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BULLETIN 7
August 1956

GEOCHEMICAL PROSPECTING BY SOIL ANALYSES IN MONTANA

By

Forbes Robertson

WITH CHAPTER ON ANALYTICAL METHODS

By

J. H. McCarthy, Jr., and H. W. Lakin

MONTANA BUREAU
of
MINES AND GEOLOGY

Butte, Montana

STATE OF MONTANA
BUREAU OF MINES AND GEOLOGY
J. Robert Van Pelt, Director

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by FORBES ROBERTSON

With chapter on

CHEMICAL METHODS USEFUL IN PROSPECTING

by J. H. McCARTHY, JR. and H. W. LAKIN

Chemical analyses by
C. J. BARTZEN
X-ray spectographic analyses by
F. A. HAMES

Butte, Montana

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FOREWORD

One of the functions of the Montana Bureau of Mines and Geology is to foster the development of mineral resources in the State. To this end, the Bureau has conducted field work and published reports on the geology of mining districts, oil and gas fields, and ground water resources in many parts of the State.

In order to promote mineral development, the Bureau contributes to the development of new exploration techniques. One of these is geochemical prospecting. This is a relatively new prospecting tool which has been developed principally since World War II. It offers unusual promise of helping the geologist to find mineral deposits, especially in regions where the bedrock is not exposed. It depends on the fact that soils over an orebody contain abnormaly large traces of metal derived from the orebody; these traces can be measured by various analytical methods. This bulletin presents the findings of the Bureau in its investigation of soil sampling and analysis in many known mineralized areas of western Montana. The study shows that the method is highly useful under certain conditions existing in Montana, and less so under certain other conditions; these are described in this bulletin.

The United States Geological Survey, which has been investigating geochemical prospecting methods for a number of years, has been a leader in developing colorimetric methods of analysis of sufficient accuracy to distinguish abnormal metal concentrations in the soil from normal or background concentrations. The Survey has generously permitted two of its chemists, Messrs. J. H. McCarthy, Jr., and H. W. Lakin, to write a part of this bulletin (Chapter VII) on these analytical techniques. The chapter has been written for the field man rather than the laboratory chemist; step-by-step descriptions of the authors' analytical methods are given and can be used in the field by anyone who is willing to exercise the required care.

The Montana Bureau of Mines and Geology has also investigated the use of X-ray spectography as a means of making the necessary soil analyses. F. A. Hames of the Bureau staff has used this technique in making many analyses for this report, and has contributed new information on the application of X-ray spectography to geochemical exploration.

Like every new technique, geochemical prospecting will eventually find its rightful place in the search for minerals. Geologists of leading exploration companies are using it in many parts of the world and are learning by experience what results can or cannot be expected from it. The present bulletin will help prospectors and geologists, especially in Montana and geologically similar areas, to know where and how to use this method. At this stage of development, we can at least say that geochemical prospecting is a powerful tool in the geologist's kit, and that it can deliver full value only when used in conjunction with other geological techniques. It supplements rather than replaces the older, more familiar methods of prospecting.

The professional geologist or prospector who is seriously interested in geophysical prospecting probably will wish to study this entire report. The "week-end prospector," and others who wish to get a less comprehensive view, will be able to learn the essentials of geochemical prospecting by studying Chapters I, II, and VI.

J. R. VAN PELT
Director

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The fact that no appreciable quantity of base metals is in the soils over so strong a structure is significant. It seems apparent that the alteration of the quartz monzonite present in the strong structure was not produced by hydrothermal solutions containing important amounts of base metals; rather, lead and zinc were introduced later and localized in individual ore shoots.

The Comet-Gray Eagle structure has been caremapped in detail by recent work by the U. S. Geological Survey. It is possible that a systematic geochemical soil-sampling program over the entire structure would serve to pick the tops of the ore shoots, or to indicate "highs" which may be related to mineralization at depth.

Figure 8 illustrates the difference in intensities of the geochemical anomalies over known ore shoots and a barren part of the structure. Even in the barren zone near the Gray Eagle mine (Table 5), however, a small amount of arsenic is present over the vein structure. Lead occurs in very minor amounts in the wall rock south of the alteration zone, but not in the core of the structure. Zinc and copper are conspicuously absent. The manganese roughly follows the arsenic pattern, but is more erratic.

Table 6 gives the data for the barren zone traverse between the Comet and Gray Eagle mines. Arsenic does not appear to show any consistency at all relative to the zone of alteration; lead, zinc, and copper are all absent. More revealing, Table 4 shows a strong lead, zinc, arsenic, and manganese over the vein structure. Copper is not present.

BUTTE DISTRICT

The Butte district is the most important mining district in the State. Popularly known as the "Richest Hill on Earth," it is a major copper, silver, zinc, and manganese producer of world-wide fame. The geology of Butte is complex, and much has been written on the subject. The reader is referred to the works of Weed, Sales, and Meyer for the details that may be desired. (Weed, 1912.) (Sales, 1914). Sales and Meyer (1938 and 1949).

Quartz monzonite of the Boulder batholith comprises the country rock at Butte. Aplite and quartz porphyry dikes predate the veins occurring in three major groups, the most important if which are the east-west veins of the Anaconda group. The ore minerals have a definite zonal arrangement with copper in the center, and zinc and manganese toward the margins. The wall-rock alteration varies in intensity from the central zone outward, and consists of pervasive sericite alteration in the innermost zone. Rhyolite dikes are younger than the mineralization.

The main part of the hill is so cut up by mine dumps, railroads, roads, and mine buildings that soil traverses of any significance in uncontaminated areas are really out of the question. One group of traverses were made at the Marget Ann mine in the northern part of the district.

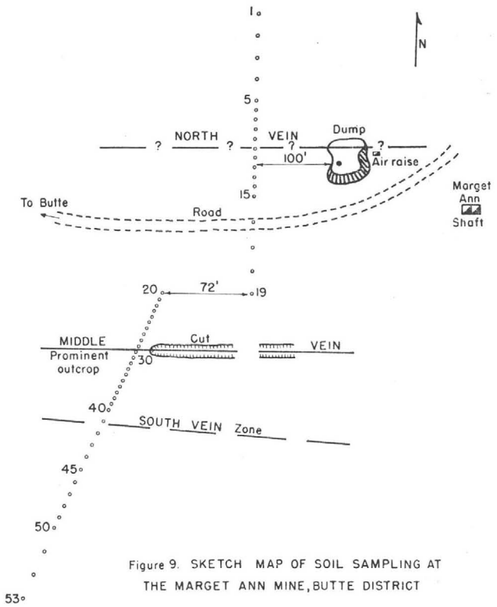


Figure 9. SKETCH MAP OF SOIL SAMPLING AT THE MARGET ANN MINE, BUTTE DISTRICT

Marget Ann Mine.—One long traverse was made across three veins as shown on the map in Figure 9, which is a sketch map of the surface at the mine showing the line of traverse. Figure 10 shows the anomalies recorded by the soil sample traverse. The soil is thin and granular. Table 7 shows the copper, zinc, and manganese chemical analyses. The north vein shows only a minor zinc concentration, and it is doubtful whether the vein could be picked up by geochemical methods in an area of such a high background of copper, zinc, and manganese. The middle vein gives a

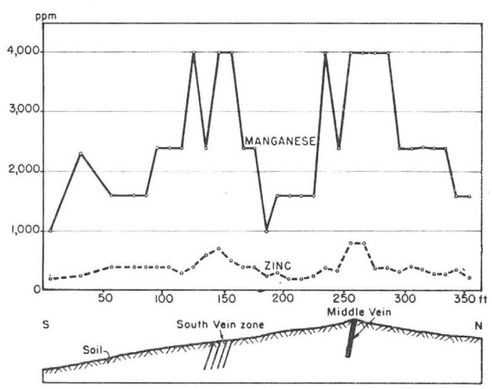


Figure 10 SAMPLE PROFILE, MARGET ANN MINE, BUTTE DISTRICT

GEOCHEMICAL PROSPECTING BY SOIL ANALYSIS IN MONTANA

By
FORBES ROBERTSON

CHAPTER I

INTRODUCTION

Most of the metalliferous mineral deposits which have been or are being mined were found by the prospector who tramped the hills searching for "float" pieces of ore, or the sourdough who, with his gold pan, systematically panned the creeks for "colors" of gold. From the original discovery on the surface, further exploration has often led to continued uncovering of mineral wealth, both laterally and at depth.

But these surface discoveries are becoming more and more difficult to make. Probably most of the large base metal (copper, lead, zinc) deposits which crop out conspicuously at the surface have already been found, at least those in this country. As population grows and technology advances, the need to find new mineral deposits increases. To meet this increasing demand new methods are needed which will aid in finding deposits which do not crop out on the surface. Geochemical prospecting is just such a method.

Geochemical prospecting may be used in two different ways. One is to aid in finding deposits close to the surface which are buried under a few feet of soil. The prospector can conduct this type of search, especially in and around known mineralized areas. He can do this without detailed geologic knowledge of the area, though much time, effort and expense will be saved by basing the work on a knowledge of the local geology.

The other method is to outline new "favorable" areas suitable for deep testing in the search for blind orebodies hidden at depths of several hundreds or thousands of feet. This type of exploration is important, but requires the greatest possible coordination of geologic, geochemical, and geophysical skills, and usually demands large capital outlay.

This report covers only the first of these two uses. It is written as an aid to the prospector or geologist who wishes to add geochemical methods to others at his disposal.

What is Geochemical Prospecting?—In its broadest sence, the term geochemical prospecting includes any chemical method which may be used in the search of mineral deposits. These include the sampling of stream waters, soils, and vegetation for metals. Stream water samples have been collected and analyzed for such metals as zinc and copper. Zinc is especially soluble in surface water, and the test for zinc is very sensitive. It is reported that in one instance, systematic sampling of stream waters has led to a galvanized iron tub. The high sensitivity of the zinc test sometimes presents difficulties in areas where there are dumps from small mines or prospects, but offers possibilities for exploration in virgin territory.

Leaves and stems or twigs from shrubs and trees have been collected and burned and the ash analyzed for zinc, copper, lead, and other metals. The sap carries the metals in solution from the soils through the roots to the leaves. Particularly high concentrations of metals in a given area may indicate an ore deposit at depth. Many factors, however, influence the results, such as the age of the plant, the season of the year, and even the time of day when the sample is collected.

Probably the most successful of the geochemical methods to date has been the sampling of surface soils which are analyzed for lead, zinc, copper, manganese, silver, tungsten, cobalt, nickel, arsenic, and other metals. In this report, attention is given only to the application of soil methods to the discovery of metallic mineral deposits. Soil sampling has already led to important discoveries in this country and many foreign countries. These methods can be used wherever soils of suitable depth and nature exist.

What is the Basis of Geochemical Prospecting by Soil Analysis?—Modern soil sampling is a natural outgrowth of older, simpler methods long used by prospectors. In their search of the "mother lode", these men systematically panned upstream for "colors" and then panned hillslope soils from

the stream uphill. As a result of weathering, gold is set free from the vein or mineral deposit, and then migrates downhill. Long ago the prospector learned the principle that gold (along with the other material released by weathering) creeps downhill and downstream. The same principle, with variations, can be used in geochemical prospecting for other metals. Gold is easily recognized in the gold pan, but such metals as lead, zinc, and copper are not so readily detected nor so easily concentrated; yet, above any important mineral deposit, traces of the metals found in the deposit are usually present in minor amounts in the soils. In geochemical prospecting, the method is similar to that employed by the gold prospector as far as sampling is concerned, but the detection of the metals is a chemical operation. Since some of the tests are very simple, they can be carried out on the spot in the field; others, requiring a considerable amount of equipment as well as skill, are the job of the chemist or assayer.

The difference between older methods and modern geochemical methods is in the quantity of metal detected. Modern geochemical analysis will reveal small differences in metal content between soils over a mineral vein and those over barren rock. Geochemical methods make it possible to extend the search for metals to areas where bedrock is covered by grass or forest.

Even where buried by thick soils, mineral deposits usually leave telltale traces of their whereabouts. In the search for new ore deposits both physical and chemical clues are important. When a mineral deposit is exposed at the surface by weathering and erosion, the minerals in the deposit may be released from the deposit physically as mineral particles (such as quartz or gold) and start slipping or creeping downhill. When the prospector recognizes such clues as boulders of vein quartz, gossan or "iron capping" in the float on a hillside, he systematically endeavors to locate the deposit in place by tracing the float to their highest point on the hillside.

The metals such as lead, zinc and copper may be liberated from the ore minerals by the chemical action of surface and ground-water solutions which likewise trickle or seep downhill. As some of the solutions evaporate, soluble salts are deposited, or as the solutions percolate through the soils, small traces of the metals are commonly "caught" (adsorbed) by clays and decayed vegetation. Where soils obscure all traces of the bedrock, panning of soils may reveal such chemically stable minerals as gold; but chemical tests may be necessary to show traces of chemically active metals such as lead, zinc, and copper.

Most of the work described in this bulletin represents the testing of soils over known mineral deposits to determine the presence of metals, their concentration, and the distance they may extend downhill from their source. Thus the tests enable us to determine how effective the method would be in areas where the mineral deposits are unknown.

How Do Metals Get Into Soils?—At some time in the geologic past some parts of the earth's crust were soaked to varying degrees by solutions containing valuable metals. The ore minerals were deposited in favorable spots, such as in open spaces in fissures, thus forming veins; in replacement bodies in limestone; in breccia zones; or in intrusive stocks. In some places, the amount of metals deposited was sufficient to form a valuable mineral deposit.

When the bedrock weathers and forms soil, some of the metal content in the mineralized rock remain in the soil. The quantity of metal may be much reduced by leaching, but enough remains to be detected by sensitive analytical methods. This detection of metals in soils is the main point in geochemical prospecting.

Small quantities of metal are present in the soil even if there are no mineralized zones in the region. These minor amounts of metal in the soil of the region are known as "background.' Background values for a given rock may vary from one region to another, but within a distance of a few miles they are fairly uniform.

In Montana, the background for lead, for example, might be 10 or 20 parts per million (10,000 parts per million is one per cent). Near ore, the lead content may increase from 30 to 50 ppm (parts per million) and over ore, 500 to 1000 ppm. Zinc, on the other hand, may have a background of from 50 to 100 ppm and may have 500 to 1000 ppm over ore. Copper may be only 10 ppm in the background and from 100 to 200 ppm over ore.

After the prospector has received some analyses and plotted them on his map, he selects an upper limit to the local background, usually two or three times as high as the higher background values. He calls this the "threshold" value (Hawkes, 1954, p. 56). In the example just given, he might place the zinc threshold at 300 parts per million. Analyses below this threshold are recorded on the map, but are not considered significant as a guide to ore.

