bedding and dips 45° E. The outcrops lie on the west limb of an anticline having little or no plunge; they represent a true thickness of 610 feet of limestone.

Quality and quantity of limestone.—Shedd (1913, p. 132-134) reports the occurrence of limestone "on Mr. Ham's ranch one and one-half miles south of the city [Colville]." He mentions that the body was diamond drilled at one time and that the hole was drilled to a depth of about 100 feet, "all the way in limestone. . . . quite uniform . . . both in texture and color. . . . fine grained and dark colored, with veins of white calcite through it." Four analyses were made of these diamond drill cores, each sample being from a different depth below the surface. The analyses of the core samples are as follows (Shedd, 1913, p. 133):

Sample no.	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3
I 20 feet below surface	41.95	51.22	2.15	3.16	0.92
II 35 feet " "	34.90	44.88	1.20	14.84	3.40
III 60 feet " "	42.00	48.73	3.26	1.96	2.68
IV 80 feet " "	40.37	47.87	3.96	5.44	1.36

A. A. Hammer, analyst

In discussing the deposit as a whole, Shedd (1913, p. 132) says,

> There appears to be two general characters of limestone in this ridge as far as surface indications are concerned. Along the western slope of the ridge the stone is very fine grained and dark colored, while along the top of the ridge it has a coarser texture and is much lighter in color. A surface sample was collected from each of these parts of this area.

The two samples collected by Shedd, one (No. I) a "dark limestone from western slope of ridge" and one (No. II) a "light colored stone from top of ridge," have the following composition (Shedd, 1913, p. 133):

Sample no.	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3
I	42.76	53.06	1.78	2.20	1.60
II	42.64	53.55	0.76	2.00	1.08

A. A. Hammer, analyst

Hodge (1938, p. 101) mentions that "a body of limestone occurs 1½ miles south of Colville in a ridge a mile long," and he presents one chemical analysis. This analysis is the same one (No. II, above) given earlier by Shedd.

Six samples (S-70, S-72 to S-75, and S-112) were taken (fig. 46) over a combined length of 325 feet. Because outcrops and sampling are not continuous, it can only be assumed that the sampling is representative of a total true thickness of 465 feet. Sample S-113 (150 feet long) was taken over essentially the same area as samples S-73 to S-75 (165 feet combined length) as a check on the quality of the limestone.

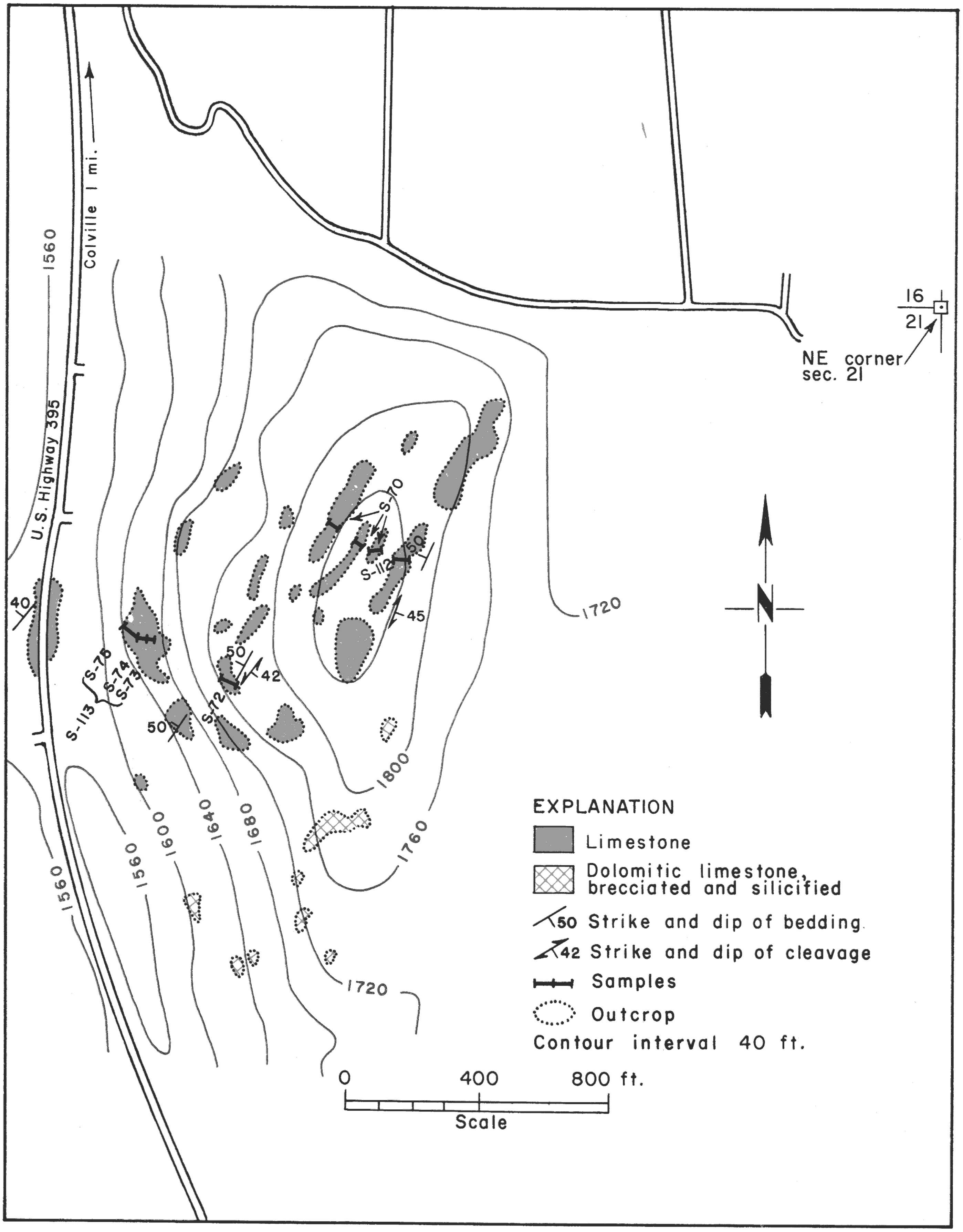

FIGURE 46.—Hoeft property. Sec. 21, T. 35 N., R. 39 E. Geology by J. W. Mills. Base map from aerial photo enlargement. Topography from U.S. Geological Survey Colville quadrangle map.

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-112	45	89.14	4.95	42.14	50.08	2.37	4.16	1.22	0.009				
S-70	65	93.91	2.47	42.64	52.76	1.18	1.99	1.14	0.012				
S-72	50	94.75	1.23	42.63	53.23	0.59	2.21	1.00	0.010				
S-73	50	93.31	1.44	41.96	52.42	0.69	2.80	1.60	0.006	225	660	270	25
S-74	50	95.09	1.17	42.65	53.42	0.56	1.93	1.17	0.008				
S-75	65	92.54	1.59	42.11	51.99	0.76	3.06	1.67	0.008				
S-113	150	95.37	1.17	42.76	53.58	0.56	1.81	0.95	0.010				

The limestone is not suitable for uses requiring a high-calcium rock. The MgO content is low enough on the west slope of the hill for the rock to be of potential value for the manufacture of portland cement. It is estimated that there is about 4½ million tons of cement rock available over a length of 900 feet and a width of 650 feet between the highway and the summit of the hill. The lower limit of this block of ground is the top of the underlying dolomitic, silicified, and brecciated limestone.

Spokane Indian Reservation

Cayuse Mountain Area

Location and accessibility.—Cayuse Mountain is in the Spokane Indian Reservation, approximately 30 miles northwest of Spokane. It extends from the SW¼ sec. 21, through sec. 20, to the SE¼ sec. 18, T. 27 N., R. 38 E.; its total length is 2 miles and its width 1 mile. The area is reached by driving north from Reardan, on U.S. Highway 2, to Little Falls, on the Spokane River, thence west along the north side of the Spokane River for a distance of approximately 8 miles. The nearest railroad facilities are in Spokane.

Geology.—Cayuse Mountain is in the southeastern part of the Turtle Lake 15-minute quadrangle, the geology of which has been mapped by Becraft and Weis (1957). According to them and according to Becraft (1959, p. 17), Cayuse Mountain is underlain by a metamorphic complex composed of quartzite (oldest); hornfels; and a series composed of a limestone marble unit overlain by a phyllite unit, a second marble, a second phyllite, and a third marble (youngest). These metamorphic rocks "appear to be part of the southwest limb of a very broad southeast- or east-plunging syncline" (Becraft, 1959, p. 72). In discussing the attitude of the beds, Becraft (1959, p. 17-18) writes,

> Locally the bedding in the marble layers is extremely contorted, but generally the attitude of the bedding is consistent over large areas and is parallel to the bedding in the phyllite. Near the southeastern exposures of the sequence, the bedding generally strikes northwest and dips steeply to the northeast. Near the west end of Cayuse Mountain the strike of the bedding swings to the north, and on the small hill northwest of Cayuse Mountain the bedding has a northeast strike and a southeast dip.

The metamorphic complex is considered to be Paleozoic (?), and probably Cambrian, in age (Becraft, 1959, p. 23).

Quality of limestone.—Becraft (1959, p. 18) describes the limestone marble as follows:

> The marble generally forms isolated bold outcrops. It is thin bedded to massive and fine to coarse grained. The grain size is commonly different in adjacent beds and is markedly coarser at a few places along the contact with the granodiorite. The rock ranges in color from white to dark gray, and in composition from lime-silicate to almost pure marble. The rocks consist predominantly of calcite but commonly contain diopsidic pyroxene, wollastonite, scapolite, vesuvianite, grossularite, forsterite, serpentine, orthoclase, and plagioclase . . . in varying amounts.

During the current study most of the limestone was examined briefly. For the most part, it was found to be much too impure (contact metamorphic silicates) to justify further attention. One sample (S-212) was taken of what appeared to be a less impure section of the limestone marble, in the NE¼NE¼ sec. 19, T. 27 N., R. 38 E., on the west side of Cayuse Mountain. The limestone is gray, fine grained, and thin bedded, containing a few thin interbeds of limy shale. Bedding strikes due north and dips 50° to the east. Both the length of the sample and the stratigraphic thickness of the section sampled are 65 feet. The analysis of this sample is as follows:

Sample no.	Length (feet)	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
S-212	65	46.67	3.16	18.71	26.22	1.51	48.94	4.68	0.061

It is quite clear, from the field examination of Cayuse Mountain and from the analysis of S-212, that there is no appreciable tonnage of limestone of value for most uses.

NORTHEASTERN FERRY COUNTY

Orient District

The town of Orient is on the west bank of the Kettle River in northeastern Ferry County, 10 miles south of the International Boundary. Access is provided by U.S. Highway 395 and the Great Northern Railway.

In discussing limestone occurrences in Ferry County, Shedd (1913, p. 160) writes:

> To the west of Orient in the Kettle River range of mountains, are probably the largest bodies in the county. These, however, are well up toward the summit of the range and are not easily reached. This limestone varies more or less in texture and ranges from fairly fine grained to extremely coarse grained. In color it is gray or white.

In the following year, Bancroft discusses rocks of the same area and considers them to be probably Precambrian in age. He writes (1914, p. 11):

> In the vicinity of Rockcut is exposed a series of medium- to coarse-grained crystalline limestone, quartzite, and schist. These rocks extend northward into British Columbia and southward to Orient, where they dip under the supposed Paleozoic rocks and pass from view. The thickness of that part of the section contained within the area of this reconnaissance probably exceeds 2,000

feet, but definite measurements of the individual formations have not been obtained. Strata of limestone and quartzite several feet thick and schist formations of one type or another several hundred feet thick were seen. The general strike of the series is north-south and the dip is rather flat, being only about 15° E. or SE.

Bancroft continues (1914, p. 12):

The limestone is dark brown on weathered surfaces and cream white on fresh surfaces and is highly crystalline, forming a good marble.

Bowman (1950) describes a rock series in the Orient district (Boulder Creek Formation) at least 2,200 feet thick, composed of quartzite, dolomite and calcite marble, lime-silicate gneiss, sillimanite schist, sillimanite gneiss, and amphibolite. On the map accompanying his report, Bowman (1950) shows an area of Boulder Creek carbonate rocks, surrounded and intruded by granodiorite of late Mesozoic age, in the W½ sec. 3, T. 39 N., R. 36 E. Concerning these carbonate rocks, he writes (1950, p. 14 and 16):

Dolomite marble: White dolomite marble crops out in several small exposures in the vicinity of Rock Cut. The rock is very massive; no bedding was seen by the writer in any of the outcrops examined. The average grain size is about 3 mm., although a few crystals exceed a centimeter in diameter.

Calcite marble: Most of the calcite marble is distinctly foliated and is finer grained than the dolomite marble; the average grain size is approximately 1.5 mm. in the calcite marble. The calcite marbles characteristically are impure, and contain varying proportions of magnesian mica, tremolite, apatite, and diopside. The micas range in color from very dark brown to light yellow brown, and all varieties have a brilliant resinous luster. In most specimens the grain size of the accessory silicates is approximately the same as that of the calcite. Locally, however, the silicates are many times larger, as on Thompson Ridge, where abundant diopside crystals averaging about 1 cm. are embedded in calcite having an average grain size of about 1.3 mm.

The only sample analysis in the literature is one recorded and discussed by Shedd (1913, p. 162) as follows:

Only one sample . . . was analyzed. In color this sample is almost pure white. It has a very coarse texture, many of the grains being as much as 5 mm. in diameter, while some of them are as much as twice that.

The analysis of this one sample of "limestone from west of Orient, Ferry County" (Shedd, 1913, p. 162) shows the rock to contain 31.96 percent CaO, 19.31 percent MgO, 4.65 percent SiO_2, and 0.99 percent R_2O_3. Thus, the rock is not a limestone but an impure dolomite.

On the basis of a brief examination of some of these limestone occurrences, the descriptions given by Shedd, Bancroft, and Bowman, and the analysis recorded by Shedd, it is quite clear that the carbonate rocks explored to date are dolomites and very impure silicated limestones. They are of no value for most uses.

Barstow Area

Limestone crops out on the west side of the Kettle River approximately 7 miles south of Orient. Some of the limestone is Cambrian and some is Permian in age. Because these rocks are the westward extensions of rocks of the same age on the east side of the Kettle River (Stevens County) they are discussed on pages 131 to 134 of this report.

Lake Ellen District

Limestone is well exposed in cliffs along the southeast side of Lake Ellen, in the SW$\frac{1}{4}$ sec. 26 and the NW$\frac{1}{4}$ sec. 35, T. 35 N., R. 36 E. Lake Ellen is reached by driving south approximately 8 miles along the west shore of the Columbia River, from the turnoff on State Highway 3P (Sherman Pass road) 1$\frac{1}{2}$ miles west of the Columbia River. From here a good graveled road is followed to the west for approximately 5 miles to Lake Ellen.

The Lake Ellen district was not visited. The following remarks have been abstracted from a report by R. A. Anderson (1935) on file in the geology library of Washington State University.

Cliffs of limestone, cherty limestone, argillaceous limestone, chert, argillite, phyllite, and quartzite extend for 2,000 feet along the southeast side of Lake Ellen. The tops of the cliffs range from 300 to 500 feet above the lake level. East of the cliffs, outcrops of similar rocks continue to the summit of Stahley Mountain, 1,100 feet above Lake Ellen. Anderson (1935, p. 2) believes these sedimentary rocks are part of the Covada Group, of Carboniferous age (Pardee, 1918, p. 25), of the Colville Indian Reservation to the south. Anderson determined the total true thickness of the sedimentary section to be at least 1,500 feet, approximately 1,100 feet of which is limestone. The limestone, variously described as black slaty, red cherty, pink, white, gray argillaceous, siliceous, and massive limestone, occurs interbedded with the argillite, phyllite, quartzite, and greenstone, as distinct units ranging in thickness from 1.5 to 150 feet. The thickest limestone unit described, lacking such descriptive terms as argillaceous and cherty that indicate the impure nature of the rock, is one massive unit 90 feet thick having a "porcelain-like appearance" (Anderson, 1935, p. 8).

These sedimentary rocks strike N. 60° W. and dip 30° SW. Anderson concluded, on the basis of the attitude of drag folds and bedding, that the entire section is completely overturned so that the older strata now lie above the younger strata.

It is impossible to determine the potential value of these limestones without sampling and analyzing them. There was insufficient time to do so during this study.

SOUTHERN FERRY COUNTY

East Half Colville Indian Reservation

The east half of the Colville Indian Reservation is bounded on the east and south by the Columbia River, on the west by the Ferry-Okanogan County line, and on the north by the line between Tps. 34 and 35 N. of the Willamette base line. The main access to the district is by way of State Highway 4,

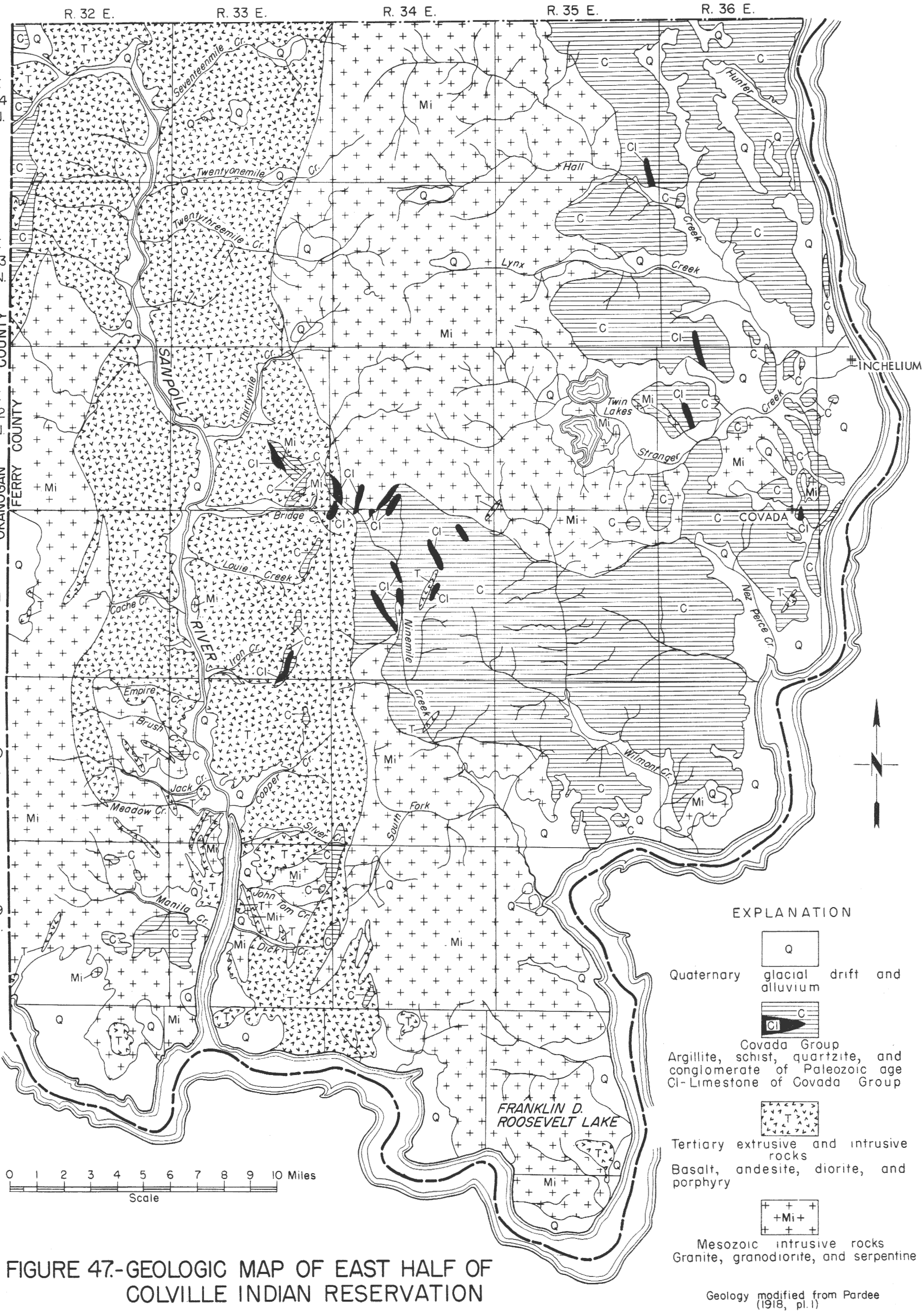

FIGURE 47.-GEOLOGIC MAP OF EAST HALF OF COLVILLE INDIAN RESERVATION

which runs north from Wilbur (on U.S. Highway 2) up the valley of the Sanpoil River to Republic. Access to parts of the reservation away from the Sanpoil valley is limited to a few graveled roads, such as the road from Inchelium to Kettle Falls, the Hall Creek road from Inchelium to Republic, the Twin Lakes road from Inchelium to Twin Lakes and State Highway 4, the road from Keller to Ninemile and Monahans, the road from West Fork to Aeneas, and the road from State Highway 4 to Nespelem. Large areas in the central part of the east half of the Colville Indian Reservation, in the heart of the Kettle River Range, are quite inaccessible except on foot. There are no railroads within the reservation.

The only published comprehensive discussion of the geology of the Colville Indian Reservation is the U.S. Geological Survey report by Pardee (1918). Most of the following discussion of the geology has been abstracted or quoted from that report. Figure 47 is a geologic map of the east half of the reservation, modified from Pardee's map (1918, pl. 1).

The oldest known rocks exposed in the Colville Indian Reservation consist of a series of sedimentary and volcanic rocks that have been more or less metamorphosed and include shale, slate, argillite, schist, quartzite, conglomerate, limestone, and greenstone. Pardee named these the Covada Group (Pardee, 1918, p. 20). Their distribution is shown in figure 47. Although large open folds and even gentle flexures are present in these rocks in some areas, for the most part the beds are in relatively small, tightly compressed folds. The average strike of the folds is north, and the variations do not generally exceed 20° to either side of the meridian (Pardee, 1918, p. 24). Faults are numerous in localities that contain mine workings and are probably widespread in the region. The more prominent of the faults observed are parallel to the folds (Pardee, 1918, p. 24). Pardee believes that the Covada Group is probably of Carboniferous age, although the group "may descend in the geologic time scale below the Carboniferous" (1918, p. 27). His assignment of a Carboniferous age to these rocks is based partly on the discovery of plant fossils and coral fragments in limestone (Pardee, 1918, p. 26) and partly upon the great similarity of the rocks of the Covada Group (1918, p. 25 and 26) to those of the Lower Cache Creek Group of southern British Columbia, which Dawson (1895, p. 37B - 49B) considers to be Carboniferous in age. In a recent paper dealing with the correlation of the Permian formations of North America, Dunbar writes (Dunbar and others, 1960, p. 1780):

> The Cache Creek group is a catchall for the late Paleozoic strata of British Columbia and Yukon Territory. It is locally very thick and probably includes numerous unnamed formations and local and even regional hiatuses. In the Lake Penchi area Dunbar has identified Wolfcampian, middle Permian, and later Permian fusulines.

The rocks of the Covada Group are similar in many respects to the rocks of Permian age mapped by Muessig and Quinlan (1959) in the Republic quadrangle to the north of the Colville Indian Reservation and to the rocks of Permian age mapped by Mills (Mills and Davis, 1962) in the Kettle Falls district of Stevens County.

The rocks of the Covada Group are intruded by serpentine dikes, granite, and granodiorite, of Mesozoic age (Pardee, 1918, p. 29 - 34). Intrusive and extrusive andesitic rocks (andesite, diorite, and porphyry) of Tertiary age occupy considerable areas in the Sanpoil drainage basin and in the vicin- of Covada and Inchelium (Pardee, 1918, p. 22).

Limestones of the Covada Group.—The following quotation is from Pardee (1918, p. 22):

> The limestone occurs in irregular lenses or podlike masses, a few of which are several hundred feet thick in places and may be traced a mile or two along the strike. Most of them, however, are smaller, and the average thickness is probably not more than 100 feet. As to the details of form and distribution, these limestones may be best described as erratic. Some of them taper to nothing at one or both ends, but more commonly they are cut off abruptly or end in a number of irregular blocks partly or wholly detached from the main mass. Although they are most abundant at certain horizons and in certain areas, as in the dark-colored argillites in the basin of Ninemile Creek, isolated masses may be found in any part of the section and anywhere within the areas occupied by the Covada group; and an apparent hit-or-miss distribution, as if each mass were independent of the other, seems to be a general and characteristic feature. In color the limestone ranges from white through bluish gray to black, and in texture from finely to coarsely crystalline. Many of the masses are rather pure calcium carbonate, as, for instance, one at the east side of Rattlesnake Mountain, for which Bancroft [1914, p. 13] gave an analysis showing 50.3 per cent of calcium oxide, equivalent approximately to 85 per cent of calcium carbon- ate. Some of them, however, appear to be very impure, containing much silica, magnesia, or other foreign substances.

The distribution of the limestones of the Covada Group is shown on figure 47, after Pardee (1918). In his discussion of the districts containing the metalliferous deposits in the eastern half of the Reser- vation Pardee makes the following remarks concerning limestone:

> Sanpoil district:
>
> p. 106. . . . Fine-grained rocks of sedimentary origin that have been altered to argillite, schist, and marble occupy the upper part of the basin of Ninemile Creek and form isolated patches scattered along the divide from Bridge Creek south to Columbia River, on Mica Mountain, and west of Sanpoil River. In the vicinity of the prospects in the Ninemile basin and on Bridge Creek and Iron Creek these rocks range from a black carbonaceous argillite to quartz-mica schist and contain interbedded lenslike layers of marble.
>
> p. 137. . . . Ninemile Creek locality. . . . The principal formations of this area are schistose argillite and limestone of the Covada group that range in strike from N. 20° E. to N. 20° W. and dip east or west at moderate angles. These rocks extend eastward to Columbia River and beyond but are cut off on the north and south by the Colville granite and on the west by still younger porphyry.
>
> Covada district:
>
> p. 144. . . . Thin nonpersistent beds of impure limestone and marble crop out on Rattle- snake Mountain and a short distance southeast of Covada, and many of the shale beds elsewhere are more or less limy.
>
> p. 170. . . . Blue Jay, Rattlesnake, and Yellowstone prospects. . . . The formation is chiefly quartz-mica schist and siliceous blue argillite, with which some thin lenslike layers of limestone are interbedded.
>
> p. 171. . . . Silver Leaf Mine. . . . The formation at this locality is siliceous argillite and quartzite, with thin interbedded layers of limestone that have an average northerly strike and nearly vertical dip.

It is not possible to evaluate the limestones of the east half of the Colville Indian Reservation, as (with two exceptions) they were not examined during this study. However, it is the writer's opinion, based upon Pardee's descriptions, upon personal observations in the Reservation and in neighboring areas, and upon the general inaccessibility of most of the limestone area, that it is very unlikely that there is any significant amount of high-calcium limestone on the east half of the Reservation.

Covada Area

Location and accessibility.—Covada is in sec. 1, T. 31 N., R. 36 E., on the Colville Indian Reservation. It is 1 mile west of the Columbia River and 7 miles south of Inchelium. Good graveled roads connect Covada with Inchelium and with Twin Lakes to the northwest.

Geology and quality of limestone.—Bancroft (1914, p. 189) reports that limestone is found on Rattlesnake Mountain, $1\frac{1}{2}$ miles northeast of Covada, intercalated with quartz-mica schist and shales, and intruded by quartz monzonite and quartz diorite. These limestones "have been largely changed to marble and show the results of contact metamorphism by the presence of garnet and other contact-metamorphic silicate minerals" (Bancroft, 1914, p. 197). An analysis of the limestone from Rattlesnake Mountain is reported by Bancroft (1914, p. 189) to contain 50.3 percent CaO; that is, approximately 89 percent $CaCO_3$.

During the present study, limestone of the Covada Group was examined in the NW$\frac{1}{4}$ sec. 1, T. 31 N., R. 36 E.; in the SE$\frac{1}{4}$ sec. 35, T. 32 N., R. 36 E.; and on the east side of Rattlesnake Mountain in sec. 30, T. 32 N., R. 37 E. At each of these localities the bedrock consists of limestone (maximum 15 percent) as lenses and beds up to 15 feet thick intercalated with schistose greenstone, argillite, and quartzite. Strikes range from north to northwest and dips are moderate to steep to the west. The limestone is light gray to gray, fine to coarse grained, and usually siliceous or dolomitic. No samples were taken.

The low CaO content of the limestone and the presence of many impurities were recognized by Bancroft and by Pardee and further substantiated by the present field work. Furthermore, the limestone occurs usually as thin beds and lenses too small to provide any appreciable volume of rock. The chances are extremely remote for finding any large tonnage of high-calcium limestone in the Covada area.

Keller Area

Pardee (1918, p. 178) reports that "limestone was burned from a small mass that crops out on Lime Creek, 9 miles north of Keller, and was used in the construction of the Keller Smelter." In 1960 the writer visited the area on Lime Creek (SE$\frac{1}{4}$ sec. 25, T. 31 N., R. 32 E. and the SW$\frac{1}{4}$ sec. 30, T. 31 N., R. 33 E.) approximately $5\frac{1}{2}$ miles north of Keller on State Highway 4. Outcrops of carbonate rocks were found at the crest of an east-west ridge approximately 800 feet higher in altitude and half a mile west of State Highway 4. All outcrops examined, in an area a third of a mile long and a quarter of a mile wide, are light-gray to gray, very fine grained dolomite.

NORTHWESTERN FERRY COUNTY

The region referred to as northwestern Ferry County lies north of the Colville Indian Reservation, east of Okanogan County, south of the International Boundary, and west of the Kettle River Range. The principal town in the region is Republic, the county seat. From Republic good paved roads extend south (State Highway 4) to Wilbur, west (State Highway 4) to Tonasket, north (State Highway 4A) to Danville and the International Boundary, and east (State Highway 3P) to Kettle Falls. Branching from these highways are numerous graveled roads. Most of them follow the valleys of streams that are tributaries to the two major rivers of the region, the Sanpoil River and the Kettle River. A branch of the Great Northern Railway extends from the northeast corner of the Curlew quadrangle at Danville up the valley of the Kettle River and Curlew Creek to Curlew Lake; from there it runs down the Sanpoil Valley to Republic.

The geology of parts of northwestern Ferry County has been discussed by Umpleby (1910), Bancroft and Lindgren (1914), Wright (1947), and others. Complete references to these papers are given by Bennett (1939) and Reichert (1960). Geologic mapping of the entire region was completed in 1959 by the U.S. Geological Survey. The reports of this work are in preparation. The preliminary geologic maps of the Wauconda and Republic quadrangles (Muessig and Quinlan, 1959) and the Curlew quadrangle (Calkins, Parker, and Disbrow, 1959) are on open file in the Spokane office of the U.S. Geological Survey and at the Division of Mines and Geology in Olympia.

The following generalized description of the geology of northwestern Ferry County has been formulated following a study of the preliminary geologic maps and after brief discussions with S. J. Muessig and R. L. Parker of the U.S. Geological Survey. The region is underlain by sedimentary, igneous, and metamorphic rocks that range in age from late Paleozoic to late Tertiary. Rocks of pre-Permian (late Paleozoic) age include marble, phyllite, quartzite, quartz schist, quartz-biotite schist, calc-silicate schist, hornblende schist, garnet-staurolite schist, granite gneiss, and quartzo-felspathic gneiss. Rocks of Permian age in the Republic and Wauconda quadrangles (Muessig and Quinlan, 1959) and rocks of Permian and Triassic age in the Curlew quadrangle (Calkins, Parker, and Disbrow, 1959) include limestone, greenstone (tuffs, flows, and intrusives), graywacke conglomerate, graywacke, argillite, phyllite, and chert. The Paleozoic rocks are intruded by granodiorite, granite, and quartz monzonite of Cretaceous age. The Paleozoic sedimentary, volcanic, and metamorphic rocks are overlain unconformably by a great thickness of tuffs, andesites, and rhyodacite of Eocene (?) age, intruded by rhyodacite and quartz monzonite. Above these are "lake beds" (Muessig and Quinlan, 1959), volcanic conglomerate, tuffaceous sandstone, and siltstone of Oligocene age, and basalt flows of Oligocene (?) and Miocene age.

The sedimentary and volcanic rocks occupy a great north-northwest-trending graben (pl. 1), at least 35 miles long and from 8 to 12 miles wide. The graben is bounded on the west by the high-angle Bacon Creek fault, which extends from the southwest corner of the Wauconda quadrangle to the center of the north border of the Curlew quadrangle. The graben is bounded on the east by the high-angle Sherman Creek fault, extending from the center of the south border of the Republic quadrangle approximately to the center of the east border of the Curlew quadrangle. Outside of the graben the rocks are principally intrusive granodiorite and quartz monzonite of Cretaceous (and Tertiary?) age, with lesser amounts of pre-Permian metamorphic rocks. Within the graben there are numerous high-angle faults striking approximately parallel to the bounding faults. The principal movement on all the high-angle faults took place in pre-Eocene time, but smaller movements have taken place in post-Eocene time. A thrust fault was mapped by Muessig and Quinlan (1959) in the northeast part of the Republic quadrangle. This fault was discussed by Muessig at the 1958 meeting of the Northwest Mining Association in Spokane. He reported that the thrusting took place after the latest movement on the high-angle graben faults and that the amount of thrust movement on the fault was at least $3\frac{1}{2}$ miles. The rocks within the graben were folded at least once in pre-Eocene time, again in late Eocene time, and once more in late or post-Oligocene time.

The limestones of northwestern Ferry County can be classified according to whether they are found within or outside the graben. Those within the graben are of Permian and Triassic age. They occur in irregular or elongate areas as much as 6,000 feet long and 3,000 feet wide, with their longer dimension approximately parallel to the strike of the bedding in the limestone. Many of them are found near, adjacent to, or interbedded with greenstone (tuffs, flows, and intrusions), graywacke conglomerate, graywacke, argillite, and chert of Permian and Triassic age. The limestone and greenstone areas appear on the geologic maps as isolated blobs or patches entirely surrounded by igneous rocks of Tertiary age or bounded on one or more sides by faults. Many of them are xenoliths within large intrusive bodies of quartz monzonite or rhyodacite. In spite of the folding, faulting, and thermal metamorphism to which they have been subjected, the limestones within the graben have retained their primary features (fine grain size, bedding, and fossils) remarkably well. In contrast, the limestones outside the graben are highly metamorphosed. They occur as marble and siliceous marble associated with phyllite, quartzite, schists, and gneisses of late Paleozoic (pre-Permian) age, and in contact with intrusive granodiorite of Cretaceous age. These pre-Permian limestone marbles generally have much greater continuity and extent than the Permian and Triassic limestones within the graben. For example, a pre-Permian marble stratum can be followed continuously for 4 miles in the northwestern part of the Curlew quadrangle.

Districts or areas within the graben discussed in the following part of this report include Curlew Northeast, Republic Northeast, Republic North, Empire Creek, Copper Lakes, and O'Brien Creek. Districts or areas outside the graben include Curlew Northwest, Peter Creek North Fork, and Wauconda Southwest.

Curlew Northeast District

The Curlew Northeast district extends south from the International Boundary near Danville, Washington, to within half a mile of Curlew (fig. 48). The district is crossed diagonally by the Kettle River, State Highway 4A, and the Great Northern Railway. Access to parts of the district remote from the valley of the Kettle River is limited to graveled roads up Shasket Creek, Goosmus Creek, Little Goosmus Creek, and West Deer Creek.

Limestones and associated greenstones and graywackes of Permian and Triassic age occur in areas of irregular shape scattered throughout the district (fig. 48). They are surrounded by quartz monzonite, rhyodacite, monzonite, and diorite of Tertiary age, or by alluvium (Calkins, Parker, and Disbrow, 1959). Examination and sampling was limited to the limestones along the valley of the Kettle River, where transportation facilities are available.

Shasket Creek Area
W$\frac{1}{2}$ sec. 17, T. 40 N., R. 34 E.

Location, accessibility, and ownership.—Limestone and dolomite crop out on a ridge northeast of Shasket Creek in the W$\frac{1}{2}$ sec. 17, T. 40 N., R. 34 E., approximately 2$\frac{1}{2}$ miles southwest of Danville. The Shasket Creek road (fig. 48) provides easy access from State Highway 4A. The Great Northern Railway is 1 mile due east of the carbonate rock outcrops. County records show the area to be U.S. public domain.

