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LIMESTONE, DOLOMITE, AND TRAVERTINE IN MONTANA

by

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Montana Bureau of Mines and Geology

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ABSTRACT

Carbonate rock, a low-cost mineral commodity used by many industries, is abundant in Montana, especially in the western part. Thick stratigraphic units consisting of carbonate rock of diverse texture and chemical composition tend to form cliffs and prominent ridges, which are readily mineable. The Meagher (Cambrian) and Lodgepole and Mission Canyon (Mississippian) Formations contain immeasurable reserves. Carbonate rock is also a minor but significant constituent of Belt rocks (Precambrian), Kootenai (Cretaceous), and Cenozoic rocks. Dolomite is most common in Cambrian strata, high-purity limestone in Mississippian and Pennsylvanian rocks, and travertine exclusively in Cenozoic deposits. Samples collected totaled 86. They were analyzed for CaO, MgO, insoluble, Al_2O_3, Fe_2O_3, P_2O_5, and S, and the results tabulated.

PREFACE

This report is one of a series in the mineral-commodity project, which, in part, fulfills the purpose of the Montana Bureau of Mines and Geology to promote the development of Montana's mineral resources. Included under mineral resources are metals and their ores; mineral fuels--coal, oil, and gas; surface and ground waters; and nonmetallic mineral commodities. This is a report on one of Montana's nonmetallic mineral resources, limestone, and two other materials closely related to it, dolomite and travertine.

I N T R O D U C T I O N

PURPOSE

In the spring of 1960 the need for more information concerning limestone in Montana to assist and attract new industry became apparent, for at that time Webb and Knapp were seriously attempting to establish a steel plant near Anaconda, and a source of limestone was important in their plans. In 1961 American Chrome Co. thought seriously of constructing a ferrochrome plant west of Butte and actively sought sources of the raw materials necessary to such an operation. The need therefor being obvious, the Bureau began a program of sampling Montana limestone strata for the purpose of informing industry and interested individuals of the widespread occurrence and quality of limestone in Montana.

SCOPE

Because of the formidable task of studying in detail each of the many limestone formations present in the state, the sampling program was directed especially to the Mission Canyon Formation. This choice was made without difficulty, as the Mission Canyon Formation (of Mississippian age) has been extensively quarried for high-calcium ("pure") limestone. It crops out as massive cliffs and ledges in many parts of central and western Montana.

This does not mean, however, that other limestone units are unproductive or have not been sampled. In the body of the report all the thick widespread carbonate units are described, and most have been sampled at several localities.

PREVIOUS WORK

In 1949 the Bureau issued Memoir 29, Gypsum, Lime, and Limestone in Montana, by E. S. Perry. This memoir to which numerous references are made throughout this report, comprehensively covers the potentially commercial limestone formations and describes and presents analyses of the limestone produced from existing quarries in the state.

ACKNOWLEDGMENTS

Samples were collected by the author and Don C. Lawson in 1960 and 1961. In 1962 David Rife assisted in the field.

The author wishes to thank all those who rendered assistance during the survey, and extends special thanks to Uuno M. Sahinen, who directed the project.

METHODS OF SAMPLING

One method of sampling consisted of chipping from the limestone outcrop a set of samples, each about the size of an orange, at 4- to 8-inch intervals, depending upon the thickness of the bedding. Samples were collected along a line perpendicular to the bedding. Each orange-size piece was trimmed of all weathered parts and reduced to about the size of a walnut. Continuous samples were taken where possible, but at any radical change in lithology or other disrupting change, the sample was broken and the individual parts of the total "channel" analyzed separately.

A second procedure, grab sampling, entailed pacing laterally the distance of the talus below the outcrop. At each step a sample about the size of an orange was chosen at random. No effort was made to clean the sample of weathered surfaces. The amount of sample collected differed with each outcrop, but averaged about 50 pounds. Samples obtained by this procedure are marked "grab".

Sampling of no deposit was extensive enough to justify computation of measured reserves; therefore, reserve figures given throughout the report indicate only the approximate tonnage of limestone present. At many sample localities the amount of limestone present is for all practical purposes unlimited, and no computation of reserves is presented.

ACCURACY OF SAMPLING

The described sampling procedures should produce results representative of the limestone sampled. One Montana company, however, in their sampling program, found that analyses of surface samples did not agree consistantly with analyses of drill-hole samples of the same material. Also to be noted here is that samples cleaned of all weathered material did not differ significantly from samples not cleaned of weathered material. This statement is supported by analyses of several samples taken at localities 9, 10, and 11.

At sample locality 9, three different samples were obtained. The first sample contained cleaned (no weathered surfaces) chip samples; the second, uncleaned (weathered surfaces) chip samples; and the third was a grab sample taken from the talus below the outcrop. At sample locality 10, this was repeated but no grab sample was collected; and at sample locality 11, a clean chip sample and a grab sample were obtained. Analyses of these samples are listed in Table 1.

Table 1.--Analyses of limestone samples collected by three different sampling procedures.

Sample no.		Insol.	MgO	CaO
LS-9	Clean chips	1.6*	8.3*	45.0*
	Weathered chips	1.5*	8.2*	45.2*
	Grab	1.2	8.2	45.4
LS-10	Clean chips	0.8	21.2	30.8
	Weathered chips	0.8	21.0	30.6
LS-11	Clean chips	2.7*	17.6*	33.5*
	Grab	2.0	16.3	35.5

*Weighted averages of 9a, b, and c, and 11a, b, c, and d. Complete analyses are found in Table 8.

GENERAL DISCUSSION

Limestone, including dolomite, occurs in some form in every state, is produced in thousands of localities, and is marketed as a low-cost mineral commodity to many different industries. Industry utilizes it either in raw crushed form or as the calcined product, lime.

The essential constituent of limestone is calcium carbonate, and if it constitutes more than 95 percent (53.2 percent calcium oxide) the rock is called high-calcium limestone[1/], which should contain less than 3 percent impurities (commonly silica, alumina, and other insoluble material) and less than 2 percent magnesium carbonate (1 percent magnesium oxide). If 10 percent or more of magnesium carbonate (4.8 percent magnesium oxide) is present, the rock is called "magnesian" or "dolomitic" limestone. If the content of magnesium carbonate approaches 45 percent (21.5 percent magnesium oxide), the rock is known as dolomite.

Impurities such as sand, clay, and iron oxide may have been mixed or interbedded with the calcareous material during deposition. Limestone is named, in part, on the basis of the impurities. Thus, siliceous or cherty limestone contains a considerable quantity of silica, ferruginous limestone contains iron oxide, and argillaceous limestone (cement rock) contains clay or shale.

Other names are applied to limestone according to the physical character. Common compact limestone is the most widespread type. It is a fine-grained homogeneous rock. Lithographic stone is a very fine grained crystalline limestone, deriving its name from one of its early uses for making

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1/ Percent calcium carbonate x 0.560 = percent calcium oxide.
Percent calcium oxide x 1.78 = percent calcium carbonate.
Percent magnesium carbonate x 0.478 = percent magnesium oxide.
Percent magnesium oxide x 2.09 = percent magnesium carbonate.

lithographic plates. Modifying adjectives are used to further describe limestone, i.e., finely crystalline thin-bedded magnesian limestone. There is almost no end to these modified names that are used to describe the appearance of the rock.

Travertine also consists primarily of calcium carbonate, but it does not usually occur in bedded deposits as does limestone. It is deposited in successive layers from water emanating from calcareous hot springs. As chemical composition and conditions of deposition may vary during the process, a banded or layered structure commonly results. The pleasantly variegated coloring of travertine and its capability of taking a high polish have made the product valuable as building stone in addition to its value as a source of carbonate.

Within Montana, where industry is not yet as varied as in the eastern and far western states, the major uses of limestone are for concrete aggregate and roadstone, flux, soil conditioner, railroad ballast, riprap, fill material, filler, sugar refining, portland cement, and lime. There are many other uses (Lamar, 1961). In tonnage and value, concrete aggregate and roadstone consume the greatest quantity and yield the greatest return of all the raw products, but the value of cement and lime, which are the major products manufactured from limestone, exceeds that of all raw limestone sold or used in the United States. Lime is the more versatile product, considering need or number of uses, which have been estimated at 7,000 (Patterson, 1960). The need for lime is paramount to many processes in many different industries. The uses are grouped in three classifications, chemical and industrial, construction, and agricultural. By far the greatest number of uses are chemical and industrial.

CARBONATE UNITS IN MONTANA

In central and western Montana vast quantities of limestone lie exposed as massive cliffs, ledges, and towering prominences where mountain-building forces have brought to the earth's surface limestone beds formed as much as 500 million years ago (Table 2). From Cambrian time to Recent, calcareous-shelled organisms have inhabited the earth's oceans and lakes; countless generations of these organisms lived and died, their shells supplemented by chemically precipitated carbonate, ever accumulating in beds that are now measured in thousands of feet and constitute today's sources of high-carbonate materials.

Large deposits of limestone of diverse chemical and textural composition are accessible where Paleozoic strata crop out in many areas in western and central Montana (Fig. 1). In the eastern and northeastern plains areas these major calcareous strata are deeply buried beneath later Mesozoic and Tertiary strata; only relatively thin impure beds of limestone are found

Table 2.--Geologic formations associated with limestone and dolomite beds in Montana.*

Geologic age	Formation		Approx. thickness (feet)	Dominant character	Location of limestone quarries
Quaternary				Stream deposits, local travertine	Gardiner and elsewhere
Tertiary			1,000	Stream and lake deposits, local limestone	
Cretaceous	Montana Group		4,500	Sandstone and shale	(Gastropod limestone member)
	Colorado Group			Sandstone and shale	
	Kootenai			Red beds, some limestone in west	Kootenai near Drummond
Jurassic	Morrison		300	Sandstone and shale	
	Ellis Group			Sandstone, shale, limestone, gypsum	
Triassic	Chugwater, etc.		400	Red sandstone and shale, gypsum	
Permian	Phosphoria		500	Sandstone, shale, and phosphate rock; some limestone	
Pennsylvanian	Tensleep-Quadrant		500	Quartzite or sandstone, some limestone	Elliston
Mississippian	Amsden		100	Limestone, some red shale	Warren
	Big Snowy Group		800	Shale and sandstone, gypsum, some dark ls.	Drummond
	Madison	Mission Canyon	1,000	Massive crystalline limestone	Anaconda Helena Albright Limespur Trident Livingston Limekiln Hill Divide
		Lodgepole		Pure and shaly limestone	
Devonian	Three Forks		1,000	Shale and impure limestone	
	Jefferson			Dolomite and dolomitic limestone	
Ordovician	Big Horn		400	Dolomite	
Cambrian	Dry Creek		2,000	Impure shale and sandstone	
	Pilgrim			Dolomite	Helena
	Park			Shale	
	Meagher			Limestone and dolomitic limestone	Helena
	Wolsey			Shale	
	Flathead			Quartzite	
Precambrian	Belt Series			Quartzite, argillite, impure limestone in Newland Formation and equivalents	
	Cherry Creek Series			Gneiss, schist, marble	
	Pre-Cherry Creek			Gneiss and schist	

*Perry, 1949.

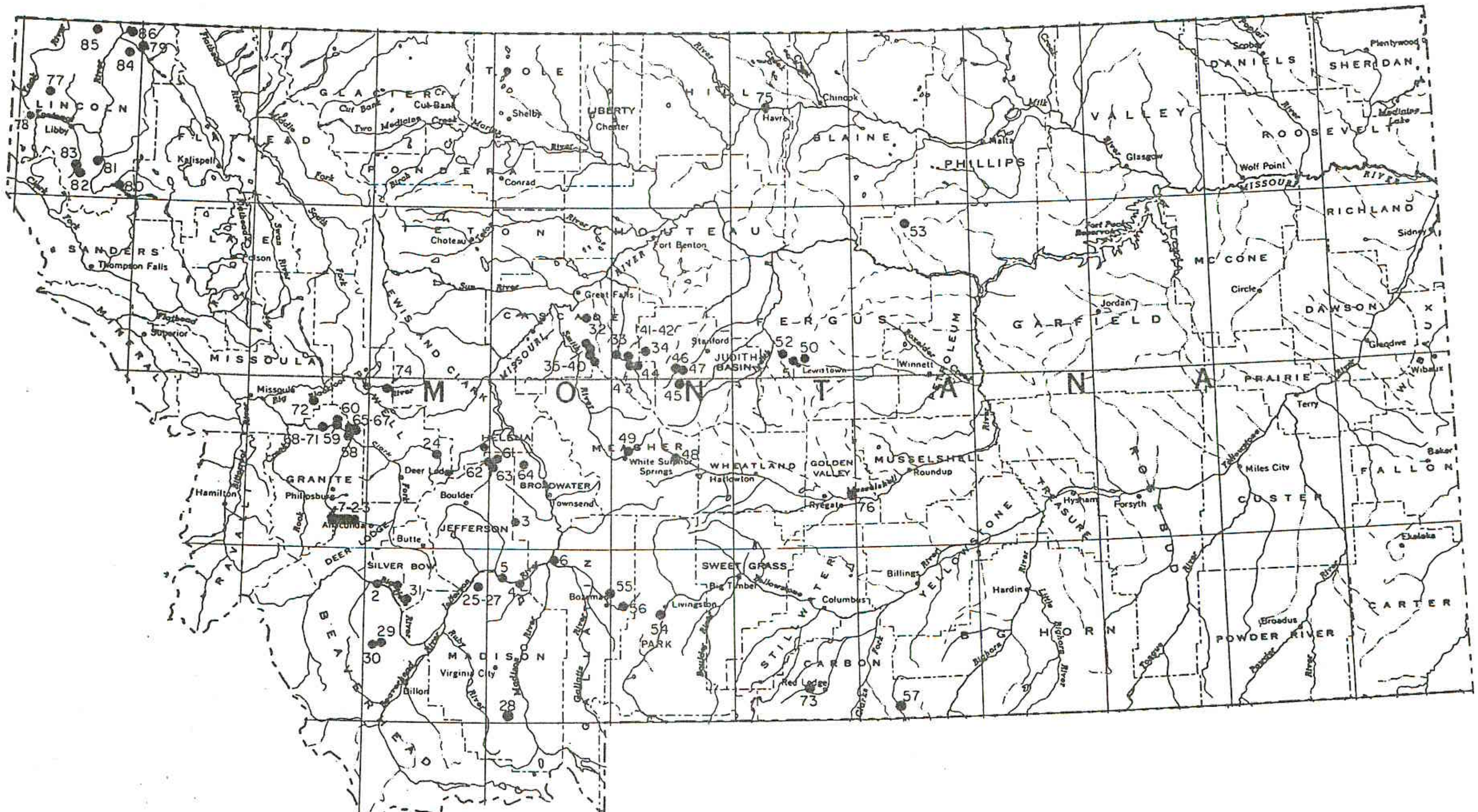


Figure 1.--Index map of Montana showing sample locations.

within these later strata. The Paleozoic units contain the greatest quantity of usable limestone; of these the most important is the Mission Canyon, followed by the Meagher (pronounced Mar) and Lodgepole Formations. Of the six producing limestone quarries in the state, three are in the Mission Canyon, two in the Meagher, and one in the Lodgepole.

In Montana, limestone is not restricted to Paleozoic strata, though in quantity and variety of limestone this geologic era is without equal. Workable deposits are also found in Precambrian (Belt Series), Mesozoic (Cretaceous), and Cenozoic (Tertiary-Quaternary) sediments (Table 2).

Within a large area of Montana, sufficient quantities of limestone of almost any composition can be found. Many of the deposits are favorably located near railroads or other transportation routes that are not too distant from population centers and industrially suitable localities. The amount and variety of stone that can be found would satisfy the needs of many industries. Many deposits can be quarried at minimum cost and under favorable conditions. Supporting power or fuel and raw materials would or could be made available from Montana deposits--electrical power, coal, oil or gas, gypsum and iron for cement manufacture, abundant iron ore for the steel industry, silica, barite, sodium sulfate, feldspar, and gypsum for the glass industry, and many others (U. S. Geological Survey and Montana Bureau of Mines and Geology, 1963).

PRECAMBRIAN CARBONATES

In the Belt Series, limestone, dolomitic limestone, and dolomite contain much shaly and siliceous impurities. In northwestern and extreme western Montana and in the Belt Mountains in the central part of the state are found great thicknesses of these sediments. The calcareous formations of this series are the Helena, Wallace, Newland, Siyeh, and Altyn Formations. Assay reports by Johns (1960, 1961) show that in general these sediments in northwestern Montana average about 44 percent silica, 10 percent alumina, between 40 and 50 percent calcium carbonate, and 4 percent magnesium carbonate. Such a composition restricts their use to those industries that use limestone for its physical properties rather than its chemical composition.

Among the Precambrian calcareous deposits deserving mention are the massive marble layers of the Cherry Creek Series. In the low foothills of the Ruby Mountains 20 miles southeast of Dillon, resistant beds of marble crop out in continuous belts. Heinrich and Rabbitt (1960) state that along Axes Canyon marble crops out, ranging in thickness from 5 to 1,600 feet. Several of the thicker layers are continuous for 4.5 to 5 miles. Reid (1957) describes Cherry Creek marble of the Tobacco Root Mountains.

Other outcrops are found in the vicinity of Virginia City about 1 mile east of Laurin, in the foothills of the Gravelly Range 15 miles south of Ennis, and low in the Bridger Range 5 miles north of Bozeman. The marble ranges in composition from nearly pure calcite to nearly pure dolomite (Perry, 1949).

PALEOZOIC CARBONATES

Meagher Formation

The Meagher Limestone, of Cambrian age, is chiefly massive but in part slabby. The upper part is characteristically mottled dark gray or black and buff, which has led to a decriptive name of "black and gold marble". This mottled pattern has made the rock desirable as a building stone. In years past it was quarried north of Radersburg in the Limestone Hills (no. 1, Fig. 2) by the Vermont Marble Co., and marketed as "Egyptian Limestone". Polished slabs for facing work were highly prized, but when quarrying became unprofitable, operations ceased and have not been reactivated. Much quarriable rock still remains at this locality.

Though most of the Cambrian calcareous strata in Montana are dolomitic, and some closely approach the composition of pure dolomite, the Meagher Formation is locally almost pure limestone and contains very little magnesium carbonate. This is confirmed by the two quarries east and south of Helena, one of which produces rock for use as flux at American Smelting and Refining Co. plant at East Helena (no. 2, Fig. 2), and the other, several miles west, produces rock for the manufacture of cement in the new Permanente Cement Co. plant (no. 3, Fig. 2). Perry (1949) states that the Meagher Formation in the Helena-Townsend region contains less than 3 percent magnesium carbonate. In the Melrose area seven samples averaged 18 percent. South of Bozeman the rock averages 1 percent. This trend is also substantiated by Hanson (1952, p. 15) who states that "East of a line connecting Ennis and Whitehall, the Meagher Formation is entirely limestone, whereas west of a line connecting Butte and the upper Ruby Valley (north of Alder) it is entirely dolomite. The intervening transitional zone covers a strip 10 miles or more wide". Hanson believes that the pattern of distribution of the transitional zone north of Helena bends to the northwest toward Missoula.