When a line of sample points approaches a mineralized area, the analyses become higher and finally cross the threshold. Over or just downhill from an ore deposit, analyses may reach ten or more times the average background (three or more times the threshold). These high values indicating a nearby mineralized area in bedrock, are an abnormal condition or "anomaly." This word is a convenient term used in geochemical literature to describe any unusually large or abnormally high metal concentration in the soil being tested. An anomaly in the soil usually points to mineralization in the rock, but this mineralization may or may not be great enough to make valuable ore. Discovery of an anomaly in the soil in a favorable

Table 5 (Continued)

Sample No.	Location of Sample	Heavy Metals (a) ppm	Lead (b) ppm	Zinc (b) ppm	Copper (b) ppm	Arsenic (b) ppm	Manganese (b) ppm
14	S side of zone?	50	0	0	0	77	1,450
15	20 ft S of structure	50	0	0	0	61	1,395
16	40 " " " "	50	0	0	0	77	1,860
17	60 " " " "	50	0	0	0	0	1,770
18	80 " " " "	100	0	0	0	61	3,110
19	100 " " " "	50	21	0	0	58	1,800
20	120 " " " "	100	52	14	0	85	2,460
21	140 " " " "	100	52	0	0	54	1,730
22	160 " " " "	50	30	0	0	0	1,220
23	180 " " " "	50	31	0	0	0	1,350
24	200 " " " "	50	0	0	0	0	1,070
25	220 " " " "	50	60	0	0	0	1,040
26	240 " " " "	50	12	0	0	23	947
27	260 " " " "	50	18	0	0	38	1,110
28	280 " " " "	50	40	0	0	97	1,070
29	300 " " " "	50	23	0	0	0	989
30	320 " " " "	50	0	0	0	38	885
31	340 " " " "	50	37	0	0	16	962

*Not shown in Figure 8.

Table 6—Between Comet and Gray Eagle Mines, Basin

Analyses of soil samples collected over strongly fractured and altered zone between Comet and Gray Eagle Mines. Sample interval 20 ft. Slope variable from 20° to 25°. Strike of structure approximately N. 80° W. Bearing of traverse N. 20° E. Thick soils for 500 ft., then thin granite sands.

a. Chemical analyses
b. X-ray spectrographic analyses

Sample No.	Location of Sample	Heavy Metals (a) ppm	Lead (b) ppm	Zinc (b) ppm	Copper (b) ppm	Arsenic (b) ppm	Manganese (b) ppm
1	240 ft N of bulldozer cut	50	0	0	0	60	952
2	220 " " " " "	50	0	0	0	127	1,030
3	200 " " " " "	50	0	0	0	100	1,240
4	180 " " " " "	50	0	0	0	60	1,020
5	160 " " " " "	100	0	0	0	100	1,105
6	140 " " " " "	100	0	0	0	97	966
7	120 " " " " "	50	0	0	0	10	923
8	100 " " ' " "	50	0	0	0	100	1,055
9	80 " " " " "	50	0	0	0	0	958
10	60 " " " " "	50	0	0	0	18	1,170
11	40 " " " " "	100	0	0	0	18	1,060
12	20 " " " " "	100	0	0	0	68	1,240
13	Edge of bulldozer cut	50	0	0	0	62	874
14	20 ft S of bulldozer cut	50	0	0	0	71	972
15	40 " " " " "	50	0	0	0	117	902
16	60 " " " " "	50	0	0	0	85	1,015
17	80 " " " " "	50	0	0	0	97	1,030
18	100 " " " " "	50	0	0	0	67	916
19	120 " " " " "	50	0	0	0	110	511
20	140 " " " " "	50	0	0	0	112	1,070
21	160 " " " " "	50	0	0	0	52	818
22	180 " " " " "	50	0	0	0	46	784
23	200 " " " " "	50	0	0	0	43	720
24	220 " " " " "	50	0	0	0	77	1,010
25	240 " " " " "	50	0	0	0	31	930
26	260 " " " " "	50	0	0	0	68	1,055

Table 4—Comet Mine, Basin

Analyses of soil samples collected over mined out area near the Comet shaft. Sample interval 20 feet, slope variable to 5°. Bearing of Structure N. 70° W., traverse bearing N. 20° E.

a. Chemical analyses
b. X-ray spectrographic analyses.

Sample No.	Location of Sample	Heavy Metals (a) ppm	Lead (b) ppm	Zinc (b) ppm	Copper (b) ppm	Arsenic (b) ppm	Manganese (b) ppm
1	120 ft N of N vein	150	565	112	0	343	2,000
2	100 " " " " "	200	589	215	0	384	1,910
3	80 " " " " "	250	1,050	99	0	793	1,910
4	60 " " " " "	250	1,350	357	0	1,040	1,790
5	40 " " " " "	175	897	25	0	581	1,000
6	20 " " " " "	300	1,850	335	0	1,460	1,940
7	Over north vein	400	1,720	1,310	0	830	2,030
8	20 ft S of N vein	400	3,490	494	0	1,870	1,670
9	40 " " " " "	250	2,180	988	0	1,270	4,190
10	60 " " " " "	400	2,620	751	0	1,685	4,340
11	80 " " " " "	200	577	530	0	1,130	4,380
12	Over middle vein?	250	1,365	518	0	969	5,000
13	" " "	250	1,360	514	0	685	2,590
14	140 ft S of N vein	200	866	988	0	400	1,760
15	160 " " " " "	300	2,170	341	0	369	2,020
16	180 " " " " "	200	350	152	0	146	1,570
17	200 " " " " "	150	123	120	0	108	1,760
18	220 " " " " "	100	100	90	0	69	1,660
19	240 " " " " "	100	62	74	0	82	1,705
20	260 " " " " "	100	127	144	0	172	2,200
21	280 " " " " "	100	96	98	0	128	1,380

Table 5—Near Gray Eagle Mine, Basin

Analyses of soil samples collected across strong fracture zone, but an area of no known commercial mineralization, north of Grey Eagle Tunnel. Sample interval 20 feet, 315 feet N. 28° W. to discovery shaft. Slope variable from horizontal to 5° as shown in Figure 8. Strike of structure N. 70° W. Traverse bearing approximately N. 15° E. Grassy slopes, soil 4 to 6 in.

a. Chemical analyses
b. X-ray spectrographic analyses

Sample No.	Location of Sample	Heavy Metals (a) ppm	Lead (b) ppm	Zinc (b) ppm	Copper (b) ppm	Arsenic (b) ppm	Manganese (b) ppm
1*	200 ft N of structure	50	0	57	0	0	1,040
2*	180 " " " "	100	38	31	0	0	1,200
3*	160 " " " "	50	0	0	0	0	902
4*	140 " " " "	50	0	0	0	0	1,130
5	120 " " " "	100	0	0	0	0	1,420
6	100 " " " "	100	0	0	0	0	1,170
7	80 " " " "	50	0	0	0	0	1,360
8	60 " " " "	50	0	0	0	0	1,630
9	40 " " " "	50	0	0	0	42	1,430
10	20 " " " "	50	0	0	0	85	1,560
11	N side of zone?	50	19	0	0	61	1,420
12	Over fracture zone	50	12	0	0	25	1,315
13	Over fracture zone	50	13	0	0	85	1,090

indication, but it takes more than this to make a mine. The prudent prospector will not jump to conclusions when he finds an anomaly, but will follow up this information with other types of data-gathering, such as drilling, before he concludes that he has a workable deposit. Figure 1 shows a typical metal curve based on analyses of soil samples collected over an ore deposit which crops out at the surface.

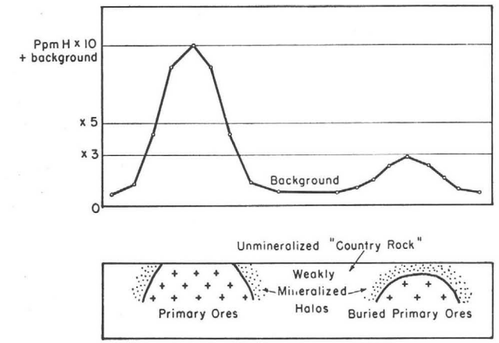


Figure 1. IDEALIZED GEOCHEMICAL HIGH (ANOMALY) OVER EXPOSED AND BURIED ORE

Over a deeply buried ore deposit which does not crop out at the surface, but which is surrounded by a weakly mineralized zone that does crop out under soil cover, a series of soil samples may reveal a background value for the valuable metal away from the deposit and an anomaly over the buried deposit. As stated in the preceding paragraph, the increase in metal content must be several times the normal background to indicate an anomaly over a buried deposit. See Figure 1. It should be kept in mind that finding an anomaly should not make the prospector unduly optimistic since a similar pattern will result from a weakly mineralized area which has no commercial mineralization below. The presence of an anomaly does not always mean an ore deposit at depth; it does, however, indicate some mineralization. Metal values running into the thousands of ppm over tens of feet in an area where the background is 100 to 200 ppm are suggestive of a minable deposit.

The curves in Figures 1 and 2 representing geochemical anomalies over primary ores are examples of the simplest kind of situation. Most mining districts contain a variety of types of rock which are brought into complex relationships by faulting and folding, the whole being complicated by a long and eventful geological history. For this reason, it is desirable, and in most cases essential, to understand the geological structures in a mining district in order to evaluate fully the geochemical results. Likewise, knowledge of the basic geological structures in a mining district will make it possible to sample soils most economically.

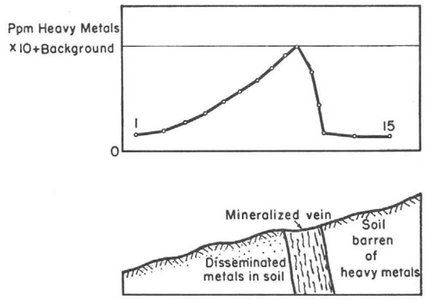


Figure 2. IDEALIZED GEOCHEMICAL HIGH (ANOMALY) OVER MINERALIZED VEIN ON HILLSIDE

Where mineral deposits or veins crop out on a hillslope, the metals are not only contributed to the soil through normal weathering, but as the soils creep downhill, some of the heavy metals migrate downhill with them. Under these circumstates, the geochemical anomaly is spread out downhill, as shown in Figure 2.

Where Has Geochemistry Been Successful?—Geochemical exploration is so new that not many case histories appear in published literature. The United States Geological Survey has developed methods which have contributed to the success of the methods in this country. Important deposits are reported to have been discovered geochemically in Europe, Africa, Australia, South America, as well as in the United States and Canada.

At Tintic, Utah, geochemical anomalies were found to occur in rhyolite containing pyrite up-rake from blind ore bodies in sedimentary rocks below the rhyolite (Lovering, 1948). At Johnson, Arizona, silicified and altered limestones and dolomites contain relatively high concentrations of copper over blind ore bodies at depth (Cooper and Huff, 1951). In the dolomite replacement bodies of zinc ores in southwestern Wisconsin, it has been found that abnormally large concentrations of zinc may be detected by geochemical methods in dolomite as much as 50 feet above ore. A number of geochemical spot surveys in Iowa, Arizona, Idaho, Colorado, and North Carolina were reported by Huff (1952). Geochemical investigations for zinc in the Appalachian states have been successful (Hawkes, 1949 and Robinson, 1947).

Where Can Geochemical Methods Be Used?—Soil sampling may be used under a very wide range of conditions. Primary residual soils provide the usual and most favorable environment, but geochemical methods may also be successful under certain favorable conditions in regions covered with glacial drift and in areas of transported soils. Much research on this subject remains to be done. Soil sampling is especially successful in hilly or mountainous regions, for

soil-covered veins may be detected because of soil creep up to several hundred feet downhill from a vein. Relatively insoluble metals such as gold may occur as mineral grains in the soil, whereas the soluble minerals such as sphalerite may leave traces of metal absorbed into clay particles. See Fig. 2.

In regions where the soil cover is thick, and where chemical weathering is important, it has been found necessary, for best results from geochemical methods, to collect samples from a specific soil zone several feet below the surface. In western Montana, however, most of the mountain soils are very thin, and it has been found that grass-root samples are just as suitable for geochemical studies as are samples collected at the base of the soil zone, which in most cases is rarely more than a foot.

The methods were successfully applied even in regions above timber line, where soils are merely disintegrated rock or gravel and sand particles derived from the parent rocks. Under these conditions, traces of the metals were detected over known mineral deposits, as shown in Figure 22. Apparently the decomposed or disintegrated rock particles of very immature soils will give reproducible results in western Montnaa.

In general it is found that the highest anomalies for soil sampling are present in areas of limestone and dolomite rocks. The anomalies are generally smaller in areas of volcanic rocks. Good anomalies are obtained over known ore bodies regardless of whether the wall rocks are in igneous, sedimentary, or metamorphic rocks.

How Are Analyses of Soils Made?—Both chemical and physical methods of analyses have proved satisfactory. The most widely applied, and the least expensive (considering initial cost of equipment), are chemical.

The United States Geological Survey has developed colorimetric chemical tests for zinc, copper, nickel, cobalt, molybdenum, tungsten, manganese, and "total heavy metals" (total of zinc, copper, lead, nickel, and cobalt as a group) in soils. Other metals are under investigation, including silver, tin, mercury, barium, and titanium. The chemical methods may be applied in the laboratory or in a mobile field laboratory. In general, the field determinations lack the precision of the laboratory tests, but have the obvious advantage of reducing the time interval between collection and determination. This is important because it permits further checking of promising areas before the party has moved to some distant location. Details of the chemical methods developed by the U. S. Geological Survey may be found in Chapter VII.

X-ray spectrographic methods have been developed by F. A. Hames of the Montana Bureau of Mines and Geology. The X-ray spectrometer yields more accurate analyses in a much shorter time than do the chemical tests. An X-ray spectrometer can handle about as many samples in an hour as the chemist can process in a day. A considerable number of analyses of this type are published herein. The method is to be described in a forthcoming publication by Hames. The principal drawback for the method is the initial cost of the equipment, about $15,000. The saving in time and the high degree of accuracy will serve to find a place for the equipment in large geochemical exploration ventures.

Spectrographic methods using the visible part of the spectrum were developed by the Russians, and work along this line is being carried out in the United States.

Sampling Procedure.—Sampling the soil is very simple. Two different methods were used in this investigation. The first method is to dig holes to shovel depth where possible (9 to 12 in.) and to sample the fine material from as near the bottom of the hole as is possible. In a great many places it is almost impossible to dig holes to this depth without considerable pick work. In such spots, the deepest easily dug hole is made, often with the aid of a geologist's pick to remove some rocks. The somewhat rigid "shovel depth" hole is imposed in the field to avoid the natural tendency to take undependable samples from the surface, and for ease in tracing traverses where necessary or desirable. After one year it is usually possible to find the original sample holes from which soil samples had been obtained.

The second method is even simpler. A very shallow hole is dug with a geologist's pick, and soil collected just below the grass roots. Pebbles, roots, leaves, and other debris are first removed from the sample before it is put into a sample sack. This method is used where speed is a significant factor in collecting a purely reconnaissance group of samples. In some localities, samples were collected both at shovel depth and by the surface method, and reproducible results were obtained as shown in Figure 14.

The samples were place in 3- by 5-inch Kraft paper envelopes, which were carefully labeled at the sample site in the field. About an ounce of sample (a small handful) was collected. The samples should be screened in the field with an iron or steel screen, or plastic window screen. A teaspoonful of sample is adequate for a simple test if it is a screened sample. No bronze, copper, or galvanized iron screens should be used, since such screen may lead to contamination of the sample.

