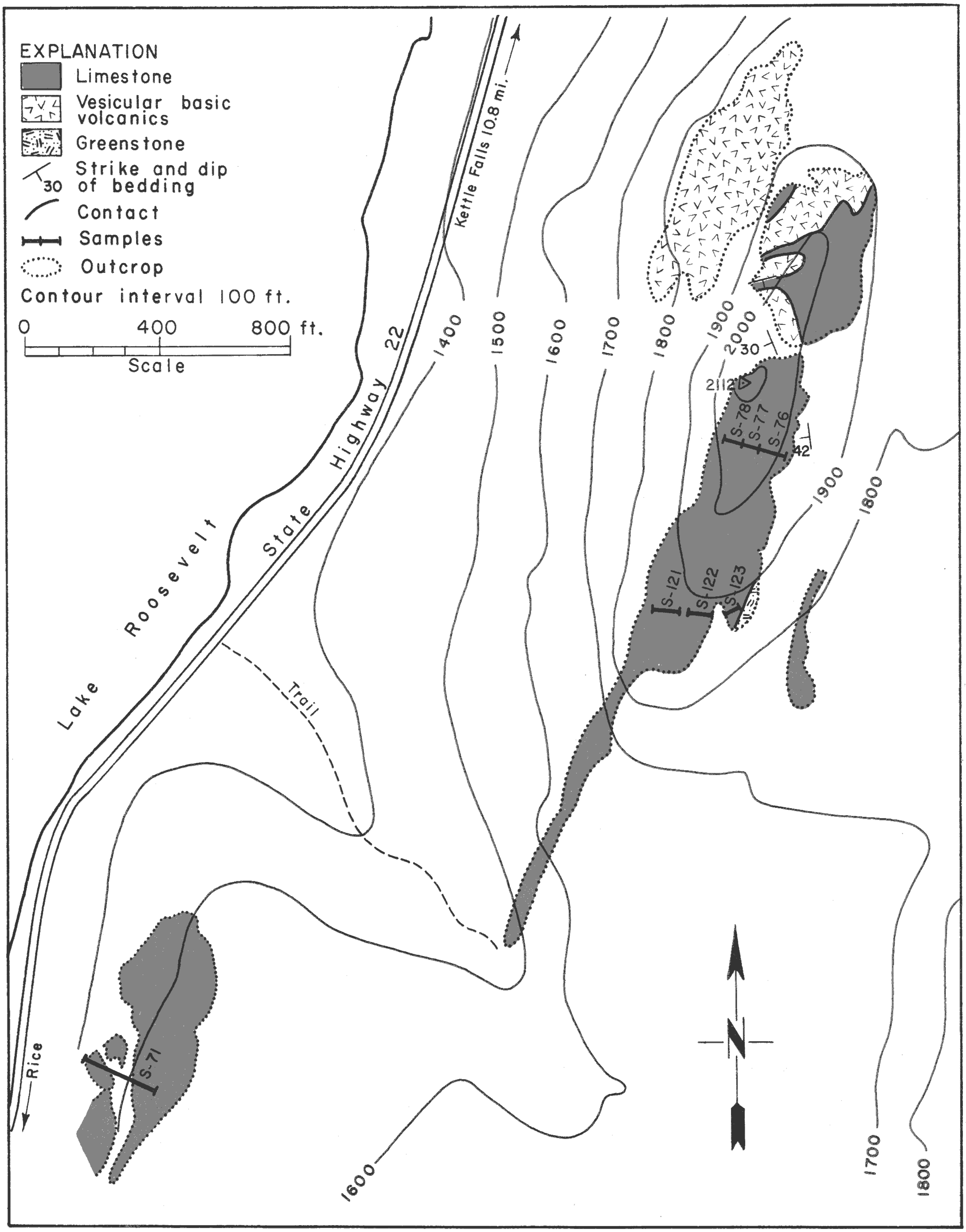

FIGURE 41.—The Splitoff deposit. Sec. 33, T. 35 N., R. 37 E. Geology by J. W. Mills. Base map from aerial photo enlargement. Topography from U.S. Geological Survey Inchelium quadrangle map.

Geology.—The Splitoff and its neighboring hill are made up almost entirely of carbonate rocks belonging to Cole's greenstone-limestone unit (Cole, 1959), overlain and underlain by amygdaloidal basic lavas and greenstone schist (fig. 41). The carbonate rock is a gray to dark-gray, fine-grained, rather massive, and slightly silicified limestone. In some places, especially in the smaller hill southwest of The Splitoff, the gray limestone contains dolomite (?) that appears on the weathered surface of the rock as brown-weathering lumps, nodules, and layers up to half an inch thick. The bedding, though not well developed, varies considerably in strike and dip. For the most part, the strike is between N. 20° W. and N. 20° E., and the dip ranges from 30° to 50° W.

Quality and quantity of limestone.—Six samples (S-76 to S-78 and S-121 to S-123) were taken across the bedding on The Splitoff, for a total horizontal length of 358 feet. One sample (S-71) was taken on the hill to the southwest of The Splitoff, over a horizontal length of 248 feet (fig. 41). The analyses of these samples are as follows:

Sample no.	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)
S-76	80	89.45	5.91	42.63	50.25	2.83	2.92	1.15	0.020				
S-77	50	94.38	1.65	42.68	53.02	0.79	2.40	1.17	0.016	220	610	315	30
S-78	50	92.81	2.97	42.33	52.14	1.42	2.77	0.94	0.027				
S-121	90	91.56	2.05	41.31	51.44	0.98	4.55	1.66	0.022				
S-122	78	93.61	1.34	41.97	52.29	0.64	3.19	1.38	0.011				
S-123	50	91.47	3.49	42.17	51.39	1.67	3.27	1.27	0.009				
S-71	248	92.35	3.51	42.55	51.88	1.68	2.61	1.08	0.019				

The analyses show that the rock contains an average of 51.77 percent CaO; it is not a high-calcium limestone. The average content of MgO (1.14 percent) is slightly below the maximum commonly allowed in rock suitable for cement manufacture. The Ideal Cement Company examined and sampled this deposit and concluded (1959, written communication) that it is "too magnesian." Assuming a uniform thickness of about 200 feet and a length of 500 feet for the limestone on The Splitoff, the volume of rock above an altitude of 1,500 feet is 2½ million tons.

Heidegger Hill Deposit
Sec. 3, T. 34 N., R. 37 E.

Location, accessibility, and ownership.—Limestone crops out prominently from 1,000 feet to 4,500 feet north of the Pleasant Valley road, 1½ miles east of State Highway 22. The limestone is on both sides of the north-south center line of sec. 3, T. 34 N., R. 37 E. The property to the west of the center line is owned by Lawrence L. Hays, of Rice. The property east of the center line is owned by E. L. Harris and M. E. Hays, of Rice, and C. A. Overman, of Colville. The closest railroad is the Great Northern Railway at Kettle Falls.

Geology.—The limestone of Heidegger Hill is the largest single body of limestone in the greenstone-limestone unit mapped by Cole (1959). It is entirely surrounded by greenstone (pl. 5 and fig. 42). The carbonate rock is a light-gray to gray, fine- to medium-grained, massive limestone. It contains 5 percent siliceous and dolomitic limestone in the form of brown-weathering hard irregular streaks, lenses, and layers from ½ inch across to 4 feet across, and as much as 5 feet long. In this respect the limestone is quite similar to, but probably more impure than, the limestone of The Splitoff. The rock is so massive that bedding is almost impossible to find. Near the southeast end of the outcrop, bedding strikes N. 23° W. and dips 63° W. Toward the west side of the outcrop the bedding strikes N. 10° W. and dips 45° E. It appears that the limestone lies along the trough of a syncline in the greenstone.

Quality of limestone.—Shedd (1913, p. 143) refers to the limestone of Heidegger Hill and lesser outcrops to the north when he writes,

> The largest body of limestone in the vicinity of Kettle Falls is situated south of the town [old Kettle Falls] about six or seven miles, in Peaceful valley. It lies in sections 27, 34, and 35, township 35 north, range 37 east, and sections 2 and 3, township 34 north, range 37 east. This body of limestone has an approximate length north and south of about two miles and an average width of about 800 feet. It appears to be steeply inclined and dip to the east. Dark-colored slightly grayish shales occur on either side of it.
>
> The limestone is very fine grained and of quite uniform texture. It is grayish in color, has a somewhat flinty appearance, and is affected but slowly by atmospheric agencies.

In spite of the obviously impure nature of the limestone, 6 samples were taken as checks on the quality of this extensive limestone outcrop. The samples (S-124 to S-129, inclusive) were taken from east to west across an outcrop width of about 580 feet. Samples S-124 and S-125 contain a much smaller proportion of the brown-weathering impure limestone than samples S-126 to S-129. The analyses of these samples and one reported by Shedd (1913, p. 143) are as follows:

Sample no.	Length (feet)	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
S-124	100	94.48	1.32	43.16	53.08	0.63	2.52	0.28	0.001
S-125	90	96.35	1.50	43.01	54.13	0.72	1.63	0.23	0.003
S-126	100	83.30	10.07	41.68	46.80	4.82	6.04	0.69	0.002
S-127	100	78.32	9.80	39.44	44.00	4.69	11.37	0.76	0.004
S-128	70	79.60	5.45	37.60	44.72	2.61	14.21	0.72	0.004
S-129	65	88.06	4.97	41.35	49.47	2.38	6.44	0.21	0.003
Shedd	—	—	—	42.18	54.57	0.56	1.70	0.56	—

The average (unweighted) content of CaO is 49.54. Shedd's sample and samples S-124 and S-125 are the only ones that contain more than 95 percent $CaCO_3$. Most of the samples are much too impure to be of interest. On the basis of the field examination, it is concluded that no continuity of higher grade parts can be relied upon and that the overall grade of the limestone is much too low to be of any value for most uses.