Lodgepole Formation

The Lodgepole Formation of the Madison Group (Mississippian) is another important limestone unit, mainly as a source of cement rock. In outcrop it is generally composed of dark-gray or brown to black thin-bedded limestone, having chert and shale layers between beds. In some localities the shale and siliceous impurities may almost equal the amount of limestone. Rock from this formation is presently being quarried by the Ideal Cement Co. at

Trident (no. 4, Fig. 2) for cement manufacture, for which purpose the shale content is advantageous.

Mission Canyon Formation

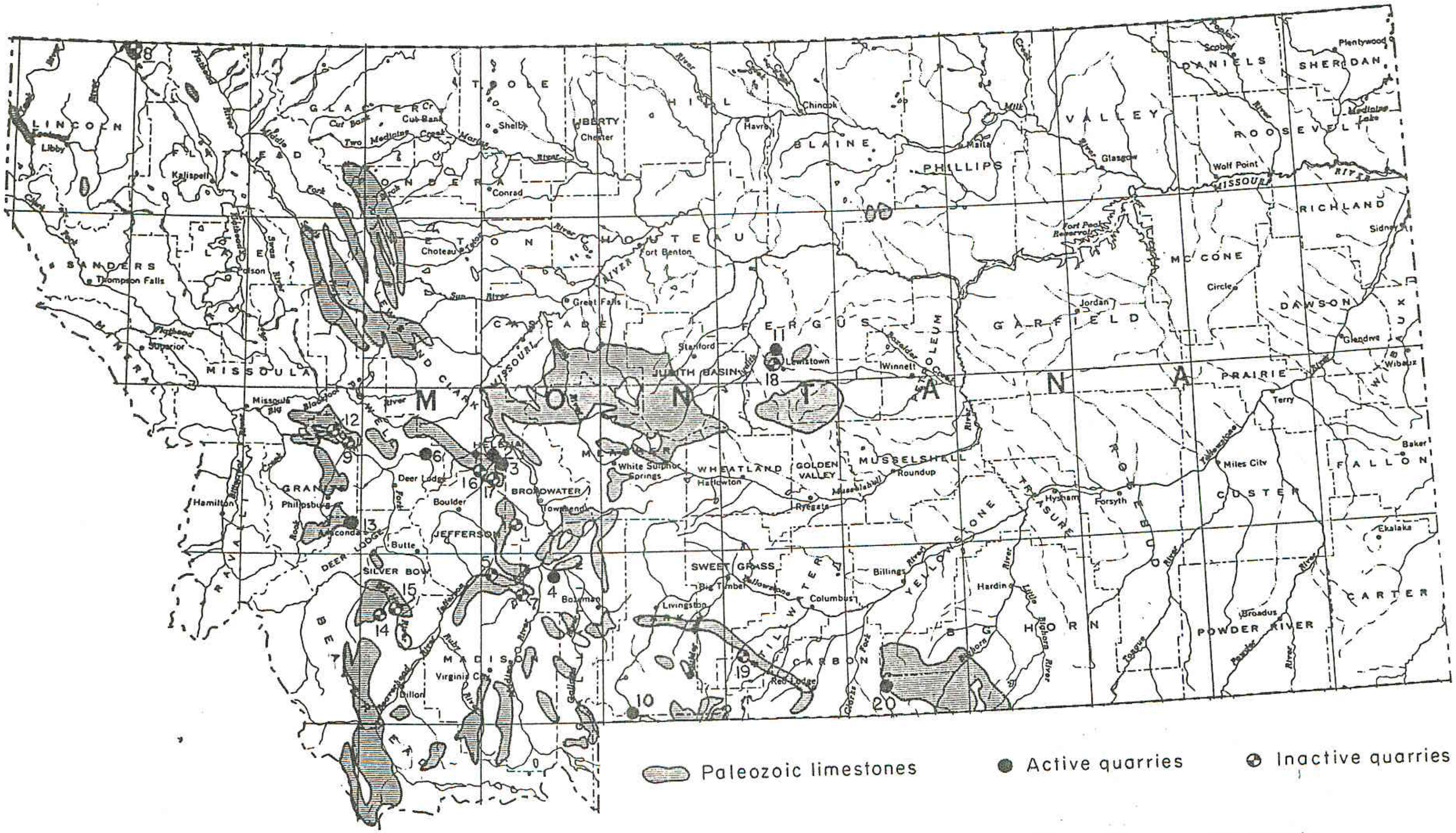
The Mission Canyon Formation of the Madison Group is the most important single source of high-purity limestone in the state. It is nearly pure calcium carbonate, although it does contain chert in large nodules in some parts of the formation in some localities. Certain zones are very fossiliferous, and locally may be almost a coquina (calcareous rock made up chiefly of fragments of shells) of crinoid and brachiopod fragments in a coarsely crystalline matrix. Much of it is dense or fine grained, and fossils may be absent.

The formation generally forms the tops of the highest ridges in its outcrop area, and streams commonly pass through its outcrop in steep-walled canyons. Physiographic conditions in areas of the Mission Canyon outcrop are generally favorable for quarrying. Cliffs or steep hills of limestone permit development of working faces above drainage level. Near areas of igneous intrusions the formation may be metamorphosed into a coarse-grained marble, which in hand specimen appears to be pure calcite.

Chemical analyses of numerous samples from this unit show more than 95 percent calcium carbonate, less than 5 percent magnesium carbonate, and less than 3 percent total impurities. In many places, as at Limespur (no. 5, Fig. 2), where the limestone was quarried for flux in the Butte smelters and for sugar refining, the calcium carbonate content is known to exceed 99 percent (Perry, 1949). The quarry at Elliston (no. 6, Fig. 2) is producing limestone for lime manufacture, which exceeds 98 percent calcium carbonate. Channel samples from the quarry at Sappington (no. 7, Fig. 2) showed a calcium carbonate content of 98 percent; magnesium carbonate, nil; and impurities, less than 1 percent. This quarry, which is adjacent to the Northern Pacific and Chicago, Milwaukee, St. Paul and Pacific Railroads, was quarried for use in the manufacture of sugar at Billings. In northwestern Montana, at Roosville, a 300-foot chip sample from what is believed to be Mission Canyon Limestone (no. 8, Fig. 2) assayed 98.6 percent calcium carbonate, 1.5 percent magnesium carbonate, 0.05 percent alumina, and 0.15 percent ferric iron--a very pure stone. A quarry here could provide limestone for part of Canada and northwestern Montana.

Other Paleozoic Carbonate Units

Other Paleozoic calcareous formations are potentially workable. Pilgrim Dolomite, parts of which are nearly pure dolomite, is massive and blocky, especially in its upper part. The lower part is more shaly and generally contains less magnesia. Big Horn Dolomite, present in south-central Montana, is massive and sugary crystalline, and it is persistent in these characteristics.



1. Vermont Marble
2. Maronick
3. Permanente Cement Co.
4. Ideal Cement Co.
5. Limespur
6. Elliston Limestone Co.
7. Sappington
8. Stahl
9. Drummond
10. Montana Travertine Co.
11. Paradise Ranch Travertine
12. Hitchcock
13. Browns
14. Maiden Rock
15. Antonioli
16. Harris
17. Montana City
18. Hanover
19. American Chrome Co.
20. Warren

Figure 2.--Map showing general areal outcrop of Mississippian carbonates and location of active and inactive quarries in Montana.

Its magnesium content is uniformly high, and the shaly and siliceous constituents are consistently low. Jefferson Dolomite is commonly a black massive outcropping unit, the lower part of which contains less magnesia than the upper part.

MESOZOIC CARBONATES

The important Mesozoic calcareous sediments are the Gastropod limestone member of the Kootenai Formation (Cretaceous) and the Ellis Formation (Jurassic). The Gastropod limestone ranges in thickness from 10 to 75 feet and is present in southwestern Montana. It is characterized by a great abundance of fossil gastropod (snail) shells of fresh-water origin, and is nearly pure limestone except for shaly constituents. It has been quarried for lime burning near Drummond (no. 9, Fig. 2). Analysis of a grab sample (LS-1-62) from the quarry shows a calcium carbonate content of 87 percent; magnesium carbonate, 2 percent; insoluble, 9.38 percent; and alumina, 1.13 percent. The Ellis Formation, which is mainly calcareous shale and sandstone, contains in its central part limestone or argillaceous limestone 50 to 100 feet in thickness (Perry, 1949). This limestone would be suitable for lime manufacture.

CENOZOIC CARBONATES

Cenozoic travertine of hot-spring origin is believed to be of late Tertiary or early Quaternary age. The deposits constitute an individual and valuable type of nearly pure calcium carbonate. Two very large and chemically pure deposits have been partly developed in the state, and several smaller ones have been found. The most extensively developed of these deposits is near Gardiner (no. 10, Fig. 2), where Montana Travertine Quarries is producing stone for interior and exterior decorative building stone.

The Gardiner deposits are a northern extension of the extensive travertine deposits formed at Mammoth Hot Springs in Yellowstone National Park. Although the deposit is 5 miles distant from Mammoth, the geologic occurrence is similar, and the amount of available material is large. Mansfield (1933, p. 7) described the deposit as two tracts, one large and one small, which amount in all to 1,250 acres. Sahinen (personal communication to J. B. Ahern, 1961), concerning the reserves of travertine on Montana Travertine Quarries ground (132 acres), stated that "Present on company ground is about 8,423,500 tons of travertine. The amount of travertine in the entire deposit is probably about four or five times that amount".

The deposit, in the past, has been used for lime burning because of its calcium carbonate content (greater than 97 percent calcium carbonate) and low percentage of impurities (generally less than 3 percent total impurities). A typical analysis of the stone is calcium carbonate, 97 percent; magnesium carbonate, 2.0 percent; silica, 0.8 percent; and iron oxide, 0.2 percent. Its use as a material for lime burning has been limited; this is partly due to lack of financing and partly due to market conditions. It is presently being marketed for rubble stone for the building industry.

The second large deposit of travertine, possibly second only because it has not been as extensively developed, is on the south flanks of the North Moccasin Mountains in central Montana northwest of Lewistown (no. 11, Fig. 2). The deposit occupies an area of about six square miles and has a maximum thickness of 250 feet (Calvert, 1909, p. 36). Locally it is massive but in other places has a layered, vesicular, or stalactitic appearance. It is being quarried for building stone, but like the travertine at Gardiner, it is a high-calcium limestone suitable for many uses requiring pure high-calcium carbonate rock.

Other travertine deposits occur in the Judith Mountains and along McDonald Creek divide in the same area. Castle Butte, about 7 miles south of Lewistown, is a remnant of a spring deposit. In the vicinity of the South Moccasin Mountains is the Square Butte deposit. Near Divide in Silver Bow County a deposit was quarried for manufacutre of lime (Perry, 1949).

DESCRIPTION OF SAMPLE SITES

Sample 1

Samples 1a, b, and c were collected from the face of Antonioli's quarry, located in the foothills northeast of Divide in the SW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 10, T. 1 S., R. 9 W. The quarry, owned by Peter and Frank Antonioli of Butte, is inactive at present but produced limestone more than 30 years ago for the manufacture of lime.

The property is reached by traveling east 2 miles over dirt road after leaving U. S. Highway 91 at a point 17 miles southwest of Butte or 1 mile north of Divide. Divide, which is only 3 miles southwest of the quarry, is the site of a Union Pacific Railroad loading dock. Truck transportation to Divide would not be difficult, as the haul from the quarry would be downhill.

The quarry is developed in the Mission Canyon Formation, which crops out in the area as a block about 2 miles long and $\frac{1}{2}$ mile wide. To the east it is in contact with quartz monzonite and granite of the Boulder batholith, to the west with lake-bed sediments. Underlying it to the south is a small segment of Three Forks Shale (Devonian) (Fig. 3). The areal geology of the sampled area is described by Richards and Pardee (1925), and Sahinen (1950).

The limestone strikes N. 70° E., and dips 37° NW. It is massive gray fine- to medium-grained rock showing faint laminations on weathered surfaces. Not present in the quarry face but found in float near the contact with intrusive rocks is a light-gray coarsely crystalline limestone. The recrystallized zone parallels the contact.

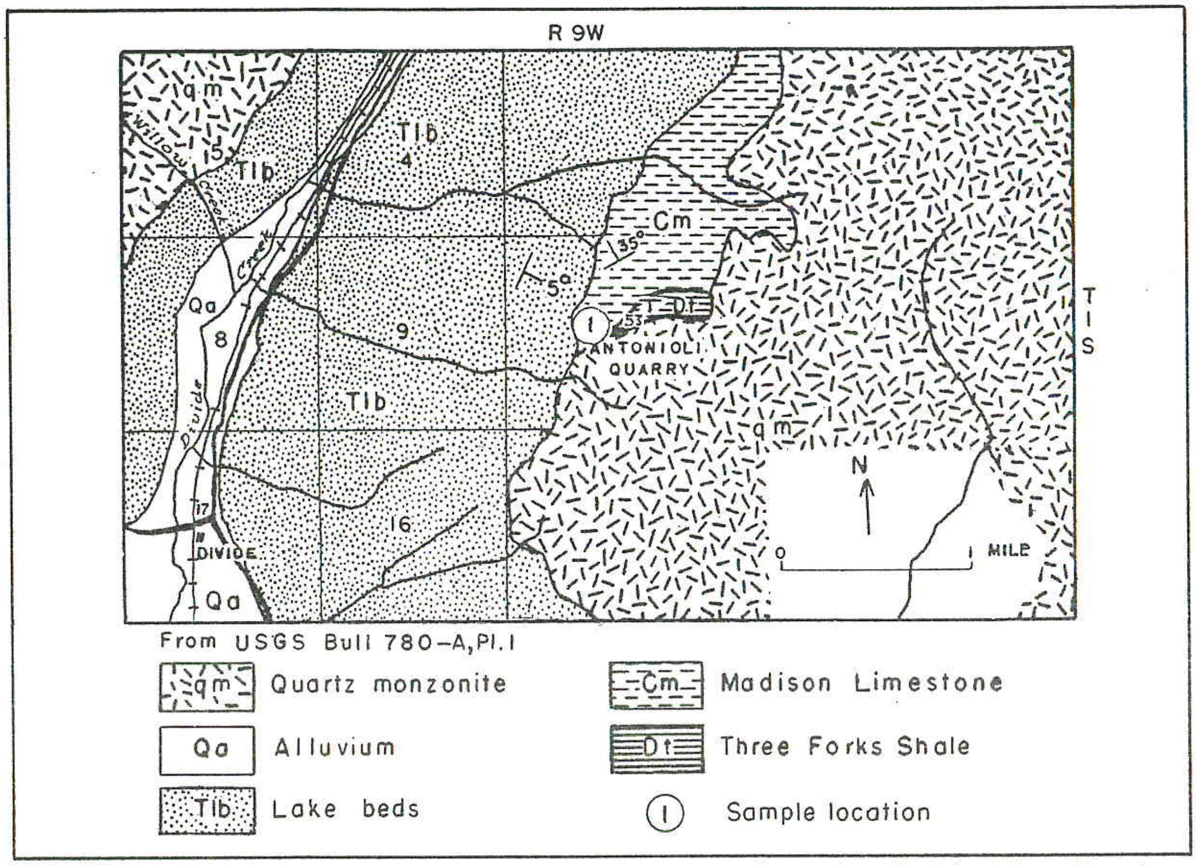


Figure 3.--Geologic map of the area northeast of Divide showing location of Antonioli quarry, Silver Bow County.

At the quarry face a 6-foot bedding-plane fault zone is offset by a "pencil-line" high-angle reverse fault. Samples were obtained from the hanging wall in the gouge zone (1a) and the material lying above (1c) and below (1b) the gouge zone. Results of analyses are shown in Table 3.

Table 3.--Analyses of Mission Canyon Limestone in Antonioli quarry in SW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 10, T. 1 S., R. 9 W.

Sample no.	Length of sample (feet)	Insol.	FeO	MgO	CaO	P_2O_5	S
1a(w)*	6	14.7	0.2	---	42.8	---	---
1b(w)	13	3.4	0.2	---	44.0	---	---
1c(w)	40	2.4	0.2	---	50.0	---	---

*(w) Weathered chip sample.

The semiconsolidated fine-grained nature of the 6-foot gouge zone is such that much of the insoluble material would be eliminated in the fines after crushing and screening.

Sample 2

Sample 2 was collected from the limestone bluffs behind and east of Dewey in the S$\frac{1}{2}$ sec. 4, T. 1 S., R. 10 W. Dewey is 6$\frac{1}{2}$ miles west of Divide on State Highway 43. The Union Pacific Railroad at Divide would be the nearest loading point for material from this general area.

Sample 2a, a weathered chip sample, was obtained from a dark-gray-weathering medium-crystalline limestone, which in outcrop is exposed for a vertical distance of 50 feet. The length of sample was 21 feet.

Sample 2b, a clean chip sample, was collected from an overlying cream-colored coarse-crystalline limestone, interbedded with medium-crystalline limestone similar in appearance to 2a. Sample 2b, having a total length of 10 feet, was collected from an outcrop about 100 yards east of 2a. The two samples are representative of the carbonate lithologies present.

Richards and Pardee (1925) mapped the carbonate rock as Three Forks (Devonian). The Montana Geologic Map (1955) shows it as Mississippian undifferentiated (Fig. 4). The author, though not making an extensive survey, agrees with the State map, because of the purity and thickness of the limestone exposed. The limestone unit in the Three Forks Formation as described by Richards and Pardee contains "20 feet of grayish brown argillaceous limestone . . ." in addition to clay and sandstone. The total thickness exposed in the bluffs measured during sampling was 80 feet. Also, the argillaceous composition of the Three Forks is not consistent with the small amount of insoluble material in the analyses reported in Table 4.

Table 4.--Analyses of limestone (Mission Canyon(?)) near Dewey in S$\frac{1}{2}$ sec. 4, T. 1 S., R. 10 W.

Sample no.	Length of sample (feet)	Insol.	FeO	MgO	CaO	P_2O_5	S
2a	21	3.4	0.2	nil	52.3	nil	nil
2b	10	0.7	0.2	nil	53.8	nil	nil

The limestone sampled in total does meet the requirements of a high-calcium limestone, as the weighted average of impurities is less than 3 percent. Further investigation of the limestone in the area is warranted should its location prove favorable to industry.