What Is the Purpose of the Montana Project?—The principal objective of this investigation is to determine whether geochemical methods may be successfully applied to the discovery of mineral deposits in Montana. The purpose of this report is to present to prospectors, mine operators, and other interested persons the results of the geo-

BASIN DISTRICT

Geological Setting.—The Basin district is about 25 miles north of Butte. The geology is briefly described by Pardee and Schrader, (1933, 286-299), and Billingsley and Grimes (1918) who published a map of the district. The recent work by Klepper, Becraft, and others of the U. S. Geological Survey is not yet available. The rocks of the district include Cretaceous andesites, which were intruded by quartz monzonite of the Boulder batholith. Dikes of dacite and rhyolite cut the batholithic rocks. Mineralized veins in the quartz monzonite, which are older than the dacites, have been mined for silver, lead, zinc, and copper. The wall-rock alteration adjacent to some mineralized veins is intense, and in the Comet-Grey Eagle zone, the alteration zone is as much as 100 feet wide.

Comet-Grey Eagle Lode.—Outside of the Butte district, the Comet-Grey Eagle lode is probably one of the largest mineralized structures in the Boulder batholith. It represents a fracture zone from 20 to 100 feet in width, in a broad intensely altered zone extending for several miles in an east-west direction. Mineralization occurs in ore shoots along the vein, some of which have been very productive as at the Comet and Grey Eagle mines. Three geochemical soil sample traverses were made, one close to known mineralization at the Comet mine, another in an area of no known base-metal mineralization—near the Grey Eagle mine, and a third across a strongly fractured and altered zone between the Grey Eagle and Comet mines. In the traverses across the structure at localities where little or no commercial ore is known, it was anticipated that the vein structure and strongly altered zone would be detectable by a moderate combined heavy-metal anomaly. Only in the vicinity of the Comet mine was a strong anomaly recorded which served to show the location of the mineralized structure. Figure 8 and Table 4 give the data at the Comet traverse. At the Grey Eagle barren zone traverse, arsenic is found over a great distance and reveals the approximate position of the altered zone, but, as shown in Table 5, no base metals were found over the main structure. It should be noted that some lead does occur at the margin of the structure. Table 6 lists the analyses on the third traverse which crossed the structure but this structure was not detected chemically.

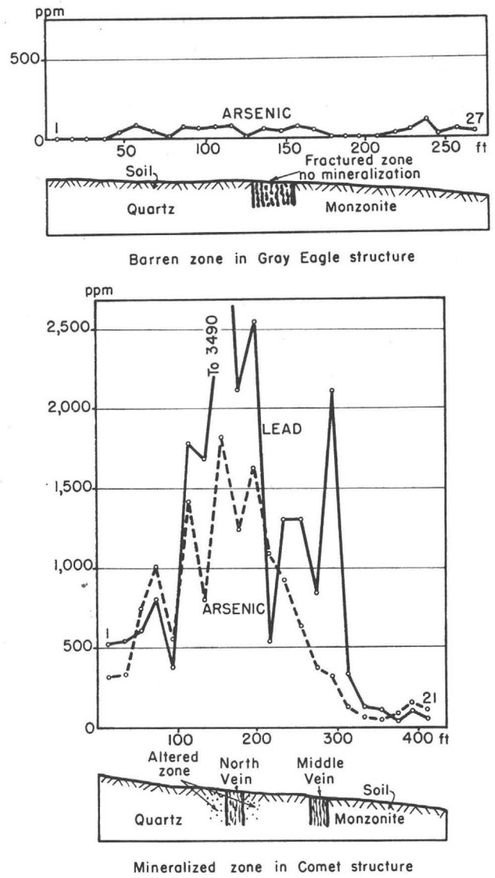


Figure 8. GRAY EAGLE-COMET STRUCTURE, BASIN

ing anomaly is shown in the soil samples. At this point, there is no surface indication of mineralization.

Although no conspicuous lead anomaly is recorded in the barren zone traverse, it should be reported that the backrogund over the area is about 200 ppm lead, which is a higher background than is commonly found in truly barren limestones. In other districts, the lead background in soils is commonly less than 50 ppm.

From the data shown in Figures 5 and 6, it is obvious that geochemical methods reveal the presence of anomalous lead concentrations adjacent to the ore shoot which crops out at the surface, whereas no significant lead concentrations are found in the barren areas.

BANNACK DISTRICT

Geological Setting. — Upper Paleozoic and Mesozoic sedimentary rocks, as well as Tertiary volcanic rocks, are found in the region. The older rocks are cut by an intrusive quartz monzonite stock. Most of the ores in the district are gold-silver ores, with very minor amounts of base metals. Some lead and zinc veins do occur, one of which was sampled. The geology of the district is described by Shenon (1931). The more recent mapping by W. B. Meyers, of the U. S. Geological Survey, is available on open file at Montana School of Mines Library.

Pomeroy Claim.—A single soil sample traverse was made across the Pomeroy vein, which strikes N. 85° E. and dips 75° N. in limestone. Samples were collected from the north side of the vein adjacent to an ore shoot exposed at the surface. By means of the grass-root method, samples were collected on a bearing N. 10° E. downslope. Partly covered with a light stand of small fir, the top soil of the area is moderately deep, up to 10 in. or more. The hillslope is moderately steep north of the vein, as shown in Figure 7. A distinct, combined heavy-metal (lead-zinc-copper anomaly of 300 ppm is shown, but individual chemical tests for lead and zinc show much more striking anomalies. Note especially that the metals in the soil are lost about 100 feet downhill from the vein on the fairly steep thick soilcovered slope. Table 3 shows the chemical analyses of the samples collected at the Pomeroy claim.

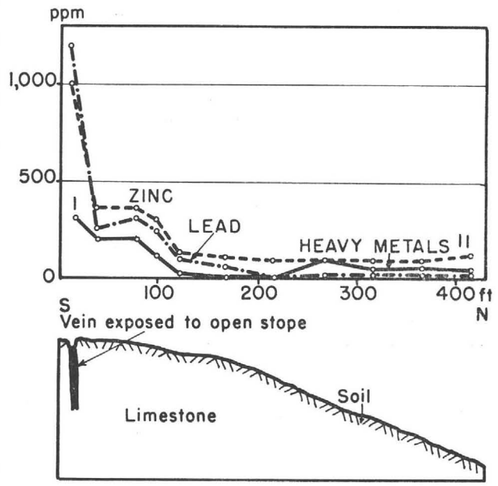


Figure 7. POMEROY VEIN, BANNACK

Table 3—Pomeroy Vein, Bannack

Chemical analyses of grass root soils collected from north edge of open stope on the Pomeroy Vein Sample interval 20 ft. Strike of vein No. 85° E. dips 75° N., traverse bearing N. 10° E., slope variable to 25° as shown in Figure 7. Thick soils support a small stand of Lodgepole pine.

Sample No.	Location of Sample	Heavy Metals ppm	Lead ppm	Zinc ppm	Remarks
1	North side ore shoot	300	1,200	1,000	5 ft from center of vein
2	20 ft north	300	250	350	
3	40 " "	200	300	350	
4	60 " "	200	250	300	
5	80 " "	100	100	150	
6	100 " "	0	100	150	
7	120 " "	0	50	100	
8	140 " "	0	20	100	
9	160 " "	100	20	100	
10	180 " "	50	20	100	
11	200 " "	50	20	100	

chemical investigations made in western Montana. Sampling was conducted in 20 mining districts in the State; the results indicate that geochemical prospecting should be of service to the prospector in the discovery of ore deposits.

Soil samples were collected over a wide variety of deposits in many kinds of rocks; the metals in the deposits investigated include zinc, lead, copper, tungsten, arsenic, gold, and silver. The types of deposits include fissure veins, disseminated deposits in massive replacement lodes, and contact and magmatic deposits associated with igneous, sedimentary, and metamorphic rock. Principal attention was paid to lead and zinc deposits in fissure veins and replacement deposits in limestones. Three different tungsten occurrences were tested, along with two copper deposits and several gold-silver deposits, several of which contain arsenic.

Summary of the Results of the Montana Work

The analyses of soil samples collected over ore deposits known to contain base metals (lead, zinc, copper) show the presence of much higher concentrations of metal than do samples collected a considerable distance away from known ore.

The best results are obtained from soils over fissure veins and replacement lodes in limestones and dolomites. Examples of this are shown in the Philipsburg, New World, Radersburg, and Elkhorn districts. Good results are obtained from fissure veins which contain known ore in many different types of rocks, including volcanic and granitic igneous rocks, metamorphic rocks, and a variety of sedimentary rocks. Successful results were obtained in the Zozell, Boulder, Wickes, Neihart, Heddleston, Philipsburg, and Radersburg districts, to mention but a few. Less conclusive results are obtained over some veins in andesitic rocks in the Elliston district. In some places, known deposits give good geochemical anomalies, whereas inconclusive results over known but small mineral deposits are likewise recorded. It is not definitely known why the results are less satisfactory over some veins, especially those in andesitic rocks.

One of the important findings of this investigation is that the metals from commercial ore shoots do not appear in the surface soils for any considerable distance downhill. That important ore shoots are frequently not detected more than 100 to 200 feet down the slope below a vein constitutes both an advantage and disadvantage in prospecting. It is a disadvantage in that prospectors cannot explore a region simply by collecting a group of samples near the valley floor, hoping to pick up important mineral deposits a quarter of a mile or more up the hillslope. It has the advantage of tending to pinpoint more nearly the location of a commercial ore shoot.

The major mining districts usually show a high metal content over a wide area. For example, the Argenta, Philipsburg, and New World districts contain abnormally high metal content in soils sampled through the district. Thus the presence of a high "background" over an area in which no mining had been done might serve to indicate the presence of important mineralization heretofore undiscovered.

Because insufficient data are available on blind undeveloped ore bodies, no attempt has been made to try to discover buried ore bodies. This will undoubtedly be an important field for future study.

Acknowledgments

The geochemical investigation was initiated by J. R. Van Pelt, President of Montana School of Mines and Director of the Montana Bureau of Mines and Geology. Walter S. March, Jr., Associate Director of the Bureau, has coordinated the many facets of the project, giving generously of his time and experience in field and office consultations. Edwin G. Koch served as chemical consultant.

In the field, Robert Meyer and Earl Lory served in 1953 and Paul Allsman in 1954 as able and congenial assistants. All chemical analyses are by C. J. Bartzen. X-ray spectrographic analyses were made under the supervision of Frederick A. Hames.

Montis Klepper of the Mineral Resources Branch, U. S. Geological Survey, and members of his party working in Montana, gave valuable suggestions and information on favorable sites for geochemical investigations.

The full cooperation of operators and prospectors is gratefully acknowledged. In many instances where operations were shut down, the proper authorities could not be found to determine the most favorable places for geochemical work. Elsewhere the operators gave valuable information which is included in this report. It would be impossible to list all who have contributed specific information incorporated in this report, but the following persons have been especially helpful: Frank Antonioli, L. E. Brooks, Wade V. Lewis, the late L. B. Manning, Dan Meschter, Henry Hieuweller, David Newman, Leo Newman, A. V. Taylor, the late Carl Trauerman, Eugene Wade, T. E. White, and Perry Yob.

The author is indebted to William W. Chance of Montana School of Mines and Uuno M. Sahinen of the Montana Bureau of Mines and Geology for the careful editing of the manuscript.

CHAPTER II

SOILS

FORMATION OF SOILS

Rocks exposed at the earth's surface are subject to weathering by chemical and mechanical agents. To these, the work of organisms both micro- (bacteria) and macro- (plants, insects, animals) contribute to the breakdown of the rocks and the development of soils. The rock-forming minerals in the rocks are broken down, the chemical constituents being leached or concentrated in the soil zones, dependent upon the soil-forming factors. A considerable amount of mixing will occur even where transportation is involved.

The ore minerals are likewise weathered, and the metals have become distributed throughout the soil zones. Elements such as copper, lead, and zinc are dispersed in the soils or removed by chemical solutions. It is the distribution of the heavy metals in the soils which is the primary concern of this report.

Mechanical weathering or disintegration involves the breakdown of rocks by the action of freezing and thawing of water in joints and cracks in rocks; the burrowing of animals; and the prying loose of particles by root action. Of these, the work of freezing water in confined cracks is by far the most important. Disintegration of this type is especially pronounced in the mountainous regions in the western part of Montana, where granular igneous rocks (such as granite and quartz monzonite) show disintegration to many feet, with but a slight amount of evidence of chemical change.

Chemical decomposition results from weak carbonic acid solutions of atmospheric derivation and organic acids produced by the decomposition of plant and animal remains in the soils. In warm, humid climates, feldspar decomposes to clay minerals; and hornblendes and pyroxenes yield insoluble iron oxides, which produce the rust colors in soils. However, in western Montana, chemical weathering is relatively minor.

MOUNTAIN SOILS IN WESTERN MONTANA

On mountainous slopes in western Montana, mechanical disintegration predominates over chemical decomposition. In the granitic rocks, feldspars are very incompletely altered to clay minerals, and limestone is very slowly weathered to produce a thin layer of soil of insoluble clay minerals. In both kinds of materials rock fragments are found even at the surface and are abundant in the soils. Quartzites and related rocks show even less weathering.

The immature soils of the mountain slopes do not have well-developed soil horizons. A typical soil developed on a granitic rock (quartz monzonite) is covered with a few inches of vegetable debris (pine and fir needles, twigs, and roots). Just below the organic matter is about a foot of brown loam containing some clay. Incompletely decomposed boulders and pebbles are common. Below, the parent material is lighter in color and distinctly granular, grading to a granitic "sand," which shows oxidation around mineral particles and along joints. The characteristic texture of the granite or quartz monzonite appears a few feet below the surface, but the mineral grains have been very largely separated from each other by mechanical means. About 3 feet below the surface, the bedrock shows prominent weathering along joints. The cores of many boulders near the surface are completely disintegrated, whereas at a depth of several feet, the cores are composed of nearly fresh quartz monzonite.

The granitic "sand" and the disintegrated granitic boulders show remarkable fresh mineral grains. Plagioclase feldspar appear to be fresh, or at the most, show a chalky whiteness on the surface of the grains. Orthoclase is not noticeably affected by chemical action. Hornblende appears to be fresh. Thus, only in the uppermost part of the soil zone, where surface water action has been most active and where organic acids have been most potent, have any clay minerals formed. The deeply weathered zone, commonly more than 6 feet thick, is dominantly mechanically produced.

The uppermost horizon of soils developed on limestone is a dark brown, humus-laden soil with some clay which is about 10 in. in thickness, containing many pebbles and boulders of relatively fresh rock. Below, a pale-brown to white "lime sand" composed of disintegrated mineral grains liberated from the parent rock, and some silt and sand grains occur for the next few feet. For the next few feet, the soil is composed of boulders and cobbles of limestone or dolomite, with decreasing amounts of lime sand between the rock particles. Massive limestone is commonly encountered at depths of 5 feet or less.