Geology and quality of limestone.—Only the carbonate rocks in the NW$\frac{1}{4}$ sec. 17, along and north of the Shasket Creek road, were examined. They are reported (1960, written communication) by R. L. Parker, of the U.S. Geological Survey, to be of Triassic age. To the north and south they are in contact with porphyritic syenite and monzonite intrusive rocks of Tertiary age. To the northwest they are underlain conformably by greenstone, argillite, and graywacke of Triassic age. To the east they are covered by alluvium. The outcrops are composed of white to light-gray, fine- to medium-grained limestone and dolomite. Clusters of tremolite crystals up to 2 inches in diameter are numerous in the carbonate rocks, especially in the dolomite. Bedding strikes range from N. 20° E. to N. 45° E.; dips range from 23° to 40° SE.

Sampling was begun in the SW$\frac{1}{4}$NW$\frac{1}{4}$ sec. 17 and continued in a direction S. 83° W. for 700 feet to a point 250 feet east of the limestone-argillite contact in the SE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 18, T. 40 N., R. 34 E. Each of the 7 samples (100 feet long each) consisted of white to light-gray, medium-grained limestone containing needles and blades of tremolite and a few small garnet crystals. The analyses of these samples are as follows:

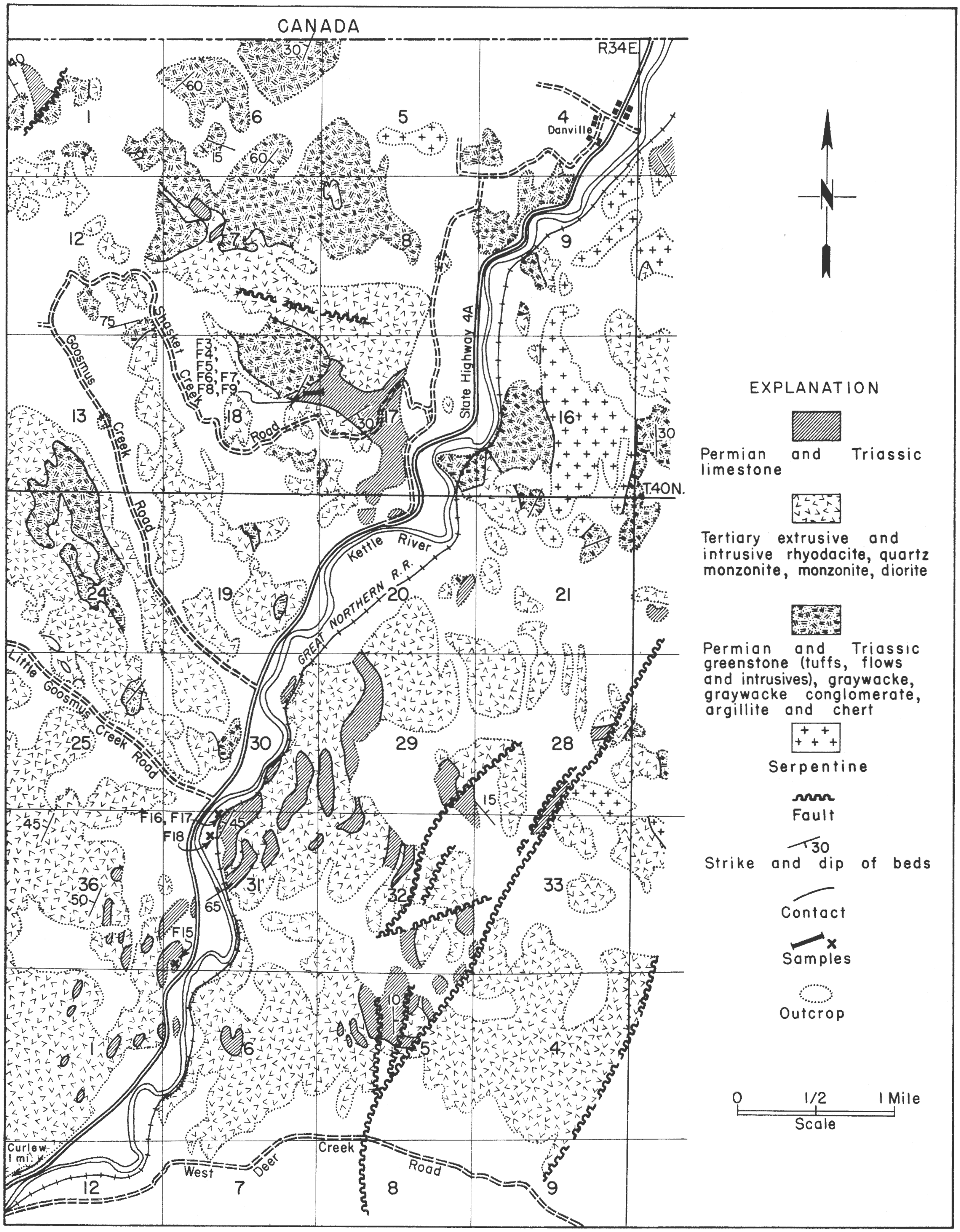

FIGURE 48.—Geologic map of Curlew Northeast district. Geology from U.S. Geological Survey open-file geologic map of Curlew quadrangle, by J. A. Calkins, R. L. Parker, and A. E. Disbrow, 1959.

Sample no.	Length (feet)	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
F-3	100	82.81	15.15	41.33	46.52	7.25	4.62	0.46	0.046
F-4	100	70.65	11.64	28.09	39.69	5.57	25.50	1.35	0.071
F-5	100	76.24	3.97	32.86	42.83	1.90	21.62	0.76	0.057
F-6	100	60.00	5.35	26.30	33.71	2.56	35.92	1.35	0.060
F-7	100	81.11	17.58	42.25	45.57	8.41	3.67	0.59	0.032
F-8	100	84.73	6.96	39.78	47.60	3.33	9.22	0.38	0.042
F-9	100	73.21	22.13	42.12	41.13	10.59	5.35	0.54	0.043

The analyses show that the limestone is much too impure (magnesian and siliceous) to be of any value. The outcrops for which these samples are representative may not be representative of the entire area of outcrop on the ridge. However, no other outcrops were found that appeared to be more pure, and many were found to be less pure, than those sampled.

Little Goosmus Creek Area

NW¼ sec. 31, T. 40 N., R. 34 E.

Location, accessibility, and ownership.—Rock cuts expose limestone of Permian age along the Great Northern Railway opposite the mouth of Little Goosmus Creek in the NW¼ sec. 31, T. 40 N., R. 34 E. The limestone is the western extension of similar rocks mapped by Calkins, Parker, and Disbrow in 1956-1959 (fig. 48). The outcrops are not accessible by auto. They can be reached most easily from State Highway 4A by fording the Kettle River just south of the mouth of Little Goosmus Creek. The sampled limestone outcrops are on the right-of-way of the Great Northern Railway. Their extension on the forested hill to the east of the railroad is on U.S. public domain.

Geology and quality of limestone.—Sampling was done in two areas, approximately 750 feet apart. One is in the NE¼NE¼NW¼ sec. 31. Outcrops here are gray fine-grained limestone containing small white blebs of silica. Bedding strikes N. 57° E. and dips 42° NW. Samples were taken at right angles to the strike of the bedding. Sampling was begun (F-16) on the west side (10 feet) and continued (34 feet) on the east side of the railroad to the edge of the outcrop. Thirty-two feet southeast of the southeast end of sample F-16, sampling was begun again (F-17) and continued for 90 feet to the edge of the outcrop.

The other sampled area is in the SE¼NE¼NW¼ sec. 31. Sampling was begun (F-18) at the railroad and continued in a direction S. 72° E. for 100 feet to the edge of the outcrop. The limestone is gray, and fine to very fine grained. It contains up to 2 percent of black chert as blebs and nodules as much as 1 inch in diameter. Bedding strikes N. 40° E. and dips 86° NW. Eighty feet east of the east end of sample F-18 are numerous outcrops of rhyodacite. The analyses of samples F-16, F-17, and F-18 are as follows:

Sample no.	Length (feet)	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
F-16	44	83.13	8.44	39.75	46.70	4.04	8.09	1.32	0.061
F-17	90	93.82	2.93	41.59	52.71	1.40	3.87	0.50	0.035
F-18	100	92.35	4.95	42.75	51.88	2.37	2.73	0.37	0.048

None of the rock is high-calcium limestone. The silica and magnesia content is too high for most uses. It is not likely that there is any significant volume of limestone sufficiently free of MgO to be acceptable for the making of portland cement, even though the MgO content of sample F-17 is low enough for this purpose.

Vandiver Property
SW¼SW¼ sec. 31, T. 40 N., R. 34 E.

Location, accessibility, and ownership.—Limestone crops out on a ridge approximately 300 feet northwest and 200 feet above State Highway 4A and 900 feet northwest of the Great Northern Railway in the SW¼SW¼ sec. 31, T. 40 N., R. 34 E. The land is owned by W. P. Vandiver, of Curlew.

Geology and quality of limestone.—The limestone is one of three outcrops of limestone of Permian age that lie between the highway and the intrusive rhyodacite to the west, in the SW¼ sec. 31. It forms a cap on the ridge, approximately 50 feet thick underlain by rhyodacite. The limestone is light gray, fine grained, and massive. Sample F-15 was taken toward the highway from the top of the ridge across the entire thickness of limestone. The analysis of this sample is as follows:

Sample no.	Length (feet)	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
F-15	50	87.72	8.67	42.17	49.28	4.15	3.75	0.62	0.103

The analysis shows that the limestone is too impure to be of any value for most uses.

Limestone in the SW¼NW¼ sec. 6, T. 39 N., R. 34 E.

Road cuts along the west side of State Highway 4A in the SW¼NW¼ sec. 6, T. 39 N., R. 34 E. expose well-bedded chert with interbeds (20 percent) as much as 1 foot thick of dark-gray to black fine-grained limestone of Permian age. The bedding strikes N. 60° E. and dips 30° NW. There is insufficient limestone to justify sampling or development.

Helphrey Property
NW¼SW¼ sec. 6, T. 39 N., R. 34 E.

Location, accessibility, and ownership.—The Helphrey property is 2 miles northeast of Curlew in the NW¼SW¼ sec. 6, T. 39 N., R. 34 E. It can be reached by driving from Curlew on the West Deer Creek road to the NW¼ sec. 7, T. 39 N., R. 34 E., then north for approximately 1 mile on a very poor road to the portal of a mine tunnel in which the limestone was found. The portal is 500 feet east of the Great Northern Railway. The tunnel was driven many years ago in a search for copper ore. The property was owned for several years by E. C. Lancaster (deceased); it is now owned by W. B. Helphrey, of Curlew.

Geology and quality of limestone.—The portal of the tunnel and the hillside around it is composed of quartz monzonite. A geologist of the Hecla Mining Company, who examined the tunnel in 1956, reported (1959, written communication from the Hecla Mining Company) that the tunnel had been driven for a total length of 1,600 feet in a direction N. 85° E. He reported further that, although most of the tunnel is through igneous intrusive rock, limestone is exposed continuously in the tunnel from 156 feet to 300 feet from the portal. The limestone-intrusive contacts are steep to vertical. The limestone is white, fine to coarse grained, and massive.

The writer traversed the hill slope to the north, south, and east of the portal to an altitude of 500 feet above the portal. Although most of the outcrops on the hill slope are of quartz monzonite, a few xenoliths of hornfels and white coarse-grained limestone (marble) were found between altitudes of 100 feet and 200 feet above the portal. These outcrops of hornfels and limestone are irregular in form and erratic in distribution, and they are entirely surrounded by quartz monzonite. None of them contain more than a few thousand tons of limestone. No samples were taken by the writer. However, the Hecla Mining Company geologist sampled the limestone in the south wall of the tunnel over its exposed length of 144 feet. Analysis of this sample showed the limestone to contain 96.3 percent $CaCO_3$ and 1.21 percent MgO.

On the basis of the Hecla sampling and analysis, the rock may be considered to be a high-calcium limestone. In view of the small size and irregular distribution of the limestone in the outcrops on the hill slope and in view of the xenolithic nature of the limestone exposures, no regular or extensive mass of limestone is known to exist. For this reason the property is considered to be of little value as a source of high-quality limestone.

Republic Northeast District

The Republic Northeast district is in the northeast corner of the Republic quadrangle, between 4½ miles and 8 miles east of Curlew Lake. It includes the NW¼ of T. 37 N., R. 34 E., and the southern extremity of the SW$\frac{1}{4}$ of T. 38 N., R. 34 E. The district is reached by driving north from Republic on State Highway 4A for 12$\frac{1}{2}$ miles to the Lambert Creek road, thence up the Lambert Creek road for 4$\frac{1}{2}$ miles to the border of the district. The Lambert Creek road ends within the district 6 miles from State Highway 4A and 7$\frac{1}{2}$ miles from the Great Northern Railway.

The Republic Northeast district is divided into an east half and a west half by the Sherman Creek fault (fig. 49). The outcrops east of the fault and outside the regional graben are composed entirely of quartz monzonite of Cretaceous and Tertiary (?) age (Muessig and Quinlan, 1959). The outcrops west of the fault and within the graben are composed of limestone, greenstone, graywacke, argillite, and phyllite, all of Permian age, and rhyodacite of Tertiary age. Bedding in the older rocks has strikes that range from due north to N. 30° E. and dips that range from 48° to 75° W. All the limestone lies between the Sherman Creek fault and a sub-parallel high-angle fault in the western part of the district. Small, isolated, and remote outcrops of limestone, in the S$\frac{1}{2}$ sec. 18, T. 37 N., R. 34 E., were not examined. The largest and most accessible outcrops of limestone extend for 1$\frac{1}{2}$ miles to the north and south of the end of the road on Lambert Creek. These outcrops were examined, mapped, and sampled, as shown on the geologic map of the Lambert Creek area, figure 50.

Lambert Creek Area
Sec. 32, T. 38 N., R. 34 E., and
secs. 5, 6, 7, and 8, T. 37 N., R. 34 E.

Location and accessibility.—The limestone of the Lambert Creek area is well exposed south of Lambert Creek on two hills bordering a small creek, tributary to Lambert Creek, in the E$\frac{1}{2}$ secs. 6 and 7, T. 37 N., R. 34 E. The limestone west of this tributary was not examined. Limestone crops out north of Lambert Creek in the NW$\frac{1}{4}$ sec. 5, T. 37 N., R. 34 E., and in sec. 32, T. 38 N., R. 34 E. Outcrops both to the north and south of Lambert Creek were traversed to their northern and southern extremities, to altitudes approximately 1,000 feet above the terminus of the Lambert Creek road. The terminus of this road is 6 miles east of State Highway 4A and 7$\frac{1}{2}$ miles from the Great Northern Railway at Karamin.

History.—The Lambert Creek area is part of a mining district recorded (1906) in the office of the county clerk as the Belcher mining district. The area was visited by Howland Bancroft in 1910; the following remarks are taken from his report (Bancroft, 1914, p. 166-179) of that investigation. At the time of Bancroft's visit only one mine, the Copper Key, of the three mining properties (Oversight, Copper Key, and Belcher) was active. The deposits (iron, copper, gold) are found on the limestone ridge south of the terminus of the Lambert Creek road. All are located "within a few miles of one another and occupy a belt about a mile wide extending north and south through the center of the district" (Bancroft, 1914, p. 169). The positions of two of the principal portals of the Belcher mine are shown on figure 50. In his discussion of the ore deposits of the district, Bancroft (1914, p. 170) reports:

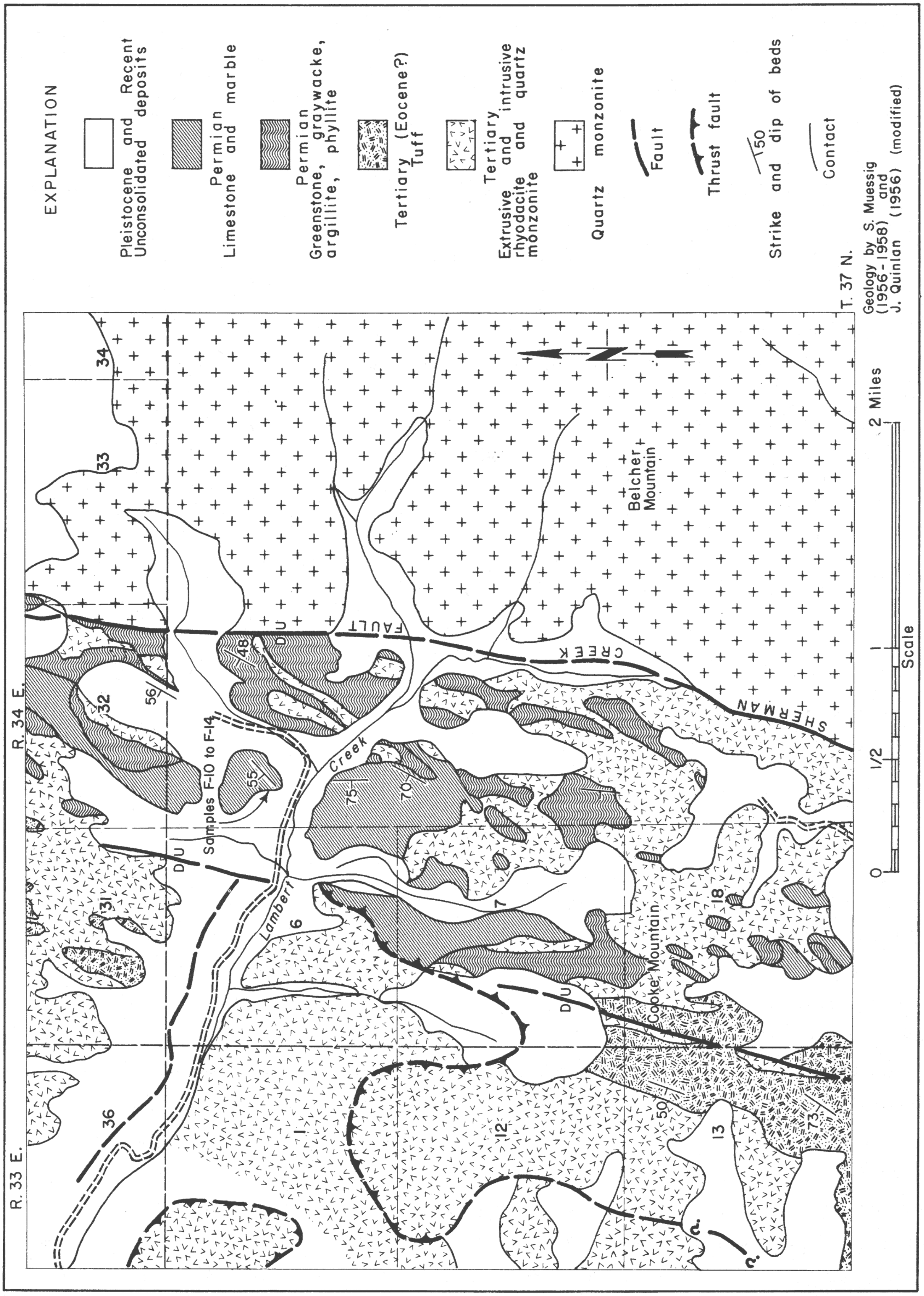

FIGURE 49.—Geologic map of Republic Northeast district. Geology from U.S. Geological Survey open-file geologic map of Republic and part of Wauconda quadrangles, by S. J. Muessig and J. J. Quinlan, 1959.

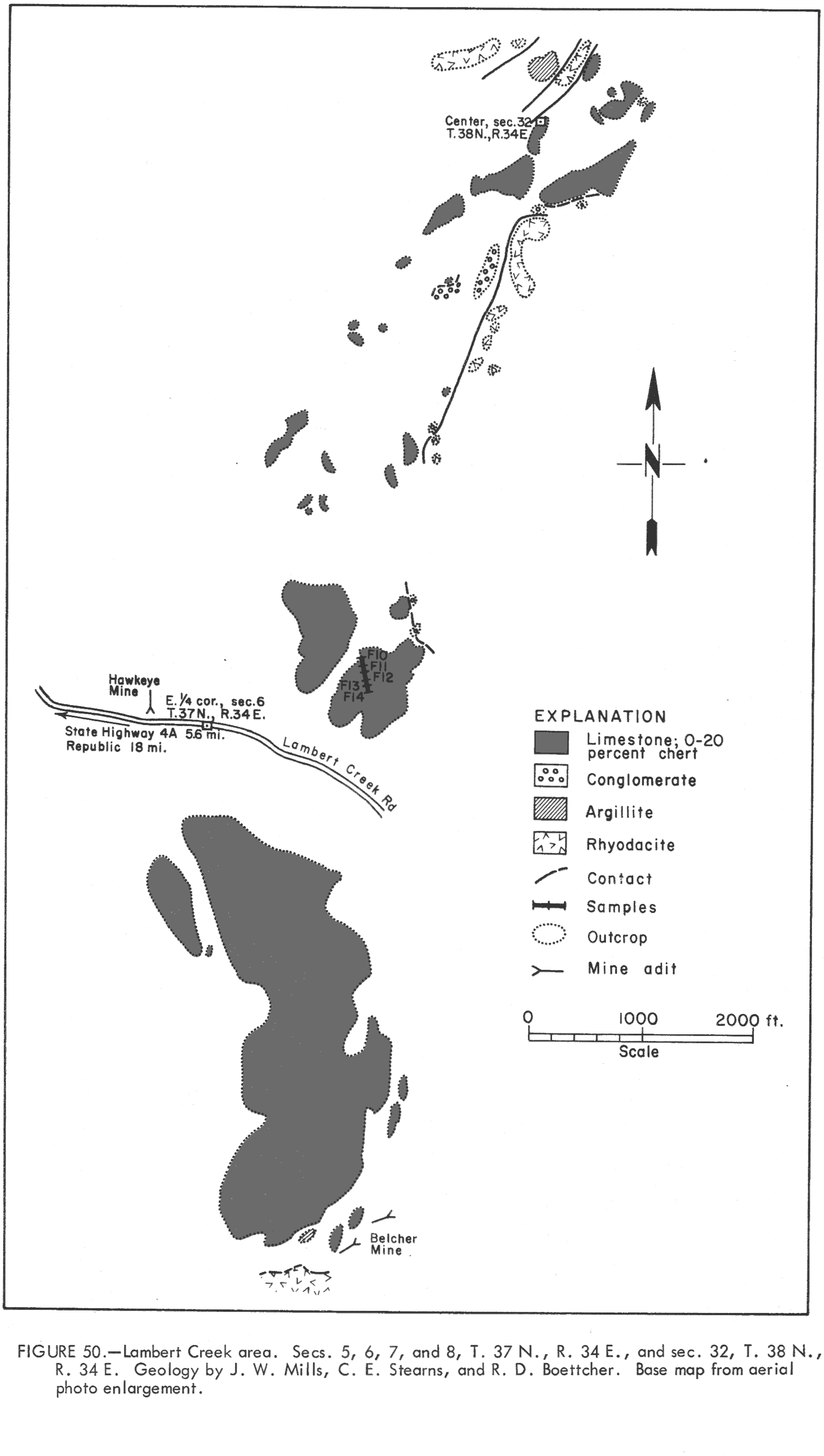

FIGURE 50.—Lambert Creek area. Secs. 5, 6, 7, and 8, T. 37 N., R. 34 E., and sec. 32, T. 38 N., R. 34 E. Geology by J. W. Mills, C. E. Stearns, and R. D. Boettcher. Base map from aerial photo enlargement.

> The ore occurs as irregular and more or less complete replacements of the limestone and dolomite strata in the vicinity of intrusive masses of monzonite porphyry. The replaced strata range from a few feet to 25 feet or more in thickness. Their extent along the strike and dip of the ore bodies has in few places been determined, but these dimensions have been proved to exceed 100 feet and are probably considerably greater. The ore is chiefly in the form of magnetite and pyrite, with considerable quantities of pyrrhotite and a little chalcopyrite. It is reported to carry a little gold, and the gossans contain 80 cents' worth of gold or more to the ton. These ores at present are economically important as a flux for smelting other ores, the chief consumers in the past having been the Granby and Trail smelters, in British Columbia.

In the early 1900's the ore was transported from the Belcher mine to Lambert Creek by a gravity tramway, some of the timbers of which are still standing. From there it was transferred to the narrow-gauge Belcher Mountain Railroad and transported down Lambert Creek to the Great Northern Railway.

Geology.—In his discussion of the geology of the district, Bancroft (1914, p. 168) reports that "a sedimentary series of limestone, dolomite, argillite, and limestone shale, more or less metamorphosed, constitutes the major part of the geologic section. . . . The rocks have a general north-south strike and dip to the west or east at angles ranging from 15° to 60°. . . . The thickness of these sedimentary rocks in the Belcher district is several thousand feet, and that of the individual formations from a few feet to 100 feet or more. Blue and white limestones predominate, although limestones of various other colors are present. They are in general of fine-grained crystalline texture, but some are coarsely crystalline and highly marmarized. They contain various amounts of magnesia, and some of the strata are dolomites." Bancroft (1914, p. 169) records partial analyses of three specimens of carbonate rock taken "from different parts of Cooke Mountain, near top" as (1) 31.41 percent CaO, 20.00 percent MgO; (2) 41.22 percent CaO, 11.15 percent MgO; and (3) 31.96 percent CaO and 17.60 percent MgO.

During the present study, the distribution of the rock types was plotted on aerial photo enlargements and reproduced as figure 50. Argillite, limestone-pebble conglomerate, and limestone of Permian age are well exposed to the north and south of the Lambert Creek road. These rocks are intruded by rhyodacite of Tertiary age.

Quality and quantity of limestone.—All the limestone is light gray to light brownish-gray and very fine grained. It contains gray chert as nodules, stringers, and highly irregular masses from an inch to 2 feet in diameter and 10 feet long. Because of their resistance to weathering, the chert nodules and masses stand in relief on the weathered limestone surfaces. The chert content ranges from 1 to 20 percent over large areas; the average is probably close to 5 percent. Sampling was confined to an outcrop, in the SE$\frac{1}{4}$NW$\frac{1}{4}$ sec. 5, T. 37 N., R. 34 E., where the chert content appeared to be considerably less than average. Five contiguous samples (F-10 to F-14) were taken in a direction S. 15° E., for a combined length of 250 feet, along the top of a limestone cliff approximately 1,000 feet north of the end of the Lambert Creek road (fig. 50). County records show that the samples were taken on property owned by the Curlew Cattle Company, of Republic. 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)
F-10	50	95.05	0.50	41.52	53.40	0.24	4.00	0.52	0.016				
F-11	50	91.72	0.61	39.98	51.53	0.29	7.08	0.75	0.012				
F-12	50	97.76	0.63	43.42	54.92	0.30	0.59	0.45	0.019	165	590	-30	27
F-13	50	98.35	0.59	43.42	55.25	0.28	0.50	0.29	0.015				
F-14	50	96.46	0.71	42.26	54.19	0.34	2.34	0.30	0.016				

The average content of CaO and SiO_2 is 53.86 percent and 2.90 percent, respectively, over the total sample length of 250 feet. The rock qualifies as a high-calcium limestone, but the silica content is too high for most uses. The chert content generally is much higher than this and is so widespread that it is not likely that any quarrying operation started in the high-grade material could be expected to continue in high-grade for any great distance. Although there are many millions of tons of siliceous, low-magnesia limestone in the area, it is quite unsuitable for most uses, with the possible exception of use as a filler or for portland cement manufacture. The remoteness of the area is a serious handicap to any mining operation.

Republic North District

The Republic North district lies 7 miles northeast of Republic. It extends for 2 miles east of Curlew Lake, in secs. 3, 4, 5, 8, 9, 10, 15, 16, 17, 20, 21, and 22, T. 37 N., R. 33 E. State Highway 4A and the Great Northern Railway run the length of the district (fig. 51).

Bedrock exposures are limited to that part of the district lying to the east of Curlew Lake. They consist of argillite, greenstone, and graywacke, all of Permian age, intruded by rhyodacite of Tertiary age (Muessig and Quinlan, 1959). The strike of the bedding in the older rocks ranges from N. 10° E. to N. 35° E.; dips are to the west, generally at angles greater than 60°, although some dips are as low as 30°. Five high-angle sub-parallel faults divide the district into 6 north-trending blocks. These faults, like the other high-angle faults within the graben, were initiated in pre-Eocene time, but there has been some movement on them in post-Eocene time (Muessig, oral communication). A small klippe of andesites, in sec. 3, T. 37 N., R. 33 E., is the erosional remnant of rocks that formerly composed an extensive thrust plate above the pre-Permian rocks.

Curlew Lake Area
Secs. 4 and 9, T. 37 N., R. 33 E.

Location and accessibility.—The Curlew Lake area is that part of the Republic North district adjacent to State Highway 4A, in secs. 4 and 9, T. 37 N., R. 33 E., 1 mile east of Curlew Lake. The Great Northern Railway follows the west shore of Curlew Lake.

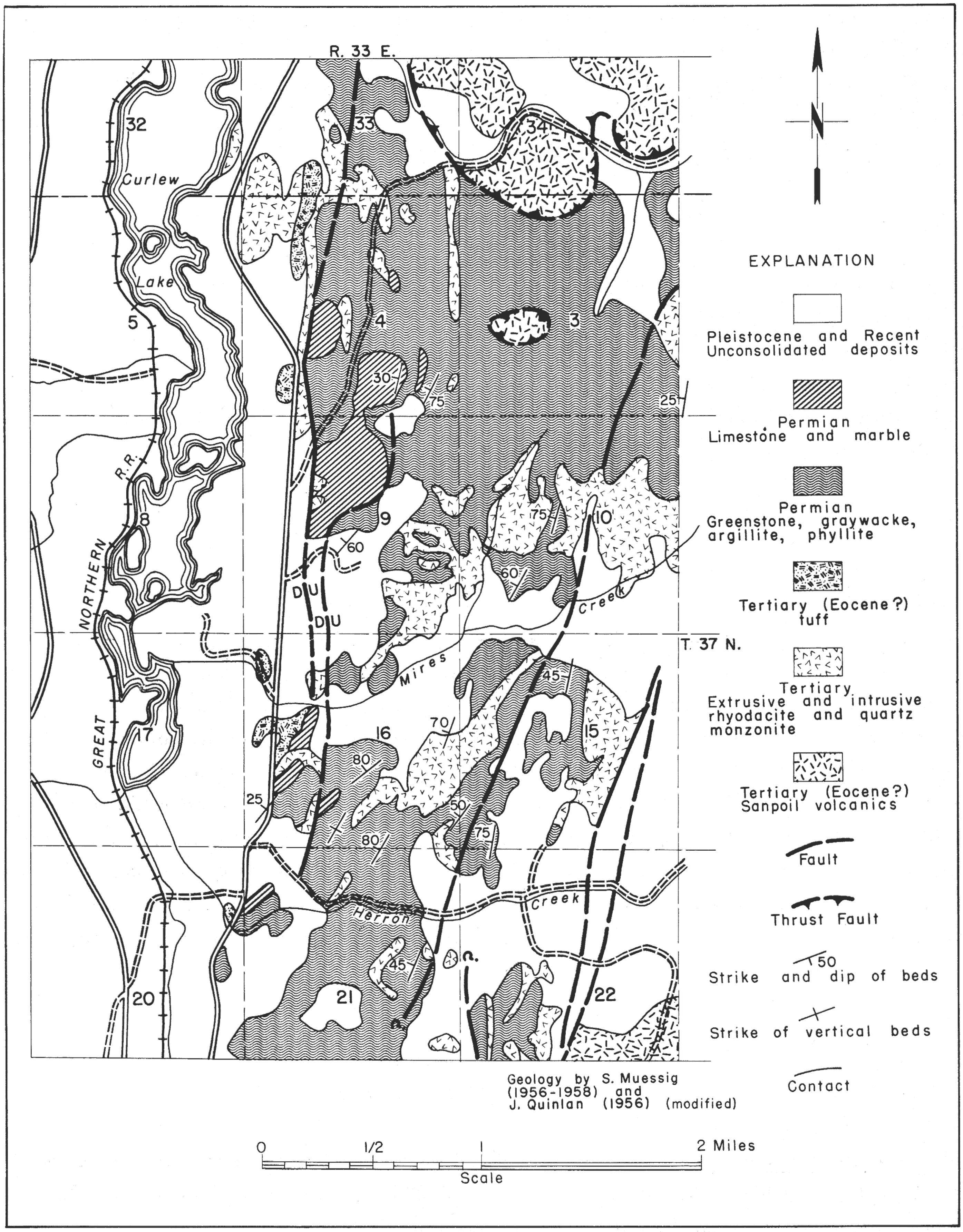

FIGURE 51.—Geologic map of Republic North district. Geology modified from U.S. Geological Survey open-file geologic map of Republic and part of Wauconda quadrangles, by S. J. Muessig and J. J. Quinlan, 1959.

Geology and quality of limestone.—Carbonate rocks and associated argillite and greenstone of Permian age occupy a fault block approximately 2,000 feet wide (fig. 52). These rocks are intruded by small irregular bodies of rhyodacite. The carbonate rocks are interbedded gray fine-grained limestone (70 percent), gray fine-grained dolomitic limestone (20 percent), and light-gray yellow-weathering dolomite (5 percent). Each of these rocks contains from 2 to 20 percent of chalcedonic silica or chert in the form of blebs, and highly irregular stringers or "beds" up to 1 foot thick. The low-magnesia and high-magnesia carbonate rocks are so closely interbedded and intimately related in space that no mining operation could be expected to treat one without the other. No samples were taken, because the rock is obviously not a high-calcium limestone and it contains too much magnesia for the manufacture of portland cement.

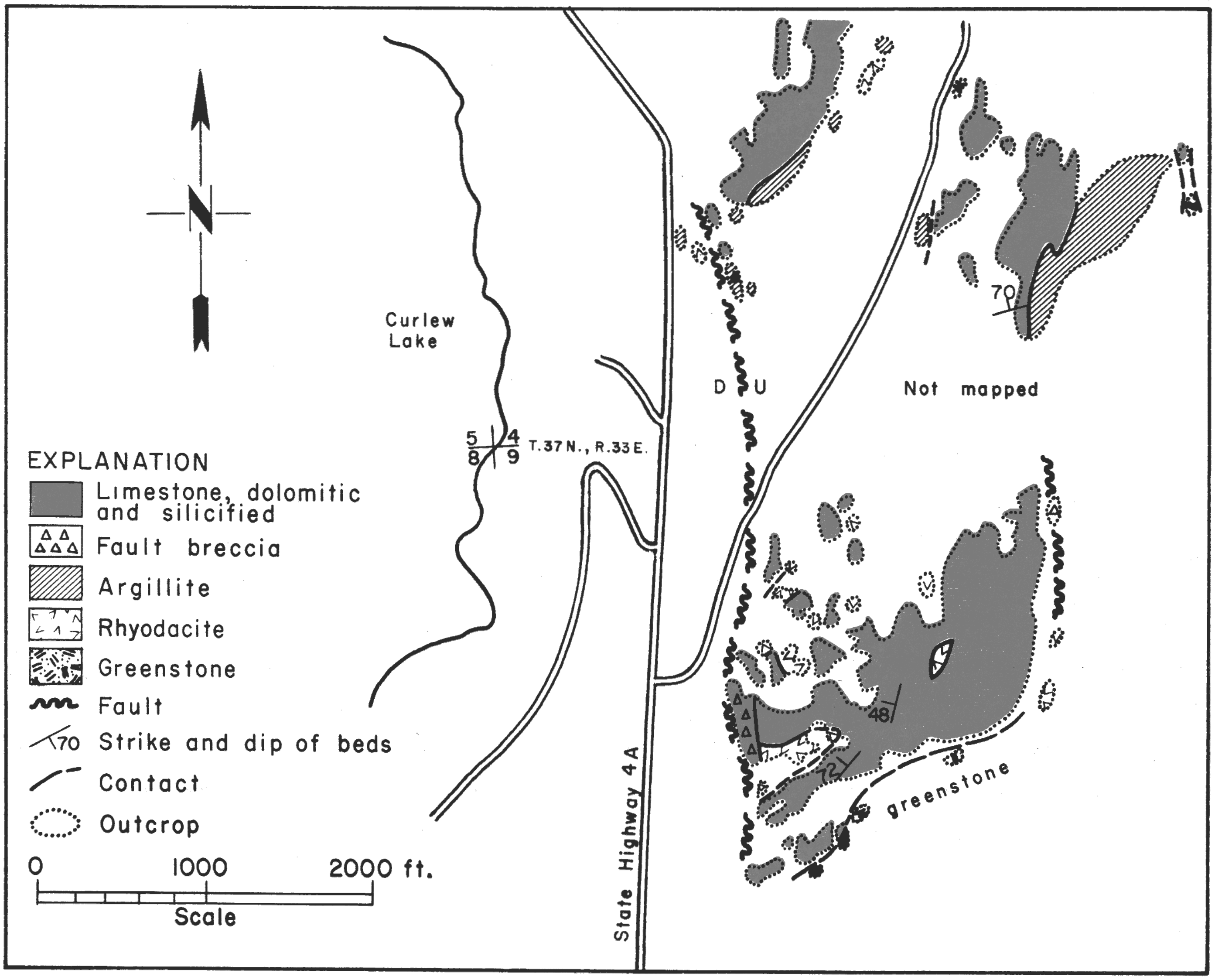

FIGURE 52.—Curlew Lake area. Secs. 4 and 9, T. 37 N., R. 33 E. Geology by J. W. Mills, C. E. Stearns, and R. D. Boettcher. Base map from aerial photo enlargement.