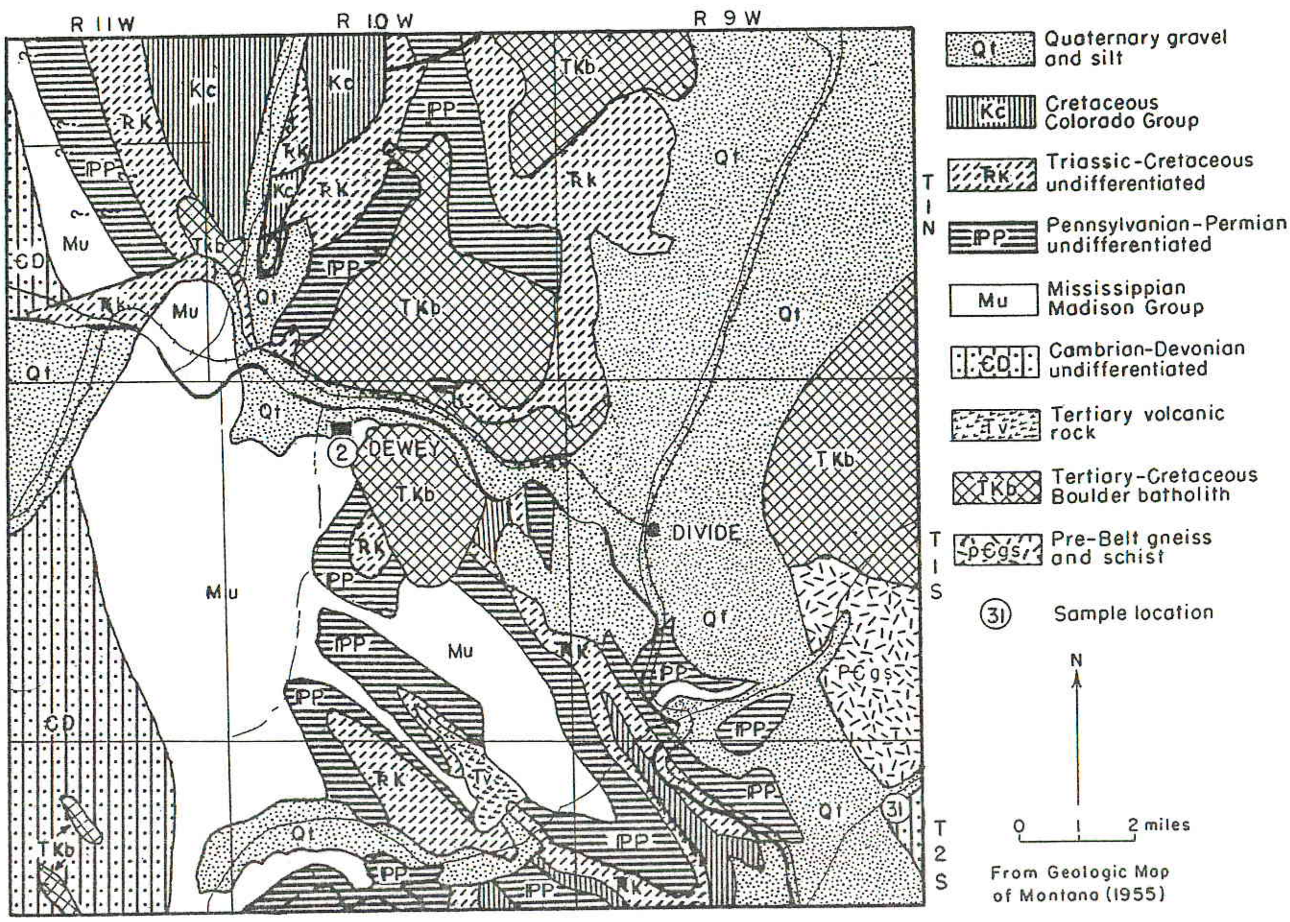


Figure 4.--Geologic map of the area south of Dewey, Beaverhead County, showing location of sample 2.

Sample 3

Sample 3 was collected from an old tunnel driven into spring-deposited calcareous material. The tunnel is about 75 yards west of the Johnny Gulch road in the SE$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 21, T. 5 N., R. 1 W. The area is reached by taking the Johnny Gulch road, which is 1 mile southeast of Radersburg. From this point the sample site is 8.6 miles.

The three samples (3a, b, and c), aggregating a total length of 33 feet, were broken at changes in lithology. Sample 3a is a sandy-textured carbonate; 3b is essentially the same texture, but more indurated; and 3c is a vuggy-banded material, suggestive of travertine. In the banded material in surface outcrop fossil leaves and pine cones were found.

The spring deposit, which occupies an area a half mile long and a quarter mile wide, is surrounded by Mission Canyon Limestone.

Thickness of the spring deposit, from road level to its highest point, is about 500 feet. Geology of the areas to the west and east is described by Klepper and others (1957) and Freeman (1954) respectively.

Results of analyses (Table 5) show the material to have a high percentage of insoluble material and in part a low percentage of calcium oxide. These analyses, however, are not representative of the Mission Canyon Limestone surrounding the spring deposit.

Table 5.--Analyses of hot-spring-deposited limestone in SE$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 21, T. 5 N., R. 1 W.

Sample no.	Length of sample (feet)	Insol.	FeO	MgO	CaO	P_2O_5	S
3a	5.5	42.7	1.7	3.3	24.5	nil	nil
3b	3.5	7.9	0.4	7.7	47.8	nil	nil
3c	24.0	2.2	0.3	3.1	52.5	nil	nil

Truck transportation would be necessary from the site for a distance of 17.5 miles to the Northern Pacific Railway Co. at Toston.

Sample 4

Sample 4, a chip sample of weathered rock, was collected from the face of an inactive quarry, commonly referred to as the Sappington limestone quarry. It is located 2 miles east of the town of Sappington in the S$\frac{1}{2}$ sec. 34, T. 1 N., R. 1 W. The property is owned by Mrs. Sappington, who resides in the town of the family name.

The quarry is cut into a gently rolling hill in the Mission Canyon Formation on the south side of the river (Fig. 5). The limestone crops out for a distance of about 4 miles. Paralleling the outcrop are the main lines of the Chicago, Milwaukee, and St. Paul Railroad and the Northern Pacific Railway.

The quarry operated from about 1925 to 1935 supplying limestone to Great Western Sugar Co. in Billings. Perry (1945) reported analysis of the limestone prepared by the Great Western Sugar Co. as 98.0 percent calcium carbonate, 1.4 percent magnesium carbonate, and 1.6 percent insoluble material (silica, iron, and alumina). Analysis of a 30-foot chip sample, taken from the quarry face and prepared by the Bureau, showed 97.5 percent calcium carbonate, 0.2 percent insoluble, 0.1 percent iron, 2.1 percent magnesium carbonate, and nil for phosphorus and sulfur.

Sample 5

One of the main sources of limestone for the Butte smelters, which began operations about 1875, was the Limespur quarry in Jefferson Canyon, 40 miles east of Butte. Limespur is

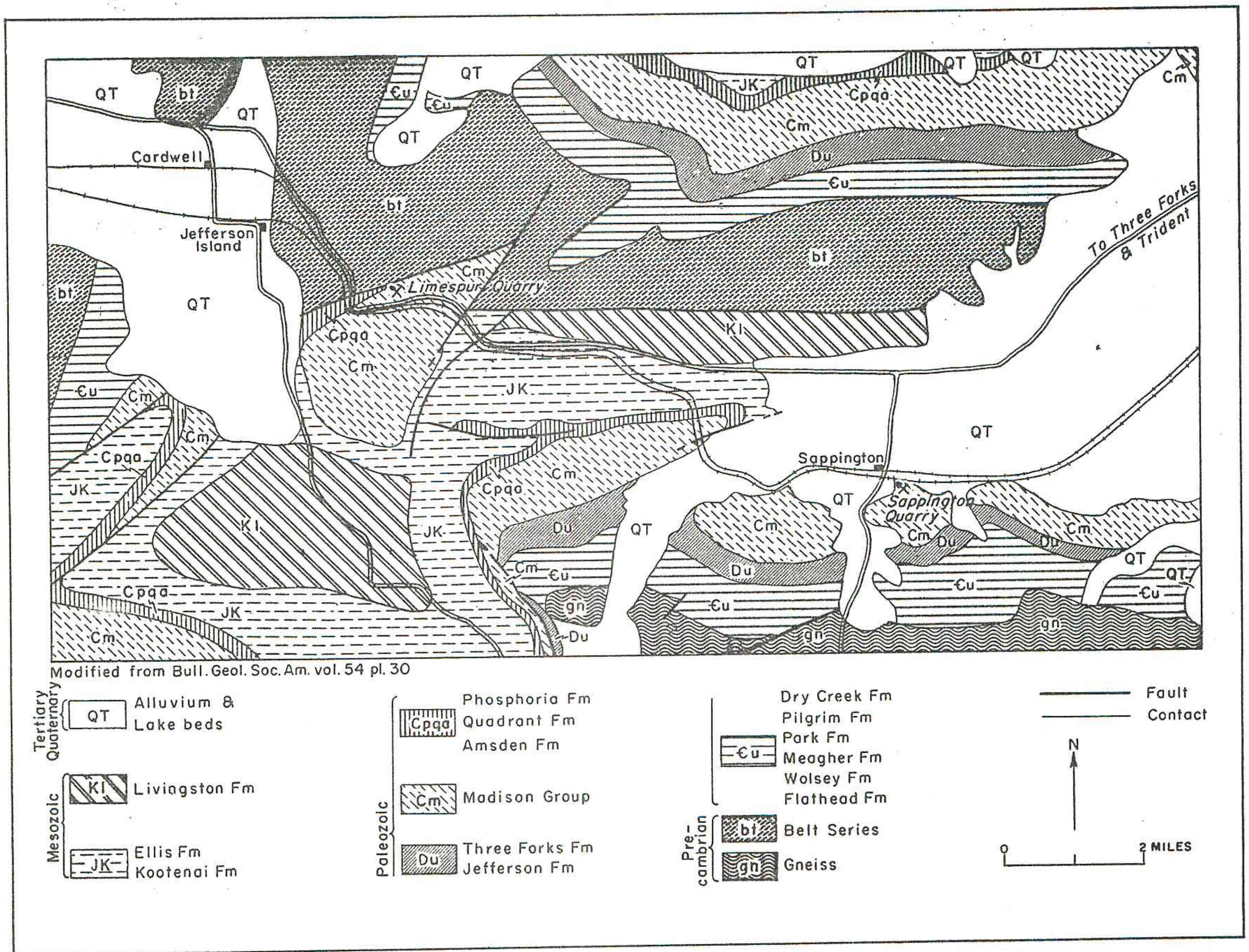


Figure 5.--Geologic map of the area around Sappington and Limespur quarries, Jefferson and Gallatin Counties.

a siding on the main line of the Northern Pacific Railway. U. S. Highway 10 passes just south of the quarry site, and the main line of the Chicago, Milwaukee, St. Paul, and Pacific Railroad is on the opposite side of the Jefferson River, about 500 feet south of the quarry. Operations were carried on by the East Butte Copper Mining Co., which closed its mine and smelter in 1925. No limestone has been produced from the quarry since 1925.

Because of topography and in order to follow certain beds selectively, the rock was quarried from a large underground stope that reached surface. Selective mining produced limestone that is reported by Perry (1949) as having 97.5 percent calcium carbonate, 1.9 percent magnesium carbonate, and 0.6 percent insoluble. An average of 11 analyses of run-of-mine material made by the East Butte Copper Mining Co. showed 95.55 percent calcium carbonate, 2.42 percent magnesium carbonate, and 1.48 percent silica.

The quarry is in the middle part of the Mission Canyon Formation, the outcrop of which forms a belt nearly a half mile wide, extending 2 miles northeastward and about the same distance southward across the river (Fig. 5).

Sample 6

The Trident quarry is located adjacent to the Ideal Cement Co. plant at Trident, which is about 6 miles north of Three Forks. The plant is serviced by the Chicago, Milwaukee, St. Paul, and Pacific Railroad, whose main line passes through Trident. The Northern Pacific Railway is on the opposite side of the Missouri River, which is close by (Fig. 6).

The quarry has been developed in the Lodgepole Formation of the Madison Group. The quarry forms a single large bench, the quarry floor being sufficiently high to permit level hauling to the head of the plant, into which the rock is fed by gravity.

The Lodgepole Formation is characteristically a thin-bedded limestone with shaly partings. The shale and limestone are in about the right proportions for cement. Magnesia content generally does not exceed 2 percent. Some rock used for making lime has been selectively mined from nearly pure beds. An average analysis of the quarried stone is silica, 8.56 percent; alumina, 1.59 percent; ferric iron, 0.87 percent; calcium carbonate, 85.41 percent; and magnesium carbonate, 2.08 percent (personal communication, Ideal Cement Co.).

Geology of the areas southwest and northwest of Trident is described by Freeman and others (1958) and Robinson (1963) respectively.

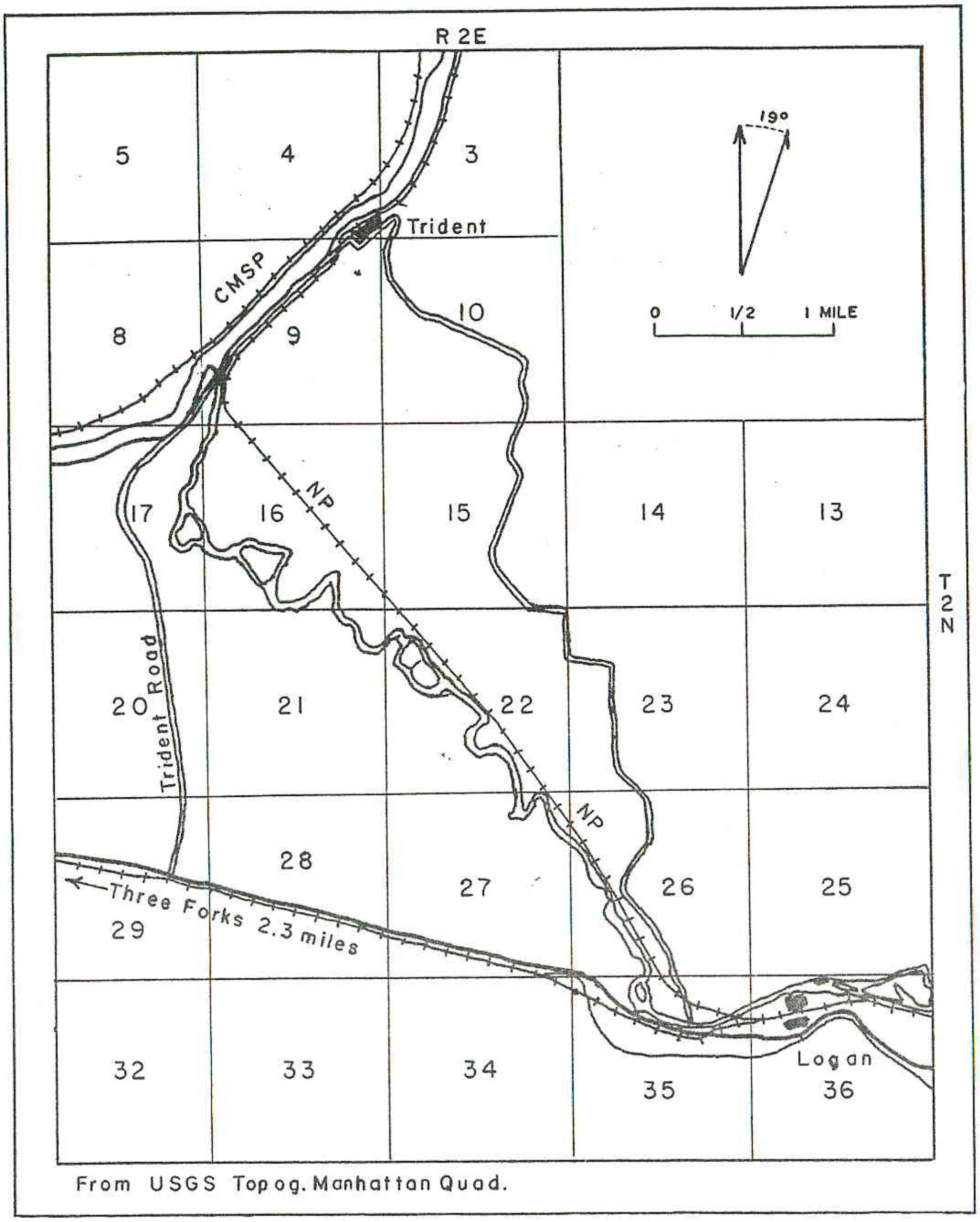


Figure 6.--Sketch map showing location of Ideal Cement Co. plant at Trident, Gallatin County.

Samples 7 through 22

As a result of the efforts of Webb and Knapp to establish a steel plant east of Anaconda, for which they would need limestone, the Bureau in the summer of 1960 collected 38 surface samples of carbonate rock from 14 exposures west of Anaconda in T. 5 N., R. 12 and 13 W. (Fig. 7). Though sufficient material of suitable grade was located, the plant has not materialized.

Many of the exposures are cliffs having a vertical height exceeding 150 feet, and some extend laterally for several miles. The outcrops sampled are accessible either by U. S. Highway 10-A or improved dirt roads.

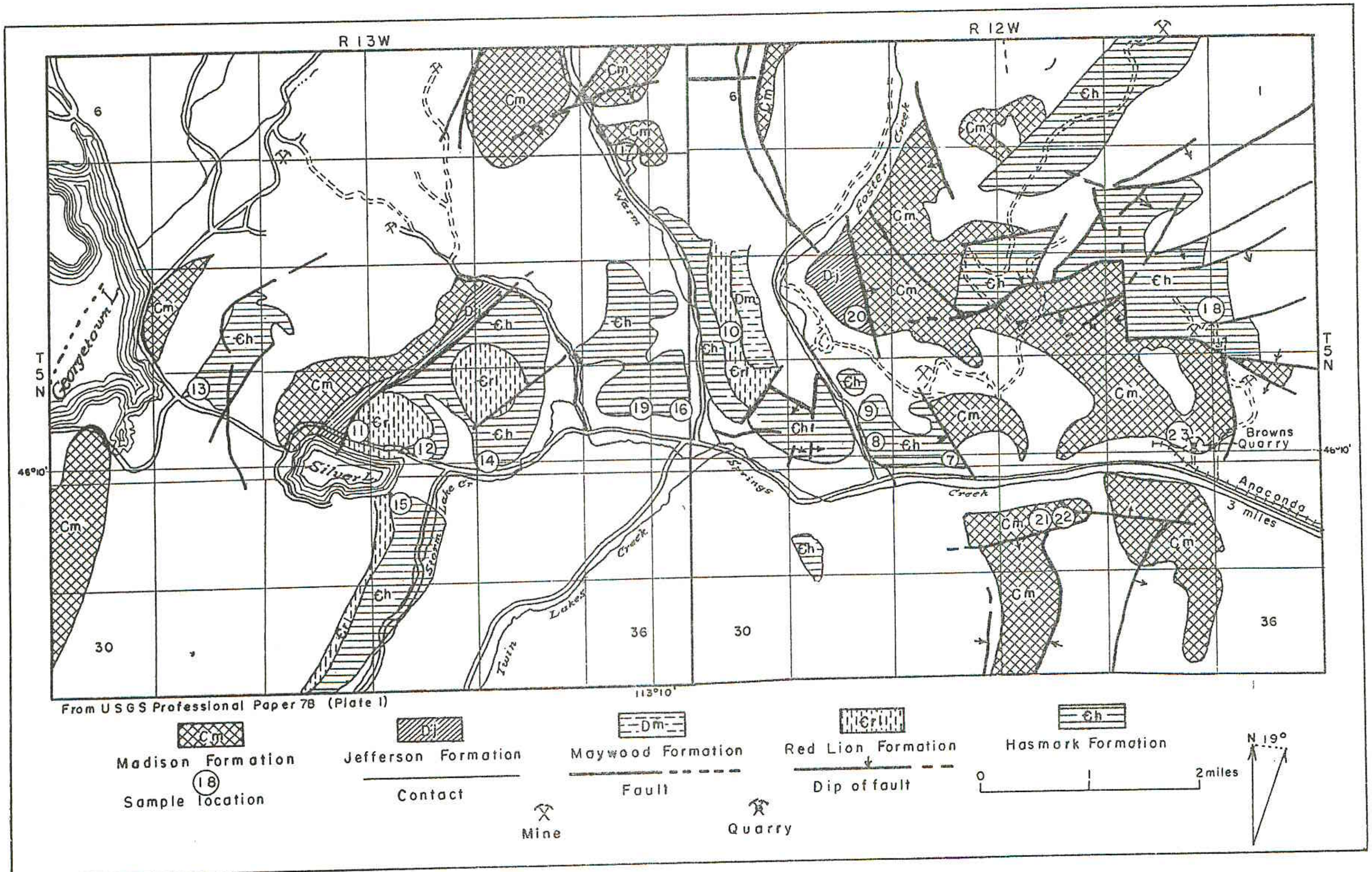


Figure 7.--Geologic map showing carbonate units and sample locations west of Anaconda.