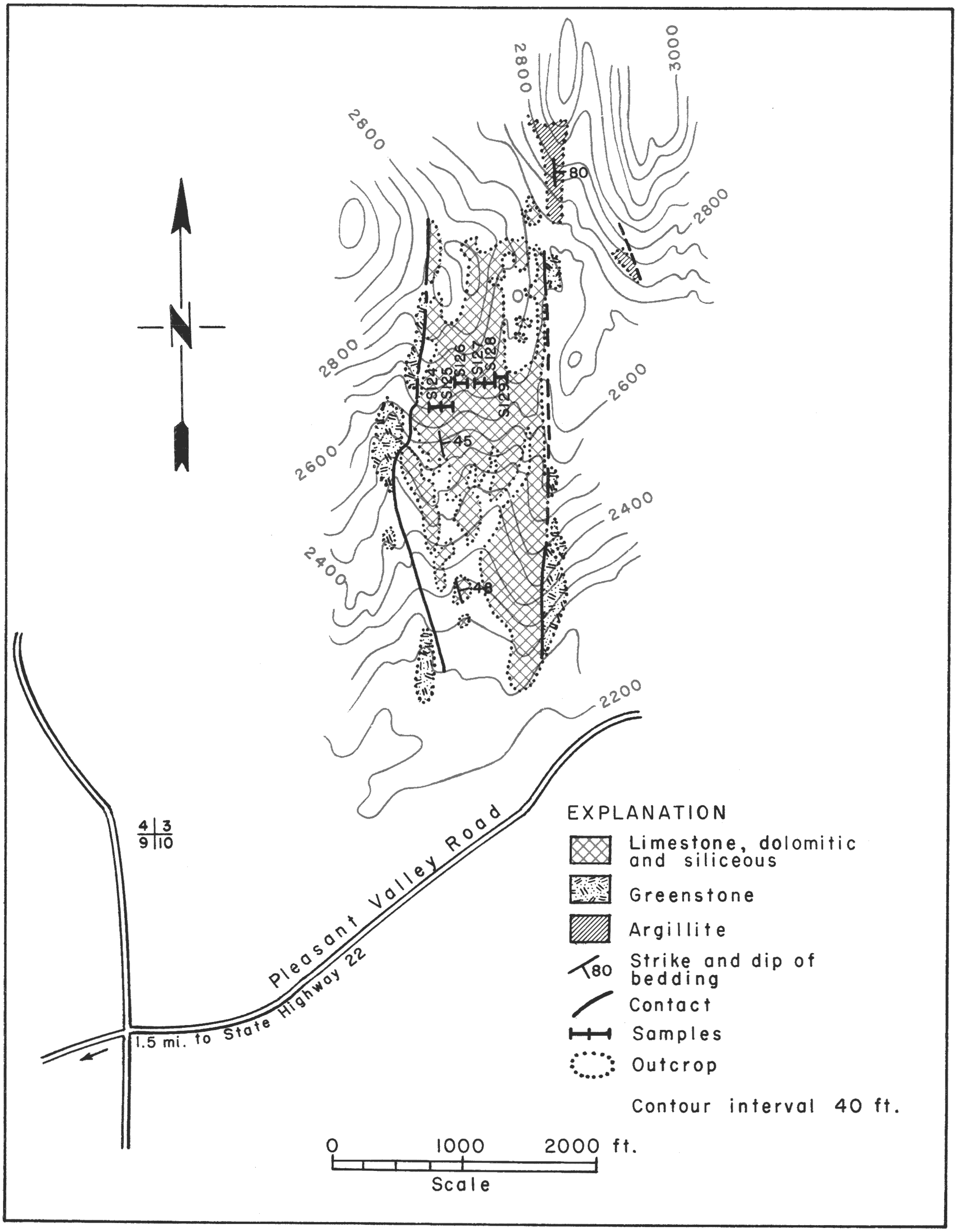

FIGURE 42.—Heidegger Hill deposit. Sec. 3, T. 34 N., R. 37 E. Geology by J. W. Mills. Base map from aerial photo enlargement. Topography from U.S. Geological Survey Inchelium quadrangle map.

Thorpe Road Area

Limestone crops out over an area of about 2,000 square feet in the SW$\frac{1}{4}$NE$\frac{1}{4}$ and the NW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 22, T. 35 N., R. 37 E. It is approximately 2,000 feet east of Highway 22 and 100 feet west of Thorpe road, 8$\frac{1}{2}$ miles south of Kettle Falls. The outcrop has been mapped by Cole (1959) as one of the limestone masses within the greenstone-limestone unit (pl. 5). It was examined and found to consist of gray to dark-gray, fine-grained impure limestone. It is estimated to contain 15 percent silica and 10 percent dolomite. These impurities weather in relief, so that the weathered surface of the rock has a rough, hackly character. The rock is too impure to be of any value for most uses, and it was not sampled.

Cole shows several small limestone outcrops surrounded by greenstone along Thorpe road in secs. 27 and 34, T. 35 N., R. 37 E., about three-quarters of a mile east of The Splitoff. Examination of the outcrops revealed them to be composed of gray siliceous limestone similar to the more impure parts of the Heidegger Hill limestone. No samples were taken. The limestone is of no value for most uses.

Hunters Creek District
Tps. 30 and 31 N., R. 37 E.

Hunters Creek originates in the Huckleberry Mountains and flows west, across the northern part of T. 30 N., into the Columbia River near Hunters, Washington. The town of Hunters is on State Highway 22, about 39 miles south of Kettle Falls. The area about Hunters Creek is accessible by way of the Hunters Creek road, the Locke road, and the Springdale road.

The Hunters Creek area is within the Hunters quadrangle topographic map of the U.S. Geological Survey. In 1961 the quadrangle was being mapped geologically by A. B. Campbell of the U.S. Geological Survey. Campbell and Loofbourow (1957) mapped the "Magnesite Belt" that lies east of the Hunters Creek area. Weaver (1920, pl. 1) shows the Hunters Creek area to be underlain by "undifferentiated argillite" as far east as sec. 1, T. 30 N., R. 37 E. He believes that the schist and argillite of the "undifferentiated argillite" may be a part of the formation he has called the Chewelah Argillite. East of the argillite is a wide northeastward-trending belt of quartzite that Weaver (1920, p. 61) calls the Addy Quartzite. Twenty miles to the northeast of the Hunters Creek area, the Addy Quartzite is known to be Early Cambrian in age (Okulitch, 1951, p. 405). Between the undifferentiated argillite and the Addy Quartzite Weaver has mapped a northeastward-trending belt of undifferentiated limestone about 6 miles long and $\frac{1}{4}$ mile wide. Seven and one-half miles northeast of Hunters, in sec. 18, T. 31 N., R. 38 E., Weaver mapped an additional area of undifferentiated limestone, west of the main limestone belt and within the Chewelah Argillite. Concerning the undifferentiated limestones, Weaver writes (1920, p. 83), Numerous areas of limestone in the county are disconnected from any of the definitely known belts. They exhibit all degrees of variation in composition. The majority of these areas are situated on the western side of the Huckleberry Mountains and as a rule constitute only a fraction of a square mile in extent. Among the more important of these are areas near the headwaters of Harvey and Hunters creeks. The limestone is usually of a bluish-gray color and more or less argillaceous with intercalated bands of nearly pure white limestone.

While examining some of the undiferentiated limestones, the author was impressed by the great similarity of the rock types (graywackes, greenstone with lenses of limestone, argillite, phyllite) in the Hunters Creek area with those of the Heidegger Hill area and the Kettle Falls area farther north. It appears that the western part of the Hunters Creek area is underlain by metasediments and metavolcanics of late Paleozoic (Permian ?) age, and the eastern part of the area by limestone and quartzite of early Paleozoic age.

The author's study of the Hunters Creek district was restricted to the larger, more accessible, outcrops of limestone. The locations of these areas were brought to my attention by A. B. Campbell, of the U.S. Geological Survey.

Hunters Creek Road Area
Sec. 2, T. 30 N., R. 37 E.

Limestone is well exposed in a rock cut on the Hunters Creek road 4½ miles east of Hunters, in the center of sec. 2, T. 30 N., R. 37 E. The exposure is 50 feet long and 6 feet high on the north side of the road. It is made up of interbedded black fine-grained limestone (60 percent) and gray thin-bedded argillite (40 percent). The limestone beds are as much as 16 inches thick. They strike N. 28° E. and dip vertically. Small outcrops at grass roots on the hillside to the north are made up entirely of argillite. The volume of limestone is insignificant. No samples were taken.

Hunters Creek Road North Area
Sec. 35, T. 31 N., R. 37 E.