Mires Creek Area

Three small areas of outcrop of limestone south of Mires Creek, in the W½ sec. 16, T. 37 N., R. 33 E., are shown in figure 51. Examination of these outcrops showed them to be composed of brown-weathering dolomite (60 percent) and gray-weathering dolomitic limestone (40 percent) containing interbeds of purer limestone up to 2 feet thick. The rock is of no value for most uses.

Herron Creek Area

A small outcrop of dolomite (70 percent) and dolomitic limestone (30 percent) occurs at the east side of State Highway 4A, on the north bank of Herron Creek, in the NW¼ sec. 21, T. 37 N., R. 33 E. The rock is similar to the impure limestone and dolomite of the Mires Creek area; it is of no value for most uses.

Copper Lakes District

The Copper Lakes district comprises secs. 3, 4, 5, 8, 9, 10, 15, 16, 17, 20, 21, and 22, T. 36 N., R. 32 E. It is crossed from southwest to northeast by the Swan Lake road, which joins State Highway 4 in the northeast corner of the district 2.4 miles west of Republic.

The district is divided into a west half and an east half by the major high-angle Bacon Creek fault that forms the western boundary of the regional graben (fig. 53). The rocks to the west of the fault, outside the graben, are granodiorite of Cretaceous age intruded by dikes of rhyodacite of Tertiary age. The rocks extending for 1 mile to the east of the Bacon Creek fault in the south half of the district are schists and quartzite of late Paleozoic (pre-Permian) age intruded by granodiorite and rhyodacite. The rocks extending for 1 mile east of the Bacon Creek fault in the north half of the district are limestone, argillites, and greenstones, all of Permian age. Strikes of bedding in these pre-Permian and Permian rocks are to the northwest; dips are moderate toward the northeast. The rocks in the eastern part of the district, including andesites, rhyodacite, and tuffs of Tertiary age, are separated from the central belt of late Paleozoic rocks by a high-angle fault striking approximately parallel to the Bacon Creek fault. Limestone is found in the northern part of the district (Doblasue property), in the central part of the district (Union Lime quarry), and in the southeastern corner of the district. Only the first two of these were studied.

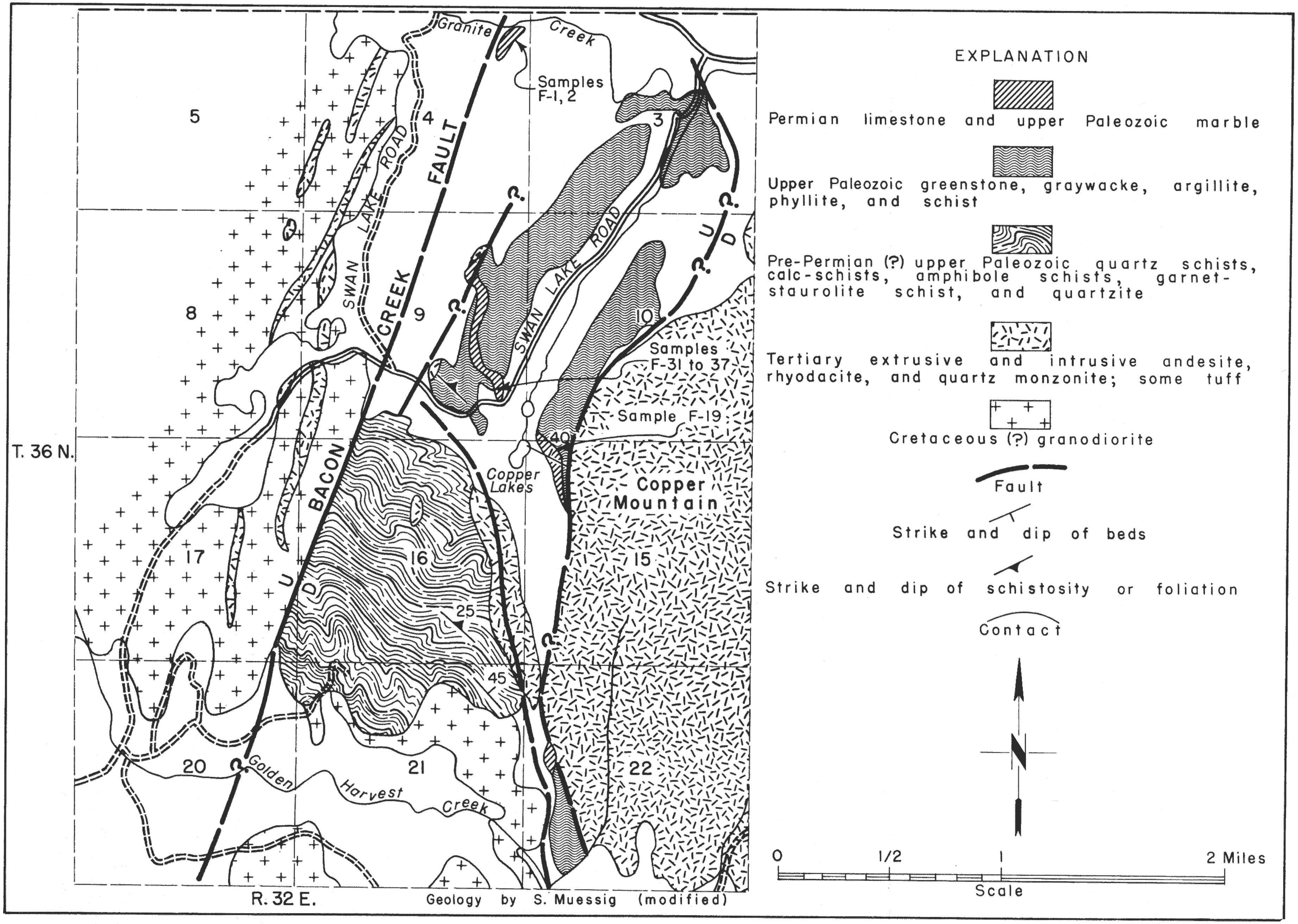

FIGURE 53.—Geologic map of Copper Lakes district. Geology modified from U.S. Geological Survey open-file geologic map of Republic and part of Wauconda quadrangles, by S. J. Muessig and J. J. Quinlan, 1959.

Doblasue Property

NE¼NE¼ sec. 4, T. 36 N., R. 32 E.

Location and accessibility.—The Doblasue property lies 3 miles west of Republic and approximately 1,000 feet south of State Highway 4, in the NE¼NE¼ sec. 4, T. 36 N., R. 32 E. It can be reached by way of an old graveled road that branches to the southeast from State Highway 4 approximately 5 miles west of Republic.

Geology and quality of limestone.—Limestone makes up several small outcrops in a forested area approximately 400 feet long and 125 feet wide. An old quarry 60 feet long, 50 feet wide, and 20 feet deep at its deepest part was found at the north end of the outcrop area. The remains of an old limekiln stand approximately 100 feet north of the quarry. The limestone outcrops are part of the area of limestone of Permian age mapped by Muessig and Quinlan (1959) adjacent to the Bacon Creek fault (fig. 53). Two contiguous samples were taken over a length of 50 feet each in a due east direction across an outcrop 20 feet south of the quarry. The limestone is gray, very fine grained, and massive. 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
F-1	50	92.99	0.54	41.12	52.24	0.26	5.88	0.48	0.012
F-2	50	93.54	0.46	41.27	52.55	0.22	5.63	0.25	0.032

The analyses of F-1 and F-2 show that the limestone is too siliceous to be classified as a high-calcium limestone. The total amount of limestone that is known with certainty is only a few thousand tons. It is unlikely that this limestone occurrence is of any value for most uses.

Union Lime Quarry Area

SE¼ sec. 9 and NW¼NW¼ sec. 15, T. 36 N., R. 32 E.

Location and accessibility.—The abandoned quarry and limekiln of the Union Lime Company is adjacent to the Swan Lake road appoximately a quarter of a mile northwest of Copper Lakes. The property can be reached by driving from Republic west on State Highway 4 a distance of 2.4 miles to the Swan Lake road, thence south 2.2 miles to the quarry in the SE¼ sec. 9, T. 36 N., R. 32 E. Another limestone outcrop lies a quarter of a mile southeast of here in the NW¼NW¼ sec. 15, T. 36 N., R. 32 E., on the east side of Copper Lakes.

Geology.—The limestone in the quarry and the limestone east of Copper Lakes have been mapped by Muessig and Quinlan (1959) as part of the series of limestones, argillites, graywackes, and greenstones, of Permian age, that lie in the graben east of the Bacon Creek fault (fig. 53).

The limestone quarried by the Union Lime Company is exposed over a length of 700 feet in the quarry and for an additional 500 feet to the north and south of the quarry. It ranges in thickness from 50 to 70 feet, approximately half of which is exposed in the quarry walls (fig. 54). The strike of the limestone ranges from N. 60° W. to N. 80° W.; dips are generally toward the northeast, into the ridge, at angles ranging from 24° to 37°. Greenstone is exposed in the quarry floor, which suggests that the limestone is underlain by greenstone. Argillite overlying the limestone is exposed in the southern part of the quarry, where its thickness is at least 30 feet. The presence of argillite rubble in the soil over much of the hillside north of the quarry is interpreted as indicating that the thickness of argillite lying above the limestone is several hundreds of feet. Limestone cropping out from 50 feet to 100 feet north of the southeast end of the quarry is probably the quarry bed repeated by faulting (fig. 54). Limestone cropping out south of the quarry may be part of a second bed underlying the greenstone.

The limestone east of Copper Lakes forms 3 outcrops, 2 of which are very siliceous. The largest of the 3 outcrops lies approximately 500 feet east of Copper Lakes; it is 400 feet long, 70 feet wide, and 50 feet high. Small outcrops of greenstone are found on all sides of the large outcrop of limestone, showing that the limestone is a podlike mass within the more extensive greenstones. Bedding strikes N. 77° W. and dips 30° NE. The true thickness of the limestone in the large outcrop is 80 feet. All outcrops are within the Colville National Forest.

Quality and quantity of limestone.—The limestone of the Union Lime quarry is gray, very fine grained, and apparently quite free of any impurities. Most of it is laced with extremely narrow fractures healed by calcite. In the northwestern part of the quarry the limestone is highly fractured and brecciated; this is probably due to the movement on the Bacon Creek fault to the west of the quarry. Six samples (F-32 to F-37) were taken across part or all of the limestone (fig. 54). Another sample (F-31) was begun on the quarry face, but was discontinued after sampling for 100 feet when it was recognized that the sample was being taken parallel to the strike of the limestone. The part (100 feet) of the sample that had already been cut was kept and analyzed. It is representative of only a few feet of thickness of the limestone and hence furnishes little information. The analyses of these samples are as follows:

Sample no.	Length (feet)	Equivalent 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)
F-31	100	3	97.94	0.71	42.58	55.02	0.34	1.41	0.42	0.006				
F-32	40	28	98.49	0.54	42.41	55.33	0.26	1.15	0.42	0.008				
F-33	35	20	99.09	0.63	42.76	55.67	0.30	0.72	0.40	0.004	160	750	-30	26
F-34	50	38	89.87	0.50	38.60	50.49	0.24	9.51	1.17	0.015				
F-35	50	42	98.84	0.61	42.61	55.53	0.29	0.57	0.23	0.008				
F-36	40	40	98.45	0.52	41.98	55.31	0.25	1.86	0.27	0.013				
F-37	70	50	89.12	0.59	38.56	50.07	0.28	10.15	0.96	0.017				

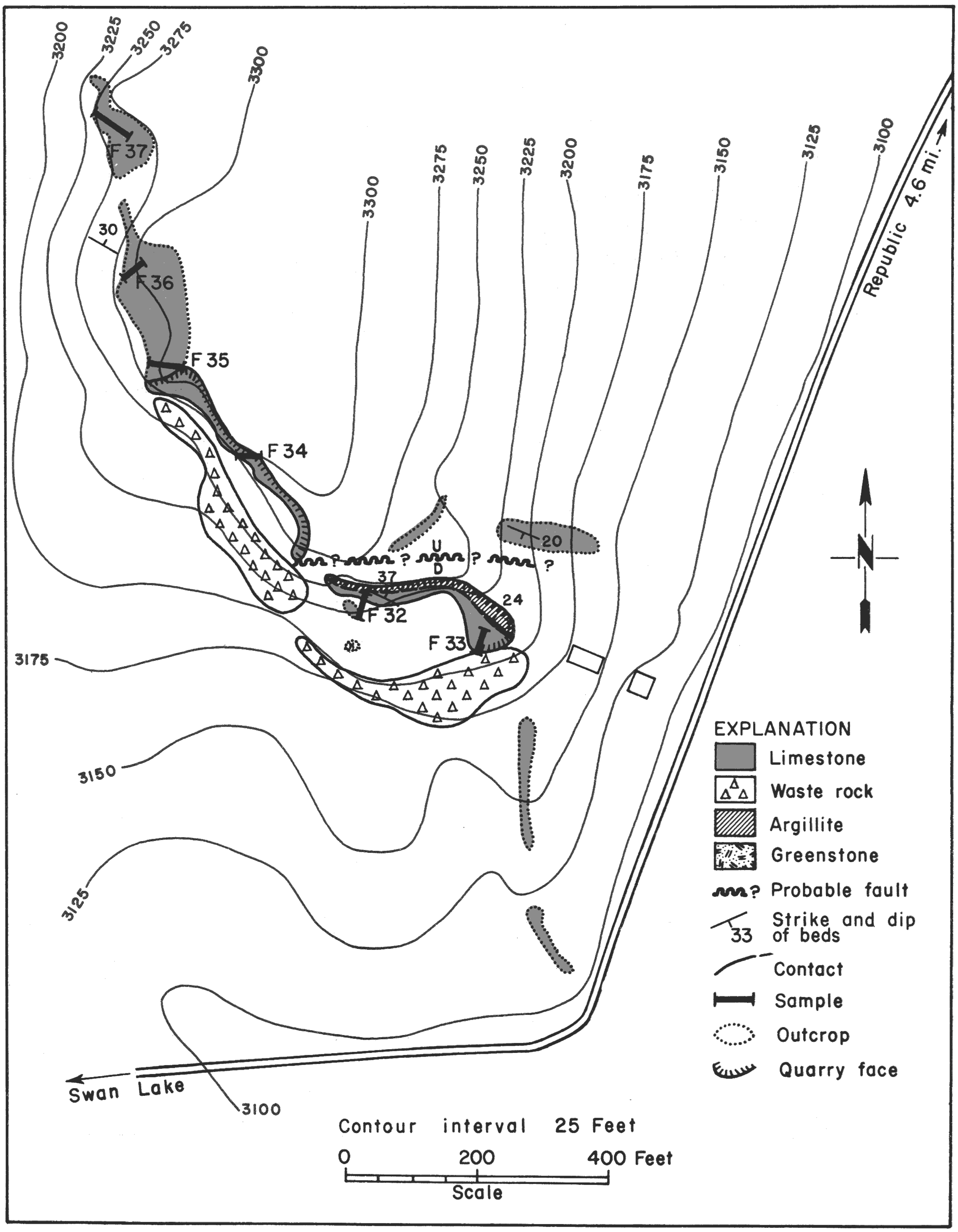

FIGURE 54.—Union lime quarry area. Sec. 9, T. 36 N., R. 32 E. Geology by C. E. Stearns and R. D. Boettcher. Base and topography by plane table and alidade survey.

The earliest reference to this limestone occurrence is one by Landes (1906, p. 381) in which he states:

> A few miles west of Republic there is a large outcrop of a bluish limestone which is very compact and hard. A limekiln is in operation here and a high grade of quicklime is manufactured.

He reports further, on the same page, that this limestone contains 98.6 percent $CaCO_3$, a trace of $MgCO_3$, 1.1 percent SiO_2, and a trace of iron and aluminum oxides.

The average content of CaO in samples F-32 through F-36 is 54.47 percent. This corresponds to a $CaCO_3$ content of 96.96 percent. The rock is classified as a high-calcium limestone. The MgO content is very low, but SiO_2 is present in amounts that would be deleterious for most high-calcium limestone uses. Approximately 600,000 tons of high-calcium limestone is available below the quarry floor and above the level of the Swan Lake road. In making this estimate it is assumed that the limestone maintains its length (900) feet and thickness (50 feet) with depth. In spite of the high CaO content and easy accessibility of the limestone, it is not likely that the deposit can be worked profitably because (1) of the large amount of rock overburden that would have to be removed, (2) of the small tonnage of limestone, and (3) of the deleterious silica content.

One sample, F-19, was taken for 80 feet across the bedding of the limestone in the outcrop east of Copper Lakes. This limestone is similar to the limestone exposed in the Union Lime quarry. The analysis of this sample is as follows:

Sample no.	Length (feet)	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
F-19	80	97.49	0.40	42.84	54.77	0.19	1.46	0.39	0.012

The analysis shows the limestone to be almost identical chemically to the limestone of the Union Lime quarry. The amount of limestone of this quality that is readily available above the lowest point on the outcrop is approximately 100,000 tons.

Empire Creek District

Empire Creek is approximately 4 miles south of Curlew. Scattered low outcrops of limestone of Permian age are found on the lower slopes of Franson Mountain, north of Empire Creek in the SW¼ sec. 33 and the W½ sec. 34, T. 39 N., R. 33 E. Associated with the limestone are greenstone, argillite, and graywacke, of Permian age. To the north, east, and west of these outcrops the exposed bedrock is glassy basalt and associated pyroclastic rocks of Tertiary age.

The limestone is gray to dark gray, fine grained, and very siliceous. Black chert, in nodules and irregular masses, constitutes approximately 25 percent of the exposed limestone. The rock is much too siliceous to be of any value for most uses.

Iron Mountain District

Iron Mountain is 9 miles southeast of Republic in the W½ sec. 5, sec. 6, and the N½ sec. 7, T. 35 N., R. 34 E., and the S½ sec 31, T. 36 N., R. 34 E. According to Muessig and Quinlan (1959), the bulk of the mountain is composed of greenstone, argillite, phyllite, and limestone, of Permian age. They show a limestone bed, approximately 100 feet thick, extending from the NW¼ sec. 7, T. 35 N., R.34E., to the SE¼ sec. 31, T. 36 N., R. 34 E. This bed was not examined by the writer. However, limestone in the NW¼NW¼ sec. 5, T. 36 N., R. 34 E. was examined. This outcrop can be reached from Republic by driving 8 miles east on State Highway 3P to the South Fork O'Brien Creek road, thence southeast 5.5 miles to the foot of Iron Mountain in the NW¼ sec. 5 in the Colville National Forest. The limestone is found cropping out in small cliffs at an altitude of 4,200 feet above sea level on the east side of the mountain. The limestone is cream white to light gray, fine grained, and slightly argillaceous. Bedding strikes N. 16° E. and dips 65° W. Sample F-38 was taken across the full width of the outcrop for a length of 35 feet. The true thickness of the limestone is 35 feet. Bedrock upslope from the outcrop, although not exposed, is probably argillite, as there are numerous fragments of argillite in the soil. There are no outcrops between the limestone cliffs and the foot of the mountain. The analysis of F-38 is as follows:

Sample no.	Length (feet)	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
F-38	35	93.45	3.72	42.25	52.50	1.78	2.46	0.96	0.021

The rock does not contain quite enough CaO to be classed as a high-calcium limestone. It would serve for the manufacture of portland cement. Owing to the forest cover and alluvium, the volume of limestone of this quality is impossible to determine, but it is probably only a few thousand tons.

Other Occurrences of Limestone of Permian Age in Northwestern Ferry County

Limestone of Permian age is present in eight areas other than those described, according to Muessig and Quinlan (1959) and Calkins, Parker, and Disbrow (1959). These were not examined during this study because of their small extent and their inaccessibility. They are at the following locations:

(1) W½ sec. 1, T. 40 N., R. 33 E.
(2) NW¼ sec. 3, and NE¼ sec. 4, T. 39 N., R. 33 E.
(3) NE¼ sec. 9, T. 38 N., R. 34 E.
(4) NE¼ sec. 28, T. 38 N., R. 34 E.
(5) SE¼ sec. 7, T. 36 N., R. 34 E.
(6) SW¼ sec. 29, T. 36 N., R. 34 E.
(7) NW¼ sec. 19, T. 35 N., R. 34 E.
(8) NE¼NE¼ sec. 20 and W½ sec. 21, T. 35 N., R. 32 E.

Curlew Northwest District

A belt of limestone marble extends almost continuously from the west side of sec. 35, T. 40 N., R. 32 E., to the east side of sec. 5, T. 39 N., R. 33 E. The western end of this belt can be reached easily by driving 9 miles on the Toroda road from Curlew up the valley of the Kettle River.

According to R. L. Parker, of the U.S. Geological Suvery (1960, written communication), the limestone marble belt is composed of a series of marble beds (calc-silicate rocks) that occur between gneiss and quartzite units in the high-grade metamorphic rocks on the north side of the Kettle River valley (fig. 55). Parker also states that the marble bodies were produced from pre-Permian limestones; they were metamorphosed probably in Cretaceous time. Strikes of foliation in the metamorphic rocks range from due east to a few degrees north of east; dips are low toward the north.

The writer examined the marble belt in sec. 35, T. 40 N., R. 32 E., where the rock unit containing the marble is approximately 50 feet thick. It consists of foliated layers of gneiss, amphibolite, and limestone marble. The limestone marble is in beds, few of which are more than a foot thick, composing probably less than 30 percent of the entire unit. The limestone is white, coarsely crystalline, and spotted with silicate minerals produced during the metamorphism of the limestone. The part of the marble belt exposed in sec. 35 is certainly far too impure to be of any value. Further, the marble beds are too thin to be mined individually.

North Fork St. Peter Creek District

Calkins, Parker, and Disbrow (1959) have mapped a belt of marble from 1,500 to 2,000 feet wide on the south side of the North Fork of St. Peter Creek, extending from the S$\frac{1}{2}$ sec. 16 to the SW$\frac{1}{4}$ sec. 22, T. 38 N., R. 34 E. The district is reached from Malo, on State Highway 4A and the Great Northern Railway, by driving up the North Fork St. Peter Creek road approximately 5$\frac{1}{2}$ miles. From near the creek bottom the area underlain by marble extends toward the southeast up the flank of Mount Leona. The marble and its associated schist and quartzite are of pre-Permian age (Parker, R. L., 1960, written communication).

During this study, the marble belt in the S$\frac{1}{2}$ sec. 16, T. 38 N., R. 34 E., was examined by Stearns and Boettcher. They report that most of the marble in this area is dolomite marble, although there are a few scattered small outcrops of limestone marble. No samples were taken.

Wauconda Southwest District

The Wauconda Southwest district includes secs. 31 to 34, T. 36 N., R. 32 E., and secs. 3 to 10, 15 to 22, and the N$\frac{1}{2}$ secs. 27 to 30, T. 35 N., R. 32 E. (fig. 56). The west boundary of the district is the Ferry-Okanogan County line. Access to the district can be gained either by driving up the

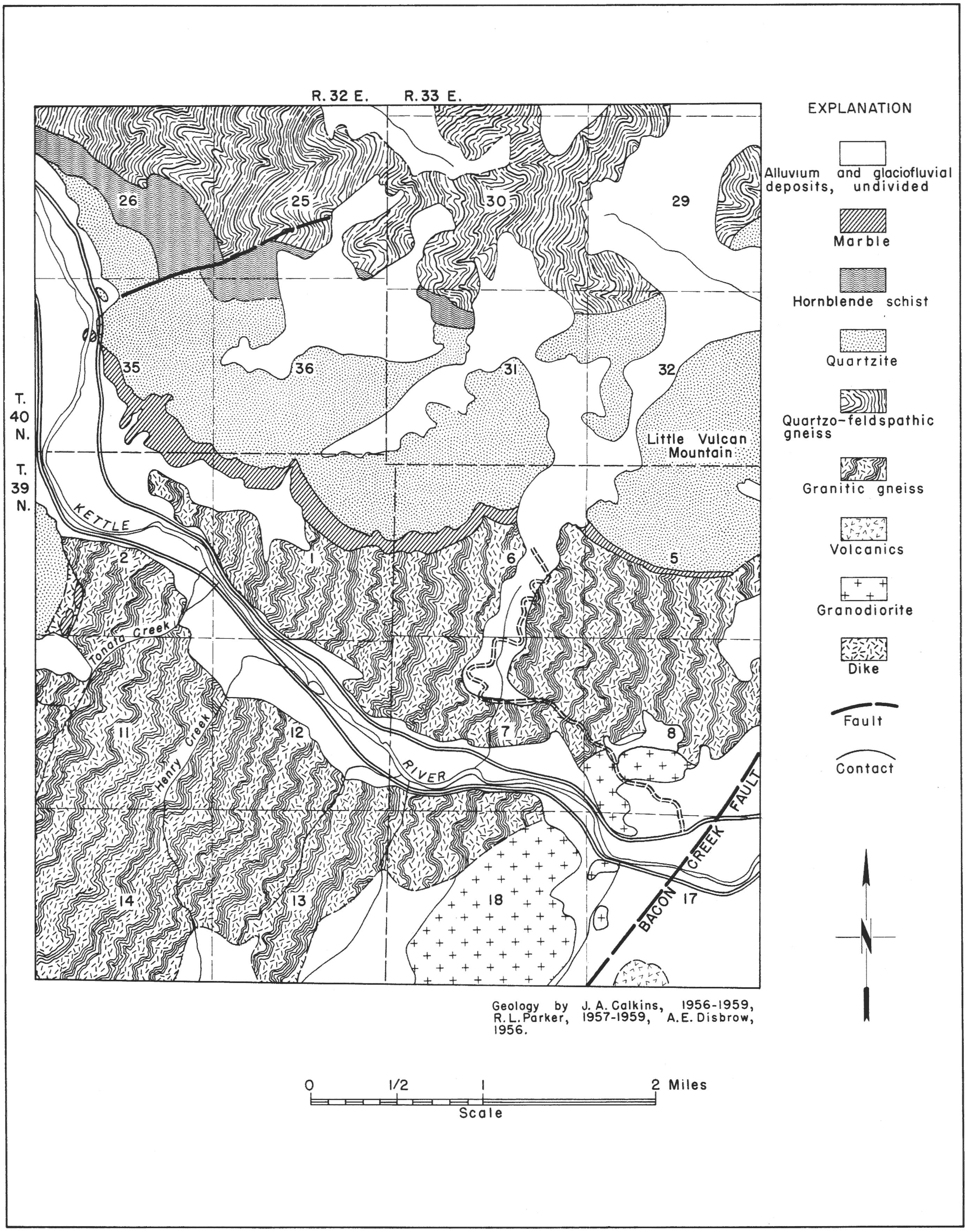

FIGURE 55.—Geologic map of Curlew Northwest district. Geology from U.S. Geological Survey open-file geologic map of Curlew quadrangle, by J. A. Calkins, R. L. Parker, and A. E. Disbrow, 1959.

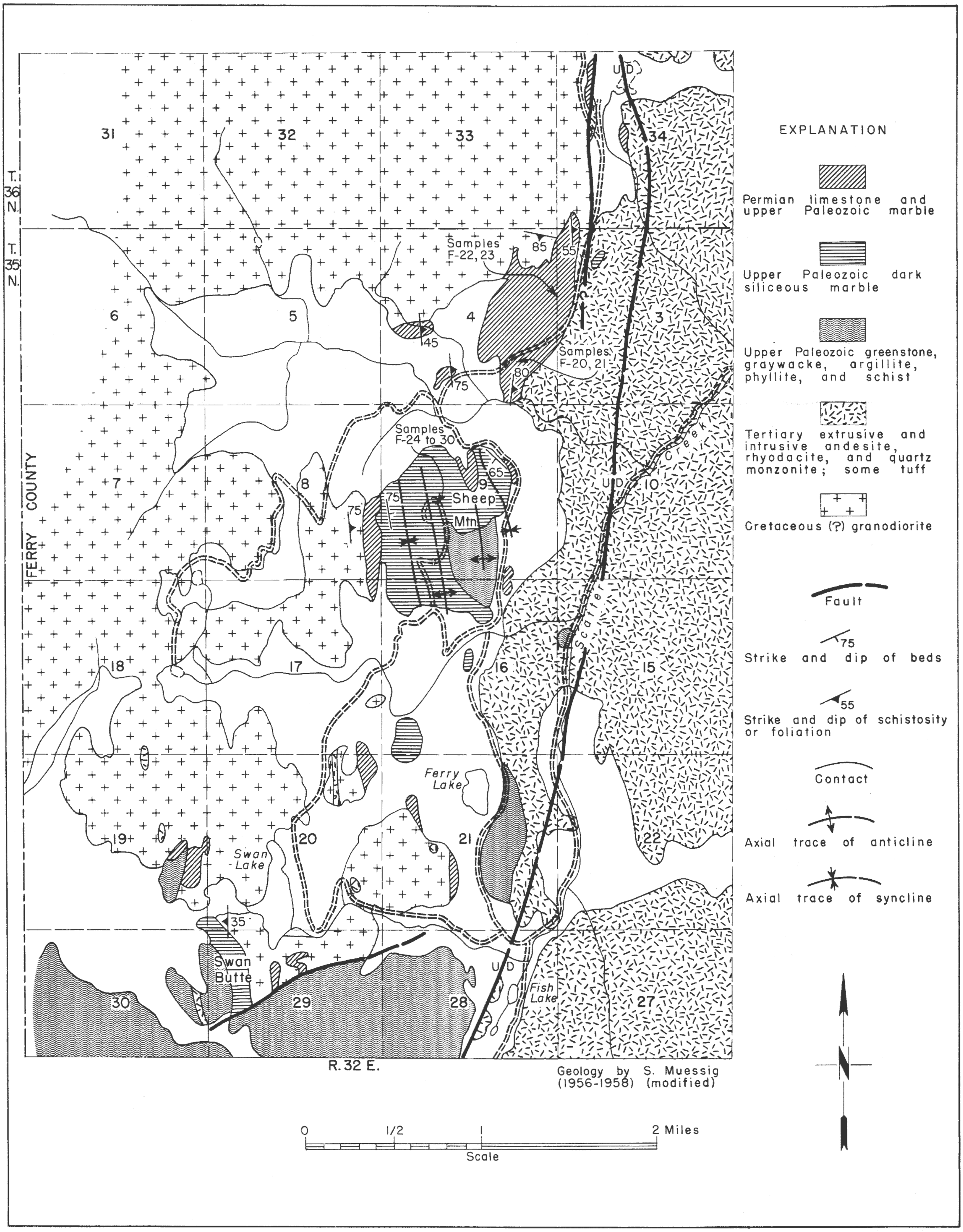

FIGURE 56.—Geologic map of Wauconda Southwest district. Geology modified from U.S. Geological Survey open-file geologic map of the Republic and part of Wauconda quadrangles, by S. J. Muessig and J. J. Quinlan, 1959.

Scatter Creek road from its junction with State Highway 4, approximately 7 miles south of Republic, or by driving south on the Swan Lake road from its junction with State Highway 4, approximately 2.4 miles west of Republic. The district is within the Colville National Forest.

The geology of the district is shown on figure 56, modified from Muessig and Quinlan (1959). Briefly, the western half and northern quarter of the district are underlain principally by granodiorite of Cretaceous age; the central part of the district is underlain by closely folded metamorphic rocks, including schist, phyllite, quartzite, marble, and dark siliceous marble, of pre-Permian age, into which the granodiorite is intrusive; the eastern part of the district is underlain principally by extrusive and intrusive rhyodacite of Tertiary age. This eastern part is within the regional graben, whereas the central and western parts are outside the graben.

During this study, parts of two of the larger areas underlain by marble were examined. One of these, referred to as the Swan Lake road area, is in the W½ sec. 4, T. 35 N., R. 32 E.; the other is on Sheep Mountain in sec. 9, T. 35 N., R. 32 E.

Swan Lake Road Area
W½ sec. 4, T. 35 N., R. 32 E.

Location, accessibility, and ownership.—The Swan Lake road area is in the W½ sec. 4 and the most westerly part of sec. 3, T. 35 N., R. 32 E. The Swan Lake road crosses the southern part of the area. County records show that the areas sampled during this study are on property owned by the Columbia Lumber Company of Kettle Falls.

Geology.—According to Muessig and Quinlan (1959), the area underlain by marble is approximately 1 mile long and ½ mile wide (fig. 56). To the north and west the marble is in contact with granodiorite, and to the east and south with rhyodacite. Low north-trending ridges were examined for 1,000 feet to the south and 1,500 feet to the north of the Swan Lake road. They are composed of white, light-gray, and pale yellow, coarse-grained limestone. Foliation in the limestone strikes due north and dips steeply west in some places and steeply east in others.

Quality and quantity of limestone.—Two contiguous samples (F-20 and F-21) were taken approximately 150 feet south of Swan Lake road, in the SE¼SE¼ sec. 4, T. 35 N., R.32 E., spanning the entire width of a low north-trending limestone ridge. The samples were taken in a direction N. 45° W. for a combined length of 105 feet. The limestone is white, with some gray and pale yellow layers, and coarse grained (crystals up to a quarter of an inch across).

Two contiguous samples (F-22 and F-23) were taken approximately a quarter of a mile north of the Swan Lake road, in the SE¼NE¼ sec. 4, T. 35 N., R. 32 E., spanning the entire width of a low-trending ridge. Sample F-22 was taken in a direction N. 43° W. for a length of 80 feet. Sample F-23 was taken in a direction N. 70° W. for a length of 52 feet. The limestone of both samples is white, with a few thin light-gray layers, and coarse grained (crystals 0.2 inch in diameter). The strike of the layering is N. 27° E., and the dip is 38° SE. 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
F-20	50	98.24	0.29	42.98	55.19	0.14	1.19	0.47	0.060
F-21	55	94.25	2.34	42.60	52.95	1.12	2.65	0.56	0.007
F-22	80	90.96	5.56	40.63	51.10	2.66	5.22	1.02	0.027
F-23	52	95.66	2.91	43.40	53.74	1.39	1.11	0.39	0.005

The analyses show that the average $CaCO_3$ content of the limestone (94.77 percent) is not quite high enough to classify the rock as a high-calcium limestone (95 percent $CaCO_3$). The average content of magnesia is low enough (1.33 percent) to permit the rock to be acceptable for the manufacture of portland cement. This limestone, with its color banding and layering, its bright sparkle on freshly broken surfaces, and its compact nature, is the most beautiful limestone seen in Ferry County during this study. From all appearances, it would make very handsome dimension stone. The relative inaccessibility of the district and the great distance to potential markets are serious handicaps to its commercial exploitation. Probably 600,000 tons of limestone is available within 1,000 feet of the Swan Lake road and to a depth of 50 feet below the tops of the outcrops.

Sheep Mountain Area
Sec. 9, T. 35 N., R. 32 E.

Location and accessibility.—The Sheep Mountain area is in sec. 9, T. 35 N., R. 32 E., Colville National Forest. Access is gained by way of the Swan Lake road and a Forest Service branch road that skirts the east side of Sheep Mountain and ascends the mountain from the south to its summit (3,919 feet above sea level).

Geology.—Muessig and Quinlan (1959) show Sheep Mountain to be composed of marble, dark siliceous marble, and phyllite, of pre-Permian age, closely folded along north-trending axes (fig. 56). On the west side of the mountain these metamorphic rocks are in contact with granodiorite of Tertiary age.