Serving the area to Browns quarry, which is $4\frac{1}{2}$ miles west of Anaconda, is a spur of the Butte Anaconda and Pacific Railway. Truck transportation would be necessary from any quarry located beyond this point unless the operation was of sufficient size to induce extension of the spur farther west.

Rocks in the sampled area are composed of limestone, magnesian limestone, and dolomite. This nomenclature was determined by calculating the ratio of lime (calcium oxide) to magnesia (magnesium oxide) from the weighted average of lime and magnesia of each sample. The parameters are as follows:

CaO:MgO	Nomenclature
27:1	limestone
27:1 to 4:1	magnesian limestone
4:1 to 1.5:1	dolomite

Of the 14 carbonate deposits sampled, 9 are magnesian limestone and 5 are dolomite (Table 6). The dolomite deposits (samples 10, 12, 14, 15, and 16) contain less than 3 percent impurities and therefore qualify as chemical-grade dolomite. Six of the magnesian limestone deposits (samples 8, 9, 11, 18, 19, and 20) contain less than 4 percent impurities and are satisfactory for use in special metallurgical processes. The other three magnesian limestone deposits (samples 7, 13, and 17) contain so much insoluble material that they would be restricted to uses based on their physical properties rather than chemical composition.

The area is underlain by sedimentary rocks ranging in age from Paleozoic to Quaternary. The carbonate units are restricted to the Paleozoic. Found locally are intrusive bodies of granite, granodiorite, and basic diorite. The geology is made complex by faulting, which in part is illustrated in Figure 7. For a more detailed description of the geology and stratigraphy, the reader is referred to Emmons and Calkins (1943) and Hanson (1952).

Most samples were collected from the Hasmark Formation (Cambrian). Samples 21 and 22 were collected from Mission Canyon Limestone (Mississippian), samples 10 and 11 from the Red Lion Formation (Cambrian), and 17 and 20 from the Jefferson Formation (Devonian). The Hasmark, according to Emmons and Calkins (1913, p. 59), consists of a basal 500-foot blue-gray magnesian limestone, a 150-foot calcareous shale, and a 300-foot unit of mostly white magnesian limestone. These units farther to the southeast are separable and are mapped as Meagher Limestone, Park Shale, and Pilgrim Limestone.

Sample 23

The Anaconda Company's large smelter at Anaconda and the newly constructed concentrating plant at Butte require a large and continuous supply of limestone and lime. The limestone is obtained from Browns quarry, located at Warm Springs Creek, about 7 miles west of the smelter site. The quarry is serviced by a spur of the company-owned Butte Anaconda and Pacific Railway.

The quarry is developed in strata in the middle or lower part of the Mission Canyon Limestone (Fig. 7), in a west pit and and east pit, about 300 feet apart. The rock is dark-gray finely crystalline limestone. The Mission Canyon Limestone crops out for about 1½ miles along Warm Springs Creek, and it extends far northward into the mountains.

An analysis of a composite sample reported by Perry (1949) showed 50.2 percent calcium oxide, 2.0 percent magnesium oxide, 1.3 percent iron oxide, 0.6 percent aluminum oxide, and 7.4 percent silica.

A small quarry on Lost Creek on Hoodoo Gulch, 4 miles north of Anaconda, supplied limestone for early-day local use. The quarry is cut into massive coarsely crystalline white marble, which has been developed by contact metamorphism of the upper part of the Mission Canyon Limestone. In hand specimen the rock is a mass of irregular grains of pure calcite about a quarter of an inch across. Haulage distance to the nearest railroad at Anaconda is about 10 miles over improved dirt road.

Sample 24

The major source of quicklime and hydrated lime used in Montana and the surrounding area is the Elliston quarry, east of Elliston, a station on the Northern Pacific Railway 25 miles west of Helena. Limestone has been calcined at this locality for more than 50 years. The plant, operated by the Elliston Lime Co. (offices at Deer Lodge) is adjacent to the Northern Pacific Railway and less than 100 yards north of U. S. Highway 12.

Limestone has been obtained from several open quarries cut into the rolling hill slopes, 300 to 2,500 feet north of the plant. Presently, however, most limestone for calcining is obtained from underground room-and-pillar mining operations. By this method kiln feed containing more than 98 percent calcium carbonate and less than 1 percent magnesium carbonate is maintained.

The quarries are developed in the upper massive beds of the Mission Canyon Limestone, which are exposed along the north side of the valley for about a half mile (Fig. 8). The limestone lies along the crest of a north-trending anticlinal fold that is truncated by erosion so that only the upper beds of the Madison and younger strata are exposed. The topography in this locality, although mountainous, may be described as sharply rolling.

Table 6.--Description and analyses of carbonate samples collected west of Anaconda.

Sample no.	Sample length, ft.	Location	Insol.	Fe	MgO	CaO	Weighted Average MgO	Weighted Average CaO	CaO:MgO*	TiO_2	P_2O_5	S	Remarks
7a	31	Hasmark Formation in west bluffs on east side of Foster Creek and adjacent to U.S. 10-A in the NE¼ NW¼ sec. 28, T. 5 N., R. 12 W.	16.1	0.5	8.2	37.0	7.9	37.0	2.9:1	nil	nil	nil	Sa 7a is of laminated blue fine-grained magn sian limestone containing a medium-grained friable zone. Sa 7b is of a laminated blue fine-grained magnesian limestone, which over a brecciated zone (Sa 7c). Underlying brecc zone is a salt and pepper speckled medium-grained magnesian limestone that weathers ye (Sa 7d). Sa 7e is of a white massively bedd fine-grained magnesian limestone containing incipient manganese dendrites. Talus-covere below Sa 7e.
7b	8.5		9.6	0.2	0.5	49.4				nil	nil	nil	
7c	3		17.7	0.4	0.9	44.3				nil	0.08	nil	
7d	36		27.5	1.0	0.7	38.0				0.08	0.12	.003	
7e	37		17.9	0.4	16.7	26.0				nil	nil	nil	
8a	16	Hasmark Formation in west bluffs on east side of Foster Creek in the SE¼ SE¼ sec. 20, T. 5 N., R. 12 W.	1.6	0.4	6.9	47.0	5.9	47.7	8.1:1	nil	nil	nil	Sa 8a is of alternating beds of white and bl laminated medium-grained magnesian limestone Sa 8b is of blue laminated medium-grained ma sian limestone, which overlies a white massi bedded fine-grained carbonate, which is high fractured (Sa 8c). Not continuous with 8c b 50 feet farther west and about 150 feet lowe blue laminated zone (8d and 8e). Below this zone is white massively bedded material that highly fractured (not sampled).
8b	6.5		2.0	0.2	7.7	45.1				nil	nil	nil	
8c	18		1.0	0.2	8.0	46.3				nil	nil	nil	
8d	12		2.0	0.2	6.7	47.0				nil	nil	nil	
8e	25		2.5	0.2	3.2	50.3				nil	nil	nil	
9a	18	Hasmark Formation on east side of Foster Creek 0.3 mile from turnoff in the SW¼ SW¼ sec. 20, T. 5 N., R. 12 W.	1.6	0.2	6.7	47.0	8.3	45.0	5.4:1	nil	nil	nil	Sa 9a is of salt and pepper speckled light-g magnesian limestone that overlies a laminate blue fine-grained magnesian limestone (9b) t contains coarse-grained stringers. Underlyi this is a white massive magnesian limestone zones of laminated blue material. Whole bod exposed is folded and faulted.
9b	23		2.1	0.2	10.2	42.8				nil	nil	nil	
9c	41		1.3	0.2	8.1	45.4				nil	nil	nil	
10a	30	Red Lion Formation(?) on east side of Warm Springs Creek in the NE¼ SW¼ sec. 18, T. 5 N., R. 12 W.	0.8	0.2	21.0	30.6	21.1	30.7	1.5:1	nil	nil	nil	Both 10a and b are of a light-blue medium-grained, medium-bedded dolomite. Sample bro because of 50 feet of talus in central part exposure.
10b	34		1.0	0.2	21.1	30.6				nil	nil	nil	
11a	24	Red Lion Formation in second highway cut east from west end of Silver Lake in the NE¼ SE¼ sec. 21, T. 5 N., R. 13 W.	1.2	0.2	18.2	34.0	16.0	31.0	1.9:1	nil	nil	nil	Sa 11a is of white medium-grained unindurate magnesian limestone. Sa 11b is of a fault gouge. The hanging wall (11c) contains a li blue mottled magnesian limestone with gray laminated zones. Below this (11d) is a blac fine-grained magnesian limestone.
11b	2.5		33.4	2.6	5.5	22.8				0.25	0.30	nil	
11c	124		1.8	0.3	18.2	33.0				nil	nil	.003	
11d	12		1.6	0.2	12.0	40.6				nil	nil	nil	
12	60	Hasmark Formation in highway cut on north side of U.S. 10-A west of ski-area turnoff in the SW¼ SE¼ sec. 22, T. 5 N., R. 13 W.	2.0	0.2	20.4	31.0			1.5:1	nil	nil	nil	Greenish-gray blocky thin-bedded dolomite cu by many small ferruginous gouge zones.
13a	33	Hasmark Formation in highway cut on north side of U.S. 10-A at Dentons Point turnoff in the NE¼ NW¼ sec. 20, T. 5 N., R. 13 W.	20.3	0.8	8.3	33.5	3.3	41.3	12.5:1	tr	0.16	nil	Sa 13a is of a yellow-weathering light- to c tan mottled magnesian limestone. Weathered faces show "spider web" differential weatheri Sa 13b is blue and green mottled, as is 13c.
13b	59		13.8	0.6	1.1	45.2				tr	0.16	.001	
13c	22		20.5	0.6	0.3	42.7				tr	0.14	.005	

14	36	Hasmark Formation in highway cut east of ski-area turnoff on north side of U.S. 10-A in the SW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 23, T. 5 N., R. 13 W.	2.3	0.2	21.4	30.8			1.4:1	nil	0.08	nil	Gray-weathering fine- to medium-grained medium-bedded light-blue dolomite.
15	30	Hasmark Formation on west side of Storm Lake road 0.5 mile from turnoff in the SE$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 27, T. 5 N., R. 13 W.	1.2	0.2	21.4	31.0			1.5:1	nil	nil	nil	White massively bedded saccharoidal dolomite.
16a	42	Hasmark Formation in west bluffs at mouth of Warm Springs Creek in the SE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 24, T. 5 N., R. 13 W.	0.6	0.2	21.6	31.2	21.3	31.1	1.4:1	nil	nil	nil	Sa 16a is of alternating blue-gray medium-grained dolomite and tan coarse-grained dolomite. This same sequence persists throughout samples 16b, c, and d. Above Sa 16 a, b, c, and d lies a thick section of carbonate (very likely dolomite) that was not sampled, because inaccessible.
16b	2		0.6	0.2	21.4	31.0				nil	nil	nil	
16c	6.5		1.8	0.2	20.1	30.5				nil	nil	nil	
16d	4.5		0.9	0.2	20.7	31.3				nil	nil	nil	
17a	10	Jefferson Formation(?) sampled in McKay adit east of upper Warm Springs Creek campground in the SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 1, T. 5 N., R. 13 W.	0.6	0.2	1.0	54.5			54.5:1	nil	nil	.012	White unindurated limestone (Sa 17a) cut by a siliceous fault zone (Sa 17b). A small quantity of this 17a was used by Taylor and Knapp at Philipsburg. The amount of material present is not known.
17b	2		24.4	0.9	1.8	38.0			21.0:1	0.10	0.08	.004	
18a	24	Hasmark Formation above Blue Eyed Nellie shaft in the SE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 14, T. 5 N., R. 12 W.	1.7	0.1	20.3	31.0	20.0	31.5	1.6:1	nil	nil	nil	Sa 18a is of a white coarse-grained magnesian limestone containing sporadic limonite-stained vugs, which themselves contain $\frac{1}{4}$-inch mica plates. Sa 18b is same material but containing small amounts of garnet and pyrite. About 35 feet below and 75 feet south is a white coarse-grained magnesian limestone (Sa 18c).
18b	18		0.7	0.3	20.7	31.0				nil	nil	nil	
18c	27		2.4	0.3	19.4	31.2				nil	nil	nil	
19a	34	Hasmark Formation in west bluffs at mouth of Warm Springs Creek in the SW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 24, T. 5 N., R. 13 W.	1.2	0.2	19.1	31.2	19.2	31.2	1.6:1	nil	nil	nil	The total sample is of a blue-gray, a banded blue-white, and a dark-blue fine-grained magnesian limestone. Sample 19a was broken at talus. Sa 19b and c were taken about 25 feet west of 19a.
19b	15		2.1	0.4	19.4	31.4				nil	0.02	nil	
19c	6		3.5	0.2	19.1	31.5				nil	0.03	nil	
20	22	Jefferson Formation in lower part of bluffs on east side of Foster Creek road in the NW$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 17, T. 5 N., R. 12 W.	3.4	0.2	0.5	53.1			10.4:1	nil	0.03	nil	Conglomeratic zone containing angular pieces of tan and blue-gray limestone.
21	30	Mission Canyon Limestone on south side of U.S. 10-A in the NE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 28, T. 5 N., R. 12 W.	0.8	0.2	nil	54.3				nil	0.05	nil	Blue fine- to coarse-grained limestone containing calcite-filled veinlets.
22	25	Mission Canyon Limestone on south side of U.S. 10-A and below Sa 21 in the NE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 28, T. 5 N., R. 12 W.	4.0	0.3	nil	51.4				nil	0.10	nil	Breccia zone of angular blue fine-grained limestone.

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*Greater than 27:1 - limestone; 27:1 to 4:1 - magnesian limestone; 4:1 to 1.5:1 - dolomite.

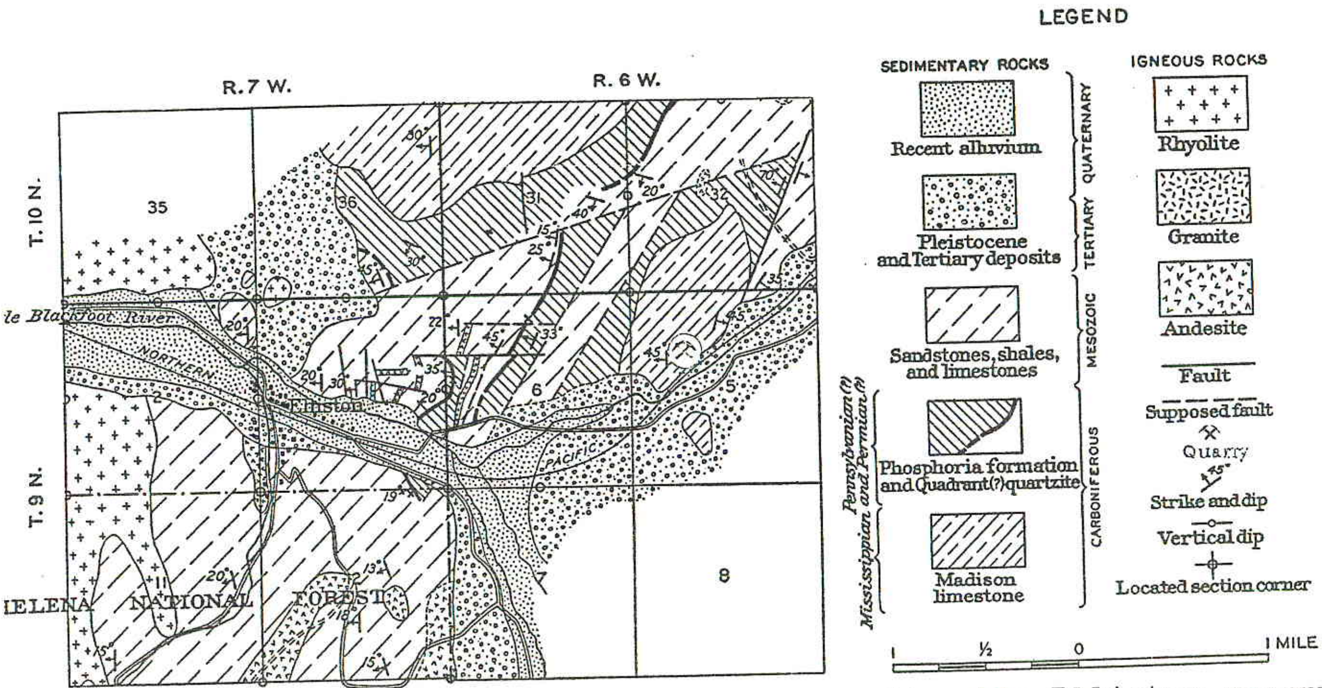

Figure 8.--Geologic map of the area surrounding the Elliston quarry, Powell County.

Analysis of a sample collected from feed bins showed 0.5 percent insoluble, 0.4 iron, 0.2 magnesium oxide, 55.5 calcium oxide, and nil for titanium dioxide, phosphorus, and sulfur. Analysis of average rock quarried in 1948 was 98 percent calcium carbonate, 1.0 percent magnesium carbonate, 1.0 percent insoluble, and trace of iron and aluminum oxide (Perry, 1949, p. 35).