Approximately 1 mile due north of the Hunters Creek road exposure there is another exposure of limestone in the SW¼NE¼ sec. 35, T. 31 N., R. 37 E. The outcrop is near the top of a southeast-facing slope and has an area of about 250 by 150 feet. The rock is a gray medium-grained massive siliceous limestone. Weathered surfaces are gray and very rough. The rock is similar to the siliceous limestone on Heidegger Hill. Small outcrops to the east and west of the limestone outcrop are composed of greenstone. The limestone is too impure to be of any value for most uses, and no samples were taken.

Adams Mountain Area

Sec. 12, T. 30 N., R. 37 E.

A narrow dirt road, the Forbes road, branches south from the Hunters Creek road about 5½ miles east of Hunters. For the first mile along the Forbes road, which skirts Adams Mountain, there are a few small outcrops of dolomite in the W½ sec. 12, T. 30 N., R. 37 E. Some of this dolomite is banded in the same manner as the "zebra" rock that Park and Cannon (1943, p. 42) describe in the Metaline Limestone of the Metaline district, Washington. In the SW¼ sec. 12, T. 30 N., R. 37 E., to the east of the dolomite, there is a series of small ridges trending northeastward for a distance of at least 700 feet and a width of about 200 feet. Light-gray coarse-grained limestone marble is exposed over a width of 50 feet along the crests of these ridges. The lower slopes are composed of medium-grained thin interbedded limestone and dense siliceous and argillaceous rocks. The bedding is quite contorted, with an average strike of N. 12° E. and steep dips to the west. This carbonate rock outcrop area is at the southern end of Weaver's undifferentiated limestone belt referred to earlier. It is assumed to be early Paleozoic in age on the basis of its nearness to the Early Cambrian quartzite and its lithologic similarity to the Metaline Limestone of Middle Cambrian age. Because of the small volume, the association with dolomite, and the relative inacessibility of the limestone, it is very unlikely that the deposit is of any commercial value. No samples were taken.

Locke Road Area

Sec. 6, T. 30 N., R. 38 E., and secs. 16, 29, and 32, T. 31 N., R. 38 E.

The Locke road branches to the northeast from the Hunters Creek road 6½ miles east of Hunters. The region is heavily forested, but there are numerous small road cuts in carbonate rocks and argillaceous rocks in sec. 6, T. 30 N., R. 38 E., and secs. 32 and 29, T. 31 N., R. 38 E. The carbonate rocks are the northeastward extension of the carbonate rocks of Adams Mountain described in the preceding part of this report. They are the rocks mapped by Weaver (1920, pl. 1) as "undifferentiated limestone." The rocks exposed in the road cuts are interbedded argillite and dark-gray argillaceous and dolomitic limestone, and dolomite. A quarter of a mile north of the center of sec. 32, T. 31 N., R. 38 E., these dolomites and dolomitic limestones strike N. 12° E. and dip 60° E. They are all much too impure to be of any value for most uses. They were not sampled.

Farther to the northeast along this same belt, in the NE¼SE¼ sec. 16, T. 31 N., R. 38 E., an old road cut 75 feet long and 4 feet high exposes gray to dark-gray clastic limestone. The limestone is highly siliceous, containing numerous blebs and stringers of black chert. No samples were taken.

Harvey Creek North Fork Area
Sec. 13, T. 31 N., R. 37 E.

Limestone crops out approximately 7 miles northeast of Hunters, on westward-facing slopes of the North Fork of Harvey Creek drainage. The outcrops are reached by driving 5 miles northeast from Cedonia, on State Highway 22, to the Huckleberry School. From this point a farm road leads west across sec. 18, T. 31 N., R. 38 E., for a distance of 2 miles to the center of sec. 13, T. 31 N., R. 37 E.

From the center of section 13 toward the northeast, for at least half a mile, there are numerous outcrops of schistose and carbonated greenstone. Intercalated with the greenstone are numerous pods and lenses of gray siliceous massive limestone, very few of which are more than a few feet long or wide. The limestone is very similar to the limestone intercalated with greenstones elsewhere in the Hunters Creek area, the Heidegger Hill area, and the Kettle Falls region. The volume and purity of the limestone are far too low for the deposits to be of any value for most uses. No samples were taken.

Springdale-Valley District

Springdale and Valley are two towns in the Colville River valley 34 and 44 miles north of Spokane on "old" U.S. Highway 395. The area of interest in this study lies on the east side of the valley and is serviced by the Great Northern Railway, the "new" U.S. Highway 395 (Loon Lake to Chewelah) and many county and farm graveled roads.

The geology of this area and surrounding areas is described by Weaver (1920), Jones (1928), and Howd (1956). The carbonate rocks are confined to a north-trending fault block from 1 mile to $1\frac{1}{2}$ miles wide (Howd, 1956, p. 17). To the east and west of the carbonate rocks, and separated from them by major fault zones, are older argillites, siltstones, and quartzite. In all the sedimentary rocks the prevailing strikes are northerly and dips are westerly. The sedimentary rocks have been intruded by quartz monzonite of Cretaceous age, and younger plugs, dikes, and stocks of andesite porphyry (Howd, 1956, p. 33, 34, 37-38). These older rocks are unconformably overlain by basalt of Miocene age (Howd, 1956, p. 37).

Carbonate Rocks of the Fault Block

The carbonate rocks are confined to a fault block from 1 mile to $1\frac{1}{2}$ miles wide that extends from Springdale for at least $7\frac{1}{2}$ miles north, to the vicinity of Valley. A large part of this fault block is shown on figure 43, illustrating the geology of the Jumpoff Joe Lake area.

In discussing these carbonate rocks, Howd (1956, p. 23-24) writes:

> Weaver (1920) mapped many limestone and dolomite outcrops as "undifferentiated limestone" because of the lack of paleontological evidence for correlation.
>
> The dolomites and limestones . . . are the youngest metasedimentary rocks in the mapped area. They vary in color from medium gray to dark gray in the case of the dolomite, and light to dark gray for the limestone. There is very little difference in color between the fresh and weathered surfaces. Dolomite is more common in the lower part of the sequence, while limestone is more common near the top.
>
> These thick-bedded to massive strata are almost pure calcite and dolomite . . . The carbonates have a crystalline, mosaic texture, the grain size averaging one to two millimeters.
>
> Valleys and low rounded hills are the topographic expressions of this unit; outcrops are small and widely scattered between Springdale and Jumpoff Joe Lake. The best exposure of limestone occurs on the south and southwest slopes of the hills one half to one mile northeast of Springdale, while the most extensive dolomite outcrops are present along the railroad cut one to two miles east of Springdale. Both upper and lower contacts show faulted relationships . . .

Based upon earlier paleontological studies (McLaughlin and Simons, 1951; and Enbysk, 1954) and his own field investigations, Howd concludes (1956, p. 28) that,

> . . . the age of the dolomite-limestone sequence, the complete time range of which is not known, is interpreted as Mississippian and/or Pennsylvanian . . .

Rocks East of the Fault Block

East of the fault block is a great section, at least 8,000 feet thick (Howd, 1956, p. 22), of argillite, arkosic siltstone, and phyllitic argillite. Howd calls these argillaceous rocks the Deer Lake Argillite. Conformably overlying the argillaceous rocks is a massive quartzite formation—Eagle Mountain Quartzite—at least 2,600 feet thick (Howd, 1956, p. 22). The formation names used by Howd were orginally give to these rocks by Weaver (1920). In considering the age of these formations, Howd writes (1956, p. 29),

> Although the metasediments of the . . . area can not be directly correlated with the strata of the Bead Lake area and northern Idaho, the similar lithologies suggest that the Deer Lake units and the conformably overlying Eagle Mountain quartzite be tentatively classed as Precambrian Beltian in age.

Rocks West of the Fault Block

To the west of the fault block are argillites that Weaver (1920, p. 63-66) calls Chewelah Argillite. Howd concludes (1956, p. 28) that,

> . . . lithology and structural relationships . . . indicate that the metasediments at this locality are the uppermost unit of the Deer Lake argillite, repeated by faulting.

Springdale Area
Secs. 26 and 27, T. 30 N., R. 40 E.

Location and accessibility.—Springdale is 34 miles north of Spokane on "old" U.S. Highway 395. Shedd (1913, p. 123) mentions the occurrence of limestones, which have been used more or less at different times in the manufacture of lime, north and east of Springdale in secs. 22 to 27, T. 30 N., R. 40 E. The principal limestone outcrop areas shown by Howd (1956) are 1 mile north of Springdale in secs. 26 and 27 (east half).

Geology.—The limestones are part of the carbonate rock section of the fault block that extends from Springdale to Valley. The reader is referred to the preceding section of this report for a discussion of the geology.

Quality of limestone.—Shedd writes (1913, p. 123) that, "samples from various places . . . appear to show more or less variation in composition, but in general it has considerable magnesia." Hodge (1938, p. 98) makes a brief reference to the limestone here, ". . . in general, magnesia is present." The Ideal Cement Company has informed the author that it has examined the limestones in the Springdale area and found them to be too "high magnesian and high chert" for use in cement making. A brief examination of the outcrops north of Springdale sufficed to substantiate the reports of earlier workers. All the carbonate rocks were found to be dolomitic limestone or dolomite. None of the rock is high-calcium limestone and none is of any use for the manufacture of cement.