Quality of limestone.—Sampling was limited to an area of dark siliceous marble approximately 300 feet north of the former site of the Forest Service lookout, at the summit of Sheep Mountain, in the NE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 9, T. 35 N., R. 32 E. The rock is a dark-gray to black, fine- to medium-grained, thin-bedded limestone containing from 1 percent to several percent of lath-shaped crystals, probably of tremolite or actinolite. The strike of the bedding in the limestone ranges from N. 15° E. to N. 55° E., and the dip is 32° SE. Seven contiguous samples (F-24 to F-30) were taken across the entire width (350 feet) of the outcrop north of the lookout site. 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
F-24	50	55.77	3.30	26.77	31.33	1.58	36.05	3.87	0.173
F-25	50	57.07	2.26	26.61	32.06	1.08	37.83	2.20	0.153
F-26	50	52.39	4.18	25.48	29.43	2.00	39.45	3.53	0.330
F-27	50	81.99	2.34	38.11	46.06	1.12	13.52	1.05	0.056
F-28	50	83.73	1.92	38.34	47.04	0.92	12.51	0.99	0.051
F-29	50	67.34	1.59	31.12	37.83	0.75	28.99	0.98	0.060
F-30	50	77.25	2.95	36.23	43.40	1.41	18.09	0.85	0.040

The analyses show that the rock is very siliceous; the SiO_2 content of some samples exceeds the CaO content. The rock has no apparent value. An industry that could make use of this rock could secure similar or much more suitable limestone from other districts that are more accessible.

OKANOGAN COUNTY

Buckhorn Mountain-Havillah District

This district in northeastern Okanogan County extends southwest for 10 miles from Buckhorn Mountain in the central part of T. 40 N., R. 30 E., to Havillah, near the center of T. 39 N., R. 29 E. Good paved and graveled roads connect the region with U.S. Highway 97 and the Great Northern Railway at Tonasket to the southwest and Oroville to the west.

Very little is known about the geology of that part of the region around Havillah, but it appears to be very similar to the geology of the Myers Creek district, which includes Buckhorn Mountain. The geology of the Myers Creek district has been described by Umpleby (1911, part 1). The following descriptive material, though not a direct quotation, has been taken from Umpleby's report (1911, part I, p. 17-22).

The oldest rocks in the area are probably of Paleozoic age and consist of quartzites, slates, schists, and limestones with intimately associated intrusive and extrusive igneous rocks of basic composition, all of which have been subjected to a great period of diastrophic movement that resulted in their regional metamorphism. At least part of the series is thought to be Carboniferous. Intruded into these are two great batholiths, one of quartz-bearing hornblende syenite and the other of granite, which show no evidence of having passed through a period of intense crustal movement and are for that reason assigned provisionally to the late Mesozoic.

West of the Myers Creek valley the beds dip, with few exceptions, to the west, whereas on the east side the dip is in the opposite direction. Many beds that are well defined can not be traced for more than a few hundred feet along the strike. In the limestone they seem to pinch out, but in the clastic rocks the breaks are probably due in large measure to cross faulting and sharp bends along the strike, which have resulted in increasing or decreasing the resistance of the beds to weathering.

The igneous rocks intimately associated with the sedimentary series are basic and so completely altered that the original mineralogical composition was not determined satisfactorily. They fall either in the gabbro or the diorite family, although in their present forms they may well be designated by the term "greenstones."

Buckhorn Mountain Area

Location, accessibility, and ownership.—The village of Chesaw is at the junction of Dry and Myers Creeks, about 20 miles by road east of Oroville. Buckhorn Mountain is 1 to 3 miles east of Chesaw and 3 to 5 miles south of the International Boundary. Excellent exposures of limestones are to be found, particularly at the summit and on the west slopes of Buckhorn Mountain, over an area 1-3/4 miles square between elevations 3,500 feet and 5,200 feet above mean sea level. The most extensive outcrops are within secs. 26 and 27, T. 40 N , R. 30 E., in the Okanogan National Forest. Six "lime claims" have been staked (fig. 57) by W. G. Hallauer, of Oroville.

Geology.—Umpleby (1911, part I) points out that quartzites, slates, greenstones, limestones, and schists are distributed widely in the area. He assigns a Carboniferous age to the limestones, based upon the presence of crinoid fragments and the similarity in lithology and structure with the Cache Creek Series of Dawson (1895). The limestone of Buckhorn Mountain is described by Umpleby (1911, part I, p. 20), in part, as follows:

> The average rock is dark gray to dove color on exposed surface, but on fresh fracture is either uniformly bluish gray or shows alternating blue and white bands. In a few places the more solid color is mottled by blue spots. Usually the limestone is greatly crushed although not recrystallized, but in places beautiful marble occurs in parts of a bed . . . One bed outcrops on the west face of Buckhorn Mountain . . . It begins in the bluffs east of Chesaw at an elevation of 3,600 feet and continues up the mountainside to a height of 5,000 feet, throughout the entire distance dipping east at an average angle of about 30 degrees . . . this bed, if its lower part continues on its dip under the mountain, is approximately 4,000 feet thick.

Mapping, principally in sec. 27, T. 40 N., R. 30 E., for 1 mile north of Ethel Creek (fig. 57), essentially substantiates Umpleby's findings. Outcrops on the lower slopes along the east side of Myers Creek are composed of very thin bedded, light-gray to dark-gray, fine-grained limestone. Strikes range from northeast to northwest; dips range from 15° E. to 60° E. and average 27° E. Impurities in this limestone are chiefly cryptocrystalline silica or chert blebs and nodules up to a quarter of an inch across, ranging in amount from 1 to 10 percent. The average silica content of the thin-bedded limestones is probably close to 3 percent. On the higher slopes half a mile north of Ethel Creek there are extensive areas of limestone outcrop. This rock differs from the limestones farther west in that it lacks any markedly bedded character, it is somewhat lighter in color, and it contains much more chert. Silica, in the form of chert blebs, nodules, stringers, and layers several feet long and up to 1 foot thick, is quite common and is estimated to compose at least 10 percent of the rock. These silicified limestones strike from east to northeast and dip south to southeast at approximately 20°. The true stratigraphic thickness of all the limestones illustrated in figure 57 is approximately 3,000 feet.

To the south and east of the limestones, along the hill slopes north of Ethel Creek, are numerous inconspicuous outcrops of graywacke and argillite. Bedding attitudes are not readily determined here, so the relationship between the graywackes and the limestones is not clear. Such attitudes as were found indicate that the graywackes and argillites overlie the limestones unconformably.

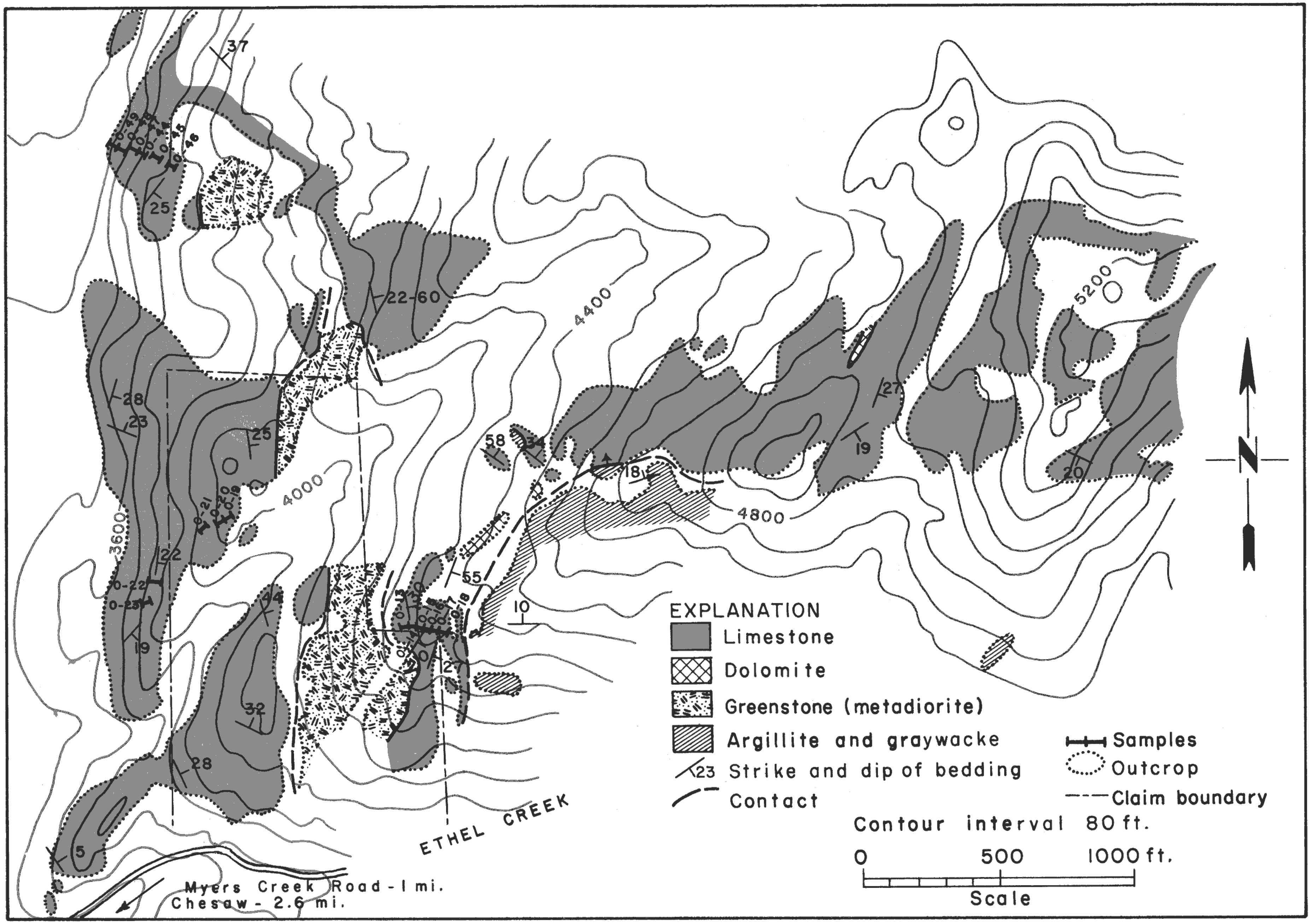

FIGURE 57.—Buckhorn Mountain area. Secs. 27 and 28, T. 40 N., R. 30 E. Geology by J. W. Mills, C. E. Stearns, and R. D. Boettcher. Base map from aerial photo enlargement. Topography from U.S. Geological Survey Mt. Bonaparte quadrangle map.

The only other abundant rock type is greenstone (fig. 57). It was formerly an intermediate to basic igneous intrusive, a diorite or a gabbro, but it has been so intensely altered that the original rock-forming minerals have been destroyed. Of the several very fine grained minerals now constituting the rock, only chlorite was readily identifiable. The intrusive nature of the body is recognized by the strongly discordant nature of its borders with the limestones. It is younger than the Carboniferous (?) limestones it cuts, but its precise age is not known. The greenstone did not materially affect the texture or the mineralogy of the limestone into which it was intruded.

Quality and quantity of limestone.—The principal impurity in the limestone is chert. Dolomite is present in three small areas shown in figure 57. The results of the analyses of two samples taken on Buckhorn Mountain by Shedd (1913, p. 164) and a composite of random grab samples taken by W. G. Hallauer on his claims are as follows:

Sample	$CaCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	S	P
Shedd I	96.62	42.50	54.10	0.35	0.86	0.72	—	——
Shedd II	90.51	42.85	50.59	1.21	4.54	0.61	—	——
Hallauer	96.3	——	——	0.24	3.09	0.19	nil	0.007

In the present study, no samples were taken of the more massive limestone toward the summit of the mountain because the chert content is much too great for the rock to be of any value. Sampling was confined to good exposures of the thin-bedded limestones lower on the mountain. Seventeen samples were taken (O-13 to O-23, O-44 to O-49) over a combined horizontal length of 904 feet, representative of a total (but not continuous) stratigraphic thickness of approximately 1,315 feet. The locations of these samples are shown in figure 57. The sampling is representative of only a fraction of the entire section (approximately 3,000 feet thick) of the relatively pure thin-bedded limestones, but it does indicate the general quality of the parts of this section which surface examination indicates to be higher grade. The analyses of these samples are as follows:

Sample no.	Horizontal 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)
O-13	50	84.21	1.23	37.21	47.31	0.59	14.30	0.34	0.005				
O-14	50	96.78	1.32	43.07	54.37	0.63	1.51	0.33	0.006				
O-15	50	97.54	1.11	43.34	54.80	0.53	0.96	0.20	0.004				
O-16	50	98.68	0.67	43.32	55.44	0.32	0.71	0.23	0.004				
O-17	50	97.29	0.86	42.95	54.66	0.41	1.52	0.38	0.005				
O-18	40	97.06	0.84	42.80	54.53	0.40	1.97	0.22	0.007	200	720	-30	70
O-19	50	95.46	0.82	42.23	53.63	0.39	3.32	0.31	0.028				
O-20	50	87.38	0.63	38.46	49.09	0.30	11.98	0.43	0.014				
O-21	45	96.94	0.94	43.13	54.46	0.45	0.90	0.17	0.012				
O-22	80	98.56	1.07	41.14	55.37	0.51	5.70	0.40	0.028				
O-23	51	97.92	0.77	43.58	55.01	0.37	0.51	0.38	0.008				
O-44	60	97.19	0.69	42.78	54.60	0.33	1.46	0.27	0.005				
O-45	55	94.25	0.71	41.47	52.95	0.34	4.14	0.78	0.009				
O-46	51	93.98	1.25	42.30	52.80	0.60	3.55	0.63	0.006				
O-47	68	88.39	0.61	38.82	49.66	0.29	9.96	0.88	0.005				
O-48	61	87.99	0.67	38.93	49.43	0.32	9.74	0.80	0.006				
O-49	43	94.52	0.90	41.86	53.10	0.43	3.61	0.72	0.009				

Of the 6 samples O-13 to O-18, the last 5 contain, on the average, 54.76 percent CaO, (97.47 percent $CaCO_3$), 0.46 percent MgO, 1.33 percent SiO_2, 0.27 percent R_2O_3, and 0.005 percent P_2O_5. These 5 samples represent a true thickness of 150 feet of high-calcium limestone. Owing to the limitation of these beds by the greenstone to the south and with depth, and probably by the graywacke to the east, it is concluded that the amount of available limestone is not more than 600,000 tons.

Samples O-19 to O-23 have a composition very similar to samples O-13 and O-14. The unweighted average of their analyses is 53.51 percent CaO, (95.25 percent $CaCO_3$), 0.40 percent MgO, 4.48 percent SiO_2, 0.34 percent R_2O_3, and 0.018 percent P_2O_5. These samples (O-19 to O-23) are representative of a stratigraphic thickness of 320 feet of high-calcium limestone. The amount of limestone, of the quality indicated by the analyses, available on the ridge over a width of 250 feet, a length of 1,500 feet, and to the level of the fields immediately west of the ridge, is 15 million tons. Of the three areas sampled on Buckhorn Mountain, this one is the closest to roads and is the most accessible. Owing to the variable silica content it would be necessary, before attempting exploitation of the deposit, to take many more samples to determine accurately the purity of the rock.

Samples O-44 to O-49, taken from an outcrop in the northwestern part of the map area (fig. 57), are shown by the analyses to contain, on the average, 52.09 percent CaO (92.72 percent $CaCO_3$), 0.38 percent MgO, 5.41 percent SiO_2, 0.68 percent R_2O_3, and 0.007 percent P_2O_5. The rock is not a high-calcium limestone.

The areas sampled on Buckhorn Mountain were those that field examination showed to be the purest of all outcrops mapped. The sample analyses show the limestones to be remarkably free of magnesian impurities and of a generally high lime content. Samples O-14 to O-18 have a composition suitable for limestone use in making chemical lime, metallurgical lime, builders' lime, ceramic whiting, mineral filler, and for use in the pulp and paper industry and the portland cement industry. The other sampled areas have, at best, an average silica content that would prohibit their use by most consumers of high-calcium limestone. It is quite likely, with careful exploration, mapping, sampling, and analytical studies, that very large tonnages of limestone that would be quite suitable for the manufacture of portland cement can be blocked out on Buckhorn Mountain.

Chesaw to Muskrat Lake Area

Numerous small outcrops of limestone, interbedded with quartzites, schists, and greenstones, are found in isolated areas between Chesaw and Muskrat Lake, 6 miles southwest of Chesaw. These limestones are in general quite siliceous, and it is not likely that any appreciable tonnage of high-calcium limestone is present. Three samples taken from this area are reported by Shedd (1913, p. 164) to contain 2.36 percent, 3.56 percent, and 6.58 percent silica.

Bunch-Wildermuth Property
Sec. 20, T. 39 N., R. 29 E.

Location, accessibility, and ownership.—The Bunch-Wildermuth property is in the center of sec. 20, T. 39 N., R. 29 E., 2½ miles north of Havillah. Havillah is approximately 15 miles northeast of Tonasket and 11 miles southwest of Chesaw. Medium-duty roads connect Havillah to U.S. Highway 97 and the Great Northern Railway at Tonasket and Oroville. The mineral rights to the area of limestone outcrop are owned jointly by Darrel Bunch, of Havillah, and Walter Wildermuth, of Omak.

Geology.—Bedrock in the area is composed chiefly of the same late Paleozoic schists, quartzites, greenstones, and limestones that Umpleby (1911) describes around Chesaw and Buckhorn Mountain to the northeast. The limestones occur as relatively thin, nonpersistent layers and lenses interbedded with folded noncarbonate rocks. The limestone on the Bunch-Wildermuth property occurs as a distinct bed (fig. 58). Strikes at the west end of the outcrop are generally northeasterly. Farther to the east the strike changes to east-west and then to southeast. Dips range from almost horizontal to 42° N. and average approximately 22° N. At the west side of the outcrop the bed has a true thickness of 75 feet; to the east it thins to probably 50 feet. It is underlain conformably by quartzites and phyllites and is overlain by quartzite, gneissic amphibolite, and a second limestone bed much smaller and more siliceous than the principal limestone bed.

Quality and quantity of limestone.—The limestone is gray to light gray in color, fine grained and thin bedded. Much of the rock is traversed intimately by paper-thin parallel and sub-parallel fractures that strike from N. 65° E. to N. 80° E. and dip very steeply to the northwest. Some of these fractures are filled with calcite, but most are filled with white quartz. No other impurities were seen. Four random samples taken from different parts of the deposit by Walter Wildermuth were found to contain 97.7 percent, 97.9 percent, 98.6 percent, and 98.7 percent $CaCO_3$ (Willis H. Ott, analyst). A composite sample, taken along the outcrop for 1,500 feet by a reputable mining engineer, contained 91.8 percent $CaCO_3$, 6.2 percent SiO_2, and 1.0 percent $MgCO_3$. According to this latter analysis, the rock is not a high-calcium limestone.

During the present study four samples (O-33 to O-36) were taken. Samples O-33 and O-36 were taken contiguously up the steep west-facing cliff and on the gentler slope above it (fig. 58). Together, these two samples represent a thickness of 75 feet of limestone. Sample O-34 was taken down the cliff face 400 feet north of sample O-33 and is representative of the upper 40 feet (true thickness) of the limestone bed. The lower portion of the bed is concealed beneath alluvium at the base of the cliff. Sample O-35 was taken at the southeastern extremity of the outcrop and is representative of the total thickness of 50 feet. The results of the analyses of these samples are as follows:

Sample no.	True thickness (feet)	Length (feet)	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
O-33	45	50	97.76	0.59	43.15	54.92	0.28	1.34	0.31	0.008
O-34	40	40	98.95	0.54	43.43	55.59	0.26	0.42	0.16	0.005
O-35	50	110	96.89	1.46	43.13	54.43	0.70	1.40	0.28	0.011
O-36	30	200	94.04	0.84	41.45	52.83	0.40	4.90	0.31	0.014

The unweighted average of these analyses is 54.44 percent CaO, 0.40 percent MgO, 2.01 percent SiO_2, 0.25 percent R_2O_3, and 0.009 percent P_2O_5. According to the analyses, the rock is a high-calcium limestone, suitable for making ceramic whiting, builders' lime, pulp and paper, mineral filler, and portland cement.

The tonnage of limestone available is very difficult to determine because of the variable dip and thickness of the limestone, the faulting of the bed, and the topographic irregularities. The bed dips into the hill, and hence the rock overburden would become excessive quickly during any quarrying operation. It is estimated that there is approximately 5 million tons of high-calcium limestone with an overburden maximum of 100 feet. The deposit is too remote from potential markets for high-calcium limestone. This fact, together with the relatively small tonnage, makes it seem unlikely that the deposit will be of any value in the near future.

Havillah Area

Shedd (1913, p. 169) reports that a bluish-gray, finely crystalline limestone from Havillah contains 97.53 percent $CaCO_3$, and 1.80 percent SiO_2. The exact location of the sample is not given. Certainly, no limestone crops out within a mile of Havillah. Hodge (1944, p. 55) records the following analysis for a sample taken from a deposit 2½ miles east of Havillah:

$CaCO_3$	Loss on Ignition	CaO	SiO_2	MgO	R_2O_3
97.53	41.88	54.62	1.80	Tr	0.60

(A. A. Hammer, analyst)

The similarity in the analysis reported by Hodge and that reported by Shedd is probably not coincidental; they are probably referring to the same sample. A small outcrop in the NE¼SE¼ sec. 34, T. 39 N., R. 29 E., may be the one from which the sample was taken. It was not sampled by the writer because the volume of limestone is less than 100,000 tons and because the rock is similar to, though not quite as pure as the limestone on the Bunch-Wildermuth property.

Another area of limestone outcrop is in the center of the NE¼ sec. 33, T. 39 N., R. 29 E., 1-3/4 miles northeast of Havillah. The limestone crops out on a south-facing hillside for a length of 300 feet

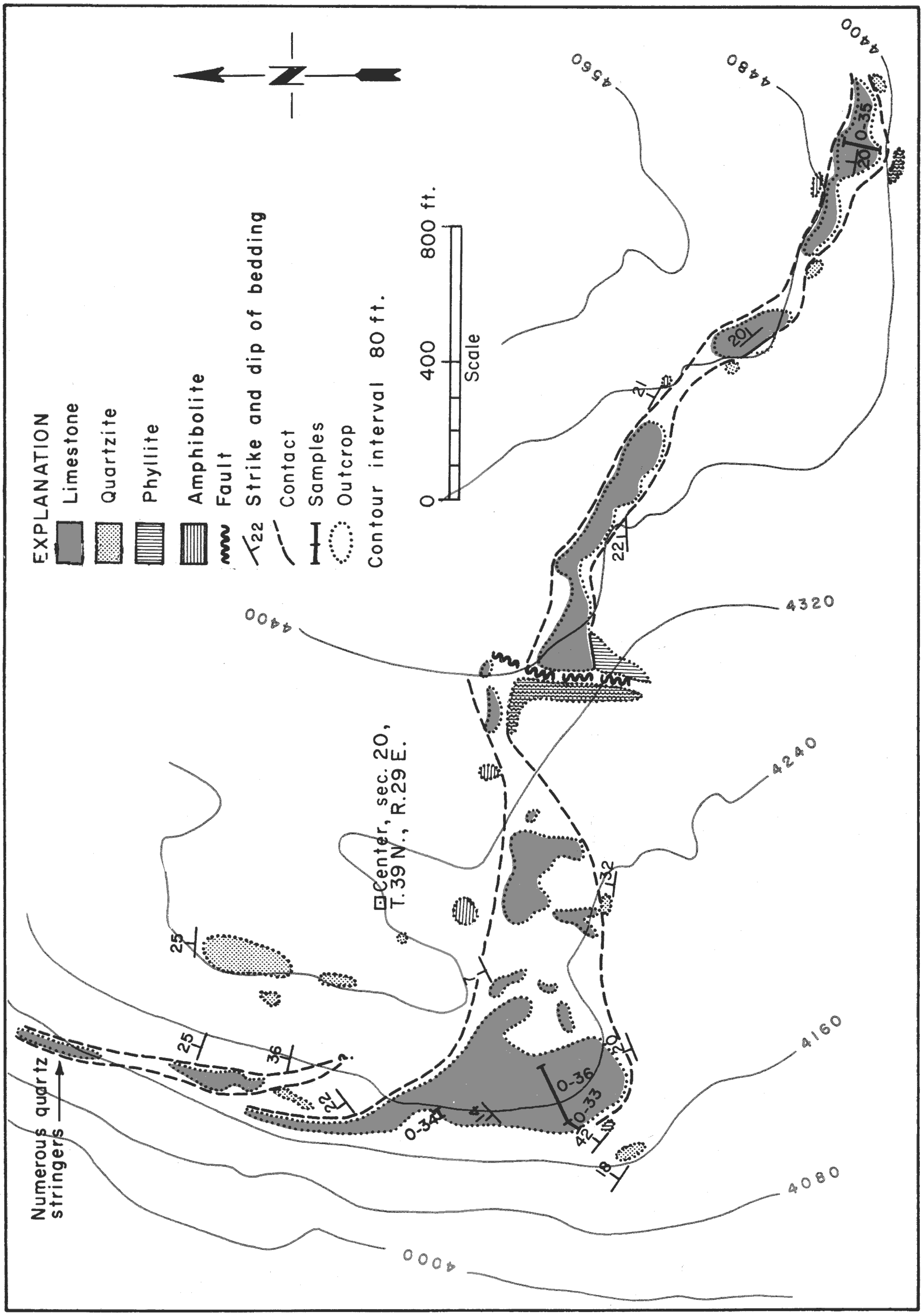

FIGURE 58.—Bunch-Wildermuth property. Sec. 20, T. 39 N., R. 29 E. Geology by J. W. Mills, C. E. Stearns, and R. D. Boettcher. Base map from aerial photo enlargement. Topography from U.S. Geological Survey Mt. Bonaparte quadrangle map.

and a maximum width of 50 feet. The true thickness is approximately 20 feet in the central part of the outcrop and it diminishes toward both ends. This lenticular body of limestone is entirely enclosed by phyllites and quartzites. The volume of limestone is too small to merit further attention.

Another outcrop of limestone is at the southwestern end of Knob Hill in the extreme southwest corner of sec. 22, T. 39 N., R. 29 E. It is about 500 feet long and from 100 to 200 feet wide. The rock is similar to the gray and white thin-bedded limestone to be found elsewhere in the Havillah area except that the bedding is greatly contorted. The limestone is surrounded by fine-grained quartzite, highly silicified limestone, and diorite. The presence of silica impurities and the small volume of limestone rule out the possibility of commercial development.

Wauconda District

Numerous limestone outcrops are in secs. 13, 14, and 25, T. 38 N., R. 30 E. The area is accessible by driving north on the Toroda Creek road for a distance of 4 miles from Wauconda on State Highway 4. The limestone in secs. 13 and 14 is accessible from the Toroda Creek road by lesser roads and farm lanes. The limestone in sec. 25 lies along the west side of the Toroda Creek road.

Shedd (1913, p. 169) reports a small body of limestone "about one mile south of Wauconda. Three or four miles north, on the headwaters of Meadow Creek, are other small bodies of lime." The limestone reported to be 1 mile south of Wauconda was not examined during this study. The limestones reported to be "three or four miles north" are those in secs. 13, 14, and 25, described below. Shedd (1913, p. 170) describes a limestone sample taken "from north of Wauconda" as "almost pure white in color, finely crystalline." The analysis he reports shows the rock to contain 88.13 percent $CaCO_3$, 49.36 percent CaO, 2.83 percent MgO, 3.64 percent SiO_2, and 2.18 percent R_2O_3. The exact location from which the sample came is not given.

To the writer's knowledge, no geologic mapping has been done in this district. During the present study the rocks were found to be principally quartzites and schists with interbedded argillaceous limestone and rather pure coarse-grained limestone. Fold axes trend north to northeast. Details are given in the following discussion of the areas examined and sampled.

Toroda Creek Road Area
NW¼ sec. 25, T. 38 N., R. 30 E.

Location, accessibility, and ownership.—Limestone crops out on a ridge on the west side of the Toroda Creek road, approximately 4 miles north of Wauconda. Most of the ridge is on the property of Victor Lesamiz, of Oroville, but the southern end is on property owned by Frank S. Jones, of Wauconda. The nearest railroad facilities are at Republic.

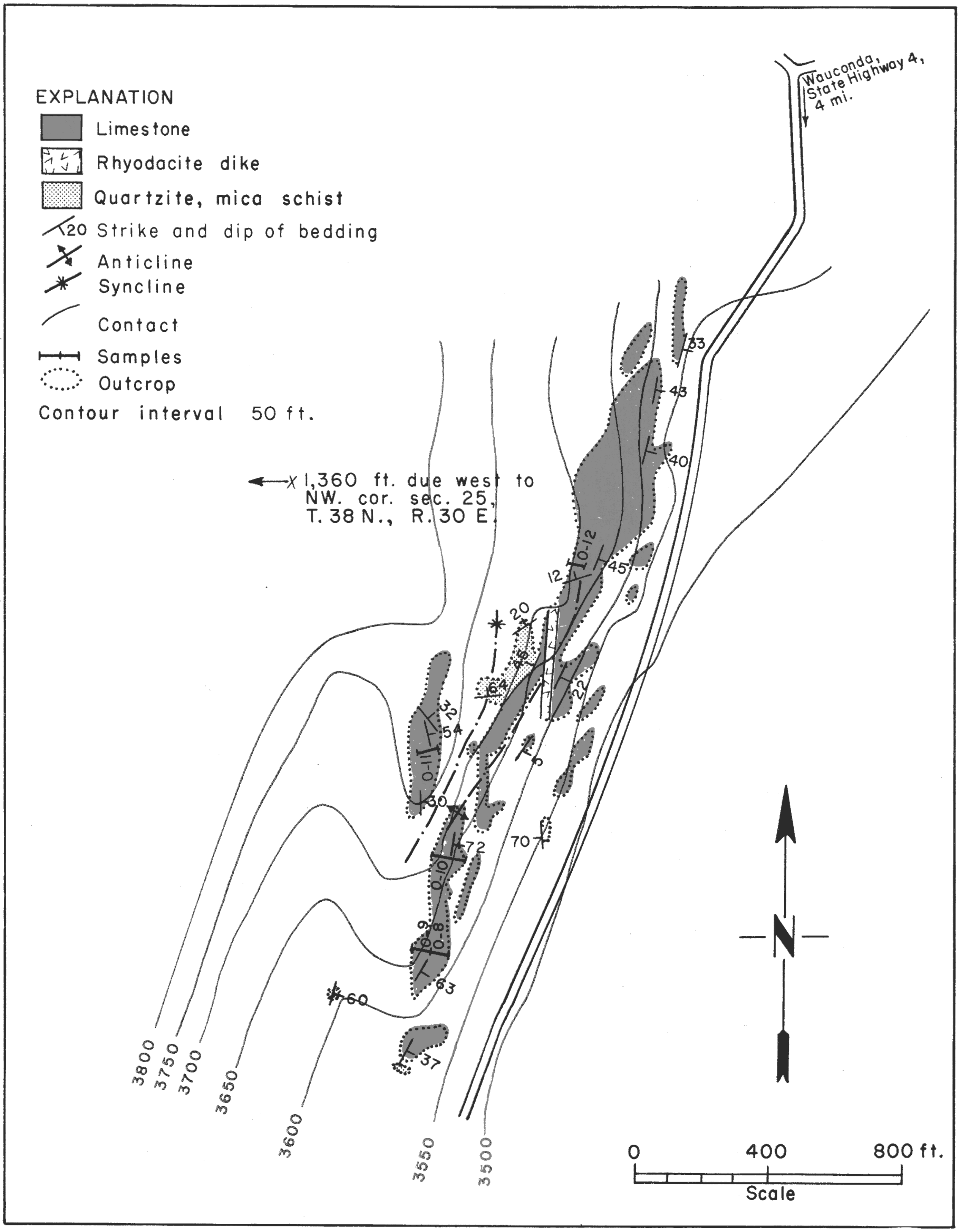

FIGURE 59.—Toroda Creek road area. Secs. 24 and 25, T. 38 N., R. 30 E. Geology by C. E. Stearns and R. D. Boettcher. Base and topography by plane table and alidade survey.

Geology.—Limestone, with some quartzite and mica schist, is well exposed over a length of half a mile and a width of 600 feet on the north slope of a hill on the west side of the Toroda Creek road. On the basis of plane table mapping by Stearns and Boettcher (fig. 59), the limestone appears to be approximately 150 feet thick and to be overlain and underlain by quartzite and mica schist. The rocks have been strongly folded to form a syncline and an anticline plunging at a low angle toward the north. The east limb of the anticline, near the Toroda Creek road, is overturned and dips steeply west. At the south end of the outcrop the lower part of the limestone seems to interfinger with the underlying quartzite and schist.

The limestone is white on a fresh surface and gray on weathered surfaces, is medium grained and well bedded. Except for the presence of a few very thin quartz seams, it appears to be pure. Five samples of the limestone were cut for a combined length of 310 feet (fig. 59). Samples O-8 to O-10 were taken on the east limb of the anticline. Sample O-11 was taken on the west limb of the syncline. The approximate true thickness represented by each of these samples is given in the table below, in which the results of the sample analyses are listed.

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)
O-8	60	38	91.74	0.88	40.46	51.54	0.42	7.38	0.09	0.016				
O-9	60	28	98.90	0.50	43.34	55.56	0.24	0.71	0.19	0.009				
O-10	100	70	97.33	0.84	43.15	54.68	0.40	1.35	0.28	0.012	210	750	-30	22
O-11	50	40	95.05	0.38	41.66	53.40	0.18	4.45	0.18	0.018				
O-12	40	?	98.52	0.73	43.46	55.35	0.35	0.30	0.18	0.014				

The unweighted average of these analyses shows a content of 54.11 percent CaO (96.31 percent $CaCO_3$), 0.32 percent MgO, 2.84 percent SiO_2, 0.18 percent R_2O_3, and 0.014 percent P_2O_5. The analyses show the rock to be a high-calcium limestone with a variable and unpredictable silica content. The composition of the limestone meets the chemical specifications for the manufacture of builders' lime, mineral filler, and portland cement. Although it is chemically suitable for the manufacture of portland cement, the limited lateral extent and thickness (150 feet?) of the limestone rule out the possibility of there being a sufficient tonnage available to attract cement manufacturers.

Toroda Creek North Area

SW$\frac{1}{4}$NW$\frac{1}{4}$ sec. 13 and NE$\frac{1}{4}$ sec. 14, T. 38 N., R. 30 E.

Location, accessibility, and ownership.—Limestone outcrops in secs. 13 and 14, T. 38 N., R. 30 E., are accessibly by farm roads leading from the Toroda Creek road, approximately 4$\frac{1}{2}$ miles north of Wauconda. The nearest railroad facilities are at Republic. The limestone crops out on property owned by Frank S. Jones, of Wauconda.

A 10-foot thick bed of white coarse-grained limestone forms a small outcrop in the SW¼NW¼ sec. 13. It is overlain and underlain by an undetermined thickness of pure argillaceous limestone. One sample, O-6, was taken across the full width of the bed. The analysis of this sample shows it to contain 55.49 percent CaO (98.77 percent $CaCO_3$), 0.14 percent MgO, 1.56 percent SiO_2, 0.23 percent R_2O_3, and 0.006 percent P_2O_5. The ignition loss was 42.34 percent. Although the rock is a high-calcium limestone, the outcrop is only a few square feet in area and so the volume available is unknown. Because the bed is only 10 feet thick, it is quite unlikely that any appreciable volume of rock of this purity is available.

White and light-gray coarse-grained limestone crops out along the crest and southeast side of a ridge slightly to the east of the center of the NE¼ sec. 14, T. 38 N., R. 30 E. The outcrop is approximately 300 feet long and 100 feet wide. Outcrops of limestone could be seen extending toward the north and northeast, but time did not permit an examination of them. Sample O-7 was taken across the outcrop examined, from the top of the ridge in a direction S. 60° E. for a total length of 70 feet down a -29° slope. The rock is a white coarse-grained limestone. Bedding striking N. 60° E. and dipping 30° NW. is weakly developed. The true thickness of the limestone represented by sample O-7 is approximately 57 feet. The analysis of this sample is: 55.39 percent CaO (98.59 percent $CaCO_3$), 0.19 percent MgO, 1.33 percent SiO_2, 0.29 percent R_2O_3, 0.006 percent P_2O_5, and 42.45 percent ignition loss. The rock is a high-calcium limestone, but it must be kept in mind that only one sample was taken, and that sample may not be representative of the extensions of the limestone. Insufficient work was done to determine the tonnage of limestone available.

Unfortunately, because of the limited time available for the study of the Wauconda district, the examination must be considered nothing more than cursory. Distant outcrops were seen but not visited. The district appears to contain numerous small outcrops of limestone that are low in magnesia. A program of careful mapping and sampling of the exposures may have a better-than-average chance of discovering large tonnages of limestone of sufficient purity for use as chemical lime, metallurgical lime, builders' lime, ceramic whiting, mineral filler, and in the manufacture of pulp and paper and portland cement.