Samples 25 through 27

Samples 25 through 27 were collected south of Whitehall in Perry Canyon. The area is reached by traveling south out of Whitehall across the Mayflower bridge to the Bone Basin road, then up the Bone Basin road. Sample 25a and b were taken from dolomite outcrops 6.3 miles up Bone Basin road in the NE$\frac{1}{4}$ sec. 13, T. 1 S., R. 4 W. Sample 26 was collected about one mile northeast in the NW$\frac{1}{4}$ sec. 12, T. 1 S., R. 4 W., and sample 27 about midway between samples 25 and 26. All are from the same outcrop of Madison Limestone, which forms the north rim of Perry Canyon and strikes N. 70° E. and dips 28° NW.

The main lines of the Northern Pacific Railway and the Chicago, Milwaukee, St. Paul and Pacific Railroad serve Whitehall. Truck transportation would be required for 14$\frac{1}{2}$ miles over good to fair dirt road.

Samples were collected from the Mission Canyon Formation, which in the area of sample 25a and b is gray-weathering fine-grained massive dolomite. In the vicinity of sample 26, the dolomite is siliceous and is composed of alternating 12-inch layers of gray-weathering dolomite and 3-inch layers of brown-weathering cherty dolomite. Above this zone is the massive zone from which samples 25a and b were collected. Sample 27 was collected from a massive gray-weathering siliceous limestone containing sporadic pods of chert. Analyses are included in Table 7.

Table 7.--Analyses of Mission Canyon Formation at Perry Canyon in sec. 12 and 13, T. 1 S., R. 4 W.

Sample no.	Length of sample (feet)	Insol.	FeO	MgO	CaO	P_2O_5	S
25a(w)*	30	2.8	0.4	20.9	31.7	nil	0.06
25b(w)	20	1.7	0.4	19.6	31.0	nil	0.06
26 (w)	23	32.8	1.0	19.4	26.0	nil	0.85
27 (w)	33	14.9	0.4	1.6	45.8	nil	0.85

*(w) Weathered chip sample.

Sample 28

Sample 28 was collected from the east slopes of the Gravelly Range in the NE$\frac{1}{4}$ sec. 14, T. 9 S., R. 2 W. (Fig. 9). The sample site is reached by traveling west across McAtee bridge on the Johnny Gulch road, which leaves U.S. Highway 287 about 18 miles south of Ennis. The sample site is north of the road about 8.5 miles from McAtee bridge.

Samples 28a, b, and c, weathered chip samples having an aggregate length of 85 feet, were collected from the Mission Canyon Formation of the Madison Group. The outcrop of the Madison Group on the east side of the Gravelly Range in this area is more than 2 miles wide and 10 miles long (Fig. 9). A distinct color change is recognized, from brownish-weathering limestone of the Lodgepole to the gray of the Mission Canyon. Topographically the Mission Canyon forms long, fairly steep, rubble-covered rock slopes. The rock is brown to gray, dense, finely crystalline, and massive. Local units as much as 30 feet thick show no clear bedding (Mann, 1954, p. 11a).

Table 8.--Analyses of Mission Canyon Limestone in Gravelly Range in sec. 14, T. 9 S., R. 2 W.

Sample no.	Length of sample (feet)	Insol.	FeO	MgO	CaO	TiO_2	P_2O_5	S
28a(w)	23	4.0	0.2	nil	53.3	nil	nil	0.05
28b(w)	5	38.4	0.9	nil	31.6	nil	nil	0.16
28c(w)	57	2.0	0.2	nil	54.5	nil	nil	0.06

(w) Weathered chip sample.

Only sample 28b is a different lithology than explained above. This 5-foot zone is fractured cherty limestone; analysis shows a 38.4 percent insoluble content (Table 8).

Rail transportation is available at Norris, which is 16 miles north of Ennis. The Northern Pacific Railway operates a

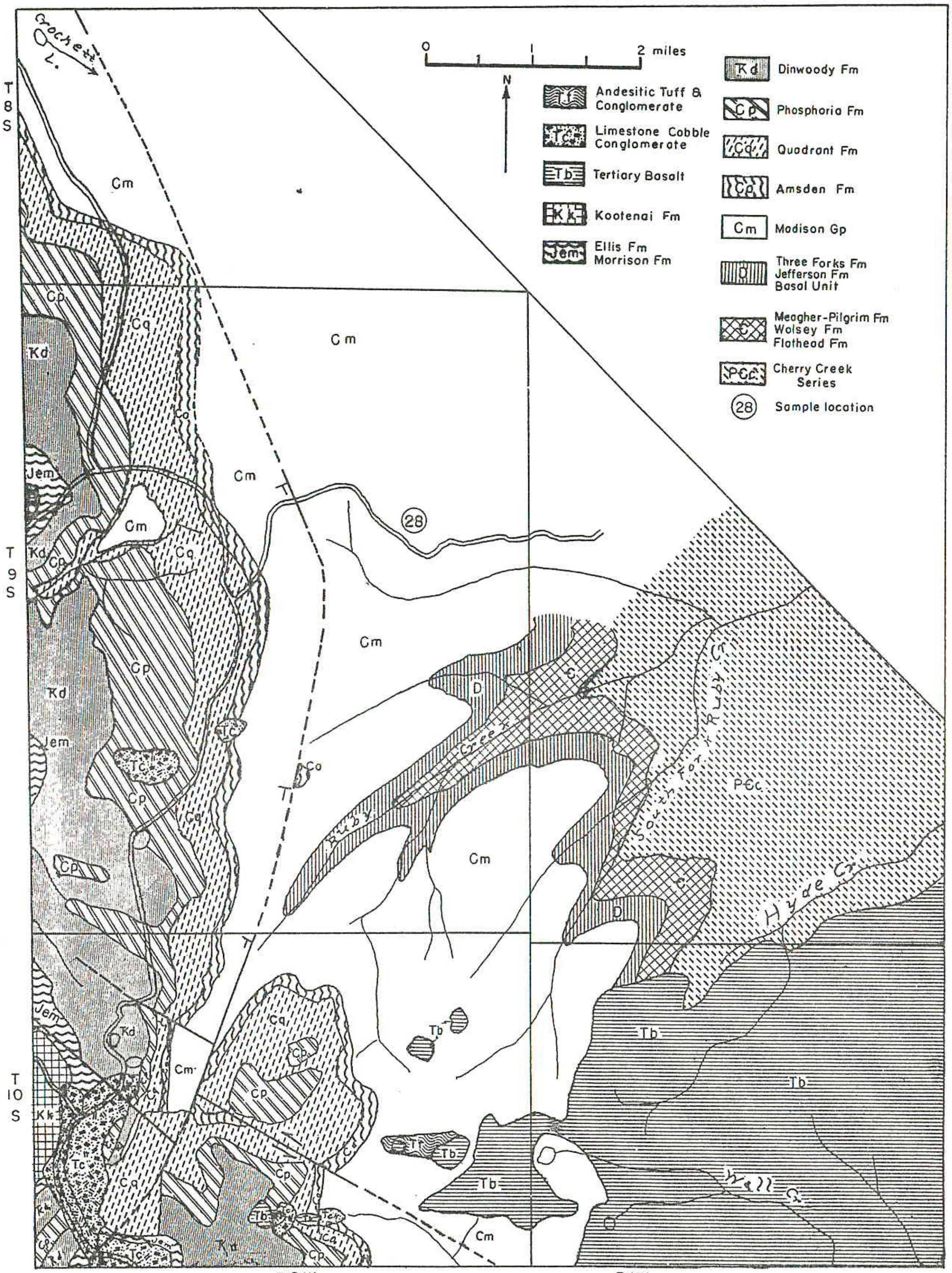

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Figure 9.--Geologic map of a portion of the Gravelly Range, Madison County, showing location of sample 28.

spur to this point. Another Northern Pacific spur serves Alder, which is 23 miles west of Ennis. Truck transportation would be necessary to either point.

Sample 29

Samples 29a, b, and c were collected from the Mission Canyon Formation, 10 miles up the Birch Creek road in sec. 15, T. 5 S., R. 10 W. (Fig. 10). The Birch Creek road leaves U.S. Highway 91 at a point 17 miles north of Dillon. The sample site is north of and adjacent to the road.

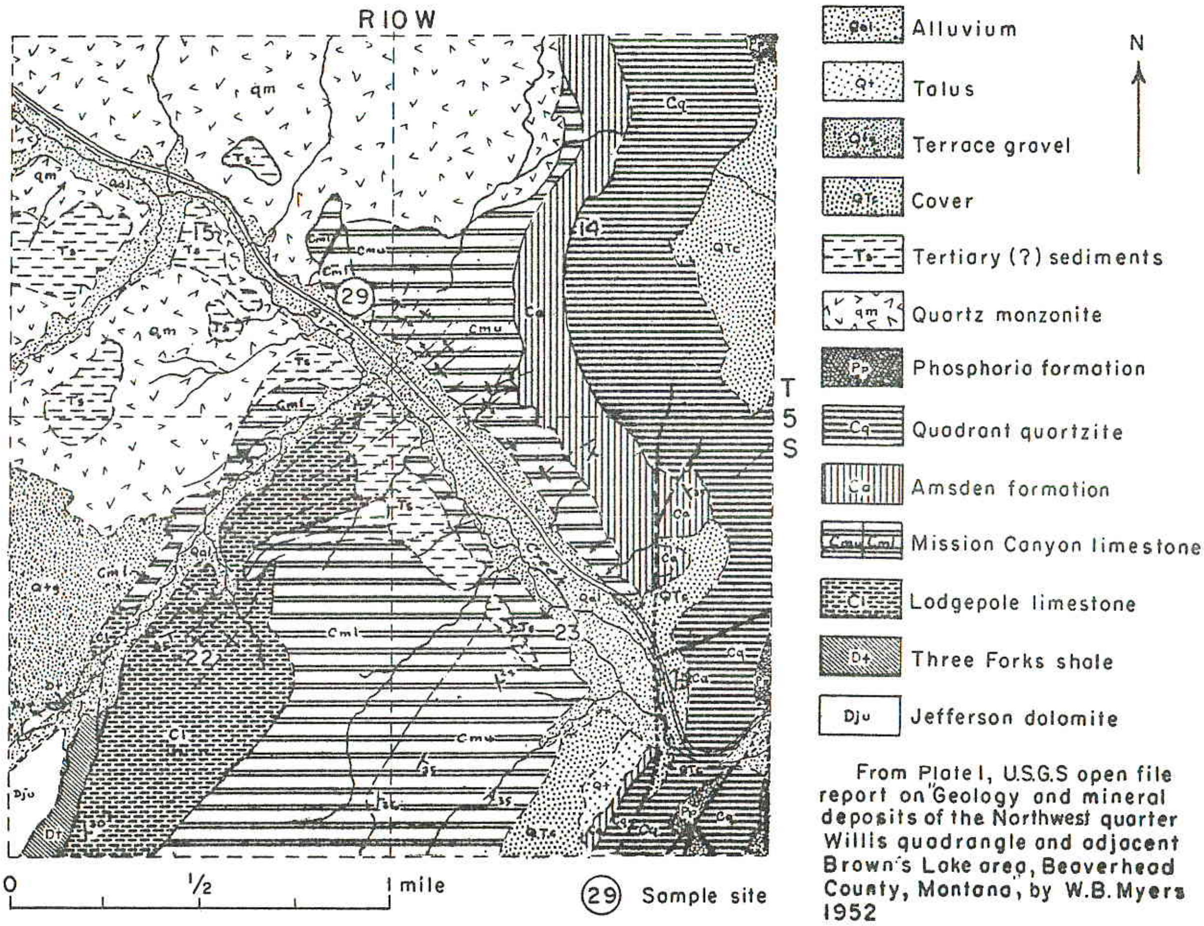


Figure 10.--Geologic map of the area surrounding sample site 29, Beaverhead County.

Sample 29a, a 54-foot weathered sample, was taken beginning at the contact of the limestone with the Mt. Torrey batholith thence east to a soil- and talus-covered area. The limestone is coarsely crystalline and weathers tan to white. The last 5 feet of the sample is a dense finely crystalline, tan speckled limestone. Sample 29b, a 48-foot weathered chip sample, was collected 200 feet farther east. This sample included limestone of different textures--blue coarse crystalline, tan coarse crystalline, and finely crystalline blue dense carbonate rock.

Sample 29c was collected from the same sequence of material and was also a weathered chip sample taken perpendicular to the bedding, which in the area strikes N. 25° E. and dips 25° NW.

Samples 29a and c show low insoluble and high lime content. Results of analyses are shown in Table 9.

Table 9.--Analyses of Mission Canyon Limestone at Birch Creek in SE$\frac{1}{4}$ sec. 15, T. 5 S., R. 10 W.

Sample no.	Length of sample (feet)	Insol.	FeO	MgO	CaO	TiO_2	P_2O_5	S
29a(w)	54	1.4	0.2	1.8	53.4	nil	0.11	nil
29b(W)	48	12.0	0.2	0.5	48.4	nil	0.10	nil
29c(w)	42	1.0	0.2	0.7	54.0	nil	0.16	nil

(w) Weathered chip sample.

Rail transportation is available at Apex, a Union Pacific Railroad siding 10 miles distant from the sample site by unimproved dirt road.

Sample 30

Sample 30 was collected about 3$\frac{1}{2}$ miles west of sample 29 in the NE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 18, T. 5 S., R. 10 W. by Stanley Fitzwater, Box 748, Dillon, Montana, and submitted to the Bureau for analysis. Mr. Fitzwater owns the three claims, Debbie S, Stanley P, and Larry P, from which the samples were collected.

Information supplied by the owner is as follows: "Thirteen excavations, approximately 4 feet wide, 8 feet long, and 10 feet deep have been made." Visually, the material from each excavation was the same, except one cut on the Stanley P claim and two cuts on the Larry P. (Author's note: The above-mentioned difference was not outlined in the correspondence.) Material from 10 of the 13 excavations supplied the sample that was analyzed.

"The above claims lie within the NE$\frac{1}{4}$ sec. 18, T. 5 S., R. 10 W., Beaverhead County (Birch Creek drainage). A National Forest Service road traverses the claims north and south. The approximate distance to the Apex siding of the Union Pacific Railroad is 13$\frac{1}{2}$ miles; the distance to U.S. Highway Interstate 15 is 17 miles; and to Dillon, 28 miles."

Analyses of samples are shown in Table 10.

Table 10.--Analyses of dolomite at Birch Creek in NE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 18, T. 5 S., R. 10 W.

Sample no.	Length of sample (feet)	Insol.	Fe	MgO	CaO	TiO_2	P_2O_5	S
30a	--	1.9	0.2	19.8	30.0	nil	nil	nil
30b	--	7.0	0.2	18.8	28.6	nil	nil	0.07
30c±	--	5.5	0.2	18.4	29.6	nil	nil	tr
30d*	--	3.32**	---	20.58	29.75	---	---	0.06

±Composite sample.
*Analysis provided by S. Fitzwater.
**SiO_2

Sample 31

Sample 31 was collected 2.8 miles from the Soap Creek road turnoff from U.S. 91, in the NW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 6, T. 2 S., R. 8 W. The unit sampled was the Jefferson Formation (Devonian), which here consists of 71 feet of blue massive finely crystalline dolomite. The unit crops out southeastward for about 9 miles. It is sandwiched between small sections of Mississippian and Cambrian rocks (Fig. 4).

The material can be classified as a high-grade dolomite, for its CaO-MgO ratio is 1:1.5, and impurities are less than 3 percent (Table 11).

Table 11.--Analysis of Jefferson Dolomite at Soap Creek in NW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 6, T. 2 S., R. 8 W.

Sample no.	Length of sample (feet)	Insol.	Fe	MgO	CaO	TiO_2	P_2O_5	S
31(w)	71	1.8	0.4	20.3	30.5	nil	0.12	nil

(w) Weathered chip sample.

Sample 32

Sample 32 was collected from a 30-foot section of massive cream-colored Mission Canyon Limestone outcrop just north of Stockett in the NE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 36, T. 19 N., R. 4 E. (Fig. 11).

The Great Northern Railroad (1959, p. 14) describes the section as the upper part of the Mission Canyon Formation, which from interpretation of well logs is 800 feet thick. This same unit, a short distance east along Willow Creek, was quarried in a minor way for building stone. Large reserves are easily accessible. Results of analyses are shown in Table 12.

Table 12.--Analyses of Mission Canyon Limestone at Stockett in NE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 36, T. 19 N., R. 4 E.

Sample no.	Insol.	Al_2O_3	Fe_2O_3	MgO	CaO	P_2O_5	S	R_2O_3
LS-32	1.49	0.44	0.28	9.34	44.60	0.019	0.012	
*	2.13±	**	**	0.92	51.30	**	**	1.25

±SiO_2
*Analyses by Great Northern Railroad.
**Not reported.

Sample 33

Not visited by the author but described in Great Northern Railroad Report 8 (1959, p. 12) is the Logging Creek quarry, located ". . . in section 22, T. 16 N., R. 6 E., on Belt Creek near the junction of Logging Creek . . . The Great Northern Railroad is seventeen road miles northeast at Raynesford (Fig. 11).

"The quarry was formerly owned and operated by The Anaconda Company for use as smelter flux at Great Falls, but was shut down prior to 1945 when the Great Northern Railroad abandoned the Armington-Neihart branch of the railroad. The land is now owned by Matt Antonich of Monarch.

"The rock was quarried from Mission Canyon Formation. More than 600 feet of section is exposed on Belt Creek. The outcrop area is in a band of limestone along the north flank of the Little Belt Mountains with ample reserves. Below is a 1911 analysis of the rock quarried by the Boston and Montana Co. (Perry, 1949, p. 40): CaO, 51.8; MgO, 3.2; R_2O_3, 1.0; CO_2, 44.0; total, 100.0."

Sample 34

Sample 34 was collected in sec. 10, T. 16 N., R. 8 E., about 3 miles south of Kibbey and 9 miles south of Raynesford. At Raynesford is the mainline of the Great Northern Railroad (Fig. 11).

Over a distance of one-half mile a grab sample was collected from the talus at the foot of the Mission Canyon Limestone, which forms the walls of a small steep-sided canyon. At the mouth of the canyon where sampling began, the material is medium-bedded (beds averaging 3 feet in thickness) gray-weathering finely crystalline limestone; relief is about 75 feet. Farther west into the canyon the limestone becomes more massive and the canyon walls rise to a height of about 250 feet. The beds strike N. 80° W. and dip 10° SW.

A quarry site could be developed without much difficulty at any spot within the canyon. The limestone crops out for a distance of 2 miles. The Great Northern Railroad sampled this site in 1959. The following is a direct quote from their Report 8 (1959, p. 14):

"Limestone Canyon: Outcrops in Limestone Mountain (Kibbey Dome), T. 16 N. R. 8 E., . . . offer the most suitable possibilities for development because of grade, accessibility and proximity to the Great Northern Railroad, 9 miles by road north at Raynesford.