Even shallower, less-weathered soil profiles are characteristic of other rocks such as argillites, quartzites, and fine-grained igneous rocks such as rhyolite, andesite, and basalt. The thickness of the soil profile varies; but usually the thin top soil, a few inches to a foot thick, immediately overlies boulders of the parent rock. In general, basalt develops a somewhat thicker soil profile than does andesite. Rhyolite usually has a very shallow soil, comparable to the very thin soils found over most quartzites. In these soils, the parent rock is poorly weathered to rock fragments with the liberation of few mineral particles.

Table 2a—Governor Tilden Claim, Argenta

Chemical analyses of soil and rock chip samples collected from edge of ore shoot at Governor Tilden claim. Sample interval 10 and 20 ft. as shown in Figure 5. Strike of structure N. 70° E., traverse bearing S. 20° W., slope variable from 5° to 10°. Grassy and small sage brush on slopes. Soil 6"-8" with pebbles of limestone.

Sample No.	Location of Sample	Soil lead, ppm	Limestone lead, ppm	Remarks
1	240 ft south of open pit	200	50	
2	220 " " " " "	300	50	
3	200 " " " " "	500	30	
4	180 " " " " "	250	150	
5	160 " " " " "	800	130	
6	140 " " " " "	500	20	
7	120 " " " " "	1,000	20	
8	100 " " " " "	1,000	20	
9	90 " " " " "	800	800	
10	80 " " " " "	1,000	500	
11	70 " " " " "	1,200	400	
12	60 " " " " "	1,000	600	
13	50 " " " " "	3,000	800	Subsidiary structure?
14	40 " " " " "	3,000	150	
15	30 " " " " "	2,000	300	
16	20 " " " " "	1,000	300	
17	10 " " " " "	3,000	300	
18	At south edge of open pit	5,000	400	

Table 2b—Governor Tilden Claim, Argenta

Chemical analyses of soil samples collected across strike of fracture system at barren zone 200 feet west of traverse at 2a. Sample interval 25 and 50 feet as shown in Figure 6. Strike of structure N. 70° E. traverse bearing S. 20° W. Slope variable from 5° at south end to horizontal to 10° or 12° at north end. South end of traverse on quartzite. Grassy slopes with small sage and juniper bushes: Soil 6 to 8 in. with many pebbles.

Sample No.	Location of Sample	Lead, ppm	Remarks
1	275 ft south	150	Quartzite float
2	225 " "	250	" "
3	175 " "	150	" "
4	125 " "	200	Limestone
5	100 " "	200	"
6	175 " "	130	"
7	50 " "	150	"
8	25 " "	150	"
9	On strike of fracture zone?	300	"
10	25 ft north	200	"
11	50 " "	200	"
12	75 " "	200	"
13	100 " "	150	"
14	125 " "	150	"
15	175 " "	200	"
16	225 " "	200	"
17	275 " "	250	"
18	325 " "	250	"
19*	425 " "	250	"
20*	525 " "	250	"

*Not shown in Figure 6.

In addition to the soil samples, rock chips were also collected and analyzed for lead. Figure 5 shows the results of lead analyses from the rock samples (chips of limestone taken from outcrop). The anomaly for rock samples is much less pronounced than for soil samples. Figure 5 illustrates a lead anomaly in the limestone traverse about 50 feet south of the lip of the open cut. A correspond-

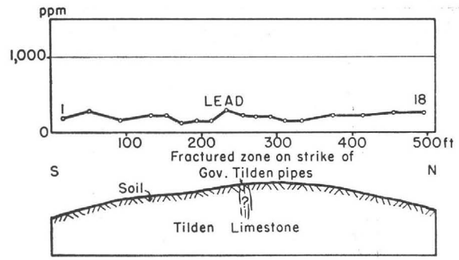


Figure 6. GOVERNOR TILDEN CLAIM OVER BARREN ZONE, ARGENTA

Table 1b—Hand Mine, Argenta

Chemical analyses of grass-root samples of soil collected over barren zone of Vein No. 6, Hand Mine.

Sample interval 25 and 10 feet as shown in Figure 4. Strike of vein approximately north, traverse bearing east. Slope 0°.

Sample No.	Location of Sample	Lead, ppm.	Remarks
1	50 ft west of vein	1,000	
2	25 " " " "	1,000	
3	over vein?	1,600	over vein?
4	10 ft east of vein	1,000	
5	20 " " " "	1,000	
6	30 " " " "	800	
7	40 " " " "	1,000	
8	50 " " " "	1,000	
9	60 " " " "	1,000	
10	85 " " " "	1,000	
11	110 " " " "	1,000	

The more comprehensive sampling done in 1954 revealed some very strong lead anomalies (from 5,000 to 30,000 ppm), where it is demonstrable that ore shoots extend to the surface. However, many strong anomalies were recorded along portions of veins where no ore shoots are known. Over stopes which have been mined at depth, but which are not known to reach the surface, lead anomalies are not strong. Almost all samples collected over the veins ran 1000 ppm or more lead. In those places where the strike of the vein is not detectable on the surface, and where the position of the vein is projected from underground development, it is probable that the location of the vein may have been missed by 10 feet or more. Figure 4 shows that a sample collected 10 feet or more from the vein may indicate a high metal content, but may fall far short of the maximum possible anomaly that would be recorded if the sample had been collected directly over the vein.

The results of the work at the Hand mine seem to indicate two important points:

1. That soil sampling serves to indicate a metallized area, and that individual ore shoots along veins may be detected where the shoots reach the surface.
2. That the systematic exploration of "high" areas may be significant for subsurface or even open-pit development.

In an area such as at the Hand mine, two types of sampling are recommended. A series of systematically spaced traverses at about right angles to the veins would serve to locate the position of the veins; then, systematic sampling over the tops of the vein would aid in indicating the tops of ore shoots. Or, systematic grid sampling would serve to outline the "high" spots, which might then be useful for exploration underground, or, in favorable situations, for exploration of the possibilities of open-pit operations.

Governor Tilden Claim.—The Governor Tilden and Tuscarora claims contain pipes of lead ore, which occur along a fracture zone in limestone, Argentiferous galena occurs in open-space fillings and in replacements in the Tilden limestone (Cambrian). Two soil-sample traverses were made on the property. One begins at the south edge of an ore shoot which had been completely mined out; the other is across the strike of the structure along which the pipes occur, but in an area of no known deposits about 200 ft west of the open stope. Samples were collected along a traverse line S. 20° W. from the stope, along the open hillslope. The soil cover is thin, from 6 to 8 in. The angle of slope along the line of traverse is from 5 to 10 degrees. Figure 5 shows a strong lead concentration adjacent to the known ore shoot. (See Table 2a.) The anomaly persists about 150 ft down the slope, but is not detectable 200 ft from the deposit on the downslope side. Table 2b shows the analyses of samples collected across the barren zone at the Governor Tilden claim. As shown in Figure 6, no significant lead anomaly was found in the barren zone.

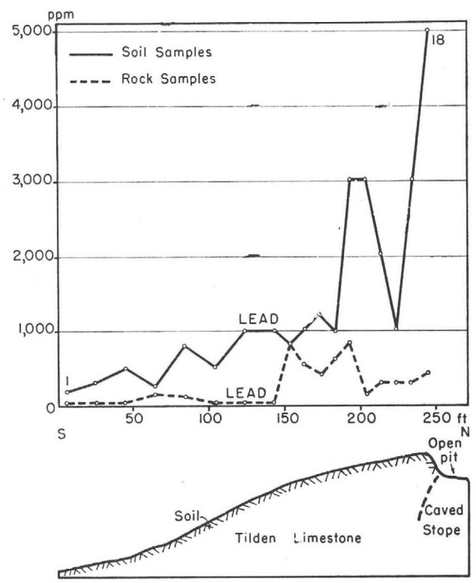


Figure 5. GOVERNOR TILDEN CLAIM ADJACENT TO ORE SHOOT, ARGENTA

In many areas, particularly on steep, forested hillslopes, the fine-grained top-soil matter is only a few inches in thickness. In some cases, the boulders of the parent rock are merely covered with a veneer of soil under the layer of organic debris. On grass-covered slopes, the surface soils are commonly darker and thicker than on comparable forested slopes, but the depth of weathered material is no greater.

HEAVY METALS IN THE SOILS

In the weathering of mineral deposits, the heavy metals such as copper, lead, and zinc become disseminated in the soil. The distribution of the metals in the soil is not precisely known. This report has undertaken no special research on the subject. From the data available, and from the known chemistry of the minerals, the following notes are offered as a partial explanation for the distribution of the heavy metals in the soil.

Lead—Galena (PbS) is the only important primary lead mineral. It is commonly oxidized at the surface to lead sulfate ($PbSO_4$) (anglesite) or lead carbonate ($PbCO_3$) (cerussite). Since all of these minerals have high specific gravities, it is probable that they tend to settle into the lower horizons, where they become disseminated between broken rock fragments at a depth not easily accessible to soil sampling. The analyses for lead obtained in soils undoubtedly represent the lead chemically adsorbed onto the surface of clays in the soils and do not indicate discrete particles of lead minerals. The amount of such lead is greatest near the deposit, and least away from the deposit. The decreased in the lead content in soils away from a mineral deposit is probably due, at least in part, to dilution with other soil particles. Background values in soils vary from 10 to 20 ppm to as much as 100 ppm. The higher lead background values are found in soils derived from limestones in which lead deposits are found. Under exceptional conditions, the background within a mineralized area is ever greater. (See Argenta and New World mining districts.)

Over the deposit itself, oxidized mineral particles may be encountered in the soils. Analyses of more than 30,000 ppm (more than 3% lead) have been recorded. Similarly high analyses have been reported from samples obviously contaminated by ore mineral particles.

Adjacent to mineralized veins, particularly in areas of limestone rocks, lead anomalies are measured by analyses of several thousand parts per million. Soils from granitic rocks record lead anomalies over veins with as few as 500 ppm lead. The background in such cases is correspondingly less. Thus, in granitic rocks and in sedimentary rocks other than limestone and dolomite, anomalies for lead were recorded with 500 ppm, or less with backgrounds of 50 ppm or less. In limestone areas, the background in a strongly mineralized area may be more than 1000 ppm, and an anomaly registered in such an area is correspondingly greater with an analysis of 5000 or more ppm lead.

Zinc—Sphalerite (ZnS) is the only important primary zinc mineral found in the State. Unlike lead, zinc is readily soluble (especially in the presence of pyrite) and is easily lost in solution by surface and ground waters. Although it is probable that much of the zinc is lost in solution from mature soils, significant traces become adsorbed onto clay mineral particles, and possibly onto other minerals, including iron oxides. The relatively larger amounts of zinc compared to lead, adsorbed onto clay minerals accounts for the larger traces of zinc detected in the soils adjacent to mineral deposits. The zinc is leached, and zinc-bearing clays are diluted by barren clays downhill from a mineral deposit. Zinc is commonly detected at greater distances from a deposit than is lead, even when the amount of zinc in the deposit is appreciably less than the lead content.

In the granitic rocks, zinc analyses in soils commonly exhibit a wider range than lead and in limestone areas, a range equivalent to lead. Zinc background values commonly range from 50 to 100 ppm. Zinc anomalies are reported from a few hundred to many thousand parts per million.

Copper—Copper occurs most commonly in sulfide minerals such as chalcopyrite and bornite in the primary deposits. In the presence of pyrite, copper minerals are taken into solution by surface waters and easily removed by ground waters. Copper is carried to below the water table, in granitic rocks, whereas in carbonate rocks (limestone and dolomite) copper minerals may become oxidized to copper carbonates (azurite and malachite) and may not move from the zone of oxidation to any appreciable extent. In the leaching process, some copper is adsorbed onto limonite in the oxidized gossans which are found over so many copper deposits. Copper may likewise be adsorbed onto other minerals in the soils. In general, the amount of copper retained in the surface soils adjacent to a copper-bearing deposit is significantly less than zinc or lead.

Copper background values, measure in 10 or 20 ppm, are less than lead and zinc in the deposits investigated. Copper anomalies may be recognized with concentrations as low as a few hundred ppm. Rarely were values of more than 1000 ppm recorded. No copper deposits in limestone were investigated so that no comparison between carbonate and silicate rocks can be made as in the case of lead and zinc.

Manganese — Manganese-bearing carbonates (rhodochrosite, $MnCO_3$, and manganiferous ankerite) are the principle manganese minerals found in many of the primary mineral deposits. They are easily oxidized to manganese oxides of different compositions. The manganese oxides are very in-

soluble, and persist in the soils in much the same way that iron oxides do. Small mineral particles of the manganese oxides, and manganese oxide coatings on mineral rock fragments, are found in the soils wherever manganese minerals are found. The fact that the manganese occurs in the soils as particles of manganese oxides seems to account for the erratic high manganese content found in many soils which have been tested for manganese. (See Philipsburg district.) It is difficult to tie a specific group of high manganese analyses to a specific manganese-producing horizon. On the other hand, in those areas where manganese is relatively minor in amount, manganiferous zones are easily detected by geochemical methods.

Arsenic—Arsenical gold deposits yielded strong arsenic anomalies over the deposits. Arsenic apparently is adsorbed onto mineral particles in the soils in much the same way that zinc is.

CHAPTER III

GEOCHEMICAL PROSPECTING IN MONTANA MINING DISTRICTS

Geochemical soil-sampling tests were conducted in 20 mining districts in the State to determine the applicability of the method to different types of deposits distributed over as wide an area as feasible with the time and funds available. Figure 3 is a map of western Montana, showing the location of districts in which geochemical tests were made.

In this chapter, a brief geological setting is given for each district to indicate the general conditions at the properties where samples were collected. References are made to published literature for those who wish additional information on the geology of the districts.

ARGENTA DISTRICT

Geological Setting — The Argenta district is about 12 miles northwest of Dillon in Beaverhead County. Paleozoic and Beltian sedimentary rocks exposed in the district were intruded by a stock of quartz monzonite of probable early Tertiary age. The mineralization is thought to be related to the intrusive. The general geology of the district was

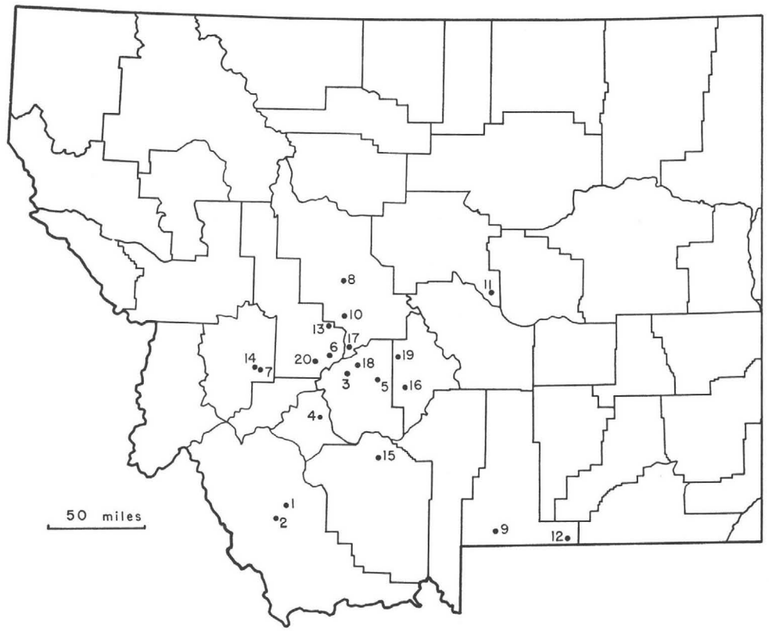


Figure 3 . MINING DISTRICTS IN WHICH GEOCHEMICAL SOIL SAMPLING WAS CONDUCTED FOR THIS INVESTIGATION

described by Shenon (1931). The result of more recent work by W. B. Meyers, of the U. S. Geological Survey, should soon be available. An open file report is in the library of Montana School of Mines.