Sinlahekin District

Wannacut Lake Area

Location and accessibility.—This limestone-bearing area lies about midway between Wannacut and Palmer Lakes, and it extends for a short distance southeast of Spectacle Lake. Most of the limestone is found in T. 39 N., R. 26 E., about 6 miles southwest of Oroville. The area can be reached easily by driving southwest from Oroville to Wannacut Lake or from Tonasket up the Sinlahekin Creek valley to Spectacle Lake, thence by secondary roads to the mountainous region in which the limestone is found. The nearest railroad is the Great Northern Railway, at Oroville.

Geology.—The geology of the region has been described by Umpleby (1911, pt. 2) and by Waters and Krauskopf (1941). The limestone-bearing terrain is composed of a great series of metamorphic rocks that Umpleby (1911, p. 64, 65) correlates with the Carboniferous Cache Creek Series of British Columbia. The complexly folded metamorphic rocks of the series include clay slates, siliceous schists, quartzites, blue limestones, and siliceous and argillaceous beds with interbedded igneous material (Umpleby, 1911, p. 65). Waters and Krauskopf (1941, p. 1360) believe these rocks belong to the middle part of the great thickness of late Paleozoic rocks named the Anarchist Series by Daly (1912, pt. 1, p. 389).

Umpleby shows the distribution of the areas of limestone on the geological map accompanying his report. He writes that the limestones are blue and that they weather to a light gray. They are fine grained, extensively crushed, and, locally, partially converted into marble. He emphasizes the fact that the limestones occur in lenticular bodies interbedded with clay slates and siliceous beds, and that their maximum thickness is 300 feet. The lenticular character he attributes to "special conditions of deposition such that the lenses now have essentially their original outline and geographic distribution."

Valentine (1960, p. 56) mentions limestones in this area under the locality headings "Golden" and "Wehesville."

The limestones and the associated argillites, metaconglomerate, and migmatites were mapped in detail by Crosby (1949), and his previously unpublished map is reproduced in this report (pl. 7) with his permission. Crosby (1949, p. 7) describes the limestone as:

> . . . rather poorly bedded, fine to moderately crystalline rock, dark gray to black on fresh surfaces, and weathering to white, gray, or buff. It is generally dolomitic and contains carbonaceous material in small quantities. Chert, which is probably secondary, occurs locally. The limestone is closely jointed and sheared, and many fissures are filled with secondary calcite. Although generally fine-grained, the limestone at places has been sufficiently recrystallized to be classified as marble.

Many of the limestone beds have been partially or completely silicified. Crosby (1949, p. 8) devoted a great deal of study to the silicified limestones and reports as follows:

> Silicified limestone is one of the more abundant rocks in the area. Weathered exposures can generally be recognized in the field by their characteristic white, light-buff, or light-red color. On fresh surfaces the silicified limestone has much the appearance of the fresh surface of the unaltered limestone, being generally dark gray or black and having the same fine-grained texture. Where the bedding of the limestone is retained in the silicified rock it is generally more pronounced than any seen in the unaltered limestone. Silicified crinoid fragments were found in the silicified limestone . . . microscopically, the silicified limestone consists almost entirely of secondary silica, but there is generally a minor amount of sericite. Occasionally, some calcite is present in the rock, and in several specimens porphyroblasts of plagioclase have been noted.

The lenticular form and irregular distribution of the limestone, which puzzled Umpleby, is shown by Crosby to be the result of silicification and migmatization and, to a lesser degree, the result of faulting. According to Crosby's interpretation, the limestone pods and lenses are the parts of one or two formerly extensive thick limestone beds that have escaped partial or complete alteration to siliceous rock or migmatite by hot rising waters.

Quality and quantity of limestone.—Because of the small amount of time available for the examination of the numerous exposures of limestones in this area, sampling was limited to a few exposures. The samples are believed to be representative of the better quality limestone. In all, nine samples were taken in three sections. The results of the sampling and brief descriptions of the rocks sampled follow:

Samples O-24, O-25, and O-26 were taken (pl. 7) in the N½ sec. 10, T. 39 N., R. 26 E., on U.S. land. The three samples have a total length of 160 feet and are representative of a true thickness of 141 feet of limestone. The rock is light to medium gray on fresh surfaces, gray on weathered surfaces, massive, and very fine grained. It contains small amounts of silica as small stringers and blebs.

Sample no.	True thickness (feet)	Length (feet)	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
O-24	55	60	98.81	0.33	43.54	55.51	0.16	0.50	0.14	0.028
O-25	43	50	97.78	0.65	43.17	54.93	0.31	1.36	0.29	0.005
O-26	43	50	93.90	1.63	41.98	52.75	0.78	3.73	0.87	0.010

The unweighted average of these analyses is 54.39 percent CaO, 0.42 percent MgO, 1.86 percent SiO_2, 0.43 percent R_2O_3, and 0.014 percent P_2O_5.

Samples O-27 and O-28 were taken in the central part of sec. 4, T. 39 N., R. 26 E., on property owned by Victor Lesamiz, of Oroville. The two samples were taken over a total length of 100 feet and are representative of a true thickness of 50 feet of limestone. The rock varies in color from light gray to dark gray and black on fresh surfaces, and it weathers gray. It is fine grained and well bedded. Analyses of samples O-27 and O-28 are as follows:

Sample no.	True thickness (feet)	Length (feet)	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_2	P_2O_5
O-27	25	50	97.22	0.50	42.98	54.62	0.24	1.56	0.41	0.006
O-28	25	50	98.83	0.29	42.26	55.52	0.14	1.43	0.34	0.017

The unweighted average of these analyses is 55.07 percent CaO, (97.47 percent $CaCO_3$), 0.19 percent MgO, 1.50 percent SiO_2, 0.38 percent R_2O_3, and 0.012 percent P_2O_5.

Samples O-29 to O-32 were taken (pl. 7) in the central part of sec. 35, T. 39 N., R. 26 E., on property owned by Ralph D. and Hugh G. Reed, of Tonasket. The limestone is light gray to gray in color and medium to thin bedded. 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
O-29	50	97.81	0.50	43.25	54.95	0.24	1.28	0.13	0.029
O-30	50	99.09	0.48	43.42	55.67	0.23	0.29	0.34	0.019
O-31	50	98.63	0.59	43.32	55.41	0.28	0.44	0.37	0.019
O-32	50	98.72	0.52	43.49	55.46	0.25	0.50	0.25	0.018

The unweighted average of these analyses is 55.37 percent CaO, (98.56 percent $CaCO_3$), 0.25 percent MgO, 0.62 percent SiO_2, 0.29 percent R_2O_3, and 0.021 percent P_2O_5.

All samples taken in the Wannacut Lake area have a very low MgO content. Samples O-24 to O-28, from the northern part of the area, have an average $CaCO_3$ content in excess of 97 percent, and may be suitable for use in ceramic whiting, builders' lime, mineral filler, and for the manufacture of pulp, paper, and portland cement. Samples O-29 to O-32 have an average $CaCO_3$ content in excess of 98 percent and contain relatively little SiO_2. Their composition is suitable for use as ceramic whiting, finishing lime, mineral filler, and in the processing and manufacturing of sugar, pulp, paper, and portland cement. Samples O-27 to O-31 were composited and analysed for soda, potash, titania, and sulfur, with the following results: Na_2O, 170 ppm; K_2O, 720 ppm; TiO_2, -30 ppm; and S, 16 ppm.

The amount of sampling carried out in the Wannacut Lake area is quite inadequate for a proper evaluation of the quality and quantity of high-calcium limestone available. The extensive and commonly intense silicification to which the rocks have been subjected demands that sampling be abundant and carefully done in order to obtain a good appraisal of the worth of the deposits. The sampling done in connection with this study does, however, show that the chances are very good of there being many millions of tons of high-calcium limestone.

Cayuse Mountain Area

Location, accessibility, and ownership.—Limestone crops out on the summit and east slopes of Cayuse Mountain about 5 miles northwest of Tonasket and 3½ miles south of the east end of Spectacle Lake. It extends southwest from the Lucky Knock antimony mine, in the SW¼ sec. 19, T. 38 N., R. 27 E, for a distance of about 2½ miles to the NE¼ sec. 35, T. 38 N., R. 26 E. The area is reached by driving north from Tonasket up the west side of the valley of the Okanogan River for 5½ miles, then west for 2½ miles to a point just east of Whitestone Lake. From here a graveled road extends to the southwest to the Lucky Knock mine, a distance of 2 miles. Most of the limestone is on the property of the Ellis-Barnes Livestock Company, of Tonasket, and Jessep, Inc., of Loomis, Washington. The nearest railroad facilities are at Tonasket.

Geology.—Bedrock here, as in the Wannacut Lake area, is a heterogeneous group of greenstones, phyllites, quartzites, chlorite schists, crystalline limestones, and partially metamorphosed conglomerates which Daly (1912, pt. 1, p. 389) named the Anarchist Series. Waters and Krauskopf (1941, p. 1362) report the occurrence of limestone of the Anarchist Series on Cayuse Mountain as follows:

> A large pod of white limestone near the base of the Middle Anarchist crosses the (Cayuse) Mountain near its north end. Though locally contorted and variable, the layers forming this pod have an average strike of about N. 50° E., and dip northwest at angles of 20 degrees to 50 degrees. A short distance south of the limestone, chlorite schists and phyllites of the Lower Anarchist are extensively exposed.

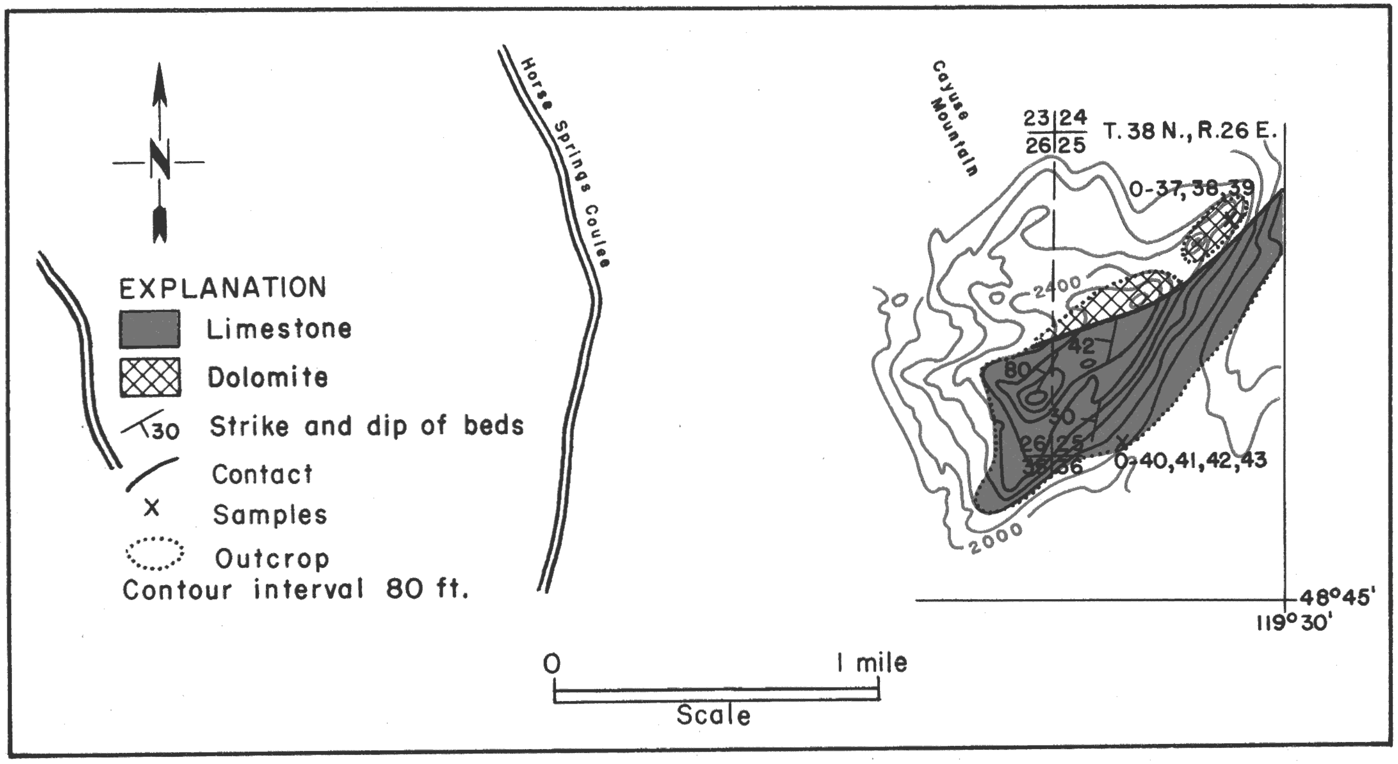

FIGURE 60.—Cayuse Mountain area. Secs. 25 and 26, T. 38 N., R. 26 E. Geology by C. E. Stearns and R. D. Boettcher. Base and topography from U.S. Geological Survey Loomis quadrangle map.

This "pod of white limestone" is the one referred to earlier that extends southwest from the Lucky Knock antimony mine.

In his report on the Lucky Knock mine, Purdy (1951, p. 97) makes reference to the limestone of the mine area in these words:

> . . . the limestone is apparently the result of the normal processes of sedimentation and is not of the reef type. . . .
>
> In the mine area, which is at the very northeastward limit of the limestone body, two rock varieties are in evidence, limestone and black phyllite. The limestone is dark to light gray, fine grained, and for the most part massive, though there are some sections containing thin beds.

The thickest section and best exposures of the limestone are in sec. 25, the SE$\frac{1}{4}$ sec. 26, and the NE$\frac{1}{4}$ sec. 35, T. 38 N., R. 26 E. (fig. 60). In the lowest exposed part of the section, where samples O-40 to O-43 were taken, the limestone is medium to dark in color, fine grained and thin bedded, containing numerous white calcite stringers parallel to the bedding. Beds strike N. 22° E. and dip 30° NW. As one goes up section toward the summit of the mountain, the limestone becomes progressively more argillaceous and slightly dolomitic and the dips steepen to 70° and 90°. The uppermost exposed part of the section is composed of white to light-gray limestone beds, containing numerous lenses and blebs of dolomite, alternating with beds of almost pure dolomite. Samples O-37, O-38, and O-39 were taken from this upper section (fig. 60), where the strike is N. 17° E. and the dip is 44° NW.

Quality and quantity of limestone.—Samples O-37, O-38, and O-39 were taken from the ridge crest downslope toward the southeast across the strike of the dolomitic limestone of the upper part of the exposed section. They are each 50 feet long and are representative of a true aggregate thickness of 150 feet. Analyses of these are as follows:

Sample no.	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
O-37	77.84	22.78	44.57	43.73	10.90	1.29	0.49	0.014
O-38	92.49	6.73	43.45	51.96	3.22	1.20	0.34	0.016
O-39	92.99	6.75	43.91	52.24	3.23	0.34	0.38	0.021

Samples O-40 to O-43 were taken from the lowermost part of the section. They were taken downslope toward the southeast across the strike of the limestone beds. Samples O-40, O-41, and O-42 are each 50 feet long, and sample O-43 is 60 feet long. Together, the four samples represent a true thickness of 200 feet of limestone. Analyses of these are as follows:

Sample no.	$CaCO_3$	$MgCO_3$	Loss on Igniton	CaO	MgO	SiO_2	R_2O_3	P_2O_5
O-40	93.79	1.55	41.80	52.69	0.74	3.98	0.79	0.055
O-41	94.59	1.25	41.94	53.14	0.60	3.45	0.86	0.075
O-42	95.25	1.13	42.45	53.51	0.54	2.34	0.92	0.075
O-43	94.93	1.50	42.28	53.33	0.72	2.94	0.73	0.058

It is concluded, on the basis of the field examination and the results of the chemical analysis, that most of the limestone in this area is too high in MgO and SiO_2 and is too argillaceous to be classified as a high-calcium limestone or cement rock. The purest limestone (O-40 to O-43) is in the lowermost part of the section, where a 200-foot thickness is relatively free of magnesian impurities. This rock may serve for the manufacture of portland cement, but it is too low in CaO (53.17 percent average) and too siliceous to be classified as a high-calcium limestone. The relative inaccessibility of the deposit will probably eliminate the possibility of its being of commercial value in the near future.

Other Areas of Limestone in Northern Okanogan County

Following are the locations of limestone occurrences mapped by Waters and Krauskopf (1941). Although these were not examined, it is reasonable to expect that this limestone is of about the same character as the limestone cropping out in the Wannacut Lake and Cayuse Mountain areas.

Blue Lake Area

Three miles southwest of Oroville; sec. 12, T. 39 N., R. 26 E.; secs. 5 to 8, T. 39 N., R. 27 E.

Whiskey Mountain Area

Seven miles south of Oroville; sec. 4, T. 38 N., R. 27 E.

Aeneas Creek Area

Six miles west of Tonasket; secs. 19, 20, and 28, T. 37 N., R. 26 E.

Kruger Mountain Area

Kruger Mountain lies to the west of Osoyoos Lake and approximately 2 to 5 miles northwest of Oroville. Umpleby (1911, pt. 2) shows a narrow north-trending belt of limestone extending from the NW$\frac{1}{4}$NE$\frac{1}{4}$ sec. 19 to the NW$\frac{1}{4}$NE$\frac{1}{4}$ sec. 18, T. 40 N., R. 27 E., on the south flank of Kruger Mountain. Valentine (1960, p. 56) describes this occurrence as "irregular lenses interstratified with slates and siliceous beds." From a conversation with W. G. Hallauer, of Oroville, who is familiar with this area, it was learned that the limestone is very impure. The area was not visited.

Jackass Butte Area

Location, accessibility, and ownership.—Limestone crops out on the north hill slope of Jackass Butte approximately three-quarters of a mile southeast of the city of Okanogan in the SW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 16, T. 33 N., R. 26 E. The city of Okanogan is on U.S. Highway 97 and the Great Northern Railway. The outcrops are a quarter of a mile south of the city airport, on Tribal Land of the Colville Indian Reservation.

Geology.—According to Pardee (1918, pl. 1), bedrock outcrops in sec. 16 are composed of argillite, schist, quartzite, conglomerate, and limestone of the Covada Group (Carboniferous), intruded by the Colville Granite (Mesozoic) and porphyry dikes (Tertiary). With regard to the limestone, Pardee (1918, p. 178) says, in part,

> Detached masses of limestone of irregular blocky or lenslike form are fairly well distributed in the areas occupied by the Covada group. . . . These masses range from a few feet to 200 feet or more in thickness, most are crystalline gray or white marble, and many appear in part to be nearly pure calcium carbonate. . . . On the slope east of Okanogan River in sec. 16, T. 33 N., R. 26 E., two small quarries are made in a bed of marble. Some of the layers contain pyrite and are colored green with chlorite; others are white and apparently consist of little else than calcium carbonate. A small amount of lime has been burned here. As exposed in the quarry, however, the marble is too badly crushed to be valuable as building stone. The total thickness of the deposit is about 200 feet.

Quality and quantity of limestone.—Several small outcrops appear on the hillside. The largest exposure of limestone is in a quarry, now largely grown over with grass and shrubs, approximately 45 by 45 feet in area; the difference in elevation between the top of the quarry face and the quarry floor is 35 feet. The rock is white to light gray on both fresh and weathered surfaces, coarse grained, slightly micaceous, and highly brecciated. Hodge (1938, p. 79) has reported an analysis of limestone "in the east bank of the river at Okanogan" as follows:

Silica (insoluble)	1.60
Iron oxide	0.42
Aluminum oxide	0.14
Calcium carbonate	95.28
Magnesium carbonate	1.90
Phosphorous pentoxide	0.08
Moisture	0.35

Hodge records this analysis following a brief description of the deposit; the description is the same one given by Pardee (1918, p. 178) and must therefore refer to the limestone in sec. 16.

Sampling of the deposit was limited to one 10-pound bag of chips taken from 20 different locations in the principal quarry referred to earlier. More elaborate sampling did not seem to be justified because of the small extent and impure character of the exposed limestone. The analysis of this sample is as follows:

Sample no.	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
O-75	86.69	11.62	42 15	48.70	5.56	2 64	0.50	0.041

The analyses of sample O-75 indicates that the rock of the quarry is too magnesian and too siliceous for cement use or for any use requiring a high-calcium limestone. A careful examination of limestone outcrops on the hillside lent no support to the idea that the bulk of the limestone in the area is as pure as suggested by the analysis reported by Hodge. The limestone is believed to have no commercial value.

West Half Colville Indian Reservation

The west half of the Colville Indian Reservation is bounded on the west by the Okanogan River, on the south by the Columbia River, on the east by the Okanogan-Ferry county line, and on the north by the line between Tps. 34 and 35 N. of the Willamette base line. The principal town within the reservation is Nespelem. From Nespelem good roads extend to the northwest (State Highway 10A) to Omak, to the south (State Highway 10A) to Coulee Dam, to the north to West Fork, and to the east to State Highway 4 in the Sanpoil valley. The closest railroad is the Great Northern Railway in the Okanogan River valley.

The geology of the Colville Indian Reservation is described by Pardee (1918). The limestones of the reservation are part of a series of sedimentary and volcanic rocks that Pardee (1918, p. 20) calls the Covada Group. For a complete discussion of the Covada Group, the reader is referred to Pardee's report. For a summary of the geology of the Covada Group, the reader is referred to this report, page 181.

Pardee shows two large areas of outcrop of the Covada Group in the west half of the Colville Indian Reservation. One of these extends north from Park City (sec. 11, T. 33 N., R. 31 E.) to the northern boundary of the reservation. The other is approximately 6 miles southwest of Park City. Most of the outcrops of the Covada Group in both of these areas are within the U.S. Geological Survey Bald Knob 15-minute quadrangle, the geological mapping of which was completed in 1960 by M. H. Staatz of the U.S. Geological Survey. Mr. Staatz (1960, written communication) kindly supplied the writer with the following geological information gained during his mapping of the Bald Knob quadrangle.

> Not counting glacial deposits, about half of this quadrangle is underlain by volcanic rocks, about a quarter by quartz monzonite, and a quarter by sedimentary rocks. The sedimentary rocks are mainly clastics with thick sequences of phyllite, shale, graywacke, and quartzite. The age is not known but it is most likely late Paleozoic or early Mesozoic. In some areas thin limestone layers and lenses are found. These are small in size and generally impure, containing quartz, biotite, tremolite, or graphite.

Staatz also supplied the following information concerning the principal limestone localities in the Bald Knob quadrangle and their composition:

Locality 1.—East side of the West Fork of the Sanpoil River at about 2,700 feet elevation, in the NW$\frac{1}{4}$ sec. 36, T. 35 N., R. 31 E. Limestone breccia band trends NNW for 1,500 feet and is about 100 feet thick. Limestone breccia contains fragments of phyllite and quartzite in a calcite matrix. Small grains of biotite and graphite scattered through rock. Limestone breccia is a lens in a thick phyllitic quartzite unit.

Locality 2.—On ridge top in the NE$\frac{1}{4}$ sec. 12, T. 33 N., R. 31 E. A band of limestone about 100 feet wide and 800 feet long is found in a black shale unit. The limestone is cut off on its north and east sides by quartz monzonite; it is covered on its south end by quartz latite flows. Limestone is impure and has been altered by contact metamorphism.

Locality 3.—Northeast side of North Star Creek along east border of sec. 36, T. 33 N., R. 30 E. North-trending band of limestone 2,500 feet long and 200 to 300 feet thick. Quartz is the chief impurity, generally in amounts less than 1 percent, but locally as much as 20 percent. Tremolite found in some places. Limestone is in a second black shale unit.

Locality 4.—Northeast side of North Star Creek, in the SE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 6, T. 32 N., R. 31 E. Band of limestone about 2,000 feet long and several hundred feet thick on the north side of a major fault. Limestone is in part brecciated. This is the same bed as is described for locality 3.

Locality 5.—Narrow north-northeast-trending band, starting in the SE$\frac{1}{4}$SE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 12, T. 32 N., R. 30 E., and trending southward for about 7,000 feet to the SW$\frac{1}{4}$ sec. 18, T. 32 N., R. 32 E. This band of limestone has been offset by several faults. It is brecciated in places and in these areas it is commonly a fetid dolomite. This limestone unit is the same bed as is described for localities 3 and 4.

From Staatz's descriptions of the limestone, it is quite clear that the rock is much too impure to be of value for most uses.

Nespelem Area

Carbonate rock outcrops are numerous in the SW$\frac{1}{4}$ sec. 18, T. 31 N., R. 31 E., on a low hill alongside the Park City road about 1$\frac{1}{4}$ miles north of Nespelem. Pardee (1918, p. 178) reports "an undeveloped outcrop that yields specimens of handsome white and gray marble."

All outcrops on the hill were examined and found to be composed of sparkling white (90 percent) to light-gray (10 percent) coarse-grained massive pure dolomite marble.

Riverside District

The Riverside district of western Okanogan County extends from 1 to 7 miles west of Riverside and from 4 to 13 miles north-northwest of Omak. Riverside and Omak are towns on U.S. Highway 97 and the Great Northern Railway, in the valley of the Okanogan River, approximately 150 miles north of Wenatchee and 45 miles south of the International Boundary. The district includes most or all of secs. 3, 4, and 5, T. 34 N., R. 26 E.; secs. 3 to 10, 14 to 23, and 26 to 35, T. 35 N., R. 26 E.; secs. 28

to 33, T. 36 N., R. 26 E.; secs. 1, 2, 11, 12, and 13, T. 35 N., R. 25 E.; and secs. 35 and 36, T. 36 N., R. 35 E.

The Riverside district is underlain by a great complex of carbonate and non-carbonate rocks. The carbonate rocks are limestone, dolomite, and marbles. The non-carbonate rocks include the clastic sedimentary rocks conglomerate, sandstone, and argillite, and the metamorphic rocks quartzite, phyllite, schist, amphibolite, and gneiss. The ages of these rocks are not firmly established. According to Bennett (1944, p. 10), "the oldest rocks that lie within the area of the dolomite deposits include sheared conglomeratic quartzite and slates or phyllites which are clearly unconformable beneath the dolomite, limestone, and other rocks making up the carbonate succession." The older rocks belong to the middle Anarchist Series and are Carboniferous, probably Permian, in age, according to Waters and Krauskopf (1941, p. 1364). The younger carbonate series is regarded by them to be of Triassic age. The relationship of the carbonate to the non-carbonate rocks is interpreted quite differently by Misch (1949, p. 673), for he writes,

> The lower part of the column consists of dolomites and limestones, most of which have been altered to banded marbles. They conformably underlie rocks equivalent to parts of the "Anarchist series" established by R. A. Daly (1912) near the border and extended to the south by A. C. Waters and K. Krauskopf (1941). Fossils locally preserved in the limestone indicate a Paleozoic and, according to a preliminary examination by H. E. Wheeler, probable Devonian, age. The upper part of the column consists chiefly of thick argillites altered to phyllites and biotite-schists, with actinolite-tremolite-schists and granulites in their lower part. Most of these latter were derived from impure dolomitic sediments, and grade laterally into amphibolites.

Misch (1949, p. 686) reports that the sedimentary and metamorphic rocks have been intensely folded. The general trend of the bedding is southeast-northwest. The rocks have been intruded by peridotite and by granite. Misch (1949, p. 688) believes that most of the granite is the product of replacement (granitization) rather than intrusion. He mentions that granitized areas covering hundreds of square miles occur to the west and southwest, and that these contain relict zones of metamorphic rocks in which the predominantly northwesterly regional orogenic trend has been left undisturbed.

The limestone-dolomite series is many thousands of feet thick and is described by Bennett (1949, p. 10) as follows:

> The carbonate succession is composed predominantly of white and gray limestone, dolomitic limestone, and dolomite with subordinate shaly limestone, sandstone, pebble conglomerate, calcareous quartzite, and calcareous siltstone . . . .
>
> The main body of true dolomite seems to form a stratigraphic zone more than 500 feet thick at or near the base of the limestone-dolomite series, extending from sec. 36 northeastward into sec. 3 (35-26E). However, toward the north its continuity is made less definite by folding, faulting, and lateral gradation into both sandy and limy phases. Minor amounts of dolomite probably occur in various stratigraphic zones throughout the series, though on the west there seems to be a predominance of limestone.
>
> The dolomite is mostly white to gray, fine grained, thick bedded to massive, and occasionally contains thin interbeds of buff limy dolomite. In places it contains sand or silt, and thin veinlets of cherty quartz which seem to occur only in the dolomite and not in the overlying gray limestone. In the vicinity of Alkali Lake where the dolomite shows a thick sequence of beds it is overlain by gray limestone.

During the present study 10 days were spend traversing and studying the outcrops of the carbonate rock series over an area of approximately 27 square miles. Most of the carbonate rock was found to be dolomite, both white dolomite that weathers to a pale-yellow color and a dark-gray dolomite that weathers to a gray color. White and gray limestones are interbedded with the respective white and gray dolomites, but these limestones, especially the gray ones, are generally dolomitic and commonly siliceous. Geologic mapping on enlargements of vertical aerial photographs and sampling were confined to the areas containing large amounts of limestone. These areas are the Dunn Mountain area in the northwestern part of the district, the Frye Lake area in the southeastern part of the district, and the Johnson Creek area in the southern part of the district. Only the Dunn Mountain area has limestone suitable for cement manufacture. None of the Riverside district contains high-calcium limestone.

Dunn Mountain Area

Location and accessibility.—The Dunn Mountain area is in secs. 1 and 12, T. 35 N., R. 25 E., and the W$\frac{1}{2}$ secs. 6 and 7, T. 35 N., R. 26 E., on the southeast side of Dunn Mountain. It is reached by driving north from Omak for 9 miles to the NE$\frac{1}{4}$ sec. 25, T. 35 N., R. 25 E., where the Blue Lake road branches north from the Johnson Creek road. The Blue Lake road is followed for a distance of 9 miles to the center of the area.

Geology.—The area (fig. 61) is underlain by complexly folded and faulted white and gray dolomite and limestone, dark-gray siliceous dolomite and limestone, quartzite, and amphibolite. Granite in the northwestern part of the area is part of an extensive body making up most of Dunn Mountain.

Quality and quantity of limestone.—Twenty-four samples were taken on what appeared to be the purest limestone; 16 are of white to light-gray limestone interbedded with white dolomite, and 8 are of dark-gray siliceous limestone interbedded with dark-gray dolomite.

Seven samples (O-3, O-4, O-50 to O-52, O-62, and O-63) were taken of white to light-gray, medium-grained limestone from three outcrops (fig. 61) in the SE$\frac{1}{4}$ sec. 1, T. 35 N., R. 25 E. The outcrops are on property owned by W. G. Scholz, of Riverside. Samples O-3 and O-4 were taken for lengths of 50 feet and 85 feet in a direction S. 50° E. across limestone beds striking N. 25° E. and dipping 27° NW. The samples represent true thicknesses of approximately 38 feet and 52 feet, respectively. The interval between the samples is covered, but it can be assumed reasonably that the samples are representative of a total thickness (including the covered interval) of 150 feet of limestone. Samples O-62 and O-63 were taken 60 feet apart on the same outcrop as O-3 and O-4. They were taken horizontally at right angles to the strike of the bedding for lengths of 50 feet and 55 feet, respectively. The bedding strikes N. 20° E. and dips 40° W. The true thicknesses represented by samples O-62 and O-63 are 32 feet and 35 feet, respectively. Three samples, O-50 to O-52, were taken (fig. 61) of light-gray to white, medium-grained limestone striking due north and dipping 60° to the

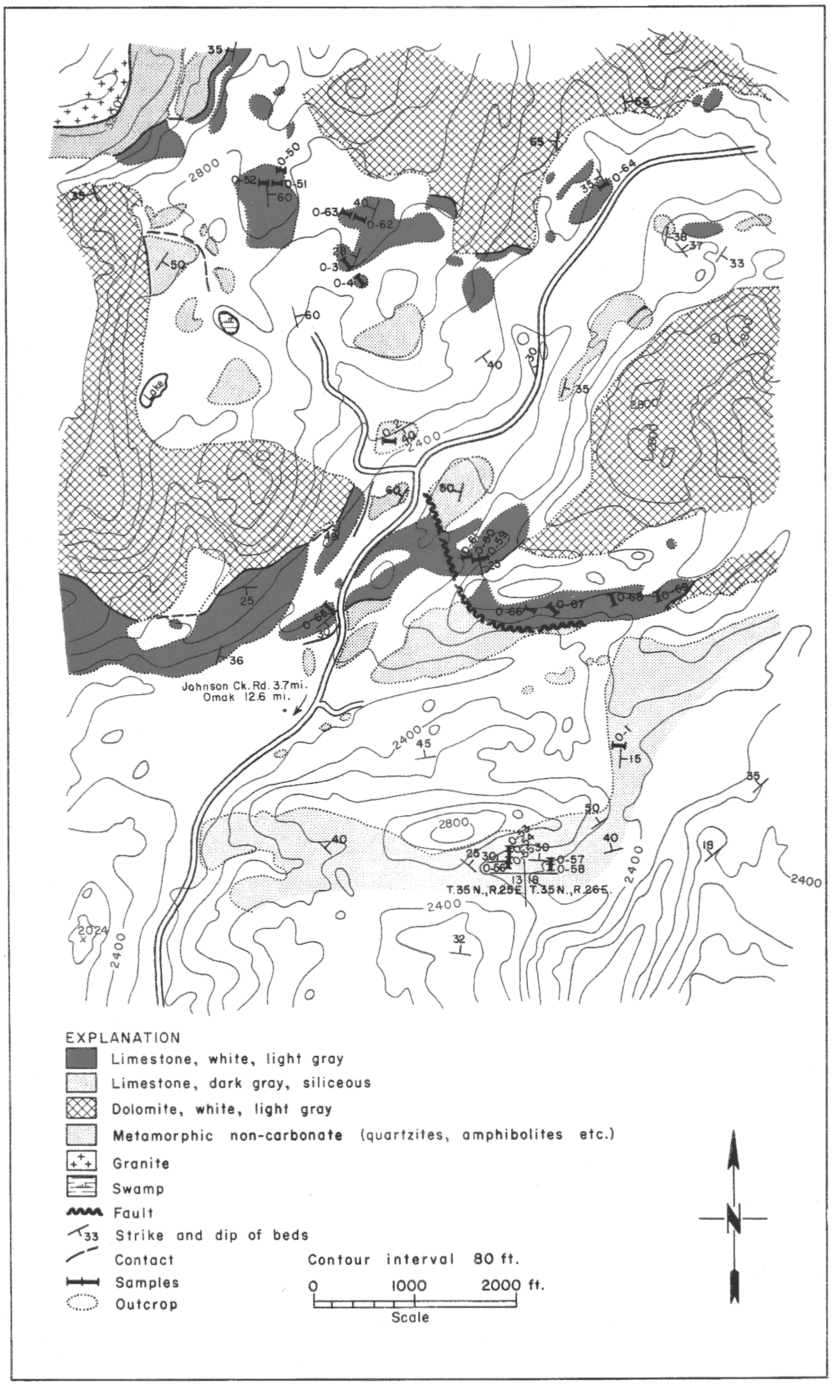

FIGURE 61.—Dunn Mountain area. Secs. 1, 2, and 13, T. 35 N., R. 25 E., and secs. 6, 7, and 18, T. 35 N., R. 26 E. Geology by C. E. Stearns and R. D. Boettcher. Base map from aerial photo enlargement. Topography from U.S. Geological Survey Conconully quadrangle map.

east. The sample lengths of 60 feet, 55 feet, and 50 feet are representative of true thicknesses of 52 feet, 48 feet, and 43 feet, respectively. According to the strikes and dips of the bedding, it appears that samples O-50 to O-52 and samples O-3, O-4, O-62, and O-63 were taken of the same limestone on opposite limbs of a small north-trending syncline. The analyses of these samples are as follows:

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)
O-3	50	38	92.67	1.61	41.77	52.06	0.77	4.43	1.06	0.105	270	700	310	390
O-4	85	52	88.18	1.76	39.78	49.54	0.84	8.75	1.25	0.154				
O-62	50	32	92.13	1.25	41.11	51.76	0.60	5.45	0.61	0.094				
O-63	55	35	90.00	2.24	41.10	50.56	1.07	5.66	0.99	0.118				
O-50	60	52	70.63	3.26	31.91	39.68	1.56	23.86	2.62	0.082				
O-51	55	48	95.32	1.48	42.60	53.55	0.71	2.09	0.70	0.076				
O-52	50	43	94.25	1.78	42.33	52.95	0.85	2.64	0.84	0.064				

The unweighted average of these analyses of white limestone is 50.01 percent CaO, 0.91 percent MgO, 7.56 percent SiO_2, 1.15 percent R_2O_3, and 0.099 percent P_2O_5. The analyses show that the limestone sampled in the SE¼ sec. 1, T. 35 N., R. 25 E. contains too little lime (CaO 50.01 percent, $CaCO_3$ 89 percent) to qualify as a high-calcium limestone. However, the rock is quite suitable for making portland cement. At least 4 million tons of limestone of this quality is available above the level of the surrounding alluvium.