"Limestone Canyon, sec. 10, T. 16 N., R. 8 E., has excellent exposures of the Mission Canyon Formation available for inspection . . . A series of vertical cliffs 10 to 75 feet in height are each terminated by a grassy bench, giving the entire section the appearance of huge steps over 300 feet in height. Samples were cut from the northwest side of the canyon between the mouth and first camp road to the northeast." Analyses of samples collected by the Great Northern Railroad are listed in Table 13. Results of analysis of the sample collected by the author show much similarity as can be seen in Table 13.

Table 13.--Analyses of Mission Canyon Limestone collected by Montana Bureau of Mines and Geology and Great Northern Railroad in sec. 10, T. 16 N., R. 8 E.

Sample no.	CaO	CO_2	MgO	SiO_2	R_2O_3	Totals
JB5817*	52.84	43.00	0.32	1.50	0.80	98.46
JB5818*	54.18	42.10	0.22	1.89	0.78	100.17
JB5819*	51.80	42.96	0.94	1.93	0.55	98.18
Weighted ave.	52.20	42.80	0.63	1.83	0.66	98.12

Sample no.	CaO	S	MgO	Insol.	Al_2O_3	Fe_2O_3	P_2O_5
LS-34±	52.74	0.027	1.65	2.73	0.13	0.14	0.034

*Great Northern Railroad.
±Montana Bureau of Mines and Geology.

This is one of the more advantageously located limestone deposits in the area. The limestone is easily accessible, abundant, and high grade. The Great Northern Railroad is but 9 miles distant. Total distance by improved and paved road to Great Falls is 45 miles.

Samples 35 through 40

Samples 35 through 40 were collected by Don C. Lawson in the summer of 1961. They will be described together in table form (Table 14) because of their similarity in lithology and close proximity to each other (Fig. 11).

The formation sampled is the Mission Canyon, which typically is a massive, dense, finely crystalline, gray limestone. The beds range in thickness from a few feet to 80 feet. Chert lenses and pods are locally concentrated. The limestone is exposed generally in coulees and cliffs in the higher elevations.

The Great Northern Railroad's Browns Spur is at Tracy, about 20 miles north of the area. Truck transportation over improved dirt road and paved road from Stockett to Tracy would be necessary. The total distance to Great Falls is 30 miles.

The limestone as can be determined from chemical analysis is in the most part high grade. Several analyses do show moderately high insoluble content, but it is the author's belief that suitable limestone could be found in the area without difficulty.

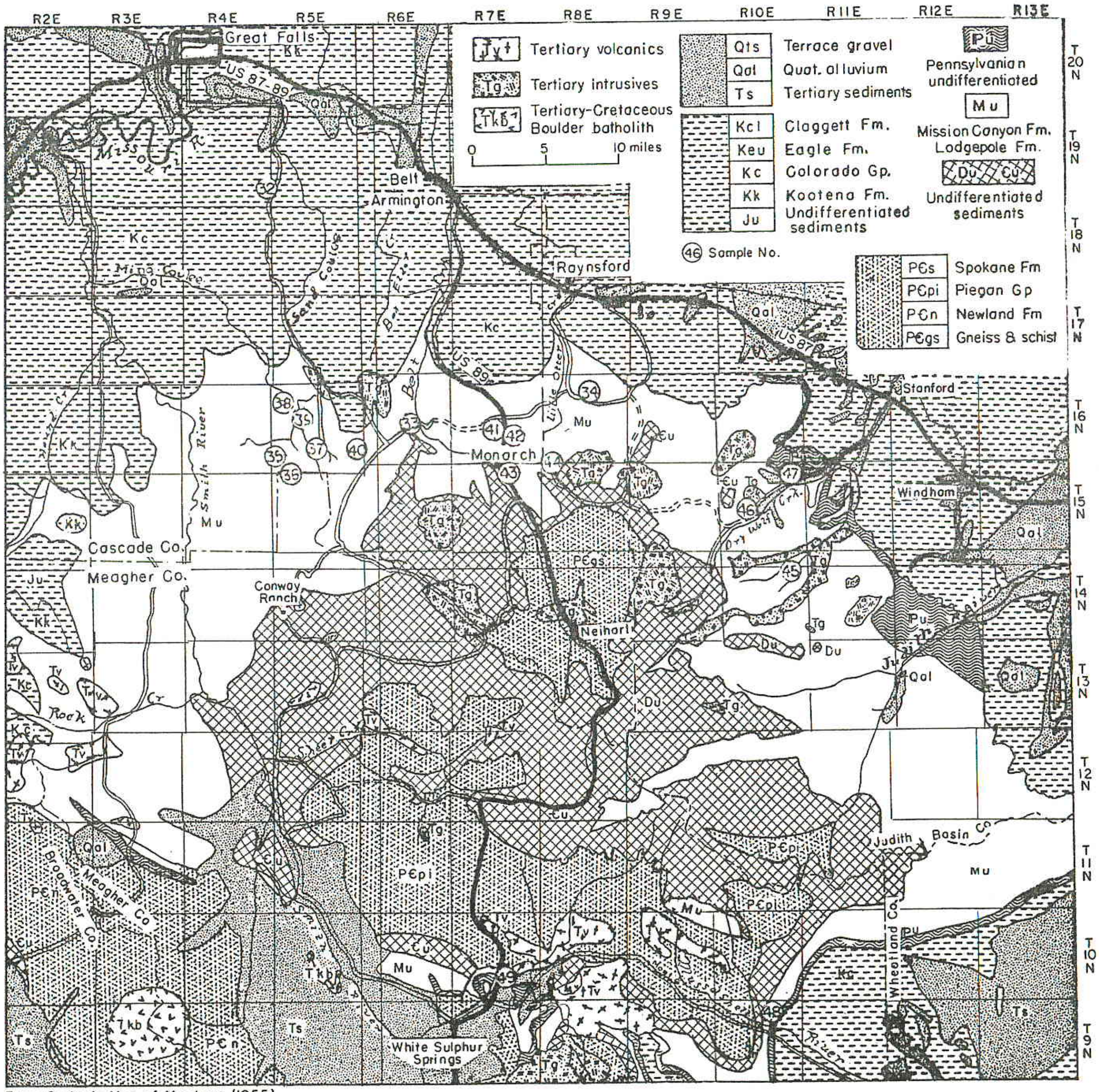
Table 14.--Analyses of samples collected south of Great Falls, Cascade County, Montana.

Sample no.	Length of sample (feet)	Location*	Insol.	Al_2O_3	Fe_2O_3	MgO	CaO	P_2O_5	S	Remarks
35	33	About 4 miles south of Calvert schoolhouse in center sec. 29, T. 16 N., R. 5 E.	1.20	0.34	0.07	0.98	54.51	0.009	0.006	Small canyon; Mission Can Limestone exposed as smal prominences. Weathered c sample. Water available site.
36a	40	Northwest wall of Ming Coulee about 400 yd. north of sample 35 in $NW\frac{1}{4}$ $NE\frac{1}{4}$ sec. 29, T. 16 N., R. 5 E.	0.90	0.30	0.07	0.65	54.08	0.017	0.002	Sample 36a is separated f 36b by soil-covered bench This section is stratigraphically below sample 35. Weathered chip sample.
36b	22		1.35	0.31	0.07	0.77	54.08	0.015	0.012	
37a	19	Ming Coulee north of where Calvert road enters Ming Coulee in $NW\frac{1}{4}$ $SW\frac{1}{4}$ sec. 28, T. 16 N., R. 5 E.	3.44	0.87	0.18	0.84	53.00	0.015	0.010	Section is stratigraphica below sample 35 and 36a a b. Weathered chip sample
37b	35		1.02	0.30	0.14	0.75	54.08	0.010	0.011	
38	49	$\frac{1}{4}$ mile south of Calvert school, adjacent to road in $NE\frac{1}{4}$ sec. 7, T. 16 N., R. 5 E.	5.19	0.31	0.40	0.94	52.14	0.019	0.040	Mission Canyon Limestone crop on south side of roa Weathered chip sample.
39a	11	Adjacent to road and about $2\frac{1}{2}$ miles north of Calvert school in $SE\frac{1}{4}$ sec. 31, T. 17 N., R. 5 E.	3.22	0.51	0.32	0.87	53.22	0.015	0.019	Sample 39a is separated f 39b by 15 feet of talus. Weathered chip sample.
39b	25		4.70	0.22	0.26	0.85	52.14	0.012	0.021	
40	57	Ming Coulee in $NW\frac{1}{4}$ sec. 25, T. 17 N., R. 4 E.	7.37	0.27	0.29	0.62	50.63	0.019	0.022	Limestone contains bands pods of chert. Weathered chip sample.

*See figure 11.

Samples 41 and 42

Sample 41, a 365-foot grab sample, was collected from Mission Canyon Limestone exposed in a road cut on U.S. Highway 89 in sec. 22, T. 16 N., R. 7 E. The cut is about a mile south of the junction of U.S. Highway 89 with Montana Highway 427 (Fig. 11).



From Geologic Map of Montana (1955)

Figure 11.--Geologic map of the Little Belt Mountains, southeast of Great Falls, showing sample locations.

Limestone is exposed in the cut on both sides of the highway. The material is medium-bedded lithographic limestone containing some oolitic zones. The beds strike N. 45° E. and dip 18° NW. Above and to the east, the rock contains small solution caverns and is more massive.

Sample 42 was taken from similar material exposed in a highway cut one-fourth mile south of sample 41. Comparison of analysis with sample 41 is shown in Table 15.

Table 15.--Analyses of Mission Canyon Limestone in U.S. Highway 89 road cuts in sec. 22, T. 16 N., R. 7 E.

Sample no.	Insol.	Al_2O_3	Fe_2O_3	MgO	CaO	P_2O_5	S
LS-41*	5.11	0.47	0.14	2.49	49.99	0.044	0.022
LS-42*	1.92	0.34	0.14	0.90	53.97	0.34	0.010

*Grab sample.

Sample 43

Sample 43, a 981-foot grab sample, was collected from a small block of Three Forks Formation (Devonian) 0.9 mile east of Monarch and adjacent to the Dry Creek road in the NE$\frac{1}{4}$ sec. 3, T. 15 N., R. 7 E. (Fig. 11). The Three Forks as sampled is mainly a gray- to cream-weathering, dark-gray, finely crystalline, thin-bedded magnesian limestone. At higher elevations the Lodgepole and Mission Canyon Formations crop out; farther east on the Dry Creek road both are found at road level. Nearest rail transportation is at Raynesford 18 miles north.

Analysis of sample 43 appears in Table 16.

Table 16.--Analysis of Three Forks Limestone collected in NE$\frac{1}{4}$ sec. 3, T. 15 N., R. 6 E.

Sample no.	Length of sample (feet)	Insol.	Al_2O_3	Fe_2O_3	MgO	CaO	P_2O_5	S
LS-43	981	4.98	0.96	0.50	19.77	29.73	0.024	0.027

Sample 44

Sample 44 was collected from talus at the base of the Lodgepole Limestone 3.4 miles east of Monarch and adjacent to the Dry Creek road in the center of sec. 6, T. 15 N., R. 8 E. (Fig. 11).

At this locale the Lodgepole is thin-bedded dark-gray-weathering fossiliferous limestone, which forms great vertical limonite-stained cliffs more than 500 feet high. At higher elevations the massive blue-gray-weathering Mission Canyon is in view.

Analysis of sample 44 is found in Table 17.

Table 17.--Analysis of Lodgepole Limestone near Monarch in sec. 6, T. 15 N., R. 8 E.

Sample no.	Insol.	Al_2O_3	Fe_2O_3	MgO	CaO	P_2O_5	S
LS-44	7.89	0.81	0.43	1.00	49.88	0.019	0.029

The area affords excellent quarry sites and contains large reserves. If quarried along strike (N. 82° E.; dip, 6° NW), no removal of overburden would be necessary and a selected product could be obtained. Rail transportation is available 21 miles north at Raynesford.

Sample 45

Sample 45, a channel sample, was taken across a black friable carbonate, believed to be the Jefferson Dolomite, in the NE¼ NE¼ sec. 12, T. 14 N., R. 10 E. (Fig. 11). The unit has been exposed by dozer cuts in the valley of Running Wolf Creek on land owned by Norman Whitaker.

At higher elevations in the area, the Jefferson Dolomite is typical dark tough dolomite, but in the sampled cut the unit is soft and friable. A porphyry dike that is found in proximity has possibly metamorphosed the unit locally. Analysis of the dolomite is found in Table 18.

Table 18.--Analysis of Jefferson Dolomite in NE¼ NE¼ sec. 12, T. 14 N., R. 10 E.

Sample no.	Insol.	Al_2O_3	Fe_2O_3	MgO	CaO	P_2O_5	S
LS-45*	2.05	0.91	0.36	20.21	30.81	0.024	0.036

*Channel sample.

Sample 46

Sample 46, a 350-foot grab sample, was collected from talus of the Lodgepole Formation on the west side of the Dry Wolf Creek road in the SW¼ SW¼ sec. 29, T. 15 N., R. 10 E. Sample site is 3.9 miles north of Dry Wolf Camp and about 15 miles southwest of Stanford. At Stanford is the main line of the Great Northern Railroad (Fig. 11).

Within the Dry Wolf Creek canyon both Mission Canyon and Lodgepole Limestone are found in outcrop to strike east-west, and dip 11° N. The Mission Canyon is exposed at road level at the mouth of the canyon and for about 3 miles up the canyon, where the contact between Mission Canyon and Lodgepole is crossed and both formations are in view. The sample was collected from Lodgepole talus.

For all practical purposes reserves are limitless and quarry sites abundant. The material is siliceous and slightly magnesian but could be used for the manufacture of cement. Report of analysis is in Table 19.

Table 19.--Analysis of Lodgepole Limestone in SW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 29, T. 15 N., R. 10 E.

Sample no.	Insol.	Al_2O_3	Fe_2O_3	MgO	CaO	P_2O_5	S
LS-46	6.19	1.06	0.36	2.42	49.56	0.019	0.037

The Mission Canyon Limestone was not sampled at this site, as the Great Northern Railroad (Report 12, 1960, p. 21) sampled this unit in the Blacktail Hills 5 miles northwest. Their sample is herein described as sample 47.

Sample 47

The Mission Canyon Formation crops out as a dome in T. 15 N., R. 10 E. (Fig 11). Though the author visited the site, no sample was taken, as it was sampled by the Great Northern Railroad (Report 12, 1960, p. 21). Their report reads as follows:

"Blacktail Hills Limestone (40): The Madison Mission Canyon Formation is exposed in the Blacktail Hills, an elliptical dome 3 miles long and 2 miles wide on the north flank of the Little Belt Mountains, 11 road miles south of Stanford. Dry Wolf Creek flows through a canyon at the northwest edge of the dome where approximately 100 feet of limestone is exposed. Stratigraphically, the beds are just below the Kibbey-Madison disconformity. The outcrop was sampled at a location 12 road miles southwest of Stanford, at the north entrance to the canyon on Dry Wolf Creek just west of the stone bridge, in NE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 12, T. 15 N., R. 10 E."

Chemical analyses as reported by Great Northern Railroad are shown in Table 20.

Table 20.--Analyses of Mission Canyon Limestone in NE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 12, T. 15 N., R. 10 E.

Sample no.	SiO_2	Fe	$CaCO_3$	$MgCO_3$	P	Total
JB5949	1.05	0.08	97.4	1.39	0.011	99.93
JB5950	1.11	0.06	97.2	1.51	0.010	99.98

Sample 48

Sample 48, a weathered chip sample, was collected from Mission Canyon Limestone cropping out in the center of sec. 10, T. 9 N., R. 10 E. (Fig. 11). This locale, 7 miles west of Martinsdale and 25 miles east of White Sulphur Springs, is a half mile west of U.S. Highway 12 on Spring Creek. The Chicago, Milwaukee, St. Paul and Pacific Railroad is at Martinsdale.

Reserves are, for all practical purposes, limitless. Mission Canyon is found in outcrop along Spring Creek road for 1½ miles. Outcrops are massive gray-tan-weathering finely crystalline limestone containing sparse chert nodules and stringers. Analysis is listed in Table 21.

Table 21.--Analysis of Mission Canyon Limestone in sec. 10, T. 9 N., R. 10 E.

Sample no.	Insol.	Al_2O_3	Fe_2O_3	MgO	CaO	P_2O_5	S
LS-48	2.82	0.30	0.14	1.69	53.00	0.024	0.001

Sample 49

Sample 49, a weathered chip sample, was collected in the foothills 6½ miles northeast of White Sulphur Springs in sec. 27, T. 10 N., R. 7 E.

The limestone is medium-bedded, gray-weathering, finely crystalline rock mapped on the State Geologic Map (Fig. 11) as Pennsylvanian undifferentiated. The quantity of limestone available is large, and possible quarry sites are many. Rail transportation is nearby at White Sulphur Springs. Analysis of sample 49 is found in Table 22.

Table 22.--Analysis of carbonate rocks in sec. 27, T. 10 N., R. 7 E.

Sample no.	Insol.	Al_2O_3	Fe_2O_3	MgO	CaO	P_2O_5	S
LS-49	8.16	0.64	0.36	1.33	52.79	0.034	0.038

Sample 50

Sample 50, a grab sample, was collected in the Judith Mountains from Mission Canyon Limestone talus for a length of 256 feet at the mouth of Limekiln Canyon in sec. 30, T. 16 N., R. 19 E. The site is reached by traveling east on improved dirt road for a distance of 4½ miles from the Chicago, Milwaukee, St. Paul, and Pacific "Ray-Winifred" junction, located 1½ miles north of Lewistown (Fig. 12).

Talus material consisted mainly of finely crystalline blue-gray-weathering carbonate rock; however, an oolitic variety was present. Massive limestone forms the sides of the canyon and crops out for about 1 mile. Three-quarters of a mile northeast of the sample site in Limekiln Canyon, igneous rocks lie in contact with carbonates. Weed and Pirsson (1896-97) describe the geology of the Judith Mountains.

The Great Northern Railroad (1960) also sampled the Mission Canyon Formation of Limekiln Canyon in the SE¼ SE¼ sec. 19, T. 16 N., R. 19 E. They report sampling a 50-foot bed of gray, iron-stained massive limestone thought to be 550 feet stratigraphically below the top of the Mission Canyon Limestone. Results of analyses of both the Great Northern Railroad and the author's samples are found in Table 23.

Table 23.--Analyses of Mission Canyon Limestone at Limekiln Canyon, Judith Mountains, SE¼ SE¼ sec. 19, T. 16 N., R. 19 E.

Sample no.	Insol.	Al_2O_3	Fe_2O_3	MgO	CaO	P_2O_5	S
LS-50	1.34	0.35	0.14	5.46	48.69	0.019	0.027

Sample no.	SiO_2	Fe	$CaCO_3$	$MgCO_3$	P	Total
FR5979*	1.91	0.15	96.60	1.06	0.010	99.73

*Great Northern Railroad.