Jumpoff Joe Lake Southwest Deposit
SW$\frac{1}{4}$ sec. 1, T. 30 N., R. 40 E.

Location, accessibility, and ownership.—Two small outcrops were found and mapped (figs. 43 and 44) in the SW$\frac{1}{4}$ sec. 1, T. 30 N., R. 40 E., along the Springdale-Jumpoff Joe Lake road, approximately 1 mile southwest of Jumpoff Joe Lake and 1$\frac{1}{2}$ miles east of the Great Northern Railway and State Highway 3. The property is owned by Katherine Brassfield, of Valley, Washington.

Geology.—The carbonate rocks belong in the upper part of the section of carbonate rocks that Howd (1956) mapped between Springdale and Valley. No bedding was recognized in the outcrops. It is assumed that these rocks dip westward like the rest of the carbonate rocks in the area. Limestone crops out along the southeast side of a ridge approximately 400 feet long and 200 feet wide. The summit of the ridge is at an altitude of 2,520 feet, or 170 feet above the Springdale-Jumpoff Joe Lake road. The west side of the ridge is dolomite. The east side is a limestone that is light gray to gray on fresh surfaces, light gray on weathered surfaces, medium grained and massive. It appears to be very pure. The remains of a small lime kiln between the ridge and the road show that the rock was burned for lime at one time.

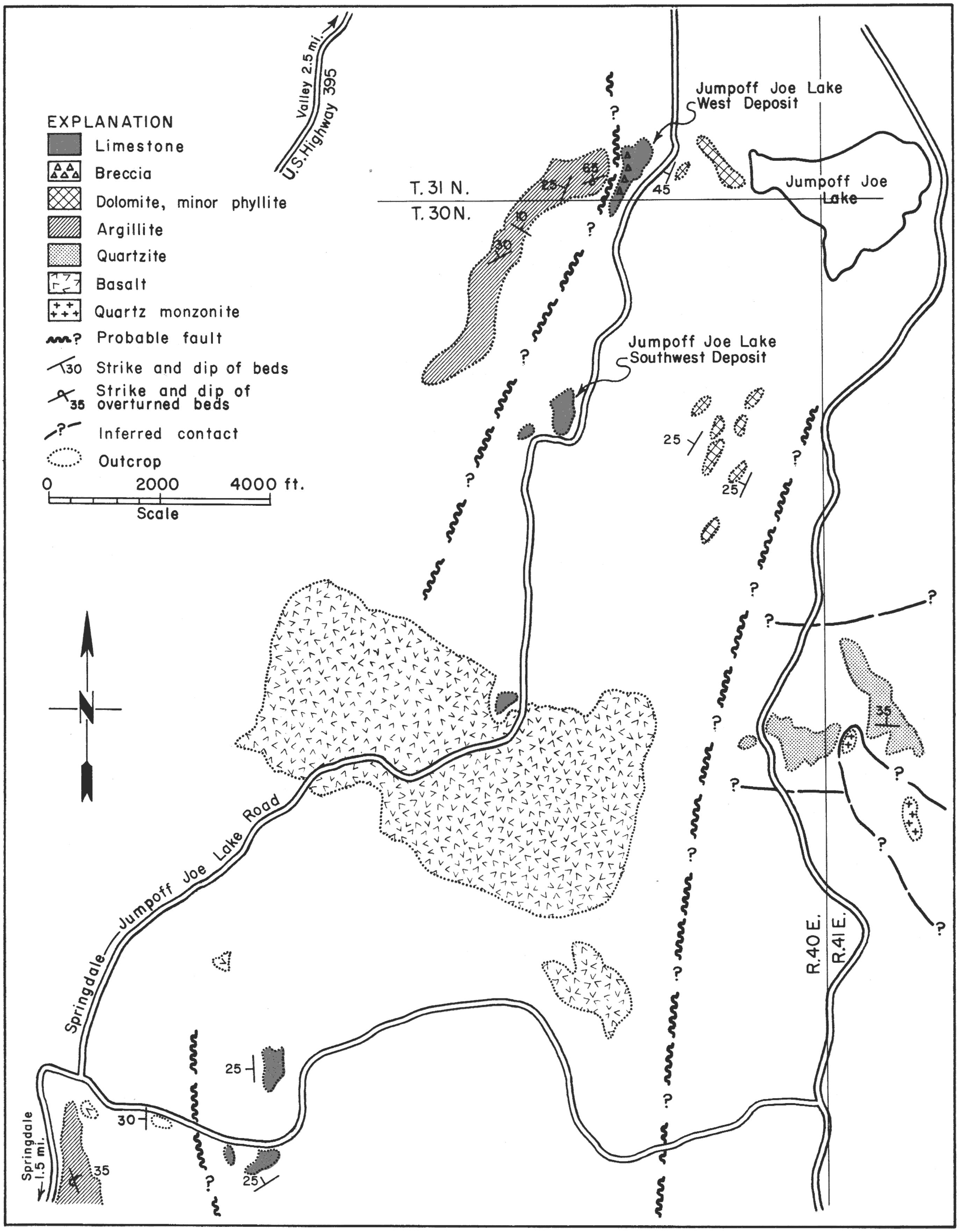

FIGURE 43.—Jumpoff Joe Lake area. Tps. 30 and 31 N., Rs. 40 and 41 E. Geology by Frank H. Howd. On contact aerial photo base, 1956.

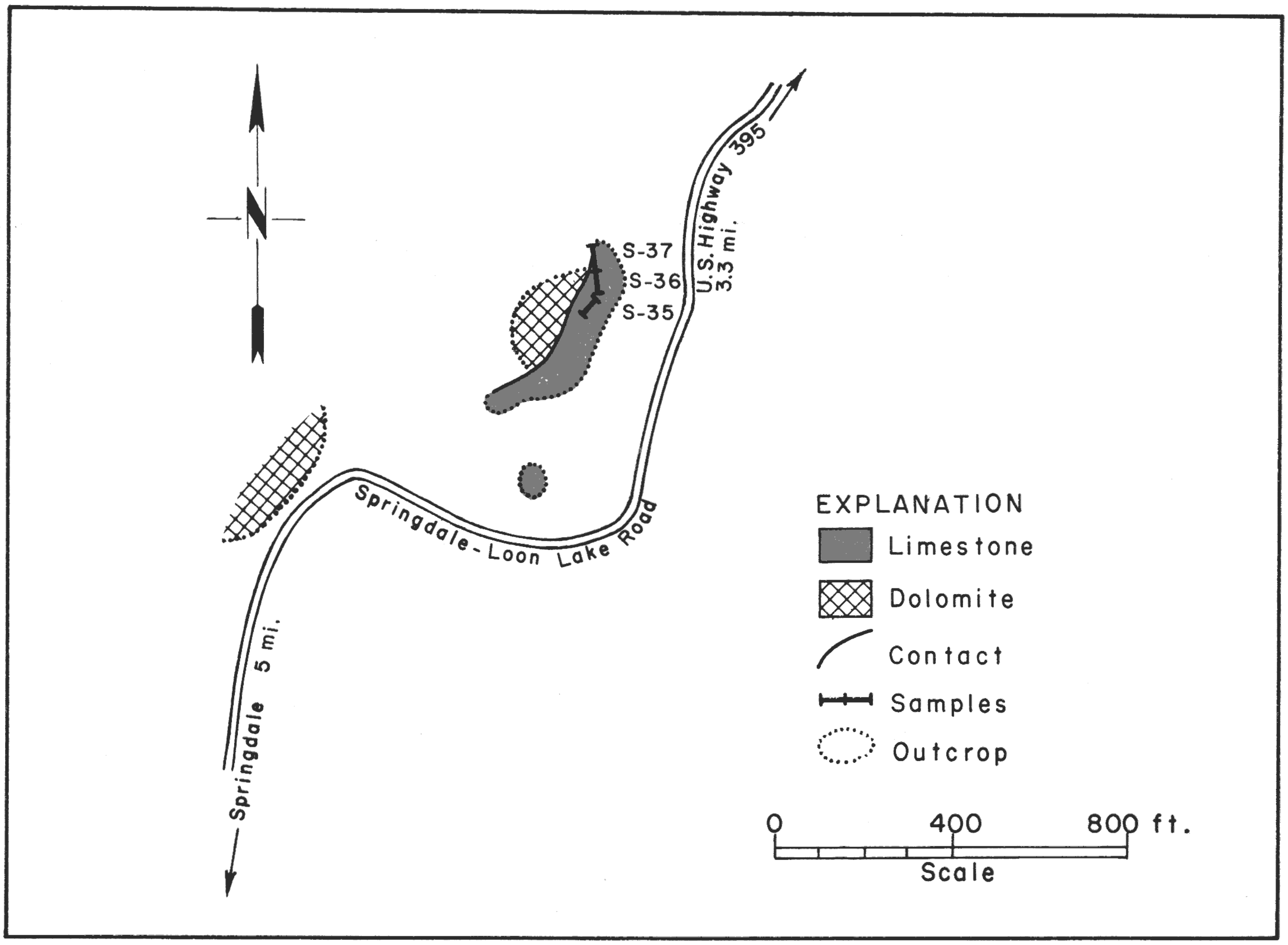

FIGURE 44.—Jumpoff Joe Lake Southwest deposit. Sec. 1, T. 30 N., R. 40 E. Geology by J. W. Mills. Base map from aerial photo enlargement.