Sample O-64 was taken on the northeast steep slope of an elongate hill of white medium-grained limestone in the SW¼SW¼ sec. 6, T. 35 N., R. 26 E. The hill is adjacent to the Blue Creek road (fig. 61) on property owned by W. G. Scholz, of Riverside. Bedding in the limestone strikes N. 20° E. and dips 40° W. The sample length of 75 feet represents a true thickness of 72 feet of limestone. The analysis of sample O-64 follows:

Sample no.	True thickness (feet)	Length (feet)	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
O-64	72	75	89.98	2.55	40.97	50.55	1.22	5.10	1.43	0.114

The analysis shows the composition of the limestone to be almost identical with the limestone in sec. 1, half a mile to the west. It is not a high-calcium limestone, but it is quite suitable for the manufacture of portland cement.

Samples O-59 to O-61 and O-66 to O-69 were taken over an extensive outcrop of white coarse-grained limestone in the SE¼NE¼ sec. 12, T. 35 N., R. 25 E. and the NW¼SW¼ sec. 7, T. 35 N., R. 26 E. (fig. 61). The property is owned by T. J. McCain, of Omak. Samples O-59 to O-61 were taken contiguously over lengths of 80 feet, 75 feet, and 100 feet; they are representative of true thicknesses of 34 feet, 32 feet, and 42 feet of limestone, respectively, or a total true thickness of 108 feet. Bedding in this coarse-grained limestone strikes N. 15° W. and dips 25° E. in the vicinity of samples O-59 to O-61, but in the area to the east, where samples O-66 to O-69 were taken, no bedding was recognized. Samples O-66 to O-69 were taken in directions approximately at right angles to the long dimension of the outcrop for lengths of 80 feet, 90 feet, 85 feet, and 50 feet horizontally. The analyses of these samples are as follows:

Sample no.	True thickness (feet)	Length (feet)	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
O-59	34	80	92.52	2.17	41.59	51.98	1.04	4.26	0.79	0.094
O-60	32	75	94.39	1.63	42.60	53.03	0.78	2.27	0.73	0.086
O-61	42	100	93.79	2.36	41.98	52.69	1.13	3.59	0.55	0.052
O-66	—	80	93.45	2.68	42.33	52.50	1.28	2.98	0.79	0.075
O-67	—	90	94.52	1.53	42.31	53.10	0.73	2.83	0.68	0.070
O-68	—	85	91.72	1.92	41.25	51.53	0.92	3.89	1.56	0.116
O-69	—	50	93.33	1.71	41.98	52.43	0.82	3.40	0.74	0.064

The average composition of the limestone is 52.47 percent CaO (93.40 percent $CaCO_3$), 0.96 percent MgO, 3.32 percent SiO_2, 0.83 percent R_2O_3, and 0.080 percent P_2O_5. It is quite similar to, but somewhat purer than, the white limestone 1 mile to the northwest (O-50 to O-52). Although samples O-59 to O-61 and O-66 to O-69 are of the purest limestone found in the Riverside district during this study, the rock is not a high-calcium limestone. However, it is quite suitable for the manufacture of portland cement. There is at least 12 million tons of white limestone available above the elevation of the Blue Lake road in the area represented by the sampling.

Sample O-65 was taken across the northeast end of a limestone outcrop on the west side of the Blue Lake road in the SW¼NE¼ sec. 12, T. 35 N., R. 25 E. (fig. 61). The property is owned by T. J. McCain, of Omak. The rock is a white coarse-grained limestone. Bedding strikes N. 45° E. and dips 30° SE. Sample O-65 was taken (horizontally) in a direction N. 45° W. for a length of 75 feet. It is representative of a true thickness of 37 feet of limestone. The analysis of O-65 is as follows:

Sample no.	True thickness (feet)	Length (feet)	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
O-65	37	75	92.65	2.36	41.54	52.05	1.13	3.97	0.68	0.082

The analysis shows the limestone to be very similar in composition to the white limestone sampled elsewhere in the Dunn Mountain area. It is not a high-calcium limestone, but it is quite suitable for the manufacture of portland cement.

The rest of the sampling in the Dunn Mountain area was of a different rock unit, a dark-gray, fine- to medium-grained siliceous limestone. Field examination demonstrated that this rock is too impure to be classed as a high-calcium limestone; consequently, sampling was limited to 8 samples. Seven of these (O-1 and O-53 to O-58) were taken in the SE¼SE¼ sec. 12, T. 35 N., R. 25 E. and the SW¼ sec. 7, T. 35 N., R. 26 E., (fig. 61) on the northern border of an extensive area of outcrop. The property is owned by T. J. McCain, of Omak. In the vicinity of samples O-53 to O-58 the bedding in the limestone strikes east-west and dips 30° N., on the average. The bedding strikes north and dips 15° E. where sample O-1 was taken. Sample O-2 was taken on a small outcrop in the NE¼NE¼ sec. 12, T. 35 N., R. 25 E. (fig. 61) on property owned by W. G. Scholz, of Riverside. The bedding of the limestone in the vicinity of sample O-2 strikes N. 5° E. and dips 40° SE. The analyses of samples O-1, O-2, and O-53 to O-58 are tabulated below, together with the lengths of samples and the (calculated) true thicknesses of limestone represented by each sample.

Sample no.	True thickness (feet)	Length (feet)	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
O-1	38	100	79.39	3.76	36.23	44.60	1.80	14.92	1.96	0.246
O-2	18	100	77.06	3.72	35.56	43.29	1.78	16.78	2.48	0.344
O-53	43	50	73.30	4.18	33.63	41.18	2.00	19.83	2.72	0.098
O-54	43	50	80.24	2.82	36.90	45.08	1.35	14.17	1.82	0.056
O-55	43	50	75.83	1.86	34.69	42.60	0.89	19.12	2.22	0.056
O-56	43	50	74.96	1.69	33.66	42.11	0.81	22.30	1.38	0.061
O-57	43	50	67.28	2.26	30.42	37.80	1.08	27.29	3.23	0.116
O-58	43	50	92.26	2.61	41.67	51.83	1.25	3.76	0.79	0.085

The average of the analyses is: 43.56 percent CaO (77.54 percent $CaCO_3$), 1.37 percent MgO, 17.27 percent SiO_2, 1.76 percent R_2O_3, and 0.108 percent P_2O_5. The analyses show the rock to be a very impure siliceous limestone quite unsuitable for most uses, including portland cement making.

Frye Lake Area

Location, accessbility, and ownership.—The Frye Lake area lies 1 mile northwest of Riverside. The area is reached easily from U.S. Highway 97 at Riverside by driving west for 0.8 mile on the Johnson Creek road to the Frye Lake road, thence north on this road for approximately 1 mile. Limestone outcrops are on the east side of the Frye Lake road (fig. 62), in the NE¼NW¼ sec. 26 and the NW¼NE¼ sec. 26, T. 35 N., R. 26 E., on property owned by N. W. L. Brown, of Sumas, Washington. The same limestone continues to crop out for 1½ miles to the northwest, but it was examined closely only in the area east of Frye Lake, illustrated in figure 62.

Geology and quality of limestone.—The outcrops on the east side of the Frye Lake road are composed of gray, fine-grained, siliceous and argillaceous limestone. The weathered surface is gray with brownish streaks and patches where the argillaceous impurities are abundant. Bedding strikes are northwesterly. Dips are to the southwest on the east side of the outcrop and to the northeast on the west side of the outcrop. The outcrop lies along the axis of a syncline. To the west and south the limestone is underlain by dolomite (fig. 62). Five samples were taken of the limestone, 2 (O-72 and O-73) on the east side and 3 (O-70, O-71, and O-74) on the west side of the outcrop. They were taken at right angles to the strike of the bedding. The analyses of these samples, their lengths, and the true thicknesses represented by each sample, are as follows:

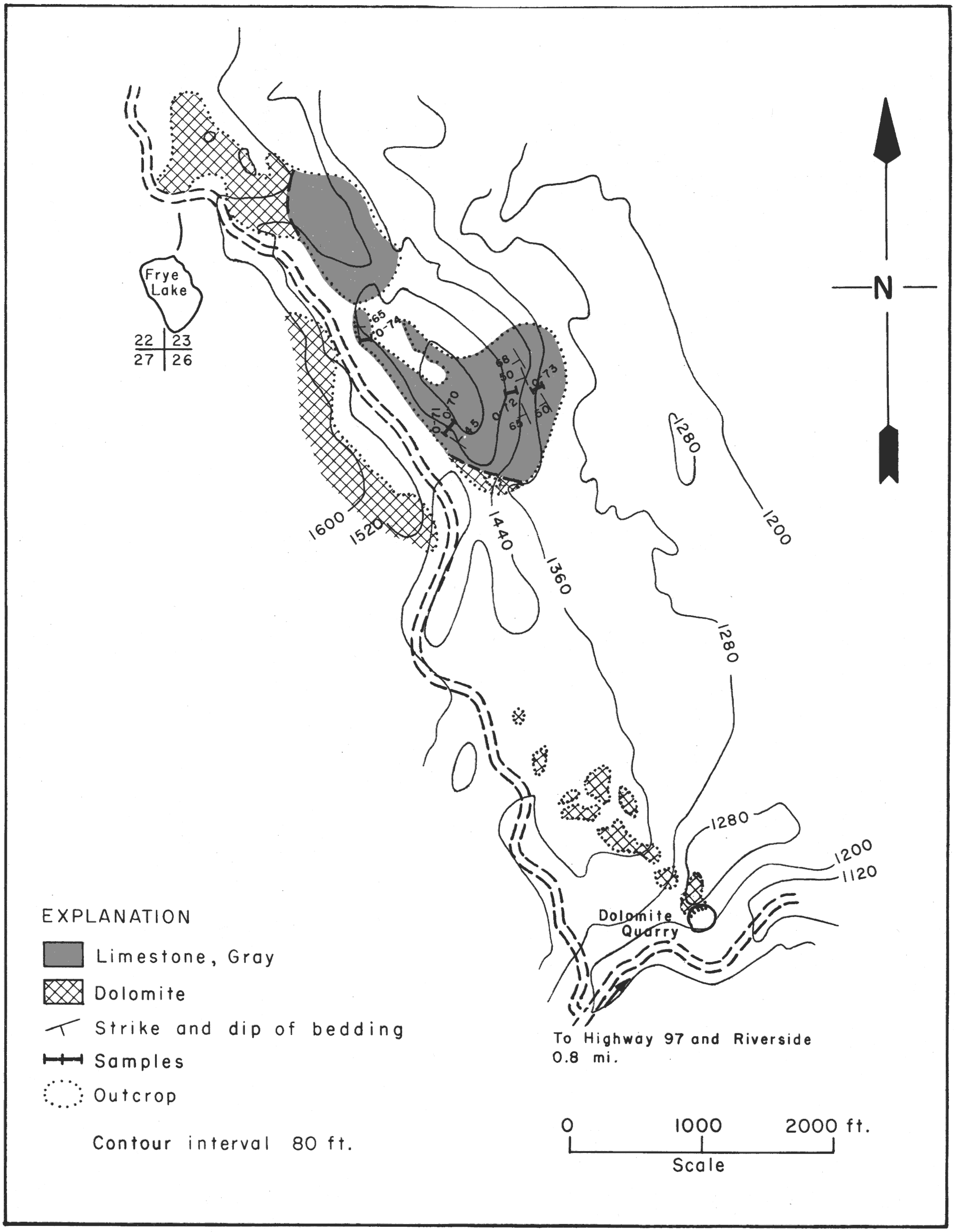

FIGURE 62.—Frye Lake area. Secs. 23 and 26, T. 35 N., R. 26 E. Geology by C. E. Stearns and R. D. Boettcher. Base map from aerial photo enlargement. Topography from U.S. Geological Survey Conconully quadrangle map.

Sample no.	True thickness (feet)	Length (feet)	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
O-70	48	50	75.17	2.19	33.63	42.23	1.05	18.55	4.33	0.090
O-71	50	50	73.43	3.14	32.98	41.25	1.50	19.83	3.93	0.098
O-72	75	75	61.23	1.92	26.09	34.40	0.92	32.30	6.29	0.074
O-73	58	60	52.88	2.09	23.36	29.71	1.00	39.27	6.27	0.064
O-74	70	70	54.34	11.12	28.72	30.53	5.32	29.40	5.48	0.096

The unweighted average composition of this limestone is 35.62 percent CaO (62.80 percent $CaCO_3$), 1.96 percent MgO, 27.87 percent SiO_2, 5.26 percent R_2O_3, and 0.084 percent P_2O_5. The limestone is much too impure to be of any value for most uses.

Johnson Creek Road Area

Limestone crops out in a field on the west side of the Johnson Creek road in the NE$\frac{1}{4}$ sec. 4, T. 34 N., R. 26 E., approximately 4 miles southwest of Riverside. It forms a strip at least 300 feet wide and 1,000 feet long between the road and a hill of dolomite to the west. All outcrops east of the road are dolomite.

The limestone is gray to dark gray, fine to medium grained, and well bedded. Bedding strikes N. 16° E. and dips 38° E. One sample, O-5, was taken at right angles to the strike of the beds in two outcrops 30 feet wide separated by a covered interval 40 feet wide. The two sample lengths total 60 feet (34 feet true thickness). The sample is probably representative of the entire width of 100 feet (true thickness 57 feet), including the covered interval. The analysis of this sample is as follows:

Sample no.	True thickness (feet)	Length (feet)	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
O-5	34	60	77.22	4.41	36.46	43.38	2.11	17.35	0.65	0.105

The limestone is physically and chemically similar to the gray siliceous limestone in the Dunn Mountain area, Riverside district. It is very impure and is of no use for most purposes.

ASOTIN COUNTY

Lime Hill Area

Location, accessibility, and ownership.—Lime Hill is in the southeast corner of Washington, approximately 25 miles south of Clarkston, Washington, and 1 mile southeast of the confluence of the Grande Ronde

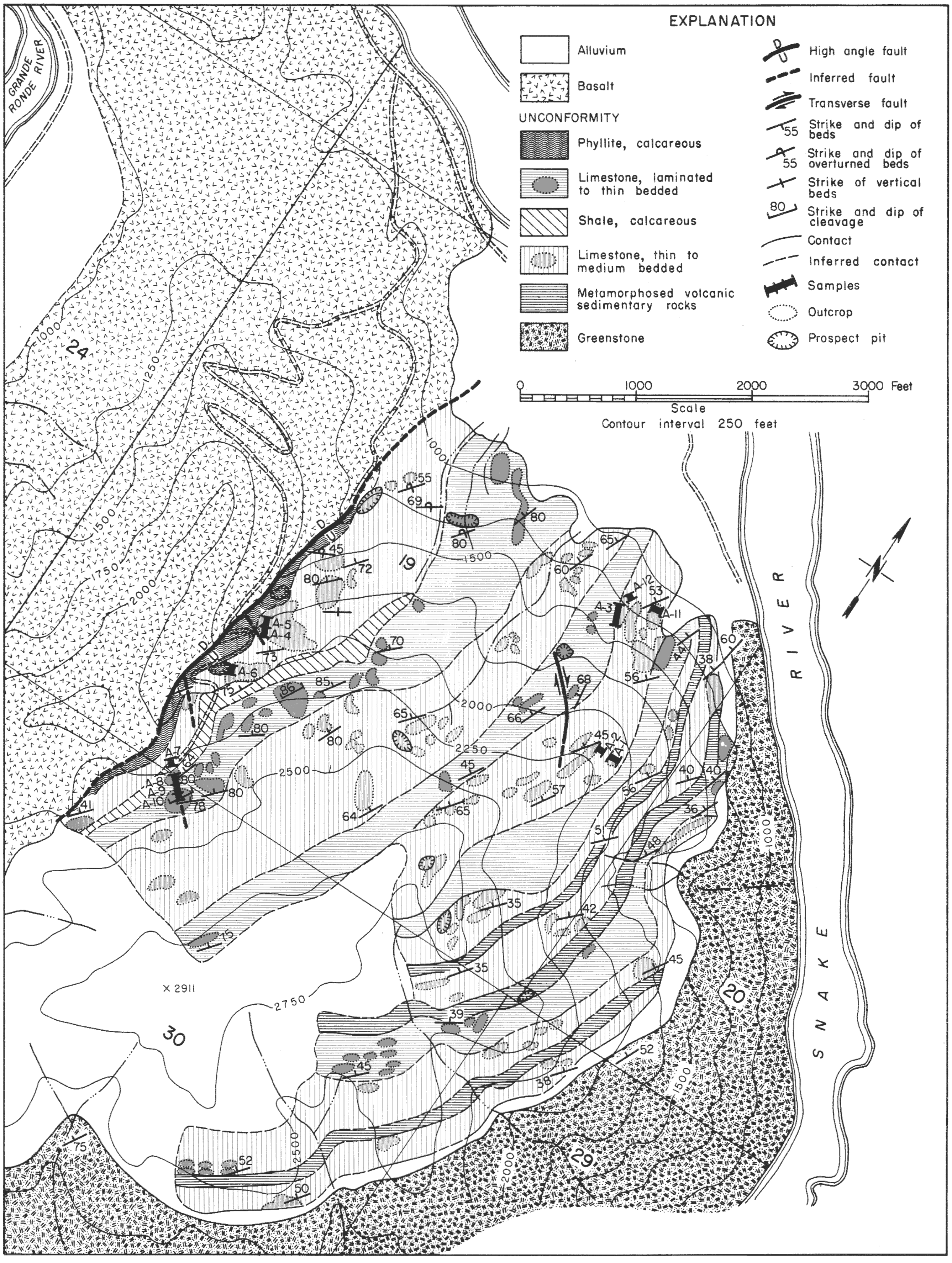

FIGURE 63.—Geologic map of Lime Hill area. Geology modified from map of geology of the Lime Hill area, Asotin County, by R. D. Shumway, 1960.

and Snake Rivers. The hill occupies most of secs. 19 and 30, and the SW$\frac{1}{4}$ sec. 20, and the NW$\frac{1}{4}$ sec. 29, T. 7 N., R. 47 E. (fig. 63). Lime Hill is reached from Clarkston by driving south on State Highway 3 to Asotin, then south along a county road on the west side of the Snake River to the mouth of the Grande Ronde River, 32 miles from Clarkston. The Grande Ronde River can be crossed on a bridge 2 miles above its mouth; a private road follows the south bank of the river downstream to the former site of Rogersburg, within half a mile of Lime Hill. Most of the limestone exposed on Lime Hill is on property owned by the Ideal Cement Company, of Fort Collins, Colorado. Property at the summit and around the base of the hill is owned by Jidge Tippett, of Joseph, Oregon.

History.—The first mention of limestone on Lime Hill was made by Russell (1897). Shedd (1913, p. 114-116) discusses the geology of the area in detail and reports (p. 118) several analyses of the limestone. Hodge (1938, p. 130) reports the analyses of three samples of limestone from the area. Gullixon (1954) reports the analyses of limestone samples taken by the U.S. Army Corps of Engineers. Between 1954 and 1959 the Ideal Cement Company acquired approximately 90 percent of the area of Lime Hill known to be underlain by limestone. This company carried out a considerable amount of exploration and development, including surveying, trenching, and diamond drilling; however, none of this information is to be published. The most recent and complete study of the geology of Lime Hill is the one by Shumway (1960). Most of the information in the following discussion, excluding the analyses of samples taken during the present study, has been abstracted from Shumway's report.

Geology.—Lime Hill is underlain by three series of rocks (fig. 63). The oldest rocks are a series of metamorphosed porphyritic andesites and associated pyroclastic rocks, of Permian or Triassic age (Shumway, 1960, p. 23), cropping out on the lower slopes of the east side of Lime Hill. Their minimum thickness is 3,000 feet. Conformably overlying the volcanic rocks is a series of sedimentary rocks, probably of late Triassic age (Shumway, 1960, p. 24). The principal sedimentary rocks are limestone

FIGURE 64.-Lime Hill, Asotin County, Washington, looking southwest. Volcanic rock series, lower left; white outcrops are limestone; Columbia River basalts, upper right. Photo by R. Shumway.

and argillaceous limestone, with interbeds of conglomerate, argillite, and chlorite schist toward the base of the series and interbeds of shale and phyllite toward the top of the series. Shumway (1960, p. 24) estimates the thickness of the sedimentary rock series to be 3,480 feet. The average strike of the sedimentary and volcanic rocks is N. 32° E. and the average dip is 60° NW. Toward the west side of the hill, dips are steep to overturned. The area lies on the northwest limb of a large anticline plunging at approximately 20° in a direction N. 27° E. (Shumway, 1960, p. 36). To the west of the sedimentary rock series, and separated from it by a high-angle fault (fig. 63), is a great series of basalt flows that Shumway (1960, p. 43) correlates with the Columbia River Basalt of Miocene age. The basalts in the area have flat or very gentle dips and a thickness of at least 2,500 feet near the mouth of the Grande Ronde River.

Quality and quantity of limestone.—Shumway (1960, p. 25 - 28) describes 11 mappable limestone units within the sedimentary rock series. The units range in thickness from 38 to 700 feet. Their aggregate thickness is 3,143 feet, or 90 percent of the thickness of the entire sedimentary rock series. The limestone units range in color from light gray to gray, and in texture from cryptocrystalline to fine grained. Bedding thickness ranges from 1/16 inch to 4 feet. All the limestone units contain numerous tiny fractures healed with calcite. Most units are siliceous and (or) slightly argillaceous.

Shedd (1913, p. 118) reports the analyses of three samples of limestone from Lime Hill as follows:

Sample no.	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
I	38.18	48.33	0.79	9.82	2.24	——
II	39.93	51.07	0.78	5.98	2.04	——
III	39.60	50.06	0.68	6.10	2.16	——
IV	40.20	49.99	0.65	5.48	3.50	——

I - West side of hill, near contact of basalt and limestone.
II - Partially decomposed limestone.
III - From near summit of hill.
IV - Weathered limestone from west side of hill.

Hodge (1938, p. 131) reports the following analyses of three samples, one of which was taken of the extension of the Lime Hill deposits on the Idaho side of the Snake River:

Sample no.	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
I	89.25	——	——	50.06	0.68	6.10	2.16	——
II	98.05	0.48	——	54.91	0.23	0.66	0.54	——
III	98.59	——	——	——	0.17	0.48	trace	——

I - Typical analysis.
II - Typical analysis of limestone on the Idaho side of the Snake River.
III - A composite of 121 samples analyzed by the Bureau of Standards.

Table 8 summarizes the results of the chemical analyses of samples of limestone taken from Lime Hill by the U.S. Army Corps of Engineers. The table is reproduced from the report of Shumway (1960, p. 50); the original table was reported by Gullixon (1954).

TABLE 8.—Chemical analyses of samples [1] of limestone from Lime Hill [2]

Constituents	Lime Hill No. 1	Lime Hill No. 2	Lime Hill No. 4	Lime Hill No. 5	Lime Hill No. 6	Lime Hill No. 7
SiO_2	0.65	0.51	16.01	6.23	3.35	0.55
Fe_2O_3	0.26	0.25	0.85	1.46	0.86	0.59
Al_2O_3	0.31	0.07	1.98	1.09	0.22	0.05
CaO	54.52	52.05	43.83	49.95	52.40	54.56
MgO	0.54	2.88	1.11	0.20	0.08	0.08
S	0.047	0.045	0.102	0.029	0.071	0.030
P_2O_5	0.020	0.005	0.117	0.025	0.014	0.027
CO_2	43.22	43.87	34.59	39.44	41.76	43.33
Mn	0.02	0.03	0.02	0.03	0.01	0.04
H_2O+	0.07	0.07	0.23	0.03	0.12	0.07
Insol.	1.71	1.16	16.89	0.62	0.45	0.08
Loss on ignition	42.99	43.78	35.20	39.74	41.86	43.32
$CaCO_3$	97.33	92.92	78.24	89.17	93.55	97.40

(1) Samples taken on a traverse west across the structure at an elevation of approximately 1,250 feet.

(2) Source: Gullixon (1954, p. 12).

During the present study 12 samples (A-1 to A-12) were taken on Lime Hill (fig. 63). Samples A-1 to A-3, A-11, and A-12 were taken of a limestone unit lying 1,113 to 1,463 feet stratigraphically above the base of the sedimentary series. Samples A-4 to A-7 were taken of the uppermost limestone unit, and A-8 to A-10 were taken of the next lower limestone unit. These three units were chosen for sampling because they appeared to be somewhat less impure than other limestone units and because their outcrops were larger and more numerous. The analyses of samples A-1 to A-12 follow:

Sample no.	True thickness (feet)	Length (feet)	$CaCO_3$	$MgCO_3$	Loss on Ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5
A-1	60	100	83.84	2.30	41.50	47.10	1.10	4.60	1.85	0.017
A-2	48	84	82.24	2.09	41.52	46.20	1.00	4.53	1.70	0.014
A-3	34	—	87.13	4.33	42.81	48.95	2.07	2.31	1.00	0.017
A-4	54	—	83.31	0.65	42.43	49.61	0.31	2.68	0.91	0.025
A-5	57	—	90.98	1.42	42.68	51.11	0.68	2.10	0.81	0.025
A-6	50	90	72.29	1.05	33.92	40.61	0.50	21.68	1.75	0.045
A-7	66	70	89.53	1.42	42.81	50.30	0.68	2.63	0.84	0.018
A-8	70	80	86.92	1.48	41.12	48.83	0.71	5.53	1.51	0.030
A-9	74	84	87.97	1.27	41.34	49.42	0.61	4.51	1.64	0.014
A-10	60	69	85.62	1.94	43.10	48.10	0.93	2.73	1.12	0.043
A-11	70	110	79.23	7.75	40.67	44.51	3.71	7.95	1.88	0.050
A-12	27	41	84.03	1.07	41.82	47.21	0.51	5.93	1.00	0.031
Average						47.66	1.07	5.60		

The analyses of samples taken during this study show a much higher content of impurities than do those of Gullixon (1954, p. 12) and Hodge's no. II composite sample, but they are in fairly close accord with those reported by Shedd (1913, p. 118) and the first sample (I) reported by Hodge (1938, p. 131). That the limestone is much more impure than Gullixon (1954) reports is further substantiated by John A. Wolfe (1959, written communication) of the Ideal Cement Company, who reports that it is far from the simple, clean-cut, high-quality calcium carbonate indicated in information published by the U.S. Army Corps of Engineers. The analyses of samples A-1 to A-12 show that the average composition of the limestone unit low in the section (A-1 to A-3, A-11, and A-12) is 46.80 percent CaO, 83.3 percent $CaCO_3$, 1.68 percent MgO, 5.06 percent SiO_2, 1.49 percent R_2O_3, and 0.026 percent P_2O_5. The average composition of the samples of the upper limestone units (A-4 to A-10) is 48.28 percent CaO, 85.9 percent $CaCO_3$, 0.63 percent MgO, 5.98 percent SiO_2, 1.23 percent R_2O_3, and 0.029 percent P_2O_5. None of the rock can be classified as a high-calcium limestone. All of the limestone is well suited to the manufacture of portland cement, although the limestone near the top of the section is most suitable because of its lower content of MgO.

The amount of limestone above an altitude of 1,000 feet in the upper 2 limestone units on the west side of Lime Hill is of the order of 90 million tons; in the lower unit on the east side of the hill it is 130 million tons. It is quite likely that much of the rest of the limestone on Lime Hill is suitable for cement manufacture also. Shumway (1960, p. 47) estimates that the total amount of limestone, above an altitude of 1,000 feet above sea level, is 935 million short tons.

APPENDIX A

CHEMICAL ANALYSES OF EASTERN WASHINGTON LIMESTONES

Sample no.	Location Sec. T. R.	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5	Na_2O (ppm)	K_2O (ppm)	TiO_2 (ppm)	S (ppm)
						ASOTIN COUNTY								
A-1	19 7N 47E	100	83.84	2.30	41.50	47.10	1.10	4.60	1.85	0.017				
A-2	19 7N 47E	84	82.24	2.09	41.52	46.20	1.00	4.53	1.70	0.014				
A-3	19 7N 47E	34	87.13	4.33	42.81	48.95	2.07	2.31	1.00	0.017				
A-4	19 7N 47E	54	83.31	0.65	42.43	49.61	0.31	2.68	0.91	0.025				
A-5	19 7N 47E	57	90.98	1.42	42.68	51.11	0.68	2.10	0.81	0.025				
A-6	19 7N 47E	50	72.29	1.05	33.92	40.61	0.50	21.68	1.75	0.045				
A-7	19 7N 47E	70	89.53	1.42	42.81	50.30	0.68	2.63	0.84	0.018				
A-8	30 7N 47E	83	86.92	1.48	41.12	48.83	0.71	5.53	1.51	0.030				
A-9	30 7N 47E	84	87.97	1.27	41.34	49.42	0.61	4.51	1.64	0.014				
A-10	30 7N 47E	69	85.62	1.94	43.10	48.10	0.93	2.73	1.12	0.043				
A-11	19 7N 47E	110	79.23	7.75	40.67	44.51	3.71	7.95	1.88	0.050				
A-12	19 7N 47E	41	84.03	1.07	41.82	47.21	0.51	5.93	1.00	0.031				
						FERRY COUNTY								
F-1	4 36N 32E	50	92.99	0.54	41.12	52.24	0.26	5.88	0.48	0.012				
F-2	4 36N 32E	50	93.54	0.46	41.27	52.55	0.22	5.63	0.25	0.032				
F-3	17 40N 34E	100	82.81	15.15	41.33	46.52	7.25	4.62	0.46	0.046				
F-4	17 40N 34E	100	70.65	11.64	28.09	39.69	5.57	25.50	1.35	0.071				
F-5	17 40N 34E	100	76.24	3.97	32.86	42.83	1.90	21.62	0.76	0.057				
F-6	17 40N 34E	100	60.00	5.35	26.30	33.71	2.56	35.92	1.35	0.060				
F-7	17 40N 34E	100	81.11	17.58	42.25	45.57	8.41	3.67	0.59	0.032				
F-8	17 40N 34E	100	84.73	6.96	39.78	47.60	3.33	9.22	0.38	0.042				
F-9	17 40N 34E	100	73.21	22.13	42.12	41.13	10.59	5.35	0.54	0.043				
F-10	5 37N 34E	50	95.05	0.50	41.52	53.40	0.24	4.00	0.52	0.016				
F-11	5 37N 34E	50	91.72	0.61	39.98	51.53	0.29	7.08	0.75	0.012				
F-12	5 37N 34E	50	97.76	0.63	43.42	54.92	0.30	0.59	0.45	0.019	165	590	-30	27
F-13	5 37N 34E	50	98.35	0.59	43.42	55.25	0.28	0.50	0.29	0.015				
F-14	5 37N 34E	50	96.46	0.71	42.26	54.19	0.34	2.34	0.30	0.016				
F-15	31 40N 34E	50	87.72	8.67	42.17	49.28	4.15	3.75	0.62	0.103				
F-16	31 40N 34E	44	83.13	8.44	39.75	46.70	4.04	8.09	1.32	0.061				
F-17	31 40N 34E	90	93.82	2.93	41.59	52.71	1.40	3.87	0.50	0.035				
F-18	31 40N 34E	100	92.35	4.95	42.75	51.88	2.37	2.73	0.37	0.048				
F-19	15 36N 32E	80	97.49	0.40	42.84	54.77	0.19	1.46	0.39	0.012				
F-20	4 35N 32E	50	98.24	0.29	42.98	55.19	0.14	1.19	0.47	0.060				
F-21	4 35N 32E	55	94.25	2.34	42.60	52.95	1.12	2.65	0.56	0.007				
F-22	4 35N 32E	80	90.96	5.56	40.63	51.10	2.66	5.22	1.02	0.027				
F-23	4 35N 32E	52	95.66	2.91	43.40	53.74	1.39	1.11	0.39	0.005				
F-24	9 35N 32E	50	55.77	3.30	26.77	31.33	1.58	36.05	3.87	0.173				
F-25	9 35N 32E	50	57.07	2.26	26.61	32.06	1.08	37.83	2.20	0.153				
F-26	9 35N 32E	50	52.39	4.18	25.48	29.43	2.00	39.45	3.53	0.330				
F-27	9 35N 32E	50	81.99	2.34	38.11	46.06	1.12	13.52	1.05	0.056				
F-28	9 35N 32E	50	83.73	1.92	38.34	47.04	0.92	12.51	0.99	0.051				
F-29	9 35N 32E	50	67.34	1.59	31.12	37.83	0.76	28.99	0.98	0.060				
F-30	9 35N 32E	50	77.25	2.95	36.23	43.40	1.41	18.09	0.85	0.040				
F-31	9 36N 32E	100	97.94	0.71	42.58	55.02	0.34	1.41	0.42	0.006				
F-32	9 36N 32E	40	98.49	0.54	42.41	55.33	0.26	1.15	0.42	0.008				
F-33	9 36N 32E	35	99.09	0.63	42.76	55.67	0.30	0.72	0.40	0.004	160	750	-30	26
F-34	9 36N 32E	50	89.87	0.50	38.60	50.49	0.24	9.51	1.17	0.015				
F-35	9 36N 32E	50	98.84	0.61	42.61	55.53	0.29	0.57	0.23	0.008				
F-36	9 36N 32E	40	98.45	0.52	41.98	55.31	0.25	1.86	0.27	0.013				
F-37	9 36N 32E	70	89.12	0.59	38.56	50.07	0.28	10.15	0.96	0.017				
F-38	5 35N 34E	35	93.45	3.72	42.25	52.50	1.78	2.46	0.96	0.021				