The greater magnesia content of sample 50, relative to the magnesia content of the Great Northern Railroad sample FR5979, is the result of contaminating magnesian limestone of Devonian age that crops out near the talus sampled.

Sample 51

Sample 51 is a grab sample of travertine quarried by Montana Stone, Inc., Great Falls. Their quarry is located on the Paradise Ranch in the North Moccasin Mountains of central Montana, northwest of Lewistown. The author was unable to visit the quarry, owing to a road washout; however, it was learned that travertine was being quarried for building stone by Montana Stone, Inc., and marketed in Canada and the United States. Chemical analysis (Table 24) of stone stockpiled at the ranch shows the travertine to be very high in calcium oxide.

Table 24.--Analysis of travertine from Montana Stone, Inc., Paradise Ranch quarry, Fergus County.

Sample no.	Insol.	Al_2O_3	Fe_2O_3	MgO	CaO	P_2O_5	S
LS-51	0.70	0.76	0.14	0.46	54.08	0.009	0.033

Calvert (1909, p. 36) reported that the travertine is contained in an area of about 6 square miles and has a maximum thickness of 250 feet. It is early Quaternary in age, and Calvert referred to it as "The Park" formation. It is thought that the travertine at one time blanketed the intermontane basins of the area. Erosion has strongly dissected the area, and all that remains of the once extensive travertine are a few large and small scattered remnants. Perry (1949, p. 32) reported other, undeveloped travertine deposits occurring in the general area north and east of Lewistown. Mr. H. L. DeKalb of Lewistown, in a personal interview, stated that he found a travertine deposit in sec. 1 and 2, T. 15 N., R. 19 E. Another is reported northwest of Forest Grove.

Miller (1959) also described isolated occurrences in the South Moccasin Mountain.

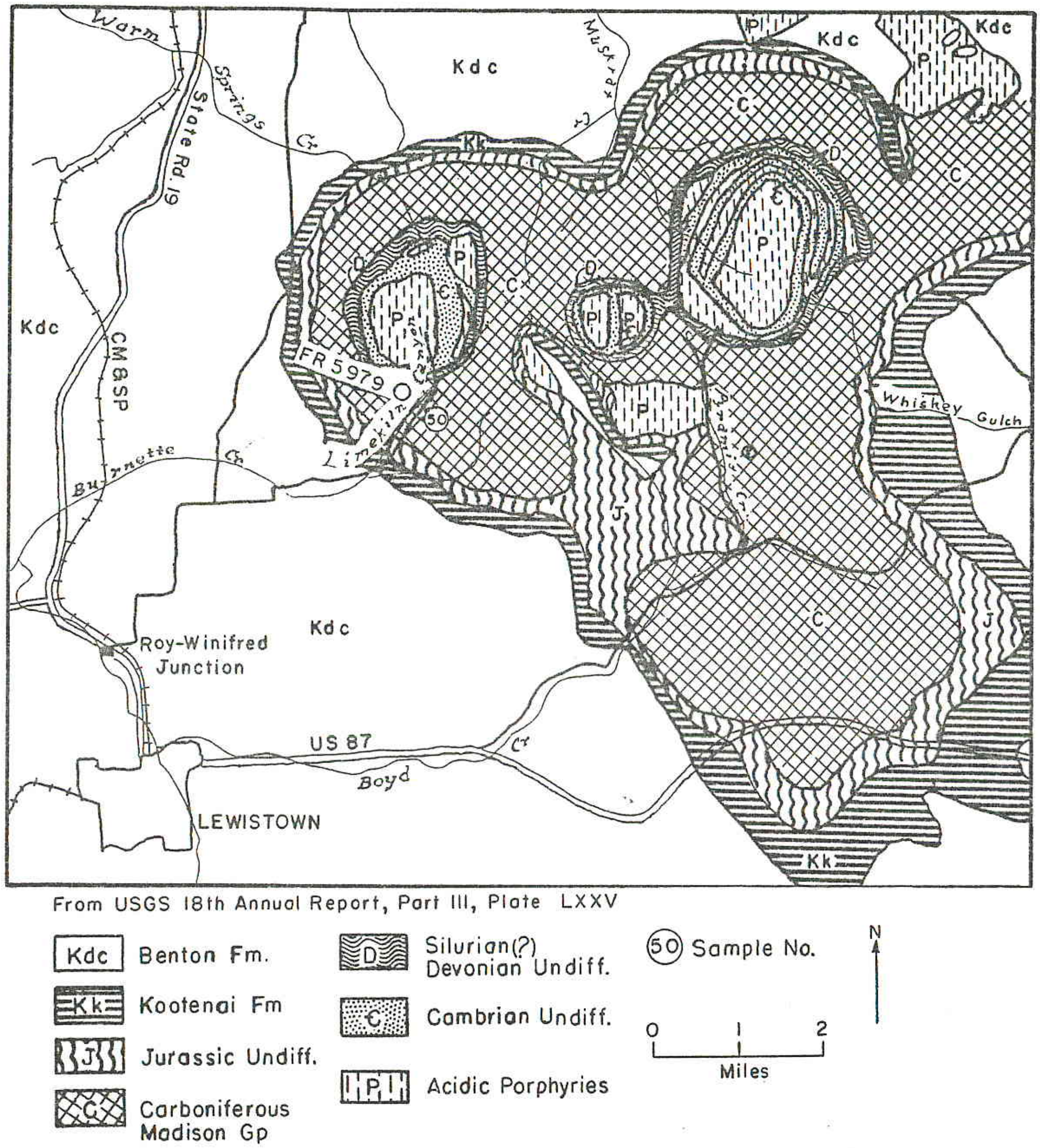


Figure 12.--Geologic map of part of the Judith Mountains, Fergus County, showing location of sample sites 50 and FR5979.

Sample 52

Sample 52, a grab sample, was collected from the Three Forks Portland Cement Co. (now part of Ideal Cement Co.) quarry in the South Moccasin Mountains in the SE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 10, T. 16 N., R. 17 E.

The quarry, which was operated from 1918 until abandoned in 1931, is at the 5,000-foot elevation on the South Peak Dome, 2 miles north and 1,200 feet above the plant at Hanover (Fig. 13). The plant presently supplies gypsum (mined at Hanover) to the Ideal Cement Co. operation at Trident. Miller (1959) reported that more than 500,000 tons of limestone was mined and crushed at the quarry and transported by aerial tramway to the cement plant.

South Peak is capped by flat-lying Mission Canyon Formation, which at the quarry face has been exposed for a length of 1,400 feet and a height of 80 feet. The quarry bench is about 100 feet wide. The limestone is blue gray in color; white calcite fills the voids. Two well-defined vertical fracture zones contain vugs 3 feet in diameter that are lined with calcite crystals.

Rail transportation is available at Hanover. Analysis of the grab sample collected from the talus at the face of the quarry is found in Table 25.

Table 25.--Analysis of Mission Canyon Limestone at Hanover quarry, $SE\frac{1}{4}$ $SE\frac{1}{4}$ sec. 10, T. 16 N., R. 17 E., Fergus County.

Sample no.	Insol.	Al_2O_3	Fe_2O_3	MgO	CaO	P_2O_5	S
LS-52	1.46	1.30	0.14	5.03	49.56	0.005	0.023

Sample 53

Sample 53, a grab sample, was collected from Mission Canyon Limestone southwest of Zortman in the Little Rocky Mountains in the $NW\frac{1}{4}$ $NE\frac{1}{4}$ sec. 20, T. 25 N., R. 25 E. (Fig. 14). The sample site is reached by traveling west up Alder Gulch on the west road leaving Zortman at Halzi General Store.

The Mission Canyon at this locality is a high-grade (Table 26), gray- to tan-weathering finely crystalline massive limestone. Farther up Alder Gulch the Lodgepole Formation crops out at road level. The Madison Group of this area, ranging in total thickness from 900 to 1,100 feet, rests on the Three Forks(?) Shale and is overlain disconformably by the Rierdon Formation (Knechtel, 1959).

Table 26.--Analysis of Mission Canyon Limestone in Little Rocky Mountains, $NW\frac{1}{4}$ $NE\frac{1}{4}$ sec. 20, T. 25 N., R. 25 E., Blaine County.

Sample no.	Insol.	Al_2O_3	Fe_2O_3	MgO	CaO	P_2O_5	S
LS-53	2.37	0.12	0.14	0.36	54.08	0.015	nil

Abundant reserves of limestone are suitably located for servicing northeastern Montana. Rail transportation is available 50 miles north at Harlem or Malta.

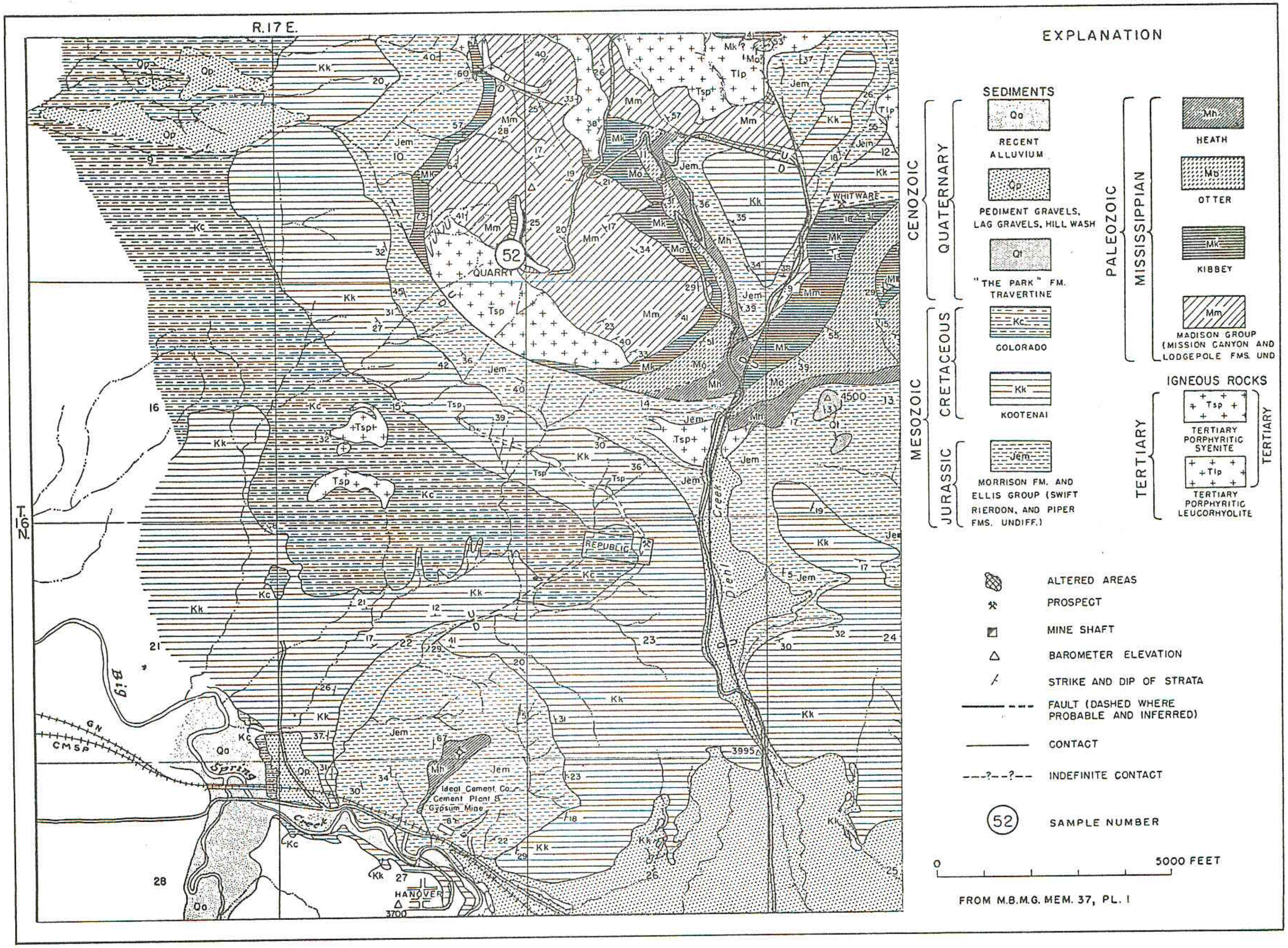


Figure 13.--Geologic map of part of the South Moccasin Mountains, Fergus County, showing location of Hanover quarry.

Sample 54

Sample 54, a grab sample, was collected from Mission Canyon Limestone cropping out several miles south of Livingston in the $NE\frac{1}{4}$ $NE\frac{1}{4}$ sec. 2, T. 3 S., R. 9 E., on the east side of the Yellowstone River. At this locality the beds strike east-west, dip 30° N., and form near-vertical cliffs on both sides of U.S. Highway 89.

Lithologically, the carbonates are typical medium-bedded to massive, blue-gray-weathering, finely crystalline Mission Canyon Limestone. Analysis in Table 27 indicate a higher content of insoluble material and magnesia than most samples collected from the Mission Canyon Formation, but the large section that is exposed is not totally represented by the sample collected. Further testing should reveal high-grade zones suitable for the most demanding processes.

Table 27.--Analysis of Mission Canyon Limestone in $NE\frac{1}{4}$ $NE\frac{1}{4}$ sec. 2, T. 3 S., R. 9 E., Park County.

Sample no.	Insol.	Al_2O_3	Fe_2O_3	MgO	CaO	P_2O_5	S
LS-54	3.15	0.37	0.24	2.07	51.93	0.019	0.015

The Mission Canyon outcrop extends both east and west of the sample site for a total distance of about 35 miles. The eastern extension borders the flanks of the Absaroka Range. Lammers (1937) describes the geology of the Livingston Peak area, an area directly south of the place where the carbonates were sampled.

Sample 55

Sample 55, a grab sample, was collected from the Lodgepole Formation north of Bozeman and 0.3 mile east of the fish hatchery adjacent to the Bridger road in the $NE\frac{1}{4}$ sec. 34, T. 1 S., R. 6 E. The material sampled is thin-bedded dark-blue-gray dense siliceous magnesian limestone (Table 28). The Mission Canyon Formation crops out at higher elevation. For a geologic description of the area, refer to Skeels (1939).

Table 28.--Analysis of Lodgepole Formation in $NE\frac{1}{4}$ sec. 34, T. 1 S., R. 6 E., Gallatin County.

Sample no.	Insol.	Al_2O_3	Fe_2O_3	MgO	CaO	P_2O_5	S
LS-55	10.80	1.69	0.64	4.33	44.82	0.019	0.048

Sample 56

Sample 56, a grab sample, was collected north of U.S. Highway 10, at a point 6 miles east of Bozeman in sec. 20, T. 2 S., R. 7 E. The formation sampled was Mission Canyon, which is exposed for a quarter of a mile on both sides of U.S. Highway 10 as large cliffs. Structural geology of the area is described by Skeels (1939).

The material where sampled is finely crystalline siliceous magnesian limestone weathering light gray white. Outcrops are adjacent to the main line of the Northern Pacific Railway. Analysis of sample 56 appears in Table 29.

Table 29.--Analysis of Mission Canyon Formation in sec. 20, T. 2 S., R. 7 E., Gallatin County.

Sample no.	Insol.	Al_2O_3	Fe_2O_3	MgO	CaO	P_2O_5	S	FeO
LS-56	10.9	0.75	0.08	17.36	29.8	0.008	tr	0.60

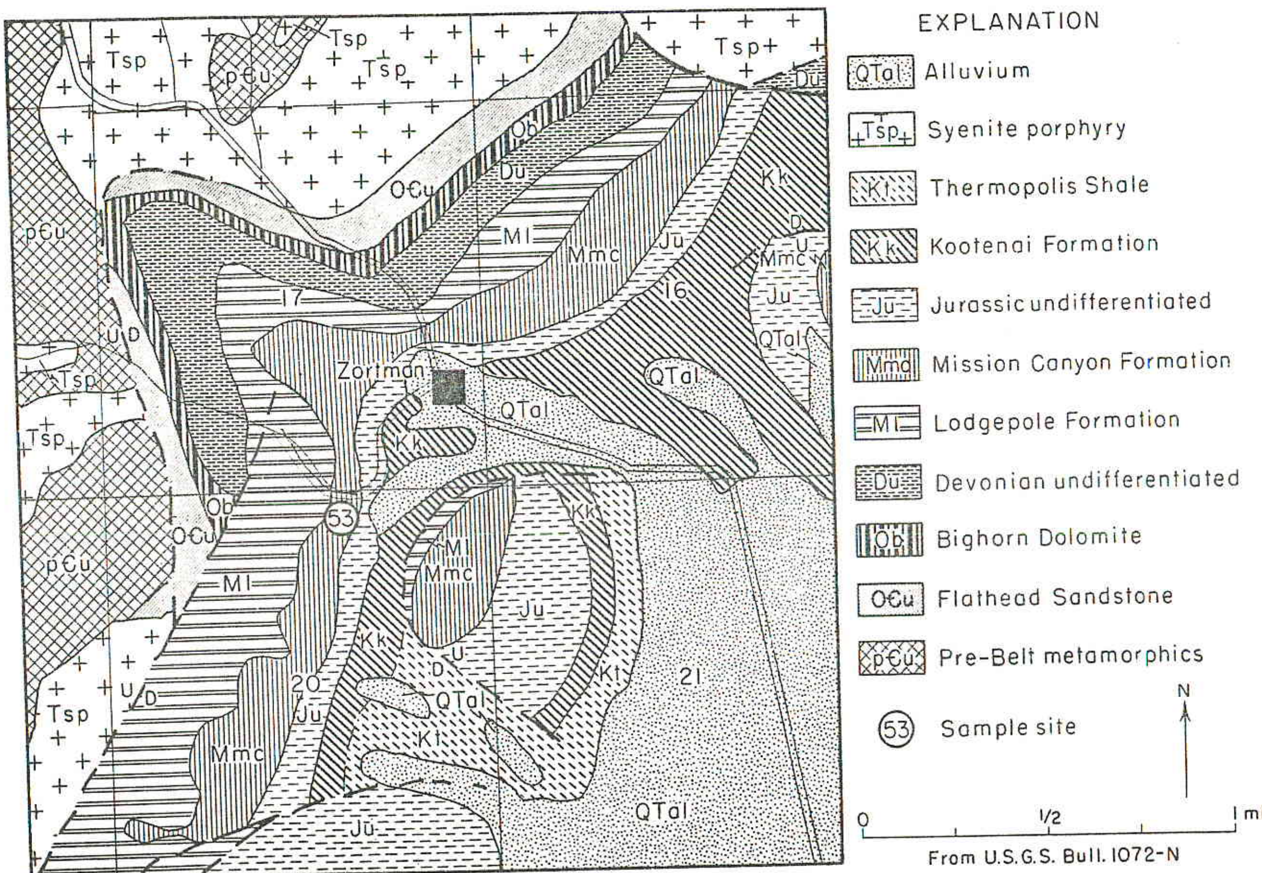


Figure 14.--Geologic map of the area around Zortman, Little Rocky Mountains, Phillips County.