Quality and quantity of limestone.—Shedd (1913, p. 123) reports that one small kiln was being operated at the time of his examination. He also records an analysis of a sample from the SW¼ sec. 1, T. 30 N., R. 40 E.

During the present study, three samples (S-35 to S-37) were taken continuously along the face of the steep bluff on the southeast side of the ridge.

The results of the analyses of Shedd's sample (A. A. Hammer, analyst) and samples S-35 to S-37 are as follows:

Sample no.	Length (feet)	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
Shedd	—	—	—	43.50	54.12	none	1.47	0.65	—
S-35	50	98.26	1.11	43.66	55.20	0.53	0.80	0.41	0.060
S-36	50	97.61	2.13	43.25	54.84	1.02	0.60	0.45	0.040
S-37	50	89.21	8.32	43.78	50.12	3.98	1.24	0.30	0.040

Unfortunately, although the limestone crops out over a width of 80 feet, exposures suitable for sampling were found only in the western 30 feet, where samples S-35 to S-37 were taken. The analyses show that away from the dolomite contact the limestone is of high purity and that it becomes more siliceous and magnesian toward the contact. A composite of samples S-34 through S-37 shows 250 ppm Na_2O, 570 ppm K_2O, 70 ppm TiO_2, and 40 ppm S.

There is estimated to be about 400,000 tons of high-calcium limestone in the hill above the level of the road. The analyses of samples S-35 and S-36 show that the rock has a chemical composition suitable for use as mineral filler, builders' lime, and in the sugar, pulp and paper, and portland cement industries. Because of the small volume of rock and the uncertainty that the high grade will persist in this dolomitic terrain, it is quite unlikely that the deposit can ever be worked on a commercial scale.

Jumpoff Joe Lake West Deposit
SW¼ sec. 36, T. 31 N., R. 40 E.

Location, accessibility, and ownership.—There is a single outcrop of limestone next to the Springdale-Jumpoff Joe Lake road, a third of a mile west of Jumpoff Joe Lake, in the SW¼ sec. 36, T. 31 N., R. 40 E. The outcrop is on property owned by Katherine Brassfield and property of Frank Tomsha, both of Valley, Washington.

Geology.—The setting is similar to that of the Jumpoff Joe Lake Southwest, in that the limestone occurs between overlying and underlying dolomite (fig. 45) in the carbonate rock fault block mapped by Howd (fig. 43). There is a small abandoned quarry at the east side of the outcrop. The limestone is light gray, very fine grained, and massive. Bedding, weakly expressed, strikes N. 66° W. and dips moderately toward the southwest.

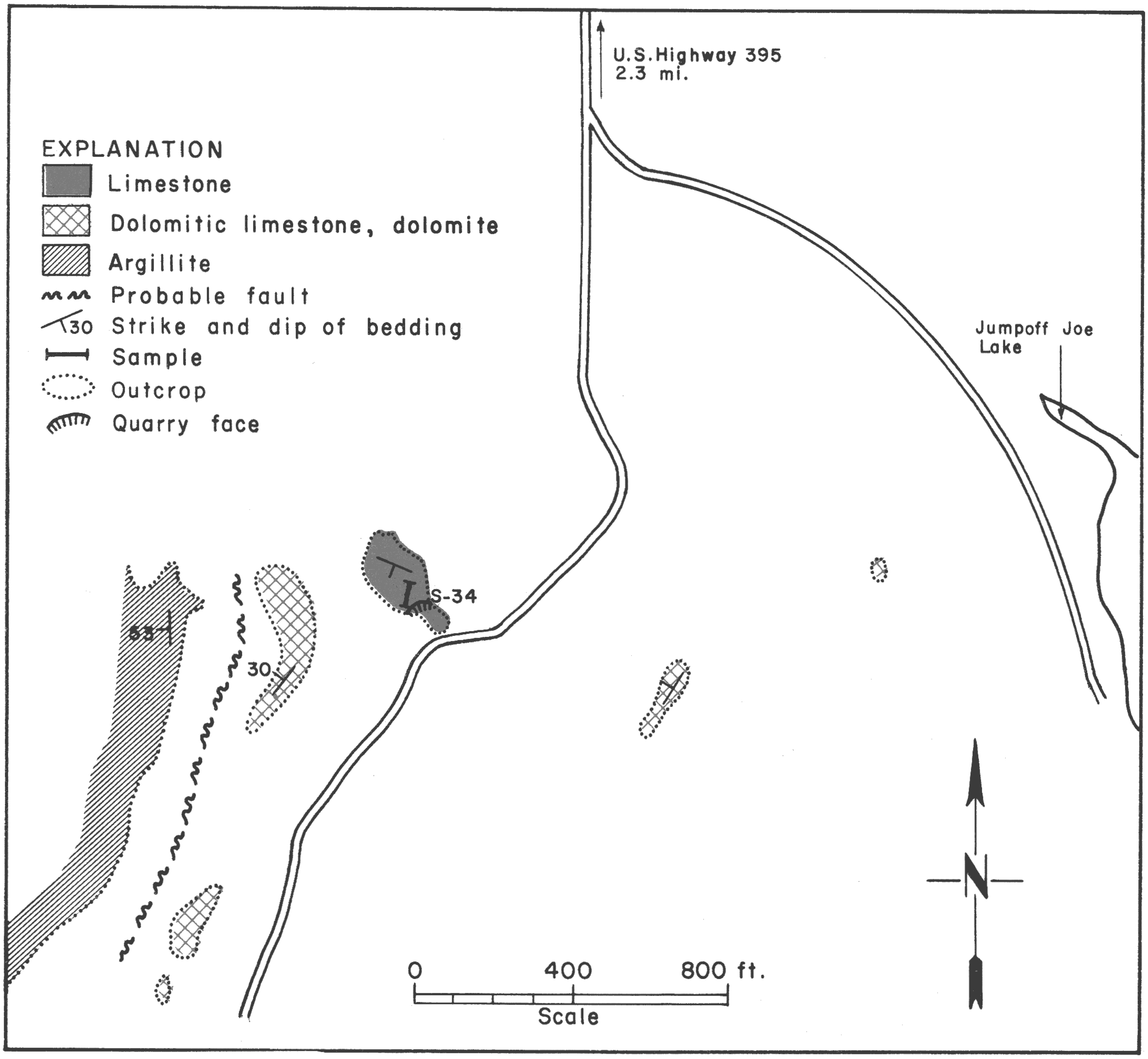

FIGURE 45.—Jumpoff Joe Lake West deposit. Sec. 36, T. 31 N., R. 40 E. Geology by J. W. Mills. Base map from aerial photo enlargement.

Quality and quantity of limestone.—Shedd reports (1913, p. 124) limestone from this area as "dark gray in color . . . flinty appearance" and records an analysis of the rock (A. A. Hammer, analyst). One sample, S-34, was taken across the bedding at the top of the small quarry (fig. 45). The analyses of the two samples, Shedd's and S-34 are as follows:

Sample no.	Length (feet)	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
Shedd	—	——	——	41.38	54.02	1.23	1.58	1.78	——
S-34	50	95.78	1.57	43.16	53.81	0.75	1.50	0.64	0.010

The analyses show that the rock is a high-calcium limestone chemically suitable for use in the pulp and paper industry, the manufacture of portland cement, and as a mineral filler. However, because the limestone is found between fractured, silicified, and dolomitized carbonate rocks near a major fault, it is quite unlikely that there is high-calcium limestone in sufficient tonnage for a commercial operation of appreciable size.

Valley District

Valley is a town in the Colville River valley on "old U.S. Highway 395 approximately 44 miles north of Spokane and 9 miles south of Chewelah, Washington. It is served by the Great Northern Railway.

Some early reports mention several "limestone" occurrences within an area that extends from 5 to 12 miles west of Valley to 8 miles northwest of Valley. For example, Shedd (1913, p. 125) tells of "deposits of limestone" in secs. 1, 8, 9, 12, and 19, T. 31 N., R. 39 E.; secs. 6 and 7, T. 31 N., R. 40 E.; secs. 30 and 31, T. 32 N., R. 40 E.; secs. 25 and 36, T. 32 N., R. 39 E.; and secs. 24 and 25, T. 31 N., R. 38 E. In the same report (p. 126) he provides "analyses of limestones from west of Valley." The analyses show that three of these "limestones" are magnesite ($MgCO_3$) and the remaining one is dolomite.

The area that Shedd refers to is the northeastern end of a great assemblage of metasedimentary and metavolcanic rocks of Precambrian age that extends as far to the southwest as the Spokane Indian Reservation. Rocks of this assemblage were named the Deer Trail Argillite and Stensgar Dolomite by Weaver (1920). Campbell and Loofbourow (1946) have discussed and mapped (1957) this area, which is referred to as the "magnesite belt of Stevens County." The only carbonate rocks that Campbell and Loofbourow report are the magnesite and dolomite rocks of the Stensgar Dolomite.