CHEMICAL ANALYSES OF EASTERN WASHINGTON LIMESTONES—Continued

Sample no.	Location Sec. T. R.	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5	Na_2O (ppm)	K_2O (ppm)	TiO_2 (ppm)	S (ppm)
						OKANOGAN COUNTY								
O-1	7 35N 26E	100	79.39	3.76	36.23	44.60	1.80	14.92	1.96	0.246				
O-2	12 35N 25E	100	77.06	3.72	35.56	43.29	1.78	16.78	2.48	0.344				
O-3	1 35N 25E	50	92.67	1.61	41.77	52.06	0.77	4.43	1.06	0.105	270	700	310	390
O-4	1 35N 25E	85	88.18	1.76	39.78	49.54	0.84	8.75	1.25	0.154	270	700	310	390
O-5	4 34N 26E	60	77.22	4.41	36.46	43.38	2.11	17.35	0.65	0.105				
O-6	13 38N 30E	10	98.77	0.29	42.34	55.49	0.14	1.56	0.23	0.006				
O-7	14 38N 30E	70	98.59	0.40	42.45	55.39	0.19	1.33	0.29	0.006				
O-8	25 38N 30E	60	91.74	0.88	40.46	51.54	0.42	7.38	0.09	0.016				
O-9	25 38N 30E	60	98.90	0.50	43.34	55.56	0.24	0.71	0.19	0.009				
O-10	25 38N 30E	100	97.33	0.84	43.15	54.68	0.40	1.35	0.28	0.012	210	750	-30	22
O-11	25 38N 30E	50	95.05	0.38	41.66	53.40	0.18	4.45	0.18	0.018				
O-12	25 38N 30E	50	98.52	0.73	43.46	55.35	0.35	0.30	0.18	0.014				
O-13	27 40N 30E	50	84.21	1.23	37.21	47.31	0.59	14.30	0.34	0.005				
O-14	27 40N 30E	50	96.78	1.32	43.07	54.37	0.63	1.51	0.33	0.006				
O-15	27 40N 30E	50	97.54	1.11	43.34	54.80	0.53	0.96	0.20	0.004				
O-16	27 40N 30E	50	98.68	0.67	43.32	55.44	0.32	0.71	0.23	0.004				
O-17	27 40N 30E	50	97.29	0.86	42.95	54.66	0.41	1.52	0.38	0.005				
O-18	27 40N 30E	40	97.06	0.84	42.80	54.53	0.40	1.97	0.22	0.007	200	720	-30	70
O-19	27 40N 30E	50	95.46	0.82	42.23	53.63	0.39	3.32	0.31	0.028				
O-20	27 40N 30E	50	87.38	0.63	38.46	49.09	0.30	11.98	0.43	0.014				
O-21	27 40N 30E	45	96.94	0.94	43.13	54.46	0.45	0.90	0.17	0.012				
O-22	27 40N 30E	80	98.56	1.07	41.14	55.37	0.51	5.70	0.40	0.028				
O-23	27 40N 30E	51	97.92	0.77	43.58	55.01	0.37	0.51	0.38	0.008				
O-24	10 39N 26E	60	98.81	0.33	43.54	55.51	0.16	0.50	0.14	0.028				
O-25	10 39N 26E	50	97.78	0.65	43.17	54.93	0.31	1.36	0.29	0.005				
O-26	10 39N 26E	50	93.90	1.63	41.98	52.75	0.78	3.73	0.87	0.010				
O-27	4 39N 26E	50	97.22	0.50	42.98	54.62	0.24	1.57	0.42	0.006				
O-28	4 39N 26E	50	98.83	0.29	42.26	55.52	0.14	1.43	0.34	0.017				
O-29	35 39N 26E	50	97.81	0.50	43.25	54.95	0.24	1.28	0.13	0.029	170	720	-30	16
O-30	35 39N 26E	50	99.09	0.48	43.42	55.67	0.23	0.29	0.34	0.019				
O-31	35 39N 26E	50	98.63	0.59	43.32	55.41	0.28	0.44	0.37	0.019				
O-32	35 39N 26E	50	98.72	0.52	43.49	55.46	0.25	0.50	0.25	0.018				
O-33	20 39N 29E	45	97.76	0.59	43.15	54.92	0.28	1.34	0.31	0.008				
O-34	20 39N 29E	40	98.95	0.54	43.43	55.59	0.26	0.42	0.16	0.005				
O-35	20 39N 29E	50	96.89	1.46	43.13	54.43	0.70	1.40	0.28	0.011				
O-36	20 39N 29E	30	94.04	0.84	41.45	52.83	0.40	4.90	0.31	0.014				
O-37	25, 26 38N 26E	50	77.84	22.78	44.57	43.73	10.90	1.29	0.49	0.014				
O-38	25, 26 38N 26E	50	92.49	6.73	43.45	51.96	3.22	1.20	0.34	0.017				
O-39	25, 26 38N 26E	50	92.99	6.75	43.91	52.24	3.23	0.34	0.38	0.021				
O-40	25, 26 38N 26E	50	93.79	1.55	41.80	52.69	0.74	3.98	0.79	0.055				
O-41	25, 26 38N 26E	50	94.59	1.25	41.94	53.14	0.60	3.45	0.86	0.075				
O-42	25, 26 38N 26E	50	95.25	1.13	42.45	53.51	0.54	2.34	0.92	0.075				
O-43	25, 26 38N 26E	50	94.93	1.50	42.28	53.33	0.72	2.94	0.73	0.058				
O-44	27 40N 30E	60	97.19	0.69	42.78	54.60	0.33	1.46	0.27	0.005				
O-45	27 40N 30E	55	94.25	0.71	41.47	52.95	0.34	4.14	0.78	0.009				
O-46	27 40N 30E	51	93.98	1.25	42.30	52.80	0.60	3.55	0.63	0.006				
O-47	27 40N 30E	68	88.39	0.61	38.82	49.66	0.29	9.96	0.88	0.005				
O-48	27 40N 30E	61	87.99	0.67	38.93	49.43	0.32	9.74	0.80	0.006				
O-49	27 40N 30E	43	94.52	0.90	41.86	53.10	0.43	3.61	0.72	0.009				
O-50	1 35N 25E	60	70.63	3.26	31.91	39.68	1.56	23.86	2.62	0.082				
O-51	1 35N 25E	55	95.32	1.48	42.60	53.55	0.71	2.09	0.70	0.076				

CHEMICAL ANALYSES OF EASTERN WASHINGTON LIMESTONES—Continued

Sample no.	Location Sec. T. R.	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5	Na_2O (ppm)	K_2O (ppm)	TiO_2 (ppm)	S (ppm)
						OKANOGAN COUNTY (continued)								
O-52	1 35N 25E	50	94.25	1.78	42.33	52.95	0.85	2.64	0.84	0.064				
O-53	12 35N 25E	43	73.30	4.18	33.62	41.18	2.00	19.83	2.72	0.098				
O-54	12 35N 25E	43	80.24	2.82	36.90	45.08	1.35	14.17	1.82	0.056				
O-55	12 35N 25E	43	75.83	1.86	34.69	42.60	0.89	19.12	2.22	0.056				
O-56	12 35N 25E	43	74.96	1.69	33.66	42.11	0.81	22.30	1.38	0.061				
O-57	12 35N 25E	45	67.28	2.26	30.42	37.80	1.08	27.29	3.23	0.116				
O-58	12 35N 25E	45	92.26	2.61	41.67	51.83	1.25	3.76	0.72	0.085				
O-59	12 35N 25E	80	92.52	2.17	41.59	51.98	1.04	4.26	0.79	0.094				
O-60	12 35N 25E	75	94.39	1.63	42.60	53.03	0.78	2.27	0.73	0.086				
O-61	12 35N 25E	100	93.79	2.36	41.98	52.69	1.13	3.59	0.55	0.052				
O-62	1 35N 25E	50	92.13	1.25	41.11	51.76	0.60	5.45	0.61	0.094				
O-63	1 35N 25E	55	90.00	2.24	41.10	50.56	1.07	5.66	0.99	0.118				
O-64	6 35N 26E	75	89.98	2.55	40.97	50.55	1.22	5.10	1.43	0.114				
O-65	12 35N 25E	75	92.65	2.36	41.54	52.05	1.13	3.97	0.68	0.082				
O-66	7 35N 26E	80	93.45	2.68	42.33	52.50	1.28	2.98	0.79	0.075				
O-67	7 35N 26E	90	94.52	1.53	42.31	53.10	0.73	2.83	0.68	0.070				
O-68	7 35N 26E	85	91.72	1.92	41.25	51.53	0.92	3.89	1.56	0.116				
O-69	7 35N 26E	50	93.33	1.71	41.98	52.43	0.82	3.40	0.74	0.064				
O-70	26 35N 26E	41	75.17	2.19	33.63	42.23	1.05	18.55	4.33	0.090				
O-71	26 35N 26E	41	73.43	3.14	32.98	41.25	1.50	19.83	3.93	0.098				
O-72	23 35N 26E	64	61.23	1.92	26.09	34.40	0.92	32.30	6.29	0.074				
O-73	23 35N 26E	54	52.88	2.09	23.36	29.71	1.00	39.27	6.27	0.064				
O-74	23 35N 26E	60	54.34	11.12	28.72	30.53	5.32	29.40	5.48	0.096				
O-75	16 33N 26E	*	86.69	11.62	42.15	48.70	5.56	2.64	0.50	0.041				
						PEND OREILLE COUNTY								
PO-1	13 40N 43E	75	96.12	2.01	43.54	54.00	0.96	0.54	0.54	0.012				
PO-2	13 40N 43E	70	96.71	1.90	43.29	54.33	0.91	0.77	0.35	0.004				
PO-3	1 37N 42E	90	96.78	0.98	43.36	54.37	0.47	0.91	0.56	0.004				
PO-4	31 38N 43E	**	84.60	6.33	40.68	47.53	3.03	5.34	2.86	0.009				
PO-5	31 38N 43E	23	52.74	40.57	44.41	29.63	19.41	3.45	2.93	0.008				
PO-6	31 38N 43E	94	85.10	4.08	39.95	47.81	1.95	6.39	3.50	0.016				
PO-7	31 38N 43E	80	83.38	4.49	38.64	46.84	2.15	7.60	4.22	0.019				
PO-8	31 38N 43E	75	91.12	1.82	41.51	51.19	0.87	3.72	2.27	0.011				
PO-9	20 40N 44E	100	97.88	0.75	43.29	54.99	0.36	0.65	0.32	0.003				
PO-10	20 40N 44E	120	97.47	1.19	43.53	54.76	0.57	0.43	0.39	0.003				
PO-11	20 40N 44E	100	96.65	1.00	43.06	54.30	0.48	1.10	0.62	0.004				
PO-12	20 40N 44E	130	97.15	0.90	43.25	54.58	0.43	1.15	0.41	0.004				
PO-13	6 40N 44E	100	97.15	0.96	42.88	54.58	0.46	1.42	0.76	0.005				
PO-14	6 40N 44E	100	97.22	1.00	43.28	54.62	0.48	0.76	0.39	0.003				
PO-15	6 40N 44E	65	97.15	1.00	42.99	54.58	0.48	0.89	0.80	0.005				
PO-16	6 40N 44E	100	95.68	1.50	42.82	53.75	0.72	1.44	0.89	0.004				
PO-17	22 40N 43E	100	98.51	0.61	43.72	55.34	0.29	0.16	0.15	0.004				
PO-18	22 40N 43E	60	98.77	0.73	43.75	55.49	0.35	0.07	0.18	0.002				
PO-19	22 40N 43E	100	97.63	0.75	43.76	54.85	0.36	0.23	0.16	0.004				
PO-20	22 40N 43E	100	98.01	0.54	43.32	55.06	0.26	0.86	0.14	0.003				
PO-21	22 40N 43E	100	98.26	0.75	43.70	55.20	0.36	0.11	0.32	0.011				
PO-22	22 40N 43E	100	98.38	0.54	43.73	55.27	0.26	0.16	0.18	0.004				
PO-23	22 40N 43E	100	97.42	1.17	43.53	54.73	0.56	0.72	0.25	0.014				
PO-24	22 40N 43E	60	98.13	0.96	43.66	55.13	0.46	0.41	0.12	0.005				
PO-25	11 39N 43E	55	97.28	0.88	42.90	54.65	0.42	0.57	0.95	0.032				
PO-26	28 35N 43E	80	46.21	37.95	36.29	25.96	18.16	19.29	0.52	0.060				
PO-27	28 35N 43E	80	55.91	44.52	46.37	31.41	21.30	0.26	0.26	0.003				

*Chip grab sample
**Grab sample

CHEMICAL ANALYSES OF EASTERN WASHINGTON LIMESTONES—Continued

Sample no.	Location Sec. T. R.	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5	Na_2O (ppm)	K_2O (ppm)	TiO_2 (ppm)	S (ppm)
STEVENS COUNTY														
S-1	17 36N 38E	20	87.22	2.51	41.83	49.00	1.20	4.60	1.46	0.032				
S-2	17 36N 38E	20	80.10	2.51	38.84	45.00	1.20	11.10	1.44	0.038				
S-3	17 36N 38E	20	86.33	2.93	42.06	48.50	1.40	4.40	1.09	0.043				
S-4	17 36N 38E	8	78.32	2.09	37.75	44.00	1.00	14.15	1.06	0.033				
S-5	12 38N 38E	50	97.06	3.32	43.44	54.53	1.59	0.70	0.41	0.010				
S-6	12 38N 38E	50	91.21	7.62	43.70	51.24	3.65	1.23	0.39	0.016				
S-7	12 38N 38E	50	91.21	7.73	43.64	51.24	3.70	0.43	0.23	0.044				
S-8	12 38N 38E	50	85.07	13.38	43.78	47.79	6.40	0.96	0.13	0.029				
S-9	12 38N 38E	50	83.57	14.00	43.64	46.95	6.70	1.61	0.16	0.004				
S-10	14 38N 38E	50	91.19	6.27	43.06	51.23	3.00	0.72	0.60	0.008	235	620	-30	30
S-11	14 38N 38E	43	96.44	2.51	42.64	54.18	1.20	0.65	0.23	0.011	235	620	-30	30
S-12	13 39N 39E	26	91.39	2.70	42.72	51.34	1.29	2.16	1.39	0.010				
S-13	13 39N 39E	60	93.34	2.97	43.65	52.44	1.42	1.40	0.74	0.004	250	620	-30	180
S-14	13 39N 39E	50	93.09	2.99	43.38	52.30	1.43	1.50	0.79	0.006				
S-15	18 39N 40E	50	94.07	1.65	42.72	52.85	0.79	2.51	1.29	0.007				
S-16	18 39N 40E	50	91.76	1.99	41.87	51.55	0.95	3.87	1.85	0.008				
S-17	18 39N 40E	50	93.98	1.84	42.43	52.80	0.88	2.82	1.27	0.011	220	630	170	30
S-18	18 39N 40E	50	91.97	2.13	41.72	51.67	1.02	3.26	1.42	0.014				
S-19	18 39N 40E	65	94.20	2.45	42.94	52.92	1.17	1.96	0.72	0.009				
S-20	33 40N 40E	52	93.11	5.18	43.18	52.31	2.48	0.90	0.32	0.035				
S-21	33 40N 40E	52	84.85	13.00	43.63	47.67	6.22	1.44	0.31	0.043				
S-22	33 40N 40E	54	93.31	5.16	43.40	52.42	2.47	0.69	0.42	0.056				
S-23	13 37N 39E	50	95.03	2.36	42.70	53.39	1.13	1.58	0.95	0.006				
S-24	29 38N 41E	100	95.14	1.57	42.72	53.45	0.75	1.67	0.70	0.006				
S-25	29 38N 41E	100	96.40	1.88	43.18	54.16	0.90	0.53	0.32	0.005				
S-26	29 38N 41E	100	97.10	1.71	43.18	54.55	0.82	0.63	0.29	0.005	235	660	-30	30
S-27	29 38N 41E	100	95.51	2.03	42.89	53.66	0.97	1.59	0.52	0.005				
S-28	29 38N 41E	100	98.47	1.09	42.79	55.32	0.52	0.81	0.35	0.004				
S-26	29 38N 41E	100	97.10	1.71	43.18	54.55	0.82	0.63	0.29	0.005	260	580	-30	30
S-29	25 39N 39E	50	97.37	1.34	43.54	54.70	0.64	0.59	0.31	0.005				
S-30	25 39N 39E	50	97.29	1.09	43.51	54.66	0.52	0.53	0.35	0.005				
S-31	25 39N 39E	50	97.49	1.30	43.30	54.77	0.62	0.54	0.29	0.003	220	570	40	45
S-32	25 39N 39E	50	97.29	1.25	42.73	54.66	0.60	0.70	0.37	0.058				
S-33	25 39N 39E	38	95.39	1.44	42.03	53.59	0.69	2.56	0.36	0.039				
S-34	36 31N 40E	50	95.78	1.57	43.16	53.81	0.75	1.50	0.64	0.010				
S-35	1 30N 40E	50	98.26	1.11	43.66	55.20	0.53	0.80	0.41	0.060	250	570	70	40
S-36	1 30N 40E	50	97.61	2.13	43.25	54.84	1.02	0.60	0.45	0.040				
S-37	1 30N 40E	50	89.21	8.32	43.78	50.12	3.98	1.24	0.30	0.040				
S-38	34 37N 38E	50	97.01	0.79	43.00	54.50	0.38	1.12	0.56	0.030				
S-39	34 37N 38E	50	97.06	0.82	43.19	54.53	0.39	1.47	0.54	0.050				
S-40	34 37N 38E	60	97.37	0.73	42.78	54.70	0.35	1.40	0.49	0.020	225	560	40	40
S-41	34 37N 38E	50	96.73	0.79	42.63	54.34	0.38	1.50	0.55	0.020				
S-42	34 37N 38E	50	97.24	0.61	42.74	54.63	0.29	1.73	0.56	0.040				
S-43	34 37N 38E	75	97.21	0.63	42.56	54.61	0.30	1.80	0.60	0.030				
S-44	35 37N 38E	50	96.85	0.50	43.51	54.41	0.24	1.18	0.34	0.023				
S-45	35 37N 38E	50	96.00	0.59	43.26	53.93	0.28	1.59	0.47	0.034	220	560	-30	470
S-46	35 37N 38E	70	96.12	0.50	43.02	54.00	0.24	2.31	0.49	0.027				
S-47	35 37N 38E	15	96.55	0.48	43.18	54.24	0.23	2.09	0.37	0.028				
S-48	33 38N 38E	75	97.88	0.56	43.62	54.99	0.27	0.83	0.20	0.017				
S-49	33 38N 38E	75	98.79	0.44	43.14	55.50	0.21	0.72	0.20	0.010				
S-50	33 38N 38E	75	98.59	0.63	43.57	55.39	0.30	0.42	0.17	0.013				
S-51	33 38N 38E	70	98.54	0.65	43.41	55.36	0.31	0.64	0.17	0.009				
S-52	14 38N 38E	95	97.85	0.79	43.54	54.97	0.38	0.45	0.27	0.006				

CHEMICAL ANALYSES OF EASTERN WASHINGTON LIMESTONES—Continued

Sample no.	Location Sec. T. R.	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5	Na_2O (ppm)	K_2O (ppm)	TiO_2 (ppm)	S (ppm)
STEVENS COUNTY (continued)														
S-53	14 38N 38E	75	98.51	1.17	43.44	55.34	0.56	0.38	0.15	0.018				
S-54	14 38N 38E	55	98.27	1.59	43.26	55.21	0.76	0.38	0.22	0.008				
S-55	10 37N 38E	100	98.72	0.77	43.29	55.46	0.37	0.91	0.11	0.008				
S-56	10 37N 38E	75	98.79	0.59	42.82	55.50	0.28	1.29	0.27	0.022	190	840	-30	45
S-57	10 37N 38E	75	99.04	0.73	43.19	55.64	0.35	0.53	0.20	0.017				
S-58	10 37N 38E	100	97.19	0.98	42.90	54.60	0.47	1.44	0.51	0.011				
S-59	15 37N 38E	75	77.20	1.02	34.11	43.37	0.49	21.52	0.70	0.047				
S-60	15 37N 38E	75	71.34	0.56	31.64	40.08	0.27	27.16	0.95	0.030				
S-61	15 37N 38E	95	86.01	0.63	38.33	48.32	0.30	2.35	0.85	0.025				
S-63	22 37N 38E	60	98.36	0.79	43.46	55.26	0.38	0.42	0.27	0.021	225	570	50	60
S-65	22 37N 38E	80	96.65	0.75	43.02	54.30	0.36	1.71	0.24	0.012	225	550	-30	75
S-62	22 37N 38E	60	98.52	0.46	43.53	55.35	0.22	0.60	0.27	0.036				
S-63	22 37N 38E	60	98.36	0.79	43.46	55.26	0.38	0.46	0.27	0.021				
S-64	22 37N 38E	80	98.52	0.59	43.69	55.35	0.28	0.36	0.29	0.013	225	600	-30	15
S-65	22 37N 38E	80	96.65	0.75	43.02	54.30	0.36	1.71	0.24	0.012				
S-66	22 37N 38E	100	96.87	1.02	43.08	54.42	0.49	1.34	0.29	0.043				
S-67	22 37N 38E	150	98.68	0.73	43.57	55.44	0.35	0.35	0.25	0.026				
S-68	25 38N 37E	50	90.44	2.30	40.94	50.81	1.10	5.11	2.04	0.133				
S-69	25 38N 37E	50	85.23	8.97	41.90	47.88	4.29	3.84	1.66	0.150				
S-70	21 35N 39E	65	93.91	2.47	42.64	52.76	1.18	1.99	1.14	0.012				
S-71	33 35N 37E	248	92.35	3.51	42.55	51.88	1.68	2.61	1.08	0.019				
S-72	21 35N 39E	50	94.75	1.23	42.63	53.23	0.59	2.21	1.00	0.010				
S-73	21 35N 39E	50	93.31	1.44	41.96	52.42	0.69	2.80	1.60	0.006	225	660	270	25
S-74	21 35N 39E	50	95.09	1.17	42.65	53.42	0.56	1.93	1.17	0.008				
S-75	21 35N 39E	65	92.54	1.59	42.11	51.99	0.76	3.06	1.67	0.008				
S-76	33 35N 37E	80	89.45	5.91	42.63	50.25	2.83	2.92	1.15	0.020				
S-77	33 35N 37E	50	94.38	1.65	42.68	53.02	0.79	2.40	1.17	0.016	220	610	315	30
S-78	33 35N 37E	50	92.81	2.97	42.33	52.14	1.42	2.77	0.94	0.027				
S-79	35 37N 38E	55	98.11	0.52	43.64	55.12	0.25	0.76	0.19	0.012				
S-80	35 37N 38E	75	97.72	0.82	43.06	54.90	0.39	1.22	0.30	0.012				
S-81	34 37N 38E	75	97.86	0.44	42.12	54.98	0.21	2.79	0.29	0.019				
S-82	34 37N 38E	70	97.86	0.56	43.08	54.98	0.27	1.10	0.42	0.029				
S-83	34 37N 38E	70	98.56	0.48	43.39	55.37	0.23	0.32	0.16	0.028				
S-84	34 37N 38E	50	98.38	0.61	43.15	55.27	0.29	0.63	0.22	0.028				
S-85	35 37N 38E	80	98.51	0.52	43.28	55.34	0.25	0.49	0.27	0.019				
S-86	35 37N 38E	80	98.18	0.48	43.16	35.16	0.23	0.79	0.18	0.017				
S-87	35 37N 38E	80	97.99	0.54	42.98	55.05	0.26	1.05	0.22	0.017				
S-88	35 37N 38E	80	97.49	0.65	42.75	54.77	0.31	1.58	0.15	0.022				
S-89	35 37N 38E	80	97.65	0.50	43.28	54.86	0.24	1.37	0.28	0.025				
S-90	35 37N 38E	80	98.27	0.40	43.66	55.21	0.19	0.80	0.21	0.020				
S-91	33 38N 38E	130	96.96	1.53	43.35	54.47	0.73	1.60	0.15	0.011				
S-92	33 38N 38E	100	97.12	1.55	43.52	54.56	0.74	1.14	0.26	0.035				
S-93	33 38N 38E	100	95.27	2.78	43.73	53.52	1.33	1.14	0.20	0.047	135	490	-30	14
S-94	33 38N 38E	100	96.23	1.42	43.15	54.06	0.68	2.12	0.19	0.030				
S-95	33 38N 38E	100	96.00	2.72	43.71	53.93	1.30	0.97	0.25	0.050				
S-96	33 38N 38E	100	95.39	3.01	43.79	53.59	1.44	1.02	0.15	0.015				
S-97	33 38N 38E	110	94.41	1.89	42.62	53.04	0.90	3.05	0.13	0.026				
S-98	33 38N 38E	75	97.94	0.82	43.64	55.02	0.39	0.70	0.10	0.010				
S-99	33 38N 38E	75	96.30	1.82	43.16	54.10	0.87	1.41	0.12	0.017				
S-100	33 38N 38E	75	95.78	2.34	43.46	53.81	1.12	0.87	0.12	0.020				

CHEMICAL ANALYSES OF EASTERN WASHINGTON LIMESTONES—Continued

Sample no.	Location Sec. T. R.	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5	Na_2O (ppm)	K_2O (ppm)	TiO_2 (ppm)	S (ppm)
					STEVENS COUNTY (continued)									
S-101	33 38N 38E	60	95.92	1.50	43.03	53.89	0.72	1.83	0.18	0.020				
S-102	33 38N 38E	80	97.60	0.69	43.21	54.83	0.33	0.96	0.16	0.017				
S-103	33 38N 38E	60	87.84	0.50	38.56	49.35	0.24	11.40	0.34	0.051				
S-104	33 38N 38E	60	98.04	0.63	43.49	55.08	0.30	0.58	0.14	0.017				
S-105	33 38N 38E	60	98.18	0.71	43.57	55.16	0.34	0.72	0.19	0.031				
S-106	33 38N 38E	60	97.94	0.71	43.52	55.02	0.34	0.42	0.12	0.041				
S-107	33 38N 38E	60	97.86	0.65	43.35	54.98	0.31	0.81	0.18	0.011				
S-108	33 38N 38E	60	97.29	0.38	43.08	54.66	0.18	1.54	0.19	0.014				
S-109	33 38N 38E	60	98.70	0.36	43.60	55.45	0.17	0.26	0.13	0.007	125	300	-30	14
S-110	33 38N 38E	60	97.44	0.56	43.20	54.74	0.27	1.31	0.14	0.016				
S-111	33 38N 38E	50	98.47	0.50	43.54	55.32	0.24	0.58	0.13	0.016				
S-112	21 35N 39E	45	89.14	4.95	42.14	50.08	2.37	4.16	1.22	0.009				
S-113	21 35N 39E	150	95.37	1.17	42.76	53.58	0.56	1.81	0.95	0.010				
S-114	26 36N 39E	48	89.91	6.04	43.08	50.51	2.89	1.86	1.38	0.004				
S-115	35 36N 39E	100	71.65	4.81	34.49	40.25	2.30	15.65	6.33	0.033				
S-116	35 36N 39E	100	78.62	4.64	37.52	44.17	2.22	10.18	4.91	0.024				
S-117	35 36N 39E	75	62.05	3.36	29.98	34.86	1.61	22.85	9.36	0.046				
S-118	35 36N 39E	60	70.45	2.70	31.99	39.58	1.29	21.63	6.21	0.055				
S-119	35 36N 39E	100	64.69	8.46	33.41	36.34	4.05	18.46	7.10	0.047				
S-120	35 36N 39E	100	74.37	16.85	41.64	41.78	8.06	5.68	2.97	0.015				
S-121	33 35N 37E	90	91.56	2.05	41.31	51.44	0.98	4.55	1.66	0.022				
S-122	33 35N 37E	78	93.61	1.34	41.97	52.59	0.64	3.19	1.38	0.011				
S-123	33 35N 37E	50	91.47	3.49	42.17	51.39	1.67	3.27	1.27	0.009				
S-124	3 34N 37E	100	94.48	1.32	43.16	53.08	0.63	2.52	0.28	0.001				
S-125	3 34N 37E	90	96.35	1.50	43.01	54.13	0.72	1.63	0.23	0.003				
S-126	3 34N 37E	100	83.30	10.07	41.68	46.80	4.82	6.04	0.69	0.002				
S-127	3 34N 37E	100	78.32	9.80	39.44	44.00	4.69	11.37	0.76	0.004				
S-128	3 34N 37E	70	79.60	5.45	37.60	44.72	2.61	14.21	0.72	0.004				
S-129	3 34N 37E	65	88.06	4.97	41.35	49.47	2.38	6.44	0.21	0.003				
S-130	22 37N 38E	77	97.54	0.69	43.24	54.80	0.33	1.16	0.15	0.013				
S-131	22 37N 38E	100	97.72	0.65	43.20	54.90	0.31	1.17	0.15	0.015				
S-132	22 37N 38E	65	95.62	0.54	42.36	53.72	0.26	2.97	0.30	0.012				
S-133	22 37N 38E	100	95.87	0.56	42.64	53.86	0.27	2.76	0.25	0.016				
S-134	15 37N 38E	50	86.45	0.50	38.50	48.57	0.24	11.71	0.94	0.026				
S-135	15 37N 38E	50	86.90	0.56	39.10	48.82	0.27	10.84	0.70	0.024				
S-136	16 37N 38E	80	97.88	0.56	43.49	54.99	0.27	0.73	0.24	0.003				
S-137	16 37N 38E	70	97.60	0.56	43.17	54.83	0.27	1.56	0.12	0.022				
S-138	12 38N 38E	70	94.29	4.60	43.62	52.97	2.20	1.01	0.20	0.009				
S-139	12 38N 38E	60	88.96	10.41	44.06	49.98	4.98	0.64	0.30	0.014				
S-140	12 38N 38E	80	83.18	14.69	43.98	46.73	7.03	1.62	0.28	0.004				
S-141	12 38N 38E	40	91.06	8.69	44.18	51.16	4.16	0.75	0.21	0.007				
S-142	12 28N 38E	80	93.27	5.04	43.31	52.40	2.41	1.42	0.15	0.005				
S-143	25 38N 37E	110	94.11	2.05	42.47	52.87	0.98	2.47	0.85	0.083				
S-144	25 38N 37E	100	90.12	6.23	42.69	50.63	2.98	2.62	0.75	0.050				
S-145	25 38N 37E	100	88.11	8.36	42.73	49.50	4.00	2.63	0.88	0.061				
S-146	17 38N 37E	100	55.09	45.06	46.97	30.95	21.56	0.69	0.49	0.037				
S-147	17 38N 37E	80	54.24	44.64	46.63	30.47	21.36	1.84	0.50	0.005				
S-148	17 38N 37E	100	56.69	41.21	45.72	31.85	19.72	0.70	0.74	0.018				
S-149	17 38N 37E	80	64.81	34.13	45.93	36.41	16.33	1.09	0.38	0.010				
S-150	8 39N 40E	100	98.47	0.88	43.71	55.32	0.42	0.21	0.10	0.006				
S-151	8 39N 40E	100	98.13	0.67	43.68	55.13	0.32	0.37	0.14	0.007	175	360	-30	43
S-152	8 39N 40E	100	98.04	1.17	43.82	55.08	0.56	0.25	0.19	0.003				
S-153	8 39N 40E	75	97.06	1.02	43.21	54.53	0.49	1.54	0.21	0.004				

CHEMICAL ANALYSES OF EASTERN WASHINGTON LIMESTONES—Continued

Sample no.	Location Sec. T. R.	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5	Na_2O (ppm)	K_2O (ppm)	TiO_2 (ppm)	S (ppm)
						STEVENS COUNTY (continued)								
S-154	8 39N 40E	100	98.52	0.73	43.93	55.35	0.35	0.14	0.20	0.004				
S-155	8 39N 40E	100	98.74	0.36	43.73	55.47	0.17	0.19	0.10	0.007				
S-156	18 39N 40E	85	98.13	1.05	43.80	55.13	0.50	0.38	0.20	0.007				
S-157	18 39N 40E	100	98.04	0.94	43.85	55.08	0.45	0.24	0.22	0.005				
S-158	18 39N 40E	75	93.63	4.28	43.25	52.60	2.05	1.15	0.76	0.008				
S-159	18 39N 40E	100	93.13	4.18	42.99	52.32	2.00	1.67	0.98	0.007				
S-160	29 38N 41E	100	92.28	2.99	42.24	51.84	1.43	2.69	1.28	0.014				
S-161	29 38N 41E	115	94.00	1.92	42.16	52.81	0.92	2.62	1.02	0.004				
S-162	29 38N 41E	50	95.64	3.28	43.78	53.73	1.57	0.55	0.34	0.003				
S-163	35 40N 41E	100	96.92	1.69	43.48	54.45	0.81	0.37	0.36	0.007				
S-164	35 40N 41E	100	95.03	3.80	43.71	53.39	1.82	0.43	0.43	0.004				
S-165	35 40N 41E	88	95.84	2.88	43.74	53.84	1.38	0.34	0.37	0.004	135	490	-30	63
S-166	35 40N 41E	100	94.29	3.80	43.84	52.97	1.82	0.53	0.50	0.005				
S-167	35 40N 41E	100	97.03	1.82	43.67	54.51	0.87	0.46	0.40	0.004				
S-168	7 32N 41E	50	49.61	30.93	26.65	27.87	14.80	27.12	3.64	0.042				
S-169	8 39N 40E	90	98.52	1.07	43.07	55.35	0.51	0.66	0.19	0.009				
S-170	8 39N 40E	60	98.67	0.65	43.30	55.43	0.31	0.25	0.19	0.005				
S-171	8 39N 40E	55	97.72	0.73	42.65	54.90	0.35	1.28	0.15	0.010				
S-172	8 39N 40E	100	96.53	2.19	42.76	54.23	1.05	0.71	0.31	0.010				
S-173	8 39N 40E	60	97.72	0.54	43.12	54.90	0.26	1.17	0.00	0.003				
S-174	8 39N 40E	60	97.72	1.42	43.03	54.90	0.68	0.22	0.20	0.003				
S-175	8 39N 40E	75	98.52	0.56	43.15	55.35	0.27	0.39	0.12	0.003				
S-176	8 39N 40E	75	98.52	0.54	43.18	55.35	0.26	0.13	0.16	0.003				
S-177	8 39N 40E	75	98.40	0.42	43.29	55.28	0.20	0.35	0.17	0.006				
S-178	8 39N 40E	75	97.60	0.71	43.34	54.83	0.34	0.69	0.14	0.006				
S-179	8 39N 40E	80	97.72	0.59	42.96	54.90	0.28	1.29	0.00	0.012				
S-180	7 39N 40E	75	95.19	1.96	43.00	53.48	0.94	1.37	0.68	0.034				
S-181	7 39N 40E	75	95.19	0.88	42.49	53.48	0.42	2.27	1.04	0.025				
S-182	7 39N 40E	62	94.66	1.23	42.21	53.18	0.59	2.68	1.17	0.032				
S-183	7 39N 40E	49	87.45	2.76	40.11	49.13	1.32	6.89	2.25	0.057				
S-184	13 39N 39E	65	85.07	3.80	39.27	47.79	1.82	9.11	2.07	0.030				
S-185	13 39N 39E	75	89.85	4.10	41.56	50.48	1.96	4.59	1.33	0.014				
S-186	13 39N 39E	75	92.67	2.53	42.22	52.06	1.21	3.13	1.18	0.014				
S-187	13 39N 39E	75	91.19	4.08	42.32	51.23	1.95	3.12	1.42	0.018				
S-188	13 39N 39E	80	87.18	5.43	41.46	48.98	2.60	5.11	1.52	0.009				
S-189	13 39N 39E	65	88.25	6.06	41.61	49.58	2.90	4.08	1.40	0.018				
S-190	13 39N 39E	82	96.80	1.17	42.91	54.38	0.56	1.33	0.65	0.011				
S-191	13 39N 39E	85	93.98	2.63	42.61	52.80	1.26	2.02	0.94	0.004				
S-192	13 39N 39E	89	88.93	1.67	40.02	49.96	0.80	6.00	2.30	0.014				
S-193	13 39N 39E	56	93.43	1.57	42.35	52.99	0.75	2.31	0.90	0.006				
S-194	13 39N 39E	60	91.19	2.51	41.62	51.23	1.20	4.17	1.56	0.009				
S-195	13 39N 39E	39	93.45	1.94	41.98	52.50	0.93	2.54	1.13	0.007				
S-196	13 39N 39E	*	96.99	0.96	43.26	54.49	0.46	1.16	0.31	0.017				
S-197	No sample	---	-----	----	-----	-----	----	----	----	-----				
S-198	No sample	---	-----	----	-----	-----	----	----	----	-----				
S-199	33 38N 38E	100	92.13	3.95	41.43	51.76	1.89	3.61	0.32	0.022				
S-200	33 38N 38E	100	92.40	3.22	42.20	51.91	1.54	3.05	0.29	0.028				
S-201	33 38N 38E	100	94.39	3.36	42.75	53.03	1.61	1.53	0.16	0.020				
S-202	33 38N 38E	100	91.19	6.71	42.76	51.23	3.21	2.37	0.03	0.027				
S-203	33 38N 38E	100	96.80	2.30	43.16	54.38	1.10	0.50	0.12	0.021				
S-204	33 38N 38E	100	82.41	15.19	43.61	46.30	7.27	1.87	0.35	0.033				
S-205	33 38N 38E	100	89.32	8.72	42.94	50.18	4.17	2.06	0.29	0.038				
S-206	33 38N 38E	100	94.52	4.56	43.49	53.10	2.18	1.01	0.00	0.021				
S-207	33 38N 38E	100	96.12	2.82	43.12	54.00	1.35	0.72	0.14	0.025				

*Grab sample

CHEMICAL ANALYSES OF EASTERN WASHINGTON LIMESTONES—Continued

Sample no.	Location Sec. T. R.	Sample length (feet)	$CaCO_3$	$MgCO_3$	Loss on ignition	CaO	MgO	SiO_2	R_2O_3	P_2O_5	Na_2O (ppm)	K_2O (ppm)	TiO_2 (ppm)	S (ppm)
						STEVENS COUNTY (continued)								
S-208	33 38N 38E	100	93.25	4.97	42.99	52.39	2.38	0.75	0.39	0.021				
S-209	33 38N 38E	100	97.33	1.84	43.38	54.68	0.88	0.67	0.03	0.014				
S-210	33 38N 38E	100	96.12	1.30	42.35	54.00	0.62	2.31	0.03	0.013				
S-211	33 38N 38E	85	93.98	3.05	42.50	52.80	1.46	2.21	0.11	0.010				
S-212	16 28N 36E	65	46.67	3.16	18.71	26.22	1.51	48.94	4.68	0.061				

APPENDIX B

SPECTROCHEMICAL ANALYSES OF EASTERN WASHINGTON LIMESTONES

ASOTIN COUNTY

Oxide \ Field No.	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10	A-11	A-12
Na_2O	.11	.13	---	---	---	.16	.05	.083	.05	.05	.15	.05
Al_2O_3	.72	.55	.22	.27	.22	.84	.31	.61	.62	.31	.67	.41
K_2O	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.053	.052	.015	.016	.011	.045	.019	.029	.035	.021	.038	.018
V_2O_5	.003	.003	---	.0098	.0081	.025	---	---	---	---	---	---
Cr_2O_3	.0005	.0005	.0005	.0005	.0005	.014	.0007	.00086	.0013	.00064	.0009	.0005
MnO	.22	.15	.13	.13	.13	.095	.059	.094	.085	.078	.07	.06
Fe_2O_3	.90	.60	.39	.35	.32	.57	.46	.54	.61	.41	.52	.38
CoO	---	---	---	---	---	---	---	---	---	---	---	---
NiO	---	---	---	---	---	.001	---	---	---	---	---	---
CuO	.0016	.0020	.0017	.0020	.0025	.0026	.0026	.0020	.0026	.0019	.0026	.0015
SrO	.10	.13	.052	.032	.025	.011	.013	.071	.049	.056	.038	.048
ZrO_2	---	---	---	---	---	---	---	---	---	---	---	---
Ag_2O	---	---	---	---	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	.0054	---	---	---	---	---	---	---	---

FERRY COUNTY

Oxide \ Field No.	F-1	F-2	F-3	F-4	F-5	F-6	F-7	F-8	F-9	F-10	F-11	F-12	F-13	F-14	F-15	F-16
Na_2O	---	---	.06	.21	.26	.78	.05	.65	.05	---	---	---	---	---	---	---
Al_2O_3	.13	.12	.15	.13	.73	1.62	.21	.10	.14	.13	.14	.15	.058	.046	.17	.21
K_2O	---	---	---	---	---	1.95	---	---	---	---	---	---	---	---	---	---
TiO_2	.0092	.0076	.014	.18	.043	.095	.023	.0084	.022	.0084	.0096	.02	.002	.0044	.014	.02
V_2O_5	---	---	---	.0053	.003	.011	---	---	---	---	---	---	---	---	---	---
Cr_2O_3	.0016	.00093	.0009	.0032	.0025	.0014	.0018	.00096	.0006	.0014	.0023	.0015	.0018	.0014	.00058	.0052
MnO	.044	.085	.078	.16	.076	.14	.09	.062	.078	.05	.068	.033	.064	.044	.023	.05
Fe_2O_3	.16	.13	.23	.97	.49	.91	.23	.11	.11	.28	.45	.16	.17	.13	.28	.52
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	---	---	---	.0022	.001	.002	---	---	.001	---	.001	---	---	---	.001	.002
CuO	.0026	.00077	.0017	.004	.0022	.0069	.0014	.0016	.0019	.0027	.0082	.0024	.0014	.0014	.0029	.0085
SrO	.018	.014	.032	.032	.034	.025	.031	.032	.027	.013	.012	.011	.019	.016	.027	.032
ZrO_2	---	---	---	.002	---	---	---	---	---	---	---	---	---	---	---	---
Ag_2O	.00055	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	.045	---	---	.30	---

Results reported as percent of the oxide on a dry weight sample basis.
CaO, MgO, P_2O_5, and SiO_2 are reported in the chemical analyses.