Sample 57

Sample 57 is representative of the limestone quarried at the Warren quarry 4 miles northeast of Warren, a station 50 miles south of Billings on the Chicago, Burlington, and Quincy Railway. A rock-surfaced road leads from Warren to the quarry. Crushed and sized limestone is hauled to the railroad by trucks. The quarry is operated by Weaver Construction Co., Box 817, Iowa Falls, Iowa.

Presently the limestone is sold to five sugar refineries located at Billings, Hardin, and Sidney in Montana, and at Worland and Lovell in Wyoming. Recently markets have been developed for agricultural limestone and grouting material. The grouting material is to be used in the construction of Yellowtail Dam. At the time of the author's visit in the summer of 1963, a fine-grind plant was being constructed at Warren.

The quarry is in the uppermost beds of the Mission Canyon Limestone where this formation rises on the west flank of the Pryor Mountains. Strata have a southwest dip of about 3 degrees at the quarry.

Analysis of the limestone made by the Great Western Sugar Co. shows 97.1 percent calcium carbonate (54.2 CaO), 1.4 percent magnesium carbonate (0.67 MgO), and 1.5 percent insoluble material (Perry, 1949, p. 36). Weaver Construction Co. provided an analysis that shows 2.85 percent silica, 0.29 percent ferric iron, 0.19 percent alumina, 53.78 percent calcium oxide, and 0.22 percent magnesia.

Sample 58

Sample 58, a 540-foot grab sample, was collected from the talus at the face of the old Drummond quarry in sec. 32, T. 11 N., R. 12 W. The quarry, located a half mile north of the east end of Drummond, is developed in the "Gastropod limestone" member of the Kootenai Formation (Cretaceous). The Kootenai Formation in this area has been described by McGuire (1957).

Limestone was quarried at this locality sporadically from 1924 to 1939. The stone was hauled by truck a half mile to the Northern Pacific Railway at Drummond.

At the quarry site the limestone ledge strikes east-west and dips 75° S. Lithologically the stone is black-brown coarsely crystalline fossiliferous (gastropods) limestone. This member occurs throughout southwestern Montana wherever Kootenai strata are exposed.

Analysis of the sample collected is shown in Table 30.

Table 30.--Analysis of "Gastropod limestone" member of Kootenai Formation, NW$\frac{1}{4}$ sec. 32, T. 11 N., R. 12 W., Granite County.

Sample no.	Insol.	Al_2O_3	Fe_2O_3	MgO	CaO	P_2O_5	S
LS-58	9.38	1.13	0.50	0.88	48.80	0.118	0.008

Sample 59

Sample 59, a 62-foot grab sample, was collected from the Mission Canyon Formation at the face of Hitchcock's quarry located in Rattler Gulch, 4.5 miles west of Drummond in the SW$\frac{1}{4}$ sec. 3, T. 11 N., R. 13 W. The quarry is owned by Mr. B. Hitchcock of Butte.

Stone was quarried for use in the Crystal Sugar Co. plant at Missoula. In more recent times limestone for the Crystal Sugar Co. plant has been quarried from the same formation, but in the next gulch east of Hitchcock's site (access is also from Rattler Gulch). Stone was mined at this site by Weaver Construction Co., the same company that is operating the Warren quarry (sample 57). Stone is quarried periodically and stockpiled at the sugar plant.

Limestone from both sites has similar lithology, being blue-gray medium-crystalline massive limestone. Small calcite veinlets are scattered throughout.

Analysis of the sample collected at Hitchcock quarry is shown in Table 31.

Table 31.--Analysis of Mission Canyon Limestone in SW$\frac{1}{4}$ sec. 3, T. 11 N., R. 13 W., Granite County.

Sample no.	Insol.	Al_2O_3	Fe_2O_3	MgO	CaO	P_2O_5	S
LS-59	4.83	0.32	0.21	2.55	49.66	0.063	0.014

Sample 60

Sample 60, a grab sample, was collected from the Lodgepole Formation 0.2 mile north of sample 59, adjacent to Rattler Gulch road.

The material strikes east-west and dips vertical, and is composed of dark-gray thin-bedded fossiliferous siliceous limestone. The high insoluble content (Table 32) results from the many chert lenses found in outcrop.

Table 32.--Analysis of Lodgepole Limestone in SW$\frac{1}{4}$ sec. 3, T. 11 N., R. 13 W., Granite County

Sample no.	Insol.	Al_2O_3	Fe_2O_3	MgO	CaO	P_2O_5	S
LS-60	24.57	0.54	0.50	0.54	40.94	0.067	0.014

The Jefferson Dolomite, Pilgrim Limestone, and Meagher Limestone crop out adjacent to the Rattler Gulch road north of sample site 60. No samples were obtained from these exposures, however.

Sample 61

Sample 61 is representative of the limestone quarried at the Maronick quarry, which is 2$\frac{1}{2}$ miles south of the American Smelting and Refining Co. lead smelter at East Helena (Fig. 15).

The quarry has been cut into limestone of the Meagher Formation (Cambrian), which underlies the hilly area on the east side of Prickly Pear Creek and dips eastward at about 30 degrees. Prickly Pear Creek flows over the outcrop area of the underlying Wolsey Shale. The quarry, which is about 500 feet long and 150 feet wide (Perry, 1949, p. 39), has been cut into strata in the central part of the formation, and develops a floor about 75 feet above the valley. A railroad spur from the smelter services the quarry.

Production in 1963 was 32,000 tons, about 53,000 tons less than in previous years. The decrease resulted from modernization of smeltering equipment and the depressed state of lead-zinc mining in Montana.

Table 33 shows an average analysis (LS-61) of limestone taken from this quarry for smelter flux during the month of June 1948. It is stated that the composition over a period of years has not varied greatly.

Table 33.--Analyses of limestone in the Helena area, Lewis and Clark and Jefferson Counties.

Sample no.	Insol.	Al_2O_3	Fe_2O_3	MgO	CaO	P_2O_5	S
LS-61*	2.70	NR	0.50	2.85	52.40	NR	NR
LS-62	0.81	0.48	0.07	0.70	54.73	0.044	0.014
LS-63a	15.20	1.15	0.50	4.72	41.80	0.063	0.026
LS-63b	10.56	0.85	0.42	1.09	48.69	0.039	tr
LS-64	12.00	1.57	0.50	1.23	46.14	0.034	0.012

*Perry (1949, p. 39), NR - not reported.

Sample 62

Sample 62, a grab sample, was collected from the Harris quarry, about a half mile west of U.S. Highway 91 or 14 miles west of Montana City (Fig. 15). Stone was quarried for use in Butte smelters.

Two pits have been developed in coarsely crystalline marble resulting from contact metamorphism of the Madison Limestone by the Boulder batholith, the northern edge of which is about a quarter mile south of the excavations. The rock is almost pure calcium carbonate (Table 33).

Samples 63a and 63b

Samples 63a and b were collected from two adjacent quarry cuts (about 500 yards apart) on the east side of Prickly Pear Creek and just east of Montana City in the SW$\frac{1}{4}$ sec. 13, T. 9 N., R. 3 W. Both cuts are visible from U.S. Highway 91, which passes about three-quarters of a mile west of Montana City. Sample 63a is from the north cut and 63b from the south cut (Fig. 15).

Both cuts are developed in recrystallized Madison Limestone, which is white coarsely crystalline limestone containing chert pods and stringers. The north cut enters the hillside for about 50 feet, is 40 feet in width and at the face is 75 feet high. The south cut is larger, having a length of 190 feet, width of 108

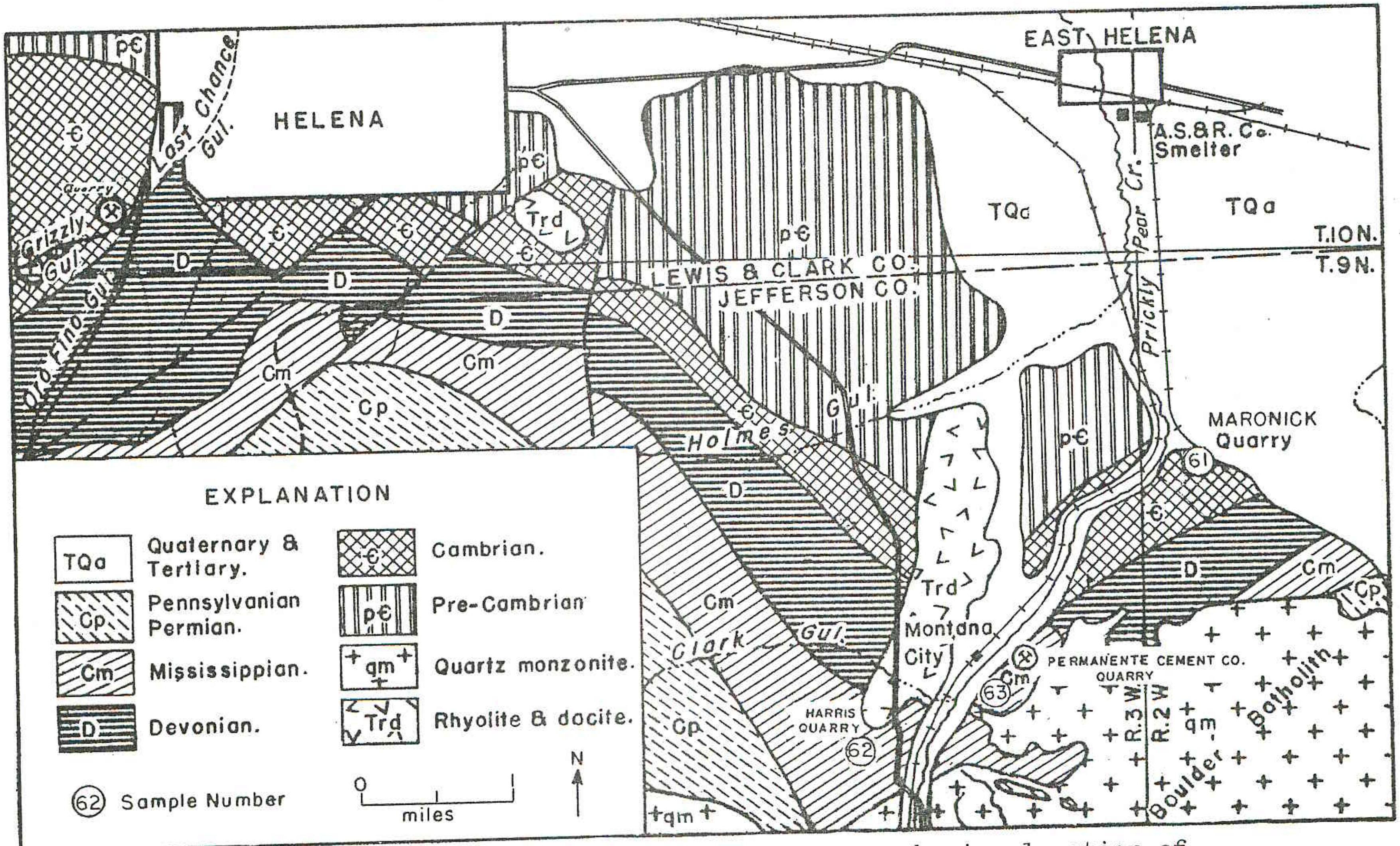


Figure 15.--Geologic map of the Helena area showing location of limestone quarries.

feet, and at the face a height of 150 feet. The limestone was quarried for use in the smelters at Butte. The Butte-Havre branch of the Great Northern Railroad follows Prickly Pear Creek and passes within 300 feet of the quarry site.

Analyses of samples 63a and 63b are found in Table 33.

Sample 64

Sample 64, a grab sample, was collected from Mission Canyon Limestone cropping out in the Spokane Hills in sec. 11 and 12, T. 9 N., R. 1 W. Access to the area is by dirt road for 1½ miles after leaving U.S. Highway 12 at a point 13 miles south of East Helena.

The material sampled was blue-gray-weathering finely crystalline limestone, which strikes generally north-south. The Jefferson Dolomite and Amsden Limestone also crop out. The carbonates are visible from U.S. Highway 12 from a point near Louisville, a station on the Northern Pacific Railway, southward for about 6 miles.

Analysis of sample 64 is found in Table 34.

Table 34.--Analysis of Mission Canyon Limestone in Spokane Hills in sec. 11 and 12, T. 9 N., R. 3 W.

Sample no.	Insol.	Al_2O_3	Fe_2O_3	MgO	CaO	P_2O_5	S
LS-64	12.00	1.57	0.50	1.23	46.14	0.034	0.012

Other Carbonate Rocks Sampled

Through the years the Bureau, in the course of evaluating Montana's mineral resources, has collected and chemically analyzed carbonate rocks at localities not visited by the author. For completeness, the results of these analyses, and also analyses made by other organizations, are included here in table form (Table 35). References are listed if available, and locations are indexed to Figure 1.

Table 35.--Analyses of other carbonate samples collected from Montana units, in percent.

Sample no.	Location	Insol.	SiO_2	Al_2O_3	Fe_2O_3	Fe	MgO	CaO	CO_2	P_2O_5	S	Remarks
65	Center sec. 15, T. 11 N., R. 12 W.	0.9	0.6	0.5	x	0.3	0.9	53.5	42.8	nil	nil	Jefferson Dolomite, 100-ft. chip sample, collected by Bureau, 1959; geol. ref., USGS Bull. 660-F.
66	Sec. 22, T. 11 N., R. 12 W.	0.4	0.2	0.5	x	0.2	0.6	54.4	43.6	nil	nil	Madison Limestone, 90-ft. chip sample, collected by Bureau, 1959; geol. ref., USGS Bull. 660-F.
67	Sec. 22, T. 11 N., R. 12 W.	11.0	9.6	0.3	x	0.8	0.1	48.0	39.7	nil	nil	Madison Limestone, collected by Bureau, 1959; geol. ref., USGS Bull. 660-F.
68	Sec. 11, T. 11 N., R. 14 W.	17.4	15.1	1.0	x	0.7	0.1	45.5	35.6	0.05	nil	Madison Limestone, 50-ft. chip sample, collected by Bureau, 1959; geol. ref., USGS Bull. 660-F.
69	Sec. 11, T. 11 N., R. 14 W.	27.4	24.9	2.9	x	1.3	9.3	28.4	32.2	0.05	nil	Madison Limestone, 100-ft. chip sample, collected by Bureau, 1959; geol. ref., USGS Bull. 660-F.
70-71	Sec. 12, T. 11 N., R. 14 W.	21.2	18.9	1.5	x	0.8	nil	42.8	33.9	0.05	nil	Madison Limestone, 65-ft. chip sample, collected by Bureau, 1959; geol. ref., USGS Bull. 660-F.
72a	Sec. 29, T. 13 N., R. 14 W., 30 miles east of Missoula, turn right at Greenough Post Office on Coloma road, approx. 5 miles from P.O.	2.51	x	0.23	0.21	x	2.90	50.78	x	0.023	0.018	Samples 72a, b, c, and d submitted by J. B. Evans, co-owner of Missoula Limestone Co., 2612 Cardinal Dr., Missoula, Mont. Sample 72a is bulk grab sample, 72b is at 11-ft. depth, drill hole no. 1; 72c is at 75-ft. depth, drill hole no. 1; 72c is at 120-ft. depth, drill hole no. 3.
72b		4.0	3.1	0.83	0.05	x	4.27	49.4	x	0.0006	0.125	
72c		0.8	1.1	0.25	0.025	x	3.62	52.05	x	0.0039	0.085	
72d		0.75	1.0	0.21	0.013	x	1.95	53.10	x	0.0034	0.033	
73	NE$\frac{1}{4}$ sec. 22, T. 7 S., R. 19 E., SW Red Lodge in Palisades.	0.80	x	6.28	0.14	x	1.43	52.79	x	0.009	0.015	Mission Canyon Limestone, old quarry sometimes referred to as Kuhal quarry. Supposedly last leased (1959) to Multi-Minerals of Helena. Collected by Bureau, 1961.
74	Sec. 25, T. 14 N., R. 10 W.	34.64	x	5.23	0.57	x	3.03	31.03	x	0.084	0.018	Submitted by E. Bierwagen, PhD. thesis, Princeton Univ., 1964.
75	Vicinity of Havre, Montana.	x	16.16	---7.55*---		x	1.59	47.09	25.05	x	x	Pepperberg, L. J., 1909, Cement material near Havre, Montana: USGS Bull. 380-J p. 327-336.
76	SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 29, T. 7 N., R. 22 E.	x	x	---7.22*---		x	1.14	41.6	x	0.041	x	Oyster bed; ref. Great Northern Railroad Rept. 16, pt. 3, 1961, Geology adjacent to the Great Falls-Billings line.
77	SW$\frac{1}{4}$ sec. 8, T. 33 N., R. 32 W.	x	2.10	6.50	x	0.40	nil	54.20	38.80	x	x	Surface float (Johns, 1959, p. 56, no. 17).
78	Jack Garrison Ranch	x	1.80	0.50	x	0.30	nil	54.00	39.80	x	x	(Johns, 1959, p. 55, no. 13.)
79	Sec. 9, T. 36 N., R. 29 W.	x	1.70	0.60	x	x	21.60	30.60	43.50	x	x	(Johns, 1960, p. 51, no. 10.) Surface, 40 ft. dolomite.
80	Sec. 17, T. 27 N., R. 27 W.	x	51.00	12.40	3.60	x	3.50	13.6	11.00	x	x	(Johns, 1960, p. 51, no. 11.) Surface, 25 ft. limy shale.
81	Sec. 28, T. 29 N., R. 29 W.	x	34.00	9.80	1.50	x	1.60	27.00	19.00	x	x	(Johns, 1960, p. 51, no. 12.) Surface grab, argillaceous limestone.
82	NE$\frac{1}{4}$ sec. 15, T. 28 N., R. 30 W.	x	0.20	nil	x	0.4	4.50	32.00	21.50	x	x	(Johns, 1960, p. 52, no. 13.)
83	SE$\frac{1}{4}$ sec. 4, T. 28 N., R. 30 W.	x	4.20	4.20	x	x	8.10	39.00	41.20	x	x	(Johns, 1960, p. 52, no. 14.)
84	NW$\frac{1}{4}$ sec. 28, T. 36 N., R. 27 W.	x	47.10	7.66	1.55	x	2.02	20.60	14.70	x	x	(Johns, 1961, p. 57, no. 11.) Wallace Formation.
85	SW$\frac{1}{4}$ sec. 10, T. 37 N., R. 29 W.	x	35.20	8.80	2.27	x	6.96	22.50	23.80	x	x	(Johns, 1961, p. 57, no. 12.) Piegan Group.
86	Sec. 1, T. 37 N., R. 27 W.	x	x	0.05	x	x	0.76	55.25	x	x	x	(Johns, 1961, p. 57, no. 14.)

x - Not reported.
* - Total Al_2O_3 plus Fe_2O_3

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