Valley to Chewelah District

The town of Chewelah is in the Colville River valley approximately 52 miles north of Spokane via U.S. Highway 395. Valley is 8 miles south of Chewelah. Both towns are serviced by the Great Northern Railway. The area of interest for this report lies along the east side of the Colville River valley between Valley and Chewelah, from 1 mile to 3 miles east of U.S. Highway 395.

According to mapping done in 1955 by the writer and students of the Washington State University geology field camp (R. Case, A. Lassila, R. Merriam, A. Wood, and D. Van Dissel), the rocks along the east side of the valley can be divided into three mappable units. From west to east and youngest to oldest, they are dolomite, quartzite, and argillite with interbedded dolomite. These units form north-trending belts of metasedimentary rocks in which the beds strike north and dip west, with some overturned beds dipping to the east.

The west belt of dolomite is bounded both to the east and to the west by large northward-trending faults. This dolomite belt is believed to be the northern extension of the carbonate-rock fault block mapped by Howd (1956) in the Springdale-Jumpoff Joe Lake area and discussed on page 155 in this report. Although no fossils were found in the dolomite east of Chewelah, the structural setting and the lithology are much the same as those of the dolomite in the lower portion of Howd's fault-block section, and so the age is tentatively given as Mississippian and (or) Pennsylvanian.

The middle unit (1,600 feet wide) is the quartzite called the Eagle Mountain Quartzite by Weaver (1920) and Howd(1956). It is believed to be in fault contact with the dolomite unit to the west.

The eastern unit lies conformably beneath the quartzite and is composed principally of argillite and siltstone, with some dolomite in the upper part of the section.

Both the quartzite and the underlying rocks are correlatives of similar rocks mapped by Howd (1956) and believed by him to be Precambrian in age.

All the carbonate rocks of this area were found to be dolomite, with the exception of three very small outcrops about 2 miles east of Valley. Shedd (1913, p. 127, 128) refers to "limestones" east of Chewelah. He mentions that a tunnel at the Blue Star mine (sec. 5, T. 32 N., R. 41 E., and sec. 32, T. 33 N., R. 41 E.) is "more than 200 feet deep, all the distance being in . . . limestone." Weaver (1920, p. 149) reports that at the time of his writing limestone was intersected in the same tunnel for a total length of 700 feet. Shedd (1913, p. 129) lists two analyses of "limestones east of Chewelah," one of which ("white") came from sec. 5, T. 32 N., R. 41 E., (vicinity of the Blue Star mine) and the other ("dark colored") from sec. 32, T. 32 N., R. 41 E. Impure limestone is exposed over a width of 50 feet in a pit in the SE$\frac{1}{4}$NW$\frac{1}{4}$ sec. 7, T. 32 N., R. 41 E., 1$\frac{1}{2}$ miles east of Chewelah. The rock is greenish gray, hard, brittle, and well bedded. Twenty-five grab samples from this pit were combined to make samples S-168. The analyses of Shedd's samples and sample S-168 follow:

Sample no.	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
Shedd-white	——	——	43.96	32.56	14.90	5.26	1.46	——
Shedd-dark	——	——	43.91	31.55	20.11	3.15	0.41	——
S-168	49.61	30.93	26.65	27.87	14.80	27.12	3.64	0.042

The carbonate rocks in the Chewelah area are very impure dolomitic limestones or dolomites and are quite worthless as a source of high-purity limestone.

Addy District

The town of Addy is in the Colville River valley on U.S. Highway 395, approximately 61 miles north of Spokane and 9 miles north of Chewelah. It is serviced by the Great Northern Railway.

Weaver (1920) mapped carbonate rocks, which he calls Old Dominion Limestone, in a belt as much as 1 mile wide extending from Addy toward the northwest for 7 miles. To the northeast and southwest the limestone is in contact with granite and argillite, respectively. The same "limestones" were mentioned earlier by Shedd (1913, p. 129) as "large areas of limestone . . . northwest of Addy . . . and . . . back to the headwaters of Stranger Creek." Shedd reports the analysis of one sample of this limestone taken from the SW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 3, T. 33 N., R. 39 E. The sample contained only 55.8 percent $CaCO_3$.

Hodge (1938, p. 101) records Shedd's analysis and some of Shedd's remarks. Hodge (1938, p. 97) also records the analysis of another sample from "bodies of limestone on the headwaters of Strange (Stranger?) Creek." The analyses given by Shedd and Hodge are as follows:

Sample	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
Shedd (1913)	43.89	31.25	19.12	2.84	1.31	—
Hodge (1938)	46.64	31.80	20.68	0.91	——	—

It is concluded, based upon the reports of Shedd and Hodge and on conversations in recent years with geologists familiar with the area, that there is no limestone of value for most uses in this area.

Colville District

The Colville district, as defined here, includes about 200 square miles in parts of Tps. 35 and 36 N., Rs. 38, 39, and 40 E., northern Stevens County. Colville, the county seat, is about 80 miles north-northwest of Spokane, with which it is connected by a branch of the Great Northern Railway and by U.S. Highway 395. Other roads traversing the district are shown on the Colville, Echo Valley, Gillette, and White Mud Lake topographic quadrangle maps of the U.S. Geological Survey and on plate 6.

The eastern half of the district is underlain principally by metasedimentary rocks of Cambrian and Ordovician age (pl. 6). The rocks of Cambrian age are divided by Bennett (Bennett, W. A. G., 1961, written communication) into three units, a lower quartzite unit, a middle unit (partly phyllite), and an upper carbonate unit. The quartzite unit, consisting of quartzite with minor amounts of silty argillite, is well exposed on Old Douglas, Gillette, Green, Rogers, and Old Dominion Mountains. This unit, part of the Colville Quartzite named by Weaver (1920, p. 68-71), probably is correlative with the Lower Cambrian Addy Quartzite in the Chewelah district, Stevens County, and with the Gypsy Quartzite of the Metaline district, Pend Oreille County. Bennett's middle unit is predominantly phyllite where it is fully exposed on the east and west slopes of Rogers and Old Dominion Mountains, respectively, but it also includes considerable limestone, dolomite, argillite, and quartzite on Gillette, Old Douglas, and Colville Mountains. This unit includes part of Weaver's (1920, p. 63-66) Chewelah Argillite, part of his Clugston Creek Limestone, and his Colville Quartzite, and probably is correlative with the Cambrian Maitlen Phyllite of the Metaline district. The upper, or carbonate, unit is composed of limestone and dolomite containing minor amounts of interbedded phyllite. It includes rocks that Weaver (1920, p. 66-68) named the Old Dominion Limestone and the Clugston Limestone. It is believed to be the equivalent of the Cambrian Metaline Limestone of the Metaline district, Pend Oreille County. The rocks of Ordovician age (pl. 6) are principally argillite with minor amounts of quartzite, limestone, and phyllite. Exposures of these rocks east of Colville are included in Weaver's Chewelah Argillite, and exposures on Clugston Creek in his basal Mission Argillite. The graptolitic Ordovician rocks in the Colville region are correlative with the Ordovician Ledbetter Slate of the Metaline district (Park and Cannon, 1943, p. 19).

The west half of the district is underlain by metasedimentary and metavolcanic rocks of middle Paleozoic and late Paleozoic age. These include argillite, siltstone, graywacke, conglomerate, chert, limestone, and greenstone. They differ from the lower Paleozoic rocks in their higher content of coarse clastics, to some extent in a lower grade of metamorphism, and in their more open folds. In a general way their average grain size increases toward the west. The youngest metasedimentary rocks, exposed in the westernmost part of the district, are Permian in age; they consist of banded argillite, silty argillite, chert pebble conglomerate, graywacke conglomerate, and limestone. The coarser clastic rocks of the middle Paleozoic section have been mapped by Weaver as part of his Colville Quartzite. The fine-grained clastics, greenstones, and limestones are included in his Mission Argillite and "undifferentiated limestone."

The metasedimentary rocks of Cambrian and Ordovician age have been intruded by granitic rocks in the northern and southeastern parts of the region; the late Paleozoic rocks have been intruded by small stocks, plugs, and dikes of diorite, and diabase. The rocks have been folded moderately to intensely and cut by major faults of large displacement. Most of the fold axes and faults trend about north to northeast. The positions of some of the larger fold axes and faults are illustrated on plate 6.

Colville Mountain Area

Secs. 4 and 5, T. 35 N., R. 39 E.; secs. 32 and 33, T. 36 N., R. 39 E.

Location and accessibility.—Limestone occurrences on the south end of Colville Mountain can be reached easily by driving north from Colville on the Colville-Eagle Peak-May Lake road (pl. 6).

Geology and quality of limestone.—A reeflike body of fossiliferous limestone within the quartzitic part of the middle unit crops out near the W. $\frac{1}{4}$ cor. sec. 4, T. 35 N., R. 39 E., and extends northward for about 1,000 feet. It has a thickness of approximately 200 feet and a moderate dip to the west at its south end. The thickness decreases and the dip steepens toward the north. The rock contains numerous Early Cambrian fossils (Archaeocyatha); it was not considered to be sufficiently pure to merit sampling. Similar limestone beds or reefs in the silty argillite facies of the middle unit are reported by Bennett (Bennett, W. A. G., 1961, written communication) to occur in SE$\frac{1}{4}$ sec. 4 and the W$\frac{1}{2}$ sec. 3, T. 35 N., R. 39 E.