A considerable amount of geochemical work was done at the Hand mine. In addition, two geochemical traverses were made at the Governor Tilden claim, about 2 miles north of the Hand mine.

Hand Mine.—The Hand mine on the Anaconda claim consists of a number of more or less north-striking veins in the Amsden (Mississippian) limestone. Lead ores occur in fissure veins and replacements in the limestone. Silver and gold occur in minor amounts. Pyrite and a manganiferous carbonate mineral are the principal gangue minerals.

During the 1953 field season, three soil sample traverses were made at the property, the results indicating the possibility that this area is well suited to a more thorough sampling program which might lead to the discovery of additional ore deposits. Consequently, Bill Hand, guided by Bureau personnel, collected a considerable number of samples, the locations of which were carefully marked on maps, and their relations to the vein structures described.

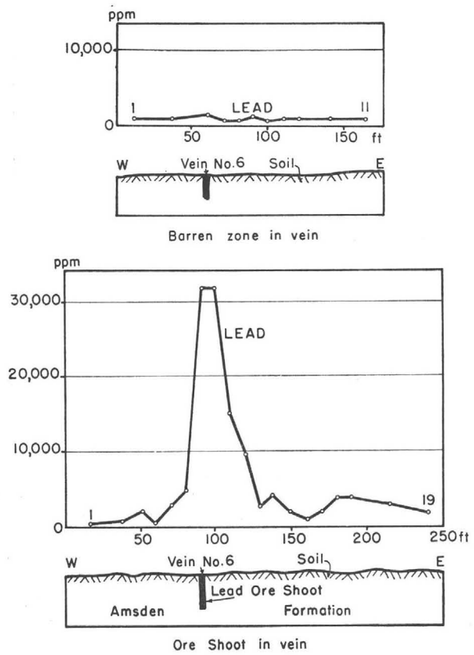


Figure 4. HAND MINE , ARGENTA

Strong geochemical anomalies were obtained over known ore shoots, which are easily distinguished from the "background" against which the veins stand out, as shown in Figure 4, is exceedingly high, about 1000 ppm lead. (ppm—parts per million.) Thus the background in the vicinity of the mine is a district anomaly when compared to 50 to 100 ppm, which is common in unmineralized limestones elsewhere.

Concerning the initial work in the area, two soil sample traverses were made, one across a known ore shoot which crops out at the surface, and another across a barren part of the same vein. The sample traverses are nearly horizontal in an area where the soils are very thin, averaging but a few inches in thickness. Both soil and "rock" samples (chips of limestone from the outcrops) were collected. The extraordinarily strong anomaly over the ore shoots, more than 30,000 ppm (over 3%) lead, is shown in Figure 4, Table 1a, whereas the vein structure is barely detectable in the barren part of the vein. (See Table 1b.) This example suggests that careful sampling along vein structures of this type should aid in discovery of hidden ore shoots which crop out at the surface, but which may be covered by soil.

Table 1a—Hand Mine, Argenta

Chemical analyses of soil samples collected over ore shoot on Vein No. 6, Hand mine. Sample interval variable as shown in Figure 4. Strike vein approximately north, traverse bearing east. Slope 0°+. Very thin rocky soils.

Sample No.	Location of Sample	Lead ppm	Remarks
1	70 ft W of vein	250	
2	50 " " " "	1,200	
3	40 " " " "	2,000	
4	30 " " " "	600	
5	20 " " " "	3,000	
6	10 " " " "	5,000	
7	Over vein	30,000+	Contaminated?
8	10 ft E of vein	30,000+	Contaminated?
9	20 " " " "	15,000	
10	30 " " " "	10,000	
11	40 " " " "	3,000	
12	50 " " " "	4,000	
13	60 " " " "	2,000	
14	70 " " " "	1,200	
15	80 " " " "	2,000	
16	90 " " " "	4,000	
17	100 " " " "	4,000	
18	125 " " " "	3,000	
19	150 " " " "	1,000	

Table 20 (Continued)

Sample No.	Location of Sample	Heavy Metals ppm a.	Lead ppm b.	Zinc ppm b.	Arsenic ppm b.	Manganese ppm b.	Remarks
21	400 " " " "	200					
22	410 " " " "	50	42	16	138	357	
23	420 " " " "	100	41	112	115	686	
24	430 " " " "	100	0	25	77	615	
25	440 " " " "	100	26	63	100	462	
26	450 " " " "	200					
27	500 " " " "	300					
28	600 " " " "	250					Vein
29	700 " " " "	300					
30	800 " " " "	300					

NEIHART DISTRICT

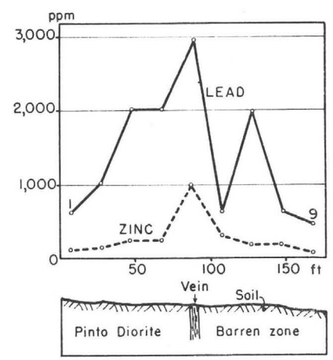
The Neihart mining district is in the central part of the Little Belt Mountains on the headwaters of Belt Creek in Cascade County, Montana. The region is mountainous and the veins crop out at elevations between 4,000 and 7,000 ft. on steep, timber-covered slopes. Though the district was developed principally for silver-lead, zinc, copper, and gold have been recovered. Molybdenite is present in large amounts but is sparsely disseminated. Some antimony and arsenic are present in the richer silver ores, and the veins contain a considerable amount of zinc. Both siliceous silver veins and complex carbonate gangue mineral veins occur in the district. The total value of the production for the district is estimated at about $20,000,000.

All of the rocks in the district are pre-Cambrian in age. A red syenite gneiss, host rock for many strong fissure veins, is the most prominent member of the pre-Beltian rocks. Included with the older rocks are dark biotite and hornblende schists, which are reported to have been intruded by the Pinto diorite. The veins are general barren in the diorite. The Neihart quartzite is of Belt age, resting unconformably on the old metamorphic rocks.

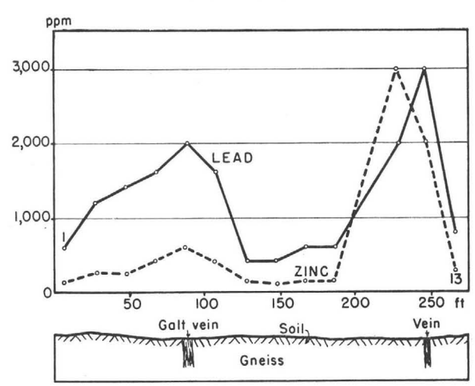
Early Tertiary (?) dikes, sills, and laccoliths cut the pre-Cambrian rocks. The Snow Creek porphyry occurs in dikes, which are frequently encountered in the principal mines. The Carpenter Creek porphyry is a granite porphyry, which occurs in a large number of dikes. Schafer (1935) has described the geology of the district.

Galt Mine.—The Galt mine is on the Queen-Galt vein, which was one of the principal producers in the district. Striking N. 20° to 30° E., the vein is vertical, and ranges from 1 to 5 ft. in width in the most productive workings. Productive in the syenite gneiss, the vein pinches to a non-productive structure in the Pinto diorite. The principal ore minerals are argentiferous galena, sphalerite, and complex sulfantimonides and sulfarsenides. The gangue minerals are ankeritic carbonates, rhodochrosite, and barite.

A soil-sample traverse was run in syenite gneiss and biotite schist at a locality where the vein was stoped through to the surface. The vein is from 3 to 4 ft. in width and nearly vertical. The soils were sampled on a course N. 60° W. across the vein at a locality where ore minerals were stoped to within a few feet of the surface. Just to the south of the traverse line, a stope holed through to the surface for more than 50 ft. along the vein. The traverse was made on contour, where the hill slopes about 25°. The soil is thin, with many



Barren zone in Galt vein



Ore shoot in Galt vein

Figure 20. GALT VEIN, NEIHART

very strong geochemical anomally for zinc and manganese, but only a slight anomaly for copper. The south vein shows a prominent zinc and manganese anomaly.

Table 7—Marget Ann Mine, Butte District

Chemical analyses of soil samples collected across three veins at the Marget Ann Mine. Strike of veins, traverse bearing, and sample interval shown in Figure 9.

Sample No.	Location of Sample	Copper ppm	Zinc ppm	Manganese ppm	Remarks
1	See Figure 9	150	100	200	
2		50	200	1000	
3		50	200	1000	
4		20	100	1000	
5		50	200	1000	
6		50	100	1000	
7		50	250	1600	
8		70	300	1600	
9		50	200	1600	
10		50	300	1000	North Vein
11		50	150	1000	
12		50	150	1000	
13		50	150	600	
14		50	150	600	
15		50	300	1600	
16		50	200	1600	
17		70	300	1000	
18		50	300	1000	
19		50	300	1600	
20		50	200	1600	
21		100	350	1600	
22		50	300	2400	
23		50	300	2400	
24		70	350	2400	
25		70	400	2400	
26		70	350	2400	
27		70	400	4000	
28		70	400	4000	
29		70	800	4000	
30		70	800	4000	Middle Vein
31		70	350	2400	
32		70	400	4000	
33		70	250	1600	
34		70	200	1600	
35		50	200	1600	
36		50	300	1600	
37		50	250	1000	
38		130	400	2400	
39		130	400	2400	
40		100	500	4000	South Vein
41		150	700	4000	
42		150	600	2400	
43		150	400	4000	
44		100	300	2400	
45		100	400	2400	
46		100	400	2400	
47		100	400	1600	

Table 7 (Continued)

Sample No.	Location of Sample	Copper ppm	Zinc ppm	Manganese ppm	Remarks
48		100	400	1600	
49		100	400	1600	
50		100	250	2400	
51		100	200	1000	
52		100	200	1000	
53		100	200	1000	

ELKHORN DISTRICT

Geological Setting.—In the Elkhorn Mountains east of Boulder, the Elkhorn district was one of the former important mining districts in the State. The geology of the Elkhorn mine is described by Barrell (1901:511) and Weed (1901:300); its geologic setting is described by Pardee and Schrader (1933:300). The recent mapping by Klepper, of the U. S. Geological Survey, is available in open-file reports in the library of Montana School of Mines.

The district is near the east side of the Boulder batholith. Paleozoic and Mesozoic sediments are overlain by late Mesozoic volcanic rocks, which were intruded by early Tertiary diorite porphyry and younger quartz monzonite. The sedimentary rocks were folded, and subsequently differentially metamorphosed, by the intrusives. The district is cut by many faults.

Elkhorn Mine.—The most important mine in the district is the Elkhorn mine, opened in about 1875. A minor fold in the sedimentary rocks appears to comprise the principal structural control for a large replacement ore shoot that contained silver, gold, lead, and some copper.

In 1952, the U. S. Geological Survey collected a series of soil samples across the mineralized zone which showed a strong combined heavy-metal anomaly*. Two additional detailed traverses were made during this investigation. The lead and zinc content of soils on the Pilgrim formation (Cambrian) is large, however, in detail, the anomaly is erratic, as indicated in Table 8. One of the traverses was re-sampled, and all of the analyses re-run by chemical and X-ray spectographic methods. The erratic character of the anomaly was definitely confirmed. A nice correspondence between chemical and X-ray spectographic analyses is shown. The metal content in the soil appears to be related to specific stratigraphic units within the formations; and as the rock layers are different chemically (dolomites, shales, etc.), the lead and zinc follow specific beds rather precisely, a selectivity manifested in the metal content of the soils. Evidence suggests but little lateral mixing of soils on the gentle hillslope along which the sample traverses were made.

The data in Tables 8 and 9 do not lend themselves to a readily understood curve. The tables need to be studied from several viewpoints: one,

*Klepper, personal communication.

the reproducibility of the chemical results; another, the erratic results along the lines of traverse which are at right angles to the strike of the beds.

The precise position of the contact between the Pilgrim and Red Lion formations is not determined, though the approximate position is indicated in the tables. The contact is better defined in Table 9 by projection of the contact exposed in a cut about 200 ft. away. Geochemically, the contact may be indicated between samples 12 and 13. The Pilgrim is in the first part of the table; the Red Lion, in the last part of the table.

Table 9 is of special interest, because along this traverse line a duplicate set of samples was collected from the same sample holes, but a year elapsed between sampling dates. There is a reasonable agreement in order of magnitude of the chemical assays.

Table 8—Elkhorn Mine, Elkhorn

Chemical analyses of soil samples collected along line of traverse across zone which is mineralized at Elkhorn mine. Sample interval 10 ft and 20 ft. Strike of sedimentary beds approximately N. 20° E. Traverse bearing N. 70° W. Slope variable but mostly horizontal. Traverse about 350 ft. northwest of main incline of Elkhorn mine. Area of traverse wooded. (a) Chemical analyses; (b) X-ray spectographic analyses.

Sample No.	Location of Sample	Lead, ppm (a) Original Analysis	Lead, ppm (a) Check Analysis	Zinc, ppm (a) Original Analysis	Zinc, ppm (a) Check Analysis	Remarks
1	300 ft. W of contact	800	800	400	400	Pilgrim Formation
2	280 " " " "	400	400	1000	1000	" "
3	260 " " " "	600	600	1000	1000	" "
4	240 " " " "	600	600	1400	1200	" "
5	220 " " " "	200	200	500	500	" "
6	200 " " " "	200	200	500	600	" "
7	180 " " " "	600	700	800	800	" "
8	160 " " " "	800	700	1200	1000	" "
9	140 " " " "	300	400	600	600	" "
10	120 " " " "	800	800	1000	800	" "
11	100 " " " "	150	150	250	250	" "
12	90 " " " "	100	100	400	400	" "
13	80 " " " "	1000	1000	1600	1000	" "
14	70 " " " "	130	130	200	200	" "
15	60 " " " "	50	100	150	150	" "
16	50 " " " "	200	250	1000	500	" "
17	40 " " " "	300	300	400	600	" "
18	30 " " " "	20	20	200	200	" "
19	20 " " " "	200	400	400	400	" "
20	10 " " " "	150	600*	200	600	" "
21	Contact	300	400	400	400	Contact
22	10 ft. E of contact	150	150	200	200	Red Lion Formation
23	20 " " " "	200	200	400	400	" "
24	30 " " " "	200	300	400	400	" "
25	40 " " " "	1000	150*	300	300	" "
26	50 " " " "	500	600	1000	800	" "
27	60 " " " "	800	800	1200	1000	" "
28	70 " " " "	500	600	800	800	" "
29	80 " " " "	200	200	300	300	" "
30	90 " " " "	500	500	800	800	" "
31	100 " " " "	300	300	300	250	" "
32	120 " " " "	800	800	1000	1000	" "
33	140 " " " "	70	70	100	100	" "
34	160 " " " "	20	50	100	100	" "
35	180 " " " "	30	50	100	100	" "
36	200 " " " "	100	200	400	400	" "
37	220 " " " "	300	200	400	400	" "
38	240 " " " "	800	800	800	800	" "
39	260 " " " "	300	300	700	500	" "
40	280 " " " "	500	500	1200	1000	" "
41	300 " " " "	1000	1000	1600	1200	" "

*Poor check analysis.