FERRY COUNTY - Continued

Oxide \ Field No.	F-17	F-18	F-19	F-20	F-21	F-22	F-23	F-24	F-25	F-26	F-27	F-28	F-29	F-30	F-31	F-32
Na_2O	---	---	---	---	---	---	---	.14	.05	---	.06	.06	.082	---	---	---
Al_2O_3	.14	.16	.087	.11	.43	.42	.15	1.15	.07	.71	.49	.57	.94	.31	.098	.098
K_2O	---	---	---	---	---	---	---	.90	---	---	---	---	---	---	---	---
TiO_2	.014	.026	.0064	.0068	.01	.039	.0092	.14	.12	.062	.054	.036	.084	.025	.008	.012
V_2O_5	---	---	---	---	---	---	---	.068	.038	.034	.007	.004	.0095	.007	---	---
Cr_2O_3	.0014	.0008	.0014	.0005	.0005	.00077	.0005	.0048	.0022	.0028	.00077	.00058	.00093	.0005	.0014	.00083
MnO	.016	.013	.10	.027	.016	.048	.02	.082	.03	.038	.035	.036	.035	.026	.09	.09
Fe_2O_3	.12	.19	.18	.25	.17	.32	.27	.87	.66	.98	.41	.72	.73	.25	.14	.21
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	---	---	---	---	---	---	---	.007	.004	.004	.001	.002	.0028	.002	---	---
CuO	.0010	.0014	.0015	.0014	.0015	.0049	.0021	.027	.016	.012	.0024	.0059	.0046	.003	.0017	.0019
SrO	.043	.032	.014	.017	.016	.013	.019	.038	.028	.034	.045	.049	.046	.039	.017	.02
ZrO_2	---	---	---	---	---	.0028	---	.0039	.002	.0033	.002	---	---	.0033	---	---
Ag_2O	---	---	---	---	---	---	---	---	.0014	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	.25	.18	---	---	---	.15	---	---	---
PbO	.011	.002	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Oxide \ Field No.	F-33	F-34	F-35	F-36	F-37	F-38
Na_2O	---	---	---	---	---	---
Al_2O_3	.12	.064	.041	.10	.14	.22
K_2O	---	---	---	---	---	---
TiO_2	.008	.0064	.0032	.008	.0092	.016
V_2O_5	---	---	---	---	.0056	---
Cr_2O_3	.0012	.0015	.0016	.0015	.0014	.00058
MnO	.17	.094	.086	.043	.26	.062
Fe_2O_3	.19	.83	.13	.14	.62	.50
CoO	---	---	---	---	---	---
NiO	---	---	---	---	---	---
CuO	.0005	.0068	.00077	.00093	.0049	.0013
SrO	.029	.015	.017	.017	.015	.013
ZrO_2	---	---	---	---	---	---
Ag_2O	---	---	---	---	---	---
BaO	---	---	---	---	---	---
PbO	---	---	---	---	---	---

OKANOGAN COUNTY

Field No. / Oxide	O-1	O-2	O-3	O-4	O-5	O-6	O-7	O-8	O-9	O-10	O-11	O-12	O-13	O-14	O-15	O-16
Na_2O	.13	.32	.05	.17	---	.05	.05	---	---	---	---	---	---	.14	---	.05
Al_2O_3	.86	1.28	.39	.67	.28	.052	.086	.033	.084	.089	.019	.031	.07	.67	.098	.10
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.064	.12	.038	.07	.014	.0052	.0064	.002	.0056	.01	.002	.002	.0044	.12	.006	.004
V_2O_5	.018	.064	---	---	.011	---	---	---	---	---	---	---	---	.0073	---	---
Cr_2O_3	.0045	.0042	.0007	.00083	.0014	.0012	.0013	.00064	.0011	.0012	.0007	.0009	.0016	.0019	.0018	.0019
MnO	.02	.033	.15	.17	.043	.043	.053	.028	.036	.048	.037	.042	.042	.079	.024	.013
Fe_2O_3	.58	.55	.58	.71	.27	.073	.25	.68	.95	.10	.071	.10	.29	.52	.12	.076
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	.0046	.0068	---	---	---	---	---	---	---	---	---	---	---	---	---	---
CuO	.0025	.004	.0043	.0025	.004	.0014	.0028	.0019	.0019	.00099	.00066	.0014	.0026	.0016	.00099	.00072
SrO	.083	.15	.0098	.0087	.036	.012	.013	.0063	.0091	.0084	.0048	.007	.024	.017	.02	.021
ZrO_2	.0045	.0039	.0042	.0045	---	---	---	---	---	---	---	---	---	---	---	---
Ag_2O	.0002	.0005	.00099	.0002	.0002	---	.0002	.0004	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Field No. / Oxide	O-17	O-18	O-19	O-20	O-21	O-22	O-23	O-24	O-25	O-26	O-27	O-28	O-29	O-30	O-31	O-32
Na_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Al_2O_3	.27	.12	.16	.13	.053	.082	.084	.036	.089	.15	.12	.098	.034	.079	.11	.10
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.015	.0068	.012	.0076	.0064	.01	.0076	.0034	.0076	.018	.016	.0088	.0036	.0088	.012	.0096
V_2O_5	---	---	---	---	---	---	---	---	---	.003	.003	.003	---	.003	---	---
Cr_2O_3	.0018	.0019	.00054	.0017	.0013	.00058	.0013	.00086	.0023	.0012	.0017	.00086	.00051	.0014	.00096	.0016
MnO	.024	.042	.016	.078	.058	.016	.072	.04	.027	.12	.036	.061	.032	.047	.043	.12
Fe_2O_3	.16	.17	.12	.29	.09	.17	.15	.07	.12	.41	.21	.16	.09	.14	.19	.21
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
CuO	.00077	.00099	.00077	.0021	.00044	.0016	.00071	.00088	.00077	.0021	.0016	.0014	.0015	.00077	.0020	.0016
SrO	.024	.029	.013	.012	.015	.015	.013	.014	.017	.014	.0096	.0088	.11	.012	.013	.016
ZrO_2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Ag_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	.0035	---	---	---	---	---	---	---	.009	---	---	---	---

OKANOGAN COUNTY - Continued

Oxide \ Field No.	0-33	0-34	0-35	0-36	0-37	0-38	0-39	0-40	0-41	0-42	0-43	0-44	0-45	0-46	0-47	0-48
Na_2O	---	---	---	---	---	---	---	.15	.09	.09	.05	.05	---	.05	---	---
Al_2O_3	.12	.05	.089	.07	.033	.058	.07	.28	.49	.32	.30	.093	.21	.27	.081	.10
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.014	.0036	.0096	.0048	.0044	.0044	.0064	.022	.029	.018	.019	.0056	.0064	.022	.0034	.0048
V_2O_5	---	---	---	---	---	---	.003	---	---	---	---	---	---	---	---	---
Cr_2O_3	.0022	.0015	.0023	.0014	.00035	.00048	.00042	.00064	.0005	.0005	.0005	.0013	.0017	.0012	.0019	.0011
MnO	.048	.031	.056	.035	.0094	.01	.0079	.036	.028	.034	.039	.02	.028	.07	.049	.035
Fe_2O_3	.11	.063	.13	.12	.21	.11	.094	.31	.34	.41	.24	.12	.53	.32	1.09	.64
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	.0019	---
CuO	.0018	.00093	.0019	.0013	.0027	.0020	.0012	.0014	.0012	.0012	.0011	.0012	.0039	.0014	.011	.0061
SrO	.02	.013	.012	.011	.15	.12	.14	.14	.13	.15	.14	.024	.014	.021	.021	.018
ZrO_2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Ag_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Oxide \ Field No.	0-49	0-50	0-51	0-52	0-53	0-54	0-55	0-56	0-57	0-58	0-59	0-60	0-61	0-62	0-63	0-64
Na_2O	---	.30	---	.05	.28	.28	.16	.18	.23	.053	.05	---	---	---	---	.05
Al_2O_3	.15	1.13	.23	.25	1.16	.80	.83	.74	1.34	.31	.31	.25	.21	.23	.32	.81
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.0076	.14	.014	.018	.088	.075	.086	.057	.096	.027	.023	.043	.015	.017	.021	.046
V_2O_5	---	.056	---	---	.028	.020	.028	.023	.018	---	---	---	---	---	---	---
Cr_2O_3	.0023	.0057	.00054	.0005	.0036	.0024	.0013	.0037	.0044	.00077	.00064	.00058	.00067	.0005	.0008	.0013
MnO	.028	.053	.017	.034	.048	.044	.044	.068	.10	.02	.015	.016	.029	.019	.024	.047
Fe_2O_3	.39	1.44	.22	.31	.95	.91	1.01	1.22	1.15	.31	.22	.24	.40	.23	.44	.54
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	---	.005	---	---	.0042	.003	.0042	.0044	.0044	---	---	---	---	---	---	---
CuO	.0037	.011	.0012	.0012	.0083	.0066	.0081	.012	.012	.0014	.00088	.00077	.002	.0015	.0035	.002
SrO	.020	.07	.10	.11	.095	.11	.07	.10	.083	.14	.14	.12	.14	.11	.10	.16
ZrO_2	---	.011	---	---	.0066	.0066	.0096	.0054	.0072	---	---	---	---	---	---	---
Ag_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

OKANOGAN COUNTY - Continued

Oxide \ Field No.	0-65	0-66	0-67	0-68	0-69	0-70	0-71	0-72	0-73	0-74	0-75
Na_2O	.05	.05	.05	.05	---	---	.06	.29	.17	---	---
Al_2O_3	.24	.23	.21	.63	.32	1.14	.76	1.56	1.33	.68	.32
K_2O	---	---	---	---	---	---	---	.25	.25	---	---
TiO_2	.014	.017	.018	.035	.023	.12	.068	.17	.16	.075	.03
V_2O_5	---	---	---	---	---	.0076	.0059	.013	.0078	---	---
Cr_2O_3	.00067	.00058	.00074	.0013	.00067	.005	.0039	.0055	.0043	.0012	.0008
MnO	.019	.016	.018	.05	.019	.22	.18	.20	.21	.049	.078
Fe_2O_3	.20	.18	.37	.60	.22	2.79	1.86	2.63	2.45	.81	.19
CoO	---	---	---	---	---	---	---	---	---	---	---
NiO	---	---	---	---	---	.0044	.0036	.0056	.0048	.001	---
CuO	.0014	.0015	.0012	.0013	.0011	.0019	.016	.018	.029	.014	.001
SrO	.17	.13	.12	.13	.11	.015	.014	.02	.021	.013	.027
ZrO_2	---	---	---	---	---	.014	.026	.032	.03	.012	---
Ag_2O	---	---	---	---	---	---	---	.0015	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---

PEND OREILLE COUNTY

Oxide \ Field No.	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PO-13	PO-14	PO-15	PO-16
Na_2O	---	---	---	.05	.05	.097	.11	.052	---	---	---	---	---	---	---	---
Al_2O_3	.19	.12	.27	1.81	.77	1.51	1.83	.91	.14	.10	.22	.18	.38	.19	.35	.46
K_2O	---	---	---	.90	.56	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.013	.0088	.011	.072	.044	.076	.084	.044	.0044	.0034	.0076	.0064	.018	.0056	.014	.02
V_2O_5	---	---	---	---	---	.003	.003	.003	---	---	---	---	---	---	---	---
Cr_2O_3	---	---	---	.0021	.0014	.00058	.00061	.0005	---	---	---	---	---	---	---	---
MnO	.019	.016	.019	.11	.06	.07	.10	.06	.036	.019	.01	.01	.01	.01	.019	.013
Fe_2O_3	.13	.12	.20	.79	1.23	.82	.92	.61	.12	.081	.15	.094	.21	.10	.23	.25
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	---	---	---	.001	.001	.001	.001	.001	---	---	---	---	---	---	---	---
CuO	.00052	.00082	.00088	.0015	.0016	.0019	.0015	.0014	.0010	.00088	.00082	.00066	.0006	.0005	.0084	.00099
SrO	.007	.010	.018	.014	.0046	.021	.018	.018	.011	.011	.011	.009	.013	.0084	.011	.012
ZrO_2	---	---	---	---	.002	---	---	---	---	---	---	---	---	---	---	---
Ag_2O	---	---	---	---	.0002	---	---	---	---	---	---	---	---	---	.00072	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

PEND OREILLE COUNTY - Continued

Oxide \ Field No.	PO-17	PO-18	PO-19	PO-20	PO-21	PO-22	PO-23	PO-24	PO-25	PO-26	PO-27
Na_2O	---	---	---	---	---	---	---	---	---	---	---
Al_2O_3	.038	.028	.028	.019	.098	.019	.098	.098	.55	.07	.064
K_2O	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.002	.002	---	---	.0056	---	.0056	.0072	.027	.002	.0036
V_2O_5	---	---	---	---	---	---	---	---	---	---	---
Cr_2O_3	---	---	---	---	---	--	---	---	---	---	---
MnO	.014	.019	.019	.015	.017	.015	.017	.017	.043	.047	.038
Fe_2O_3	.035	.047	.052	.029	.077	.042	.07	.055	.32	.31	.26
CoO	---	---	---	---	---	---	---	---	---	---	---
NiO	---	---	---	---	---	---	---	---	---	.001	.0015
CuO	.0005	.0005	.00072	.0006	.00071	.00088	.0005	.0005	.00071	.0040	.0031
SrO	.009	.0086	.0082	.008	.0068	.0082	.0084	.009	.014	.0058	.0054
ZrO_2	---	---	---	---	---	---	---	---	---	---	---
Ag_2O	---	---	---	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	.002	.0035

STEVENS COUNTY

Oxide \ Field No.	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12	S-13	S-14	S-15	S-16
Na_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Al_2O_3	.27	.325	.155	.203	.058	.035	.033	.060	.037	.035	.050	.39	.13	.22	.377	.70
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.022	.022	.014	.010	.002	.002	.002	.002	.002	.002	.002	.014	.0084	.011	.010	.032
V_2O_5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Cr_2O_3	.0018	.0016	.00074	.0014	---	---	---	---	---	---	---	.00077	.0005	.0005	.00067	.0014
MnO	.22	.33	.35	.24	.015	.035	.029	.034	.025	.014	.02	.027	.021	.025	.025	.04
Fe_2O_3	.36	.49	.37	.38	.053	.153	.050	.078	.079	.078	.11	.30	.135	.215	.395	.35
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	---	---	---	---	---	---	---	---	---	---	---	---	.0038	.001	---	---
CuO	.0014	.0022	.0017	.0014	.0010	.0037	.00093	.0017	.00093	.00077	.0010	.0024	.0126	.0010	.0024	.0016
SrO	.012	.013	.017	.014	.012	.011	.011	.012	.0098	.0098	.010	.013	.014	.012	.014	.013
ZrO_2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Ag_2O	---	---	---	---	---	.0012	---	---	---	---	---	---	---	.00045	---	.0029
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	.018	---	---	---	.023	.0041	---	---	---	---	---

STEVENS COUNTY - Continued

Oxide \ Field No.	S-17	S-18	S-19	S-20	S-21	S-22	S-23	S-24A	S-24B	S-25A	S-25B	S-26A	S-26B	S-27A	S-27B	S-28A
Na_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Al_2O_3	.47	.70	.24	.066	.114	.086	.065	.071	.54	.114	.056	.13	.13	.10	.20	.20
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.017	.048	.010	.002	.006	.006	.022	.003	.029	.002	.002	.002	.006	.019	.01	.0092
V_2O_5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Cr_2O_3	.0008	.0009	.0005	---	---	---	---	---	.0008	---	---	---	---	.0006	---	---
MnO	.025	.033	.015	.030	.055	.052	.012	.017	.049	.030	.028	.014	.024	.04	.045	.021
Fe_2O_3	.29	.44	.21	.067	.20	.11	.32	.105	.32	.90	.056	.074	.11	.33	.127	.105
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
CuO	.0016	.0014	.0010	.0005	.0007	.0006	.0052	.0047	.00093	.00052	.00047	.0013	.0006	.00077	.00066	.00071
SrO	.012	.011	.02	.009	.0097	.013	.011	.012	.0094	.011	.013	.0098	.012	.016	.011	.014
ZrO_2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Ag_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Oxide \ Field No.	S-28B	S-29	S-30	S-31	S-32	S-33	S-34	S-35	S-36	S-37	S-38	S-39	S-40	S-41	S-42	S-43
Na_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Al_2O_3	.145	.12	.079	.11	.11	.09	.31	.070	.076	.059	.12	.13	.11	.13	.08	.13
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.008	.01	.0084	.012	.011	.008	.018	.002	.002	.002	.013	.012	.0068	.0088	.006	.01
V_2O_5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Cr_2O_3	---	---	---	---	---	---	.0011	---	.00093	.0015	.0007	.0012	.0021	.0013	.0015	.0012
MnO	.019	.021	.012	.017	.014	.02	.009	.0094	.014	.025	.06	.086	.15	.11	.10	.14
Fe_2O_3	.095	.114	.106	.088	.15	.096	.178	.056	.070	.109	.202	.153	.129	.18	.14	.29
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
CuO	.00077	.00088	.00051	.0006	.00088	.00071	.0011	.00082	.00082	.0013	.0011	.0011	.0021	.0012	.00093	.0034
SrO	.013	.014	.017	.014	.014	.013	.019	.015	.011	.012	.02	.027	.016	.018	.02	.022
ZrO_2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Ag_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

STEVENS COUNTY - Continued

Oxide \ Field No.	S-44	S-45	S-46	S-47	S-48	S-49	S-50	S-51	S-52	S-53	S-54	S-55	S-56	S-57	S-58	S-59
Na_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Al_2O_3	.087	.13	.11	.033	.052	.049	.037	.074	.030	.091	.072	.035	.23	.049	.32	.31
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.002	.0076	.0076	.0044	.0048	.0056	.002	.002	---	.01	.0084	.0044	.013	.0037	.021	.024
V_2O_5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Cr_2O_3	.00054	.0016	.00093	---	---	---	---	---	---	---	---	---	---	---	---	.0008
MnO	.055	.038	.084	.086	.011	.012	.013	.013	.023	.022	.025	.012	.012	.015	.016	.066
Fe_2O_3	.155	.195	.193	.135	.075	.097	.07	.077	.098	.083	.13	.049	.105	.074	.167	.265
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
CuO	.00099	.00099	.0011	.0017	.00077	.0012	.0012	.00088	.0015	.00088	.00083	.00055	.0012	.0015	.00096	.0015
SrO	.018	.017	.013	.018	.011	.011	.011	.011	.012	.012	.011	.010	.0076	.010	.013	.015
ZrO_2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Ag_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	.002	.012	.005	---	---	---	---	---	---	---	---	---	---	---	---

Oxide \ Field No.	S-60	S-61	S-62A	S-62B	S-63	S-64	S-65	S-66	S-68	S-69	S-70	S-71	S-72	S-73	S-74	S-75
Na_2O	---	---	---	---	---	---	---	---	.054	.135	---	.05	.05	.05	.05	---
Al_2O_3	.43	.30	.076	.058	.062	.063	.075	.087	.72	.82	.62	.25	.66	1.07	.50	.96
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.033	.02	.0092	.0064	.0048	.006	.0064	.011	.043	.053	.037	.072	.035	.048	.028	.06
V_2O_5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Cr_2O_3	.0010	.0013	.00064	.00093	.0012	.0008	.0018	.0018	.00067	.00096	.0008	.0028	.00093	.0013	.00067	.0013
MnO	.066	.12	.16	.15	.24	.17	.13	.15	.34	.24	.14	.13	.032	.042	.025	.037
Fe_2O_3	.305	.320	.091	.11	.13	.098	.115	.164	.515	.56	.534	.74	.43	.64	.36	.56
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
CuO	.0019	.002	.00094	.00063	.00063	.00069	.00043	.00066	.0011	.0012	.0013	.0015	.0015	.0019	.0014	.0014
SrO	.018	.018	.015	.013	.011	.013	.015	.018	.018	.018	.022	.043	.021	.020	.015	.024
ZrO_2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Ag_2O	---	---	---	---	---	---	---	---	---	---	---	.0002	.0002	.0002	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

STEVENS COUNTY - Continued

Oxide \ Field No.	S-76	S-77	S-78	S-79	S-80	S-81	S-82	S-83	S-84	S-85	S-86	S-87	S-88	S-89	S-90	S-91
Na_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Al_2O_3	.24	.26	.31	.07	.089	.076	.12	.079	.11	.072	.041	.066	.077	.135	.040	.053
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.079	.09	.13	.005	.006	.0044	.013	.0076	.01	.0048	.0032	.0068	.0056	.015	.002	.002
V_2O_5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Cr_2O_3	.0020	.0026	.0028	.0020	.0027	.0012	.0010	.00086	.0008	.0007	.0005	.0012	---	.0024	---	---
MnO	.16	.21	.20	.033	.051	.13	.10	.092	.06	.076	.045	.075	.085	.084	.068	.017
Fe_2O_3	.81	.72	.96	.059	.12	.19	.27	.094	.13	.13	.10	.13	.10	.15	.067	.073
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
CuO	.0019	.0017	.00088	.00094	.0018	.0013	.0029	.0017	.0021	.0033	.0013	.0015	.0011	.0021	.0020	.00066
SrO	.029	.032	.020	.024	.028	.021	.020	.018	.014	.018	.019	.038	.02	.032	.017	.021
ZrO_2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Ag_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Oxide \ Field No.	S-92	S-93	S-94	S-95	S-96	S-97A	S-97B	S-98	S-99	S-100	S-101	S-102	S-103	S-104	S-105	S-106
Na_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Al_2O_3	.089	.077	.064	.070	.030	.011	.029	.055	.048	.051	.093	.14	.15	.044	.095	.080
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.002	.002	.0068	.0068	---	---	---	---	---	---	.0048	.0076	.015	.0052	.009	.002
V_2O_5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Cr_2O_3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MnO	.022	.032	.016	.017	.022	.020	.027	.017	.021	.037	.016	.017	.012	.016	.012	.039
Fe_2O_3	.13	.11	.081	.073	.074	.050	.069	.071	.076	.090	.091	.12	.16	.15	.15	.15
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
CuO	.0016	.0016	.0019	.0015	.0019	.0012	.0014	.0022	.0014	.0025	.00094	.0012	.0024	.0022	.0060	.010
SrO	.021	.021	.019	.014	.015	.011	.010	.011	.011	.015	.010	.013	.013	.014	.018	.020
ZrO_2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Ag_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

STEVENS COUNTY - Continued

Field No. / Oxide	S-107	S-108	S-109	S-110	S-111	S-112	S-113	S-114	S-115	S-116	S-117	S-118	S-119	S-120	S-121	S-122
Na_2O	---	---	---	---	---	---	---	---	.22	.29	.67	.83	.47	.11	.05	---
Al_2O_3	.065	.031	.010	.054	.060	.81	.59	.67	2.84	2.61	6.03	4.82	4.58	1.51	.63	.34
K_2O	---	---	---	---	---	---	---	---	3.07	2.40	5.25	3.67	3.23	1.50	---	---
TiO_2	.0038	.002	.002	.002	.0047	.031	.021	.024	.17	.15	.28	.39	.28	.11	.14	.094
V_2O_5	---	---	---	---	---	---	---	---	.003	.003	.003	.010	.0076	.003	.003	.003
Cr_2O_3	---	---	---	---	---	.008	.0085	.0067	.0024	.0019	.0037	.0047	.0045	.0011	.0018	.0014
MnO	.007	.008	.010	.016	.009	.060	.031	.055	.27	.34	.45	.80	.45	.45	.23	.13
Fe_2O_3	.053	.070	.034	.053	.053	.39	.32	.69	1.85	1.57	1.71	2.68	1.83	1.40	1.11	.78
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	---	---	---	---	---	---	---	---	.0038	.0026	.0028	.0044	.0028	.001	.001	---
CuO	.0027	.0038	.0018	.0095	.0031	.0097	.0053	.0095	.0018	.002	.0049	.016	.0047	.0024	.0012	.0015
SrO	.022	.023	.019	.026	.023	.11	.048	.061	.032	.038	.028	.036	.020	.018	.034	.029
ZrO_2	---	---	---	---	---	---	---	---	.006	.0036	.0084	.013	.010	.006	---	---
Ag_2O	---	---	---	.0002	---	---	---	---	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Field No. / Oxide	S-123	S-124	S-125	S-126	S-127	S-128	S-129	S-130	S-131	S-132	S-133	S-134	S-135	S-136	S-137	S-138
Na_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Al_2O_3	.38	.023	.021	.093	.040	.013	.014	.046	.059	.061	.073	.27	.28	.17	.065	.105
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.11	---	---	.0048	.004	---	---	.0052	.0076	.004	.0068	.018	.016	.011	.0052	.010
V_2O_5	.003	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Cr_2O_3	.0017	---	---	---	.00096	---	---	.00077	.00058	.00083	.0010	.0014	.0012	---	---	---
MnO	.40	.053	.056	.079	.105	.051	.04	.05	.05	.12	.038	.063	.075	.018	.01	.029
Fe_2O_3	.94	.19	.23	.61	1.32	.57	.26	.11	.11	.24	.23	.64	.45	.14	.087	.098
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	.001	---	---	---	.0022	.001	.001	---	---	---	---	---	---	---	---	---
CuO	.0015	.00088	.00083	.0029	.018	.0042	.0015	.0012	.0014	.0018	.0010	.0052	.0031	.0013	.0011	.0014
SrO	.038	.017	.015	.021	.020	.021	.021	.014	.018	.018	.024	.025	.027	.017	.015	.014
ZrO_2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Ag_2O	---	.00094	---	---	---	---	---	---	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

STEVENS COUNTY - Continued

Oxide \ Field No.	S-139	S-140	S-141	S-142	S-143	S-144	S-145	S-147	S-148	S-149	S-150	S-151	S-152	S-153	S-154	S-155
Na_2O	---	---	---	---	.14	.17	.29	---	---	---	---	---	---	---	---	---
Al_2O_3	.091	.081	.049	.020	.49	.38	.65	.013	.015	.055	.024	.024	.035	.052	.029	.022
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.0052	.0084	.004	---	.026	.022	.042	---	---	.0076	---	---	---	---	---	---
V_2O_5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Cr_2O_3	---	---	---	---	.0005	.0005	.00096	---	---	---	---	---	---	---	---	---
MnO	.038	.043	.032	.021	.21	.10	.048	.050	.075	.03	.013	.016	.027	.026	.02	.014
Fe_2O_3	.150	.140	.110	.060	.31	.35	.34	.30	.44	.19	.06	.081	.11	.24	.10	.062
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
CuO	.0013	.0019	.0017	.0014	.0018	.0017	.0022	.0021	.0048	.0014	.0011	.0011	.0017	.0014	.0019	.0027
SrO	.014	.013	.012	.014	.016	.014	.018	.0047	.006	.012	.014	.013	.015	.015	.015	.015
ZrO_2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Ag_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	.0045	.0064	---	---	---	---	---	---	---	---	---	---

Oxide \ Field No.	S-156	S-157	S-158	S-159	S-160	S-161	S-162	S-163	S-164	S-165	S-166	S-167	S-168	S-169	S-170	S-171
Na_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Al_2O_3	.065	.051	.35	.46	.70	.65	.059	.12	.11	.067	.16	.20	1.00	.040	.049	.077
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.004	.002	.024	.027	.051	.035	.0048	.014	.013	.0084	.011	.016	.105	.002	---	.006
V_2O_5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Cr_2O_3	---	---	---	.0005	.0013	.00083	---	---	---	---	---	---	.0011	---	---	---
MnO	.016	.019	.05	.054	.062	.068	.043	.02	.02	.014	.024	.020	.23	.013	.019	.013
Fe_2O_3	.074	.062	.30	.39	.38	.33	.11	.091	.16	.135	.30	.15	2.38	.097	.089	.080
CoO	---	---	---	---	---	---	---	---	---	---	---	---	.001	---	---	---
NiO	---	---	---	---	---	---	---	---	---	---	---	---	.001	---	---	---
CuO	.00066	.0012	.00077	.0016	.0017	.0026	.0017	.0014	.0018	.00099	.0010	.0010	.021	.0014	.0018	.0016
SrO	.013	.012	.013	.016	.016	.014	.0098	.0096	.012	.013	.0096	.012	.011	.011	.013	.0096
ZrO_2	---	---	---	---	---	---	---	---	---	---	---	---	.014	---	---	---
Ag_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

STEVENS COUNTY - Continued

Oxide \ Field No.	S-172	S-173	S-174	S-175	S-176	S-177	S-178	S-179	S-180	S-181	S-182	S-183	S-184	S-185	S-186	S-187
Na_2O	---	---	---	---	---	---	---	---	.05	.05	.05	.35	.43	.20	.13	.075
Al_2O_3	.14	.053	.053	.052	.034	.091	.15	.056	.28	.37	.51	1.16	1.51	.74	.85	.64
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	1.28	---	---	---
TiO_2	.011	.0048	.006	.004	.002	.010	.0056	.0048	.014	.02	.041	.052	.15	.032	.026	.027
V_2O_5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Cr_2O_3	---	---	---	---	---	---	---	---	---	.0005	.0005	.001	.0017	.0005	.0005	.0005
MnO	.044	.040	.032	.035	.021	.015	.015	.011	.10	.075	.088	.16	.29	.11	.072	.066
Fe_2O_3	.16	.064	.097	.087	.23	.18	.11	.10	.41	.50	.59	1.10	1.15	.68	.57	.62
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
CuO	.0012	.0014	.0021	.0012	.00088	.0010	.0010	.00088	.0013	.0019	.0021	.0030	.0036	.0020	.0028	.0018
SrO	.010	.011	.010	.011	.0092	.010	.011	.012	.015	.014	.027	.025	.029	.021	.025	.027
ZrO_2	---	---	---	---	---	---	---	---	---	---	---	---	.019	.002	---	---
Ag_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	.002	.005	---	---	---

Oxide \ Field No.	S-188	S-189	S-190	S-191	S-192	S-193	S-194	S-195	S-196	S-199	S-200	S-201	S-202	S-203	S-204	S-205
Na_2O	.14	.16	.071	.05	.05	.05	.05	.05	---	---	---	---	---	---	---	---
Al_2O_3	.93	1.13	.21	.53	1.22	.59	.97	.46	.23	.050	.077	.038	.067	.032	.042	.058
K_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
TiO_2	.042	.041	.014	.029	.061	.032	.054	.022	.026	.002	.008	.002	.006	.002	.002	.0036
V_2O_5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Cr_2O_3	.0005	.0005	.0005	.0007	.0014	.00067	.0012	.00064	.0005	.0005	.0005	---	---	---	.0005	---
MnO	.070	.052	.045	.033	.050	.020	.035	.017	.028	.058	.050	.032	.036	.037	.078	.048
Fe_2O_3	.67	.61	.33	.28	.70	.38	.45	.35	.28	.51	.29	.11	.14	.078	.38	.20
CoO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NiO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
CuO	.0019	.0019	.0011	.0016	.0021	.0012	.0020	.0016	.00077	.0044	.0026	.0016	.0021	.0015	.0037	.0023
SrO	.020	.020	.012	.015	.013	.018	.022	.016	.020	.016	.015	.017	.015	.015	.012	.012
ZrO_2	.0051	---	.002	---	---	---	---	---	---	---	---	---	---	---	---	---
Ag_2O	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

STEVENS COUNTY - Continued

Oxide \ Field No.	S-206	S-207	S-208	S-209	S-210	S-211	S-212
Na_2O	---	---	---	---	---	---	1.25
Al_2O_3	.055	.039	.053	.045	.033	.072	3.42
K_2O	---	---	---	---	---	---	2.78
TiO_2	.0044	.002	.012	.0036	.0032	.011	.24
V_2O_5	---	---	---	---	---	---	.0048
Cr_2O_3	---	---	.0025	---	---	---	.0038
MnO	.029	.028	.038	.028	.019	.018	.23
Fe_2O_3	.09	.15	.14	.14	.087	.10	2.16
CoO	---	---	---	---	---	---	---
NiO	---	---	---	---	---	---	.003
CuO	.0023	.0024	.0024	.0027	.0017	.0020	.0013
SrO	.015	.015	.0098	.013	.010	.011	.014
ZrO_2	---	---	---	---	---	---	.014
Ag_2O	---	---	.00055	.00088	.00041	.0005	.00047
BaO	---	---	---	---	---	---	---
PbO	---	---	---	---	---	---	---

The metallic elements not detected in the spectrochemical analysis and the detectable limits (in percentages) of these elements are reported below:

Li_2O	0.02	In_2O_3	0.005	Er_2O_3	0.01
BeO	0.0005	SnO_2	0.002	Tm_2O_3	0.01
B_2O_3	0.003	Sb_2O_3	0.02	Yb_2O_3	0.005
Sc_2O_3	0.005	TeO_2	0.1	Lu_2O_3	0.01
ZnO	0.05	Cs_2O	1.0	HfO_2	0.05
Ga_2O_3	0.001	La_2O_3	0.01	Ta_2O_5	0.2
GeO_2	0.005	CeO_2	0.02	WO_3	0.05
As_2O_3	0.05	Pr_2O_3	0.01	Re_2O_7	0.01
Y_2O_3	0.002	Nd_2O_3	0.02	Os	0.01
Nb_2O_5	0.01	Sm_2O_3	0.01	Ir	0.02
MoO_3	0.001	Eu_2O_3	0.005	Pt	0.01
Ru	0.005	Gd_2O_3	0.02	Au	0.005
Rh	0.002	Tb_2O_3	0.01	Tl_2O_3	0.01
Pd	0.001	Dy_2O_3	0.02	Bi_2O_3	0.001
CdO	0.01	Ho_2O_3	0.01	ThO_2	0.2
				UO_2	0.2

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