Limestone that is considered by Bennett to be part of his middle unit crops out over a width of 1,000 feet and a length of 9,000 feet diagonally across sec. 32, T. 36 N., R. 39 E. (pl. 6). The limestone overlies quartzite and siliceous dolomite members of the middle unit on the east, in places is in fault contact with the lower quartzite unit, and on the west is also in fault contact with Ordovician (?) rocks. Where it is well exposed in the rock cuts along the Colville-Eagle Peak-May Lake road it is dark gray to black, very argillaceous, and interbedded with thin argillite and slate beds. It is a very impure limestone, and no samples were taken.

South End Old Douglas Mountain Area

Secs. 22 and 23, T. 36 N., R. 39 E.

Location and accessibility.—According to Bennett (Bennett, W. A. G., 1961, written communication), another reef-type limestone mass in the middle unit, similar to the one described on Colville Mountain, is to be found in the SE$\frac{1}{4}$ sec. 22 and the SW$\frac{1}{4}$ sec. 23, T. 36 N., R. 39 E., near the foot of the southeast slope of Old Douglas Mountain. Access from Colville to within 700 feet of the deposit is provided by 4 miles of hard-surfaced road and 1 mile of graveled road.

Quantity and quality of limestone.—The limestone outcrop is 3,000 feet long and as much as 2,000 feet wide. The difference in altitude between the top and bottom of the limestone bed (reef?) is 400 feet. The maximum thickness is between 500 and 1,000 feet. According to information provided by Bennett, the deposit "is excellent, from the standpoint of apparent high-grade rock throughout, favorable quarrying conditions, and accessibility." Unfortunately, this information was not made known to the author until the field work had been completed, hence no field examination was made and no samples were taken.

Truman Wood Creek and Prouty Creek Areas
Secs. 5, 6, 7, 8, and 18, T. 35 N., R. 40 E.

Location and accessibility.—Limestone and dolomite extend $1\frac{1}{2}$ miles north and an equal distance south of the Old Dominion road, from 4 to 6 miles east of Colville. Access from Colville by auto is provided by the Tiger road and the Old Dominion road.

Geology.—The area is underlain by complexly folded, faulted, and intruded rocks of Bennett's middle unit and his upper carbonate unit. Bennett (1961, written communication) reports a limestone bed, about 100 feet thick, interbedded with phyllite and limy argillite, southwest of De Hart Lake in sec. 8, T. 35 N., R. 40 E. He also reports various other limestone beds in the upper part of the middle unit in the SW$\frac{1}{4}$ sec. 4 and the NE$\frac{1}{4}$ sec. 5, T. 35 N., R. 40 E., as well as in the SW$\frac{1}{4}$ sec. 33, T. 36 N., R. 40 E. None of these is thick enough to be of any value.

Shedd (1903, p. 119; 1913, p. 134) and Hodge (1938, p. 101) refer to deposits of "limestone" about 4 miles east of Colville. These are the rocks in the Prouty Creek area that Bennett has mapped as Cambrian Dolomite belonging to the upper carbonate unit. That most of the "limestone" is actually dolomite was confirmed by field examination and by reference to three analyses reported by Shedd (1913, p. 135) in which the MgO content averages 20.15 percent. Bennett (1961, written communication) mentions that in some places the dolomite contains minor interbeds of relatively pure limestone. Such a limestone is found on the ridge extending north from Peery Lake, in secs. 29 and 32, T. 36 N., R. 40 E. This limestone was not examined or sampled.

Pinkney City Area
NW$\frac{1}{4}$ sec. 35, T. 36 N., R. 39 E.

Location and accessibility.—Limestone of Bennett's upper carbonate unit is well exposed in the north bank of the Aladdin road 3 miles north of Colville and from 0.8 to 1.0 mile east of the junction of the Aladdin and Douglas Falls roads at Pinkney City.

Geology.—The limestone is typical of much of the Old Dominion Limestone in the Colville-Aladdin area. It is dark gray to black, fine grained, medium bedded, and argillaceous. Brown-weathering streaks, lenticles, and layers of dolomitic (?) limestone up to 1 inch in thickness constitute as much as 30 percent of the rock. Bedding strikes northeastward and dips steeply to the southeast.

Quality of limestone.—Because the exposures are readily accessible and typical of much of the limestone northeast of Colville, six samples were taken despite the obviously impure nature of the rock. Sampling was begun (S-115) in the north bank of the Aladdin road 1.0 mile east of its junction with the Douglas Falls road and continued westward (S-116 to S-120, inclusive). A log of the sampling follows:

Sample no.	Footage	Sample length	Sample bearing	Bedding strike	Bedding dip
S-115	0-100	100	W.	N. 25° E.	79° E.
S-116	100-200	100	W.	N. 22° E.	50° W.
——	200-410	—	——	covered interval	
S-117	410-485	75	W.	?	?
S-118	485-545	60	W.	?	?
——	545-670	—	——	covered interval	
S-119	670-770	100	S. 75° W.	N. 20° E.	75° E.
S-120	770-870	100	S. 72° W.	N. 50° E.	65° E.
	880	end of outcrop			

The analyses of these samples are as follows:

Sample no.	Length (feet)	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
S-115	100	71.65	4.81	34.49	40.25	2.30	15.65	6.33	0.033
S-116	100	78.62	4.64	37.52	44.17	2.22	10.18	4.91	0.024
S-117	75	62.05	3.36	29.98	34.86	1.61	22.85	9.36	0.046
S-118	60	70.45	2.70	31.99	39.58	1.29	21.63	6.21	0.055
S-119	100	64.69	8.46	33.41	36.34	4.05	18.46	7.10	0.047
S-120	100	74.37	16.85	41.64	41.78	8.06	5.68	2.97	0.015

The limestone is obviously too impure to be of any value for most uses.

Jones Ridge Area

SE¼NE¼ sec. 26, T. 36 N., R. 39 E.

There are several small outcrops of limestone on the west slope of Jones Ridge 3/4 mile due north of a point on the Aladdin road 1½ miles east of Pinkney City and about 5 miles northeast of Colville. The outcrops are mapped by Bennett (pl. 6) as part of his upper carbonate unit.

One sample (S-114) was taken over a horizontal length of 48 feet in a due east direction across the full width of a limestone outcrop at an altitude of 2,280 feet in the SE¼NE¼ sec. 26, T. 36 N., R. 39 E. The limestone is light gray on fresh surfaces and gray on weathered surfaces; it is fine grained and well bedded. The bedding strikes N. 43° E. and dips 40° SE. The true thickness, represented by sample S-114, is 23 feet. The sample has the following composition:

Sample no.	Length (feet)	True thickness (feet)	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
S-114	48	23	89.91	6.04	43.08	50.51	2.89	1.86	1.38	0.004

The rock is too impure to be of any value for high-calcium limestone or the manufacture of portland cement.

Churchill Ridge Area

SE$\frac{1}{4}$ sec. 13, T. 36 N., R. 39 E.

Limestones mapped by Bennett (pl. 6) as part of the upper carbonate unit crop out along the crest of Churchill Ridge. They strike N. 30° E. and dip 58° W. between overlying and underlying phyllite. These well-bedded limestones have a total true thickness of 40 feet. Because of the relatively small volume of limestone and its inaccessibility, the deposits are not considered to be of any value. No samples were taken.

Joe Creek Area

E$\frac{1}{2}$ sec. 5, T. 36 N., R. 40 E.

A few small outcrops of limestone of the upper carbonate unit were found along the Joe Creek road 8$\frac{1}{2}$ miles northeast of Colville. They are part of the belt of Old Dominion Limestone between Colville and Aladdin. The rock is a gray-weathering fine-grained thin-bedded argillaceous and dolomitic limestone. It contains numerous brown-weathering layers and lenses as much as 1 inch thick and 2 feet long, similar to those found in the limestone at Pinkney City. The impure nature of the limestone and the inacessibility of the area of outcrop made sampling unjustified.

Binger Canyon Area

W$\frac{1}{2}$ sec. 21 and NE$\frac{1}{4}$ sec. 20, T. 37 N., R. 40 E.

Limestone of the upper carbonate unit is exposed in road cuts along the Colville National Forest road that extends from the Aladdin road up Binger Canyon to Marble Creek. The rock is a gray to dark-gray, gray-weathering, argillaceous and phyllitic limestone interbedded with calcareous argillite. No single limestone bed was found to be of sufficient thickness or purity to justify sampling.

Jumpoff Joe Bluff Area

NW$\frac{1}{4}$ sec. 9, T. 36 N., R. 40 E.

Rock outcrops and talus at the southwest end of Jumpoff Joe Bluff, 11 miles northeast of Colville along the Aladdin road, are composed of gray impure argillaceous limestone of Bennett's upper, or carbonate, unit, very similar to the rock exposed in the Joe Creek and Pinkney City areas. No samples were taken.

North Fork Mill Creek Area

According to Shedd (1903, p. 120-122), the property of the Colville Marble Company

> . . . is situated on the north fork of Mill Creek about sixteen miles northeast of the town of Colville. The company has located a large tract of land in this locality for marble, there being about one thousand acres in all. The property is reached by a wagon road from Colville up Mill Creek, and for a considerable part of the distance it is a very good road for a mountain road . . . Very little work has been done on any of the deposits.