Table 19 (Continued)

Sample No.	Location of Sample	Gold, oz.	Silver, oz.	Remarks
19	90 " " " "	.02	.05	
20	100 " " " "	.04	.02	
21	120 " " " "	.03	.02	
22	140 " " " "	.04	.16	
23	160 " " " "	.04	.05	
24	180 " " " "	.04	.18	
25	200 " " " "	.04	.02	
26	220 " " " "	.02	.36	
27	240 " " " "	.005	.03	
28	260 " " " "	.02	.04	
29	280 " " " "	.005	.04	
30	300 " " " "	.005	.05	
31	320 " " " "	.005	.02	
32	340 " " " "	nil	.02	
33	360 " " " "	nil	.02	

Towsley Gulch.—Two veins strike nearly parallel to Towsley Gulch on the south slope of the gulch. A sample traverse was run at about right angles to the gulch, in an attempt to pick up the two structures at from 330 to 350 ft. and 675 ft. from starting point near the power line close to the Nile shaft. The purpose of this traverse was to note the effect of metal anomalies superimposed over one another by several veins on the same hillslope. Table 20 lists the chemical heavy-metal tests and X-ray spectographic data for lead, zinc, arsenic, and manganese. Copper was checked, but none was found in any sample.

The heavy-metal analyses show a single, isolated "high" analysis at 250 ft. and a single high lead analysis at 340 ft. Otherwise, lead is present, but quite erratic; zinc likewise shows no consistent high over the vein zone. Arsenic and manganese give no results which are useful for delimiting prospecting. These data are very largely negative.

Table 20—Towsley Gulch, Marysville

Analyses of soil samples collected on south slope of Towsley Gulch from power line close of Nile shaft, across two veins but at locations where there is no known base metal mineralization. Sample interval 10 and 50 ft. Slope variable from 10° to 20°. Thin, rocky soil. Sparse lodgepole pine cover.

a. Chemical analyses.
b. X-ray spectographic analyses.

Sample No.	Location of Sample	Heavy Metals ppm a.	Lead ppm b.	Zinc ppm b.	Arsenic ppm b.	Manganese ppm b.	Remarks
1	At Power line	(lost sample)					Nile vein
2	50 ft. from power line	200					
3	100 " " " "	200					
4	150 " " " "	200					
5	200 " " " "	200					
6	250 " " " "	200					
7	260 " " " "	100	0	114	65	945	
8	270 " " " "	100	39	172	146	895	
9	280 " " " "	100	0	204	62	713	
10	290 " " " "	100	40	104	38	1220	
11	300 " " " "	200					
12	310 " " " "	100	40	117	77	706	
13	320 " " " "	100	40	110	108	637	
14	330 " " " "	100	25	143	92	685)	
15	340 " " " "	100	115	104	77	700)	Vein zone
16	350 " " " "	400				)	
17	360 " " " "	100	15	116	10	595	
18	370 " " " "	100	54	75	31	706	
19	380 " " " "	100	12	79	10	594	
20	390 " " " "	100	0	89	62	538	

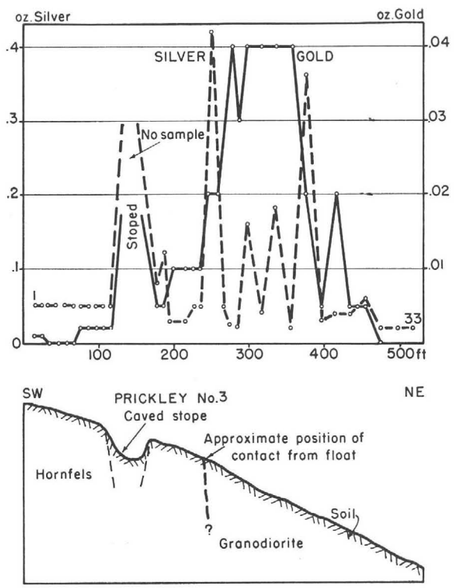


Figure 19. DRUMLUMMON MINE, MARYSVILLE

At the Drumlummon mine, 15 samples were analyzed for combined heavy-metals. The analyses average 100-ppm "heavy metals," with a few 50- and a few 150-ppm samples. The absence of heavy-base metals is manifested in the soil over a mine in which base metals are virtually unknown. The soil samples were treated by normal (fire) assays for gold and silver, results of which are shown in Figure 19 and recorded in Table 19. Note the high gold assays in the granodiorite at the contact of the stock, a completely unsuspected result of the sampling. This situation is somewhat similar to that found in the Philipsburg district, except that here the gold and silver heavy metals are concentrated in the contact zone of the igneous intrusive.

Bald Butte Mine.—The Bald Butte mine is in the SW¼ NW¼ sec. 10, T. 11 N., R. 6 W. A traverse, totaling 1,650 ft. in length, was made from above the vein outcrop downhill in a western direction to the bottom of the drainage. The soil is thin, averaging from 6 to 8 in. of loose soil in rocky float composed principally of metamorphosed Helena dolomite. Timbered with lodgepole pine, the region has almost no undergrowth. The slope is variable to maximum of about 20° parallel to the traverse. After the negative "heavy-metal" assays of the Drumlummon samples, only 9 samples, presumably over the main vein structure, were analyzed, with results from 100 to 200 ppm. There is no indication of an anomaly which could be definitely correlated with any vein structure.

Table 19—Drumlummon Mine, Marysville

Fire assays of soil samples collected across Pickley No. 3 stope of Drumlummon mine on N. 45° W. traverse. Stope strike approximately N. 45° E. Sample interval 10- and 20-ft. as shown in Figure 19. Slope 30°. Closely spaced small lodgepole in thin soils, from 6 to 8 in. Heavy with rock chips.

Sample No.	Location of Sample	Gold, oz.	Silver, oz.	Remarks
1	100 ft. uphill above stope	.001	.05	
2	90 " " " "	.001	.05	
3	80 " " " "	nil	.05	
4	70 " " " "	nil	.05	
5	60 " " " "	nil	.05	
6	50 " " " "	nil	.05	
7	40 " " " "	.002	.05	
8	30 " " " "	.002	.05	
9	20 " " " "	.002	.05	
10	10 " " " "	.002	.05	
11	0 " " " "	.002	.05	Uphill side of caved stope
12	10 ft. downhill below stope	.005	.08	Downhill side of caved stope about 70 ft. from sample stope
13	20 " " " "	.005	.12	
14	40 " " " "	.01	.03	
15	50 " " " "	.01	.03	
16	60 " " " "	.01	.05	
17	70 " " " "	.01	.05	
18	80 " " " "	.02	.42	Contact?

Table 8 (Continued)

Sample No.	Location of Sample	Lead ppm (b)	Zinc ppm (b)	Copper ppm (b)	Remarks
1	300 ft. W of contact	0	41	170	Pilgrim Formation
2	280 " " " "	0	11	138	" "
3	260 " " " "	250	110	182	" "
4	240 " " " "	950	917	216	" "
5	220 " " " "	315	312	0	" "
6	200 " " " "	710	735	0**	" "
7	180 " " " "	265	318	0**	" "
8	160 " " " "	685	615	150	" "
9	140 " " " "	980	979	77	" "
10	120 " " " "	760	820	30	" "
11	100 " " " "	175	262	50	" "
12	90 " " " "	250	351	140	" "
13	80 " " " "	270	452	150	" "
14	70 " " " "	155	164	220	" "
15	60 " " " "	510	450	205	" "
16	50 " " " "	560	598	195	" "
17	40 " " " "	280	310	205	" "
18	30 " " " "	0**	0**	185	" "
19	20 " " " "	730	830	380	" "
20	10 " " " "	460	500	300	" "
21	Contact	5	46	110	Contact
22	10 ft. E of contact	165	148	180	Red Lion Formation
23	20 " " " "	1425	1385	325	" "
24	30 " " " "	420	338	250	" "
25	40 " " " "	260	238	260	" "
26	50 " " " "	970	930	340	" "
27	60 " " " "	650	614	205	" "
28	70 " " " "	990	850	460	" "
29	80 " " " "	1125	920	240	" "
30	90 " " " "	510	427	180	" "
31	100 " " " "	570	516	240	" "
32	120 " " " "	550	780	300	" "
33	140 " " " "	1135	985	240	" "
34	160 " " " "	880	770	300	" "
35	180 " " " "	820	730	240	" "
36	200 " " " "	210	366	312	" "
37	220 " " " "	155	179	240	" "
38	240 " " " "	775	792	182	" "
39	260 " " " "	290	429	77	" "
40	280 " " " "	270	1028	2**	" "
41	300 " " " "	1270	1325	182	" "

**Below level of detection.

Table 9—Elkhorn Mine, Elkhorn

Chemical analyses of soil samples collected along line of traverse across the zone which contains mineralization at the Elkhorn Mine. Strike of sedimentary beds about N. 20° E. Traverse bearing N. 70° E. Slope variable about 5°. Soil thin, dense sagebrush cover, 90 ft. northwest of railroad cut, 100 ft. northwest of shaft. Sample interval 10 ft.

Sample No.	Location of Sample	Lead, ppm Original Sample	Lead, ppm Check Sample	Zinc, ppm Original Sample	Zinc, ppm Check Sample	
1	100 ft. W of contact		3000		6000	Pilgrim Formation
2	90 " " " "	2000	600*	1200	1200	" "
3	80 " " " "	400	600	200	1200*	" "
4	70 " " " "	200	400	100	800*	" "

Table 9 (Continued)

Sample No.	Location of Sample	Lead, ppm Original Sample	Lead, ppm Check Sample	Zinc, ppm Original Sample	Zinc, ppm Check Sample		
5	60 " " " "	800	150*	150	400	"	"
6	50 " " " "	1600	1000	1200	1600	"	"
7	40 " " " "	300	150	100	250	"	"
8	30 " " " "	2000	1000	2000	1400	"	"
9	20 " " " "	2000	800	1200	800	"	"
10	10 " " " "	3000	1200	1200	3000	"	"
11	On contact	2000	600	3000	1200	Contact	
12	10 ft. E of contact	2000	1000	1000	2000	Red Lion Formation	
13	20 " " " "	2000	1000	1200	1400	"	"
14	30 " " " "	400	800	200	1000*	"	"
15	40 " " " "	1000	1000	600	1200	"	"
16	50 " " " "	1200	500	600	800	"	"
17	60 " " " "	1200	1200	600	1500	"	"
18	70 " " " "	400	500	400	500	"	"
19	80 " " " "	1600	2000	1200	1400	"	"
20	90 " " " "	1400	1000	1200	1200	"	"
21	100 " " " "	200	1000*	200	1000*	"	"
22	120 " " " "	200		150		"	"
23	140 " " " "	1200		1000		"	"
24	160 " " " "	1600		1200		"	"
25	180 " " " "	400		300		"	"
26	200 " " " "	400		300		"	"

*Poor check analysis.

Elkhorn Queen Mine.— The Elkhorn Queen mine appears to be in a breccia pipe, which contains important amounts of silver and lead. A series of soil samples was taken at the Elkhorn Queen mine; but because of buildings, roads, and dumps, it was not possible to collect the samples immediately adjacent to, and downhill from, the deposit. A traverse was made N. 35° E. across an altered zone at the side of the known deposit. The analyses for heavy metals show 50 to 100 ppm, which is normal background. It is evident that no significant concentration of heavy metals pervades the walls of the pipe, a fact indicating the necessity of collecting samples in the immediate vicinity of an ore shoot to be able to detect the presence of the shoot.

ELLISTON DISTRICT

Geological Setting.—The Elliston district lies about 20 miles southwest of Helena at the northwest margin of the Boulder batholith. Its geology is described by Pardee and Schrader (1933:262). The writer has completed a study on the district which will soon be available. The district can be divided into two parts: a western part, where veins occur in Upper Cretaceous andesites; and an eastern part, with veins in the quartz monzonite of the Boulder batholith. In the southern part of the area, rhyolite of Tertiary age covers all older rocks. Gold and silver have been the principal metals produced; but lead, zinc, some copper, and arsenic are present in the veins, which in some places are long and persistent. The precious and base metals are concentrated in individual ore shoots along the veins. Mineralization is not pervasive, but the vein structures and wall-rock alteration are persistent. A considerable amount of sampling was undertaken because of the writer's familiarity with the district, and because of the variety of sampling conditions offered.

Ontario Mine.—Located in the extreme southeastern part of the district, the Ontario was probably the most productive mine in the area. Gold-bearing arsenical pyrite and lead, silver, and zinc minerals comprise the ores. Soil samples were collected from above an ore shoot, which had been worked by open cut, downhill for 300 ft. on a

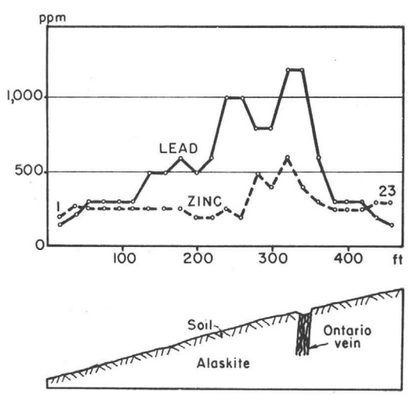


Figure 11 ONTARIO MINE, ELLISTON

Table 17 (Continued)

Sample No.	Location of Sample	Arsenic ppm a.	Arsenic ppm b.	Heavy Metals ppm a.	Tungsten ppm a.	Remarks
9	400 " "	400	1026			
10	450 " "	600	1179	50		
11	500 " "	300	972			
12	550 " "	300	819	50		
13	600 " "	200	802			
14	650 " "	400	864	50		
15	700 " "	100	639			Offset 175 ft. S 16° W
16	750 " "	200	802	100		
17	775 " "	400	963			
18	800 " "	400	666			
19	825 " "	100	873			
20	850 " "	300	837	100		
21	875 " "	100	999			W edge of road on bank 15 ft. E of road
22	900 " "	200	927			
23	925 " "	1200	1107			
24	950 " "	800	1161	100		
25	975 " "	1600	1702			
26	1000 " "	800	900			
27	1025 " "	800	990			
28	1050 " "	800	900	100	0	
29	1075 " "	400	603			5 ft. E, 4 ft. N road junction
30	1100 " "	200	594		0	
31	1125 " "	200	612	100	0	
32	1150 " "	200	405		0	

Table 18—Conrad Incline, Crevasse Mtn.

Chemical analyses of grass-root samples collected over ore shoot from 225 ft. northeast of portal of incline shaft southwest to 475 ft. below incline. Sample interval 25 and 50 ft. Strike of metamorphic rocks and pods of gold-bearing quartz, N. 30° W., dip 50° to 60° NE. Slope variable from 12° to 28° as shown in Figure 18. Soils average 6 in., sparsely timbered.

Sample No.	Location of Sample	Arsenic ppm	Tungsten ppm
1	225 ft. NW incline	600	0
2	175 " " "	600	0
3	125 " " "	600	
4	75 " " "	600	
5	25 " " "	1400	0
6	Over incline	2500	
7	25 ft. SE incline	2500	
8	50 " " "	800	0
9	75 " " "	800	
10	100 " " "	800	
11	125 " " "	800	
12	150 " " "	200	
13	175 " " "	200	0
14	200 " " "	200	0
15	250 " " "	200	
16	300 " " "	200	
17	350 " " "	100	
18	400 " " "	100	
19	450 " " "	100	
20	500 " " "	100	

MARYSVILLE DISTRICT

One of the premier gold-silver camps in Montana, the Marysville district, is about 20 miles northwest of Helena. The geology of the district is described by Barrell (1907). The Marysville stock is granodiorite. Intruded sediments includes the Helena dolomite and the Empire shale (Belt series), both of which have been extensively altered to hornfelses around the stock. The important gold-silver fissure veins are in the metamorphosed sediments, usually close to, but not at the contact of the stock itself. In the western part of the district, west of the intrusive stock, east-west fissures occur which contain gold, silver, lead, and zinc ores. The Drumlummon and the Bald Butte veins in the gold-silver part of the district were traversed. Two veins were traversed in Towsley Gulch in the base metal-bearing western part of the district.

Drumlummon Mine.—The Drumlummon mine is in the NE¼ SW¼ Sec. 36, T. 12 N., R. 6 W. The traverse was made downhill N.45° W. from the northwest edge of the Pickley No.-3 stope on the northeast end of Drumlummon vein. Samples were collected at 10-ft. intervals for 100 ft. above the caved stope, and 220 ft. north of the vein, then down the slope at 10- and 20-ft. intervals as shown in Figure 19. The slope is about 30° and parallel to the traverse. The traverse was made in densely wooded lodgepole pine, where the soil is thin (from 6 to 8 in.) and contains abundant chips of metamorphosed Helena dolomite.

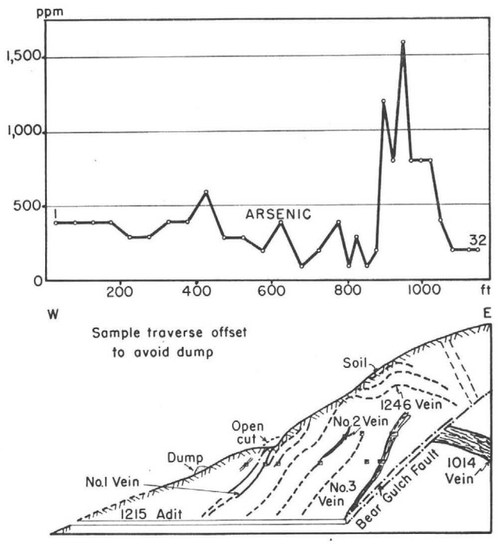


Figure 17. JARDINE MINE, JARDINE

arsenic anomaly suggests that geochemical tests for arsenic may be applied in the search for arsenical gold ores. The heavy-metals and tungsten assays were of no value for prospecting.

Crevasse Mountain.—At Crevasse Mountain a 700-ft., pace-and-compass traverse was made from 225 ft. northeast of the portal of the Conrad incline southwest to 500 ft. below the incline on a slope angle of about 15°, which ranged from 12° to 28°, as shown in Figure 18. The cummingtonite schist zone, with stringers and pods of auriferous quartz, strikes N. 30° W. and dips 50° to 60° NE. It exhibits many rolls and pinchings and swellings in an open cut at the surface. The soils are thin, averaging about 6 in. in depth. Grass-root samples were collected. The hill slopes are sparsely timbered with spruce and some aspen.

Arsenic analyses show a strong anomaly over the vein, as shown in Figure 18 and Table 18. Tungsten was not detected chemically. The striking arsenic anomalies in this district, as well as in other districts (see Ontario mine, Elliston District, and Emery Mine, Zosell District), indicate that the arsenic test may be successfully employed for prospecting arsenical gold ores. As many gold deposits of the State contain arsenopyrite, this test offers the possibility of tracing gold veins in the search for ore shoots obscured by soils.

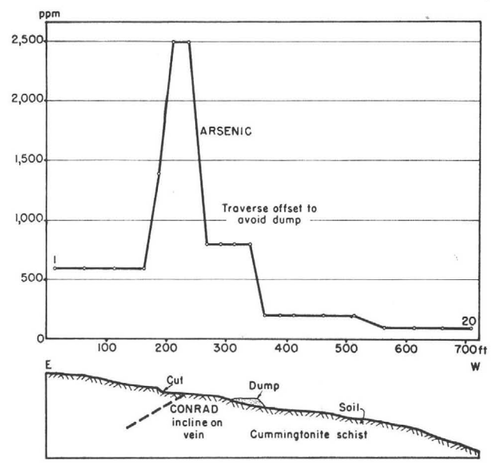


Figure 18. CONRAD INCLINE, CREVASSE MOUNTAIN

Table 17—Jardine Mine, Jardine

Chemical analyses of soil samples collected along the "cc section" of plate 9 (Seager 1944) from 1215 portal on course S. 75° E. Sample interval 25 and 50 ft. Slope variable from 25° to 35°, soils thick, 12 to 16 in. covered with lodgepole pine. See Figure 17.

a. Chemical analyses.
b. X-ray spectrographic analyses.

Sample No.	Location of Sample	Arsenic ppm a.	Arsenic ppm b.	Heavy Metals ppm a.	Tungsten ppm a.	Remarks
1	Over 1215 portal	400	945			
2	50 ft. S	400	1026			
3	100 " "	400	1044	100		
4	150 " "	400	1008			Offset 90 ft. S. 16° W. to by-pass dump of 1014 adit.
5	200 " "	300	864			
6	250 " "	300	1170	100		
7	300 " "	300	1026			
8	350 " "	400	936	50		Offset 190 ft. N. 16° E

gentle grass-covered slope. The soil is moderately thick; the country rock is an alaskitic phase of the Boulder batholith.

Figure 11 shows a conspicuous anomaly for lead and zinc. Arsenic also yields a strong anomaly. The analytical data are recorded in Table 10. Samples were originally collected at 20-ft. intervals, as indicated in Figure 10. Resampling for arsenic assays was made at 10-ft. intervals from the vein downhill for 100 ft. For convenience the two sets of data are incorporated into one table.

Table 10—Ontario Mine, Elliston

Chemical analyses of soil samples collected across ore shoot at the Ontario mine. Sample interval 10 ft. and 20 ft. Strike of vein about N. 60° E. Traverse about S. 20° E. Thin soils uphill from vein to moderately thick downhill. Slope about 10°. Lodgepole pine upper end of traverse, grassy slopes lower end.

Sample No.	Location of Sample	Lead ppm	Zinc ppm	Arsenic ppm	"Heavy Metals" ppm	Remarks
1	300 ft. S of vein	150	200			
2	280 " " " "	200	250			
3	260 " " " "	300	250			
4	240 " " " "	300	250			
5	220 " " " "	300	250			
6	200 " " " "	300	250			
7	180 " " " "	500	250			
8	160 " " " "	500	250			
9	140 " " " "	600	250			
10	120 " " " "	500	200			
11	100 " " " "	600	200			
12	80 " " " "	1000	250	400	150	
	70 " " " "			1200	250	
13	60 " " " "	1000	200	1000	250	
	50 " " " "			800	250	
14	40 " " " "	800	500	3000	250	
	30 " " " "			2500	250	
15	20 " " " "	800	400	1800	225	S side open cut on vein
	10 " " " "			2500	250	
16	Center of vein	1200	600	1400	250	
17	10 ft. N of vein	1200	400	1800	250	N side open cut on vein
18	30 " " " "	600	300			
19	50 " " " "	300	250			
20	70 " " " "	300	250			
21	90 " " " "	300	250			
22	110 " " " "	200	300			
23	130 " " " "	150	300			

Lilly Mine.—The Lilly mine is on a large vein, which contains gold, silver, lead, and zinc in localized ore shoots. The vein is steep, striking about N. 50° E. within the quartz monzonite of the batholith.

It was found that the depth at which the sample is taken in the thin mountain soils makes little or no difference. (See Table 11.) Duplicate samples from the same hole gave reasonable reproducible results. In this suite of samples, lead appears to be somewhat erratic. No significant change in concentration was noted for zinc.

Table 11—Lilly Mine, Elliston

Chemical analyses of soil samples collected along traverse north from vein structure at bulldozer cut several hundred feet east of Lilly Shaft. Sample interval 10 ft. Slope about 10°.

a, Grass-root samples.

b and c. Duplicate samples collected 6″ to 10″.

Sample No.	Location of Sample	Lead, ppm			Zinc, ppm			Heavy Metals, ppm		
		a.	b.	c.	a.	b.	c.	a.	b.	c.
1	N side of vein	600	1200	800	400	400	400	300	400	400
2	10 ft. N of vein	500	600	400	400	400	400	250	250	300
3	20 " " " "	400	600	600	400	400	400	250	200	250
4	30 " " " "	500	600	1000	300	300	600	250	250	250
5	40 " " " "	500	800	600	300	300	300	150	150	150
6	50 " " " "	600	800	1000	400	300	300	150	150	150

In addition to the traverse across the known ore shoot, a series of samples was taken along the strike of the vein for about 400 ft. east of the portal of the mine. Along this zone, no known commercial mineralization exists. The analyses of the samples ran from 125 to 250 ppm total heavy metals, whereas the normal background in the area is from 50 to 100 ppm heavy metals. Systematic sampling along the strike of the structure should serve as a means of exploring the possibilities of ore shoots which crop out at the surface. There appear to be sufficient base metals in the structure generally to determine its position by geochemical means.

Copper King Claim.—The vein on which the Copper King claim is located is one of the longest vein structures in the district, extending from the Elliston district east into the Rimini district,

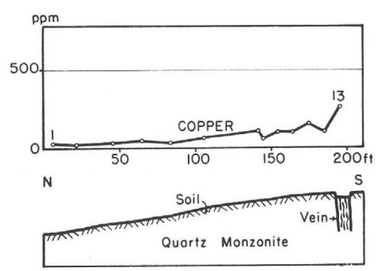


Figure 12. COPPER KING CLAIM, ELLISTON

a distance of several miles. The vein is typical of the structures in the eastern part of the district in that it is steeply dipping, striking somewhat north of east; it is a strong quartz-tourmaline vein with pyrite; and it has localized ore shoots of gold and base metals. At the Copper King shaft, a small amount of copper mineralization may be noted (as shown in Figure 12). A distinct but small copper anomaly was recorded at the site of a caved stope. Table 12 shows samples collected at 5-ft. intervals from a point 5 ft. north of the edge of an old stope northward for 30 ft., and then at 10-ft. intervals to 100 ft. The area has moderately thick soils and is timbered with small lodgepole pine.

Table 12—Copper King, Elliston

Chemical analyses of soil samples collected from edge of ore shoot at shaft northward. Sample interval 10 ft. and 20 ft. as shown in Figure 11. Strike of vein approximately N. 70° E. Traverse bearing N. 20° W. Slope 5°. Thick lodgepole pine cover.

Sample No	Location of Sample	Copper ppm	Remarks
1	170 ft. N of vein	20	Very thin soil
2	150 " " " "	10	
3	130 " " " "	20	
4	110 " " " "	40	
5	90 " " " "	20	
6	70 " " " "	50	
7	50 " " " "	100	
8	40 " " " "	50	
9	30 " " " "	100	
10	20 " " " "	100	
11	10 " " " "	150	
12	N side of vein	100	
13		250	

Bullion Claim.—The Bullion claim is on another of the long east-striking veins in the district. Samples for geochemical study were collected about 200 ft. east of the shaft in an area not known to be mineralized. They were collected at 10-ft. intervals from 100 ft. north to 100 ft. south of the presumed strike-position of the vein. There are no outcrops, and the soil is quite deep on the gentle grass-covered slopes on the west side of, but virtually astride, the Continental Divide. The sample point on the projected strike of the vein shows no anomaly for lead or zinc; however, a distinct anomaly is noted about 40 ft. south, as

Table 16—Mike Horse Mine, Heddleston

Chemical analyses of soil samples collected adjacent to holed-thru area, presumed to have been stoped on ore shoot. Sample interval 10 ft. Strike of fissure vein N. 50° W. dip 75° S. Course of traverse N. 70° E. on steep, timber-covered slope, approximately 30°. Soil coverage 10 to 12 in. with pebbles of metamorphosed shale. See Figure 16.

Sample No.	Location of Sample	Lead, ppm	Remarks
1	80 ft. E of vein (uphill)	180	
2	70 " " " " "	130	
3	60 " " " " "	200	
4	50 " " " " "	200	
5	40 " " " " "	250	
6	30 " " " " "	250	
7	20 " " " " "	150	
8	West side of vein	800	Caved stopes east and west
9	Over vein?	250	
10	10 ft. W of vein (downhill)	250	
11	20 " " " " "	250	
12	30 " " " " "	250	
13	40 " " " " "	100	
14	50 " " " " "	250	
15	60 " " " " "	100	
16	70 " " " " "	150	
17	80 " " " " "	150	
18	90 " " " " "	200	
19	100 " " " " "	200	
20	110 " " " " "	100	

JARDINE-CREVASSE MOUNTAIN DISTRICT

Geological Setting.—The Jardine-Crevasse Mountain mining district is in the extreme southern part of Park County at the southern end of the Snowy Mountains of the Absaroka Range, very close to the northern boundary of Yellowstone National Park. Jardine is at an elevation of about 6,500 ft.; the deposits at Crevasse Mountain are about 2,000 ft. higher. The region is mountainous and the mineralized structures crop out on steep forested hillslopes. The geology of the district was described by Seager (1944).

Gold occurring with arsenopyrite, is the principal valuable metal, although some tungsten has been produced. Large reserves of both gold and tungsten are reported. The total production for gold, silver, and tungsten is in excess of $5,000,000. Some arsenic, copper, and lead have been recovered from the ores.

The deposits occur in pre-Cambrian granite and diabase. The ore occurs in quartz stringers and pods in cummingtonite schists. In many particulars, the geological setting resembles the Homestake deposits of South Dakota.

Broadly speaking, the structural situation is relatively simple. In detail, the structures which control the ore deposits are "infinitely complex" (Seager 1944:38). At Jardine the schists dip at very steep angles, where at Crevasse Mountain the dips are relatively much shallower to very nearly flat-lying.

Two geochemical traverses were made: one at the Jardine mine, along a line which corresponds to the "cc section" illustrated and described by Seager (1944, plate 9); the other, at the Conrad incline at Crevasse Mountain.