Shedd provides the following analyses of a white and a dark-gray marble from this locality:

Sample	CaO	MgO	SiO_2	R_2O_3	CO_2
White	53.68	0.76	2.61	—	42.89
Dark-gray	52.04	0.67	3.12	0.12	43.22

Except for the silica impurities, the rock is quite high grade. Since the location given by Shedd is not very precise—16 miles by wagon road northeast of Colville—it is difficult to say whether or not these rocks were examined in the course of the present survey. They must be part of the Old Dominion Limestone (Weaver, 1920). Numerous exposures of this formation in the area drained by the North Fork of Mill Creek were examined, and none was found to be of the purity of Shedd's samples. It is quite unlikely, though not impossible, that a large tonnage of such pure limestone is available in this area.

Clugston Creek Area

Location and accessibility.—The area is in the NE$\frac{1}{4}$ T. 37 N., R. 39 E. and NW$\frac{1}{4}$NW$\frac{1}{4}$ T. 37 N., R. 40 E., about 12 miles north of Colville. From Colville, access is obtained via U.S. Highway 395, the Echo Valley road, and the Clugston Creek road, in that order. Narrow graveled roads branch from the main Clugston Creek road up the South Fork and North Fork of Clugston Creek. These roads climb to altitudes of 4,200 and 3,600 feet, high on the northwest slopes of Gillette Mountain.

Geology.—The greatest part of the area is underlain by carbonate rocks called the Clugstone Limestone by Weaver (1920, p. 71). He describes the lithology as follows:

> The Clugston limestone varies from a pure white, dense, fine-grained, massive crystalline rock to a bluish-gray and dark-gray, banded limestone which becomes somewhat argillaceous . . . Silicification has acted upon the rock in some instances although as a rule the percent of silica present in not high. Lead and zinc carbonates have been precipitated in the fracture zones and are in places widely disseminated in small amounts through the rock.

In discussing the structure, Weaver (1920, p. 71), says,

> The Clugston limestone lies upon the Colville quartzite and beneath the Mission argillite. At the north for a distance of over eight miles the limestone lies along an intrusive contact with the granite.

Plate 6 corroborates the general geologic setting outlined by Weaver, but Bennett (1961, written communication) reports that in the Clugston Creek area the rocks of the upper carbonate unit consist of limestone at the base, which is partly reduced in thickness by faulting, with dolomite and limestone in thick subunits making up the rest of the unit. Large areas of rocks that were limestone at one time are partially to completely dolomitized. This is especially true in the areas where there is lead and zinc mineralization.

Quarrying operations in the Clugston Creek area were carried on many years ago by two companies, the Keystone Marble Company and the Jefferson Marble Mining and Milling Company.

Keystone Marble Company Deposit
Secs. 1 and 12, T. 37 N., R. 39 E.

Location and accessibility.—Shedd (1903, p. 116-119) mentions marble quarrying operations of the Keystone Marble Company on the headwaters of Clugston Creek. The area is accessible by road from Colville, Evans, or Bossburg via the Echo Valley and Clugston Creek roads. The rock quarried is part of Weaver's Clugston Limestone.

Quality of limestone.—The following chemical analyses show the composition of three of the different varieties of the marble found in these deposits (Shedd, 1903, p. 117):

Sample	CaO	MgO	SiO_2	R_2O_3	CO_2
White	53.96	1.25	0.98	trace	43.76
Gray	54.81	0.70	0.82	trace	43.56
Dark-gray	42.60	10.05	1.89	——	44.63

Shedd (1913, p. 137-138) and Hodge (1938, p. 113, and 1944, p. 50) refer to these deposits "8½ miles east of Bossburg," but supply no information in addition to that given in the earlier Shedd (1903) report.

The property was not examined in the present study. The overall magnesian character of the Clugston carbonate rocks and the remoteness of the area reduce, but do not eliminate, the possibility of the existence of tonnages of high-calcium limestone that could be quarried on a commercial scale.

Jefferson Marble, Mining and Milling Company Deposit
NW¼NE¼ sec. 13, T. 37 N., R. 39 E.

Location, accessibility, and ownership.—The abandoned quarry of the Jefferson Marble, Mining and Milling Company is in the NW¼NE¼ sec. 13, T. 37 N., R. 39 E. One can drive from Colville via U.S. Highway 395, the Echo Valley road, the Clugston Creek road, and up the South Fork of

Clugston Creek to within 1,000 feet of the quarry. The distance by road from Colville is about 14 miles. The property is now (1960) owned by Theresa H. Moore of Sacramento, California.

Operation.—Shedd reports (1903, p. 110) that in 1902 the company had installed a complete plant for quarrying and working marble. This included a 4-foot channeling machine, by means of which blocks were cut out on four sides and then broken loose on the lower side by means of wedges, a large steam-operated derrick, a 6- by 14-foot gang saw for sawing the marble, and a 9-foot rubbing bed. Little remains of the plant today (1961). The quarry has an area of 1,200 square feet and a depth of 5 to 15 feet. Of the 120 blocks (4 by 4 by 6 feet) that must have been quarried, about 50 remain at the quarry site.

Quality and quantity of limestone.—The outcrop at the quarry site is composed of white to pinkish-white, medium-grained limestone that weathers to a white to pale-yellow color. It contains 5 percent muscovite in the form of marbleized lenticles, streaks, and irregular layers and an additional 2 to 3 percent dolomite in the form of brown-weathering grains and nodules. No bedding was recognized in the course of the examination, although Shedd (1903, p. 110) reports that "where the deposits show stratification . . . they are steeply inclined, the angle of dip being from 60° to 80°."

Shedd (1903, p. 111) provides analyses of the pure white marble and the variety having a pinkish cast, both from the Jefferson quarry. Hodge (1938, p. 102) quotes Shedd's description and analyses but adds no new information. In the course of the present study one sample (S-23) was taken over a length of 50 feet, in a direction S. 80° E., along the top of the south wall of the quarry. The results of Shedd's and the author's sampling are as follows:

Sample	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
Shedd — white	——	——	43.77	55.16	0.21	0.87	none	——
Shedd — pink	——	——	42.46	51.54	1.11	3.49	0.24	——
S-23	95.03	2.36	42.70	53.39	1.13	1.58	0.95	0.006

Three samples are insufficient to evaluate this occurrence. On the basis of the information we have, however, it must be concluded that the limestone is not a high-calcium limestone even though the $CaCO_3$ content is in excess of 95 percent. Mica and dolomite are present in all the rock examined. The limestone is probably suitable for certain uses, such as the making of portland cement, but the deposit is much too remote from good transportation facilities or markets for it to be of any value for such purposes at the present time (1961).

Outcrops are very few in number because of the heavy cover of soil and forest. Shedd (1903, p. 110) writes that "these deposits cover a large area here and are practically inexhaustible, at any rate for years to come."

Rattlesnake Mountain Area
Secs. 13, 14, 23, and 26, T. 36 N., R. 38 E.

Location and accessibility.—Limestone is found about 5 miles northwest of Colville, on the west side of Rattlesnake Mountain. Access is easy via U.S. Highway 395 and graveled county roads.

Geology and value of limestone.—The limestone occurs as gray, rather massive bodies entirely within the late Paleozoic metavolcanic rocks. One small deposit is found along U.S. Highway 395 at the east side of sec. 27, T. 36 N., R. 38 E. Similar isolated deposits are found to the northeast; one of these, in the SE$\frac{1}{4}$ sec. 14 and the SW$\frac{1}{4}$ sec. 13, extends over a length of 4,000 feet. These limestone bodies, and other smaller ones in the metavolcanic rocks, are somewhat siliceous and do not qualify as high-calcium limestone. No samples were taken.

Echo Peak Area
Secs. 30 and 31, T. 37 N., R. 39 E.

According to Bennett (1961, written communication) limestone caps Echo Peak, but the volume of rock is not large. It is entirely surrounded by upper Paleozoic metavolcanic rocks, as are the limestone occurrences on Rattlesnake Mountain. The deposit was not examined in the course of the present survey. Presumably it is of the same impure nature as limestones elsewhere in the greenstone.

Hoeft Property
Sec. 21, T. 35 N., R. 39 E.

Location, accessibility, and ownership.—Limestone is found on property owned by Art A. Hoeft, of Colville, in the NW$\frac{1}{4}$NE$\frac{1}{4}$ sec. 21, T. 35 N., R. 39 E., 1 mile south of Colville adjacent to U.S. Highway 395 and the Great Northern Railway.

Geology.—The limestone crops out on a wooded hill, about 2,000 feet long and 1,600 feet wide, that rises 300 feet above the highway. It is part of Bennett's upper, or carbonate, unit.

The limestone that crops out at the south end of the hill is gray, fine grained, brecciated, and silicified, containing an estimated 5 to 15 percent quartz as small white veins and stringers. The limestone of possible commercial interest crops out along the highway and east to the summit of the hill; it is gray on both fresh and weathered surfaces, fine to medium grained, and contains a few brown-weathering dolomitic streaks and lenticles as much as $\frac{1}{2}$ inch across and 8 inches long. In most outcrops the rock displays a platy parting, owing to the presence of a well-developed cleavage. Bedding strikes N. 20° E. to N. 30° E. and dips approximately 45° NW. Cleavage strikes parallel to the