Jardine Mine.—At the Jardine mine the traverse was begun at the 1215 portal on a course S. 75° E. Several offsets were required in the traverse to avoid mine dumps and open cuts. The slope ranges from 25° to 35°, and the area is quite heavily timbered with lodgepole pine. The soils are quite deep, averaging from 12 to 16 in. Soil samples were taken from holes 10 to 12 in. deep, and all distances were measured with a steel tape 17 and tabulated in Table 17. The conspicuous along the slope. The results are shown in Figure

fined to a breccia zone in which sphalerite was observed. The series of samples collected in 1953 revealed the highest zinc analysis recorded in the district. In 1954, a grid layout for samples was set up by pace and compass, and samples were collected at 25-ft. intervals. Figure 15 shows the shape of the geochemical anomaly, indicating a distinct northwesterly trending concentration of zinc. With this information and the available underground data, an intelligent continuation of the soil-sampling program could be expanded to aid in delimiting the size of the anomaly for possible underground exploration.

GRANITE DISTRICT

The Granite district is on the west side of the Philipsburg batholith about 5 miles southeast of Philipsburg. The Granite-Bimetallic mine was once a famous producer and the only important mine in the district. The vein system is in granodiorite of the batholith, and comprises a group of parallel veins. It was not possible to collect soil samples over known ore shoots near the principal workings; however, a suite of samples was collected from just east of the Fanny-Parnell shaft across the Fanny-Parnell and the Elizabeth veins. The traverse was nearly 500 ft. in length, and no heavy metal analysis in excess of 100 ppm was recorded. The analyses did not indicate the position of either of the two veins, although the traverse passed within 50 ft. of the Elizabeth shaft. This information seems to add further evidence that the large veins in the granitic rocks, although they may be strong quartz-filled fractures and have intense wall-rock alteration, did not necessarily contain important amounts of base metals at the time the veins were formed. The base metals are principally confined to distinctly younger ore shoots; and at the time of their introduction, the veins were not open through-going fissures along which the base metals could migrate.

HEDDLESTON DISTRICT

The Heddleston district is about 33 miles northwest of Helena on the west side of the Continental Divide at the head of Blackfoot River. The Pre-Cambrian rocks of the Belt series exposed include argillite, slate, quartzite, and dolomite. The sedimentary beds dip northerly and are intrdued by a diorite sill reported to be about 500 ft. in thickness. The geology of the district is briefly described by Pardee and Schrader (1933:87).

Mike Horse Mine.—One geochemical soil-sample traverse was made, the sampling being performed over a well-defined fissure striking N. 50° W. and dipping 75° S. The wall rocks are impregnated with pyrite near the vein. The diorite wall rock is altered to quartz and sericite. A dense spongy gossan of iron oxide containing crystals of cerussite and some galena was noted in a cut along the line of traverse. A traverse was made about 325 ft. in length on a course N. 70° E. down the slope of the hillside. It began about 60 ft. uphill above the vein, and samples were collected to a point about 300 ft. below the vein on the downhill side. The slope is steep, approximately 30°, and is densely timbered with small lodgepole pine. The soil averages 10 to 12 inches in depth, with many pebbles of metamorphosed shale in the deeper parts of the holes. Figure 16 and Table

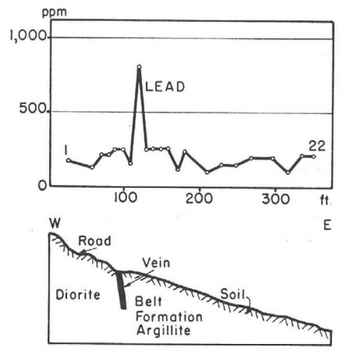


Figure 16. MIKE HORSE MINE, HEDDLESTON

16 show a distinct lead anomaly, which was recorded only over the vein. It was anticipated that the intensity and spread of the anomaly would have been much greater, especially on the downhill side. As there was no activity at the mine at the time the sample traverse was made, the precise location of the vein and ore shoots could not be determined in the heavy timber, and no information as to the location of favorable sampling areas was available. A group of several soil traverses across the vein at locations of important ore shoots and "barren" parts of vein would have been very useful in determining the applicability of the methods in the areas of the Belt argillites.

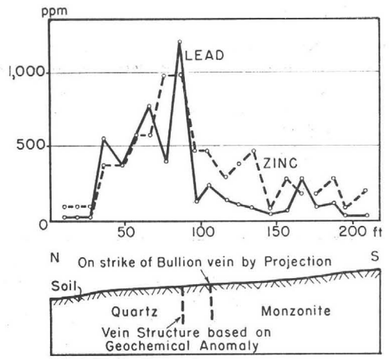


Figure 13. BULLION VEIN, ELLISTON

shown on Figure 13 and in Table 13a. A year later, a second group of samples was collected in a southerly direction from the collar of the shaft, which is on the vein. A strong lead and zinc concentration exists at, and just south of, the shaft; a single 15,000 ppm zinc analyses is reported 50 ft. south (as shown in Table 13). This may be a contaminated sample. From the two traverses run, it is suggested that the Bullion vein is offset by faulting to the south somewhere east of the shaft. Additional sampling would serve to show the true relationships.

At this locality, samples were collected from the grass roots and at about 10 in. in depth, and the samples assayed for total heavy metals. The grass-root samples contain a somewhat larger concentration of combined heavy metals than do the samples collected at a depth of 10 in. The heavy-metal analyses are likewise given in Table 13a, and are shown graphically in Figure 14.

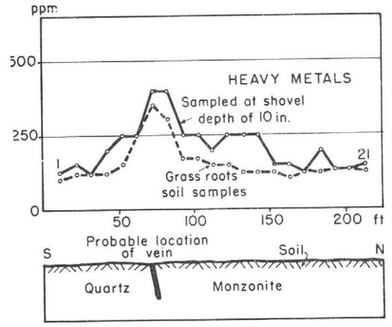


Figure 14. BULLION VEIN, ELLISTON

Table 13a—Bullion Mine, Elliston

Chemical analyses of soil samples collected across strike of vein about 200 ft. east of shaft. Sample interval 10 ft. as shown in Figure 13. Strike of vein N. 80° E. Strike of traverse N. 10° W. Slope horizontal. Thick soil on grassy park.

a. Grass-root sample.
b. 10-inch depth sample.

Sample No.	Location of Sample	Lead ppm	Zinc ppm	Heavy Metals ppm a	Heavy Metals ppm b	Remarks
1	80 ft. N of vein	10	200	150	125	
2	70 " " " "	10	100	125	125	
3	60 " " " "	100	300	125	125	
4	50 " " " "	100	200	200	125	
5	40 " " " "	300	200	125	125	
6	30 " " " "	70	300	150	100	
7	20 " " " "	70	100	150	125	
8	10 " " " "	100	500	250	125	
9	On vein?	100	400	250	125	No outcrop
10	10 ft. S of vein	150	300	250	150	
11	20 " " " "	250	500	200	150	On strike of vein by projection
12	30 " " " "	130	500	250	175	
13	40 " " " "	1200	1000	250	300	
14	50 " " " "	400	1000	400	350	
15	60 " " " "	800	600	400	250	
16	70 " " " "	600	600	250	150	
17	80 " " " "	400	400	250	125	
18	90 " " " "	600	400	200	125	
19	100 " " " "	20	100	125	125	
20	110 " " " "	10	100	150	125	
21	120 " " " "	30	100	125	100	

Table 13b—Bullion Mine, Elliston

Chemical analyses of soil samples collected from collar of Bullion shaft southward. See Table 13a.

Sample No.	Location of Sample	Lead	Zinc	Remarks
1	10 ft. S Bull. shaft	30,000+	6,000	
2	30 " " " "	30,000+	2,000	
3	50 " " " "	30,000+	15,000	Contamination?
4	70 " " " "	800	400	
5	90 " " " "	150	200	

Hubcamp Claim.—A group of samples were taken at the divide uphill east of the Hubcamp workings, the nearest place to the principal workings from which uncontaminated samples could be collected. The Hubcamp vein is another east-striking fissure in the quartz monzonite. It is, however, rather narrow at this locality, being only a foot or less in width. Lead and zinc are known to be present in the vein, although no important shipments have been made. No significant anomalies were shown by the soil samples. The background is about 100 ppm heavy metals. Three samples, which probably indicate the position of the vein, contain 150 ppm heavy metals. It would probably be difficult, by geochemical methods, to trace the position of this small vein in granite.

Julia Mine.—One of the longest vein structures known in the district, the Julia vein is a very strong quartz-pyrite structure in the quartz-monzonite. Wall-rock alteration is intense, having converted feldspars to sericite, and the iron minerals to pyrite. The trend of the vein is about east-west. It is a wide vein, which, however, splits into a group of stringers in the andesites west of the contact of the batholith. The mine has a considerable production record principally in gold, with lesser amounts of silver and lead. The ore contains some zinc. Three soil-sample traverses were made across the structure: one west of the andesite-quartz monzonite contact; one virtually along the contact, and another about 2000 ft. east of the main shaft in the quartz monzonite. Dumps and mine workings prevented traverse across an ore shoot. In each traverse area, no known commercial ore is known to be present, but it was anticipated that it would be possible to detect the presence of the vein by geochemical sampling. However, no detectable anomaly was recorded by the combined heavy-metals analyses from the three sample traverse lines and the more than 100 analyses. The background is about 100 ppm, which is the analysis for most of the soil samples. A few individual samples contain from 125 to 150 ppm combined heavy metals.

These data from the three traverses add further evidence that the presence of a large vein structure with strong wall-rock alteration does not mean that the vein-forming solutions contain significant amounts of base materials. In this case, as at the Comet-Grey Eagle structure, it is doubtful whether the vein structure can be traced by geochemical methods. However, the strike of the vein is quite well marked by numerous prospect pits and small shafts. Thus it would be possible to collect soil samples along the strike of the vein, with the hope of picking up the top of an ore shoot which does not crop out at the surface.

Nigger Mountain.—On Nigger Mountain are a number of veins in andesites, which are older than the quartz monzonite of the batholith. In the vicinity of the Big Dick and the Little Dick mines, several soil-sample traverses were made. The "Flat vein" at the Big Dick mine is a low-angle structure, varying from a few inches to about one foot in width, but containing gold, silver, lead, and zinc. The vertical veins in the district trend in nearly east-west directions and cut the "flat" vein.

The Big Dick, Black Jack, and Little Dick mines are probably all on the same nearly vertical vein. A few hundred feet uphill from the Black Jack shaft, a shallow bulldozer cut revealed a few stringers of mineralization at the probable outcrop of the vein. A group of soil samples collected along a horizontal line across the structure shows a small but distinctly "high" analysis over the vein, with relatively higher lead values on each side 10 ft. from the oxidized stringer, as shown in Table 14.

Table 14—Black Jack Mine, Elliston

Chemcial analyses of grass-root samples collected from side of bulldozer cut which exposed small mineralized stringer veins. Sample interval 10 ft. Strike of vein approximately east, traverse bearing north, slope 0°. Thin, rocky, grass-covered soils.

Sample No.	Location of Sample	Lead ppm	Zinc ppm	Remarks
1	10 ft. S of stringers	50	150	
2	Over stringers	130	150	
3	10 ft. N of stringers	70	100	
4	20 " " " "	20	100	
5	30 " " " "	20	100	
6	40 " " " "	20	100	

At the Big Dick shaft, east of the Black Jack shaft, a series of soil samples was collected across the vein at the site of an open stope. Samples from 100 ft. north of the vein (uphill) to 1800 ft. south of the vein do not show any indication of the vein structure or any anomaly. A remarkably uniform 100-ppm heavy metals, with a few samples 50 and 125 ppm, persist throughout the line of traverse.

Two traverses across the vein near the Little Dick shaft west of the Black Jack shaft show twice as much heavy-metal value over the vein as the barren soils away from the vein. As shown in Table 15, a background count of 100-ppm heavy metals is present at both ends of the traverse for about 150 ft. on each side of the vein. The anomalies appear to be small, but are probably significant; for in all cases where a "total heavy-metal" anomaly has been recorded, the anomaly shows up much more convincingly when separate assays for lead and zinc are made. (See particularly the Emery vein traverse, Zozell District.)

Table 15—Little Dick Mine, Elliston

Chemical analyses of soil samples collected across vein in area presumed to have been mined underground close to surface. Strike of vein S. 48° W. Traverse line S. 40° E. Sample interval 10 ft., slope 8° to 9°. Grassy slope, thin soils.

Sample No.	Location of Sample	Heavy Metals ppm
1	40 ft. SE of vein (downhill)	100
2	30 ft. SE of vein	100
3	20 " " " "	125
4	10 " " " "	150
5	Over vein	200
6	10 ft. NE of vein	125
7	20 " " " "	125
8	30 " " " "	100
9	40 " " " " (uphill)	100

Above the adit on the same vein below the Little Dick shaft, about 100 ft. above the Little Blackfoot River, zinc was recorded in the soils to 150 ppm for 40 ft. across the vein structure. Other samples had no zinc except traces. Many chunks of ore containing massive sphalerite may be found on the dump of this project.

The small magnitude of the geochemical anomalies in the andesites of Nigger Mountain is not understood. The most probable explanation is that at no place was the top of a base metal-bearing ore shoot sampled. However, in those places where base metal-bearing minerals were observed in oxidized vein structures, the anomalies are surprisingly low.

Hopkins Mine.—The Hopkins mine is located on the Little Blackfoot River on the west side of Nigger Mountain and is one of the most important producers in the district. Silver, lead, and zinc, and some gold have been recovered from the property. A series of north-east-striking veins dipping steeply to the northwest crop out on the steep hillslopes. The first geochemical traverse was made at the Hopkins mine below an ore shoot in which 30 in. of massive galena had been seen by the writer in a bulldozer cut. It was not possible to collect an uncontaminated sample less than 26 ft. downslope from the ore shoot. Samples were taken on the steep, heavily timbered slope; and an anomaly was recorded, with 250-ppm heavy metals in the first sample below the ore shoot, 150-ppm heavy metals persisting for 90 ft. downhill in an area where the normal background is from 50 to 100 ppm. It is probable that samples collected closer to the ore shoot, would show more spectacular anomaly, and if separate lead analyses had been prepared, the anomaly would undoubtedly be very pronounced. As there are a number of veins on very steep, timber-covered hillslopes, systematic soil sampling up the hillslopes might prove useful in detecting the presence of the veins, and detailed sampling along the veins might reveal the tops of covered ore shoots.

Monarch Mine.—Two vein systems are present at the Monarch mine. One vein strikes about east and contains gold and some copper. A second vein, which strikes N. 20° E. and dips steeply to the west, contains lead and zinc ore rich in silver. This structure is in the shaft uphill from the adits. One series of soil samples was taken across the vein in an area where gold was reported but no lead and zinc were known, and no detectable base metal anomaly was recorded. This traverse substantiates the observations that vein structures are detected by any specific geochemical tests only when the specific metal is present in the vein structure at the location of the traverse.

Clark Prospect.—The Clark prospect is on the west side of Little Blackfoot River in the pre-batholithic andesites. The mineralization is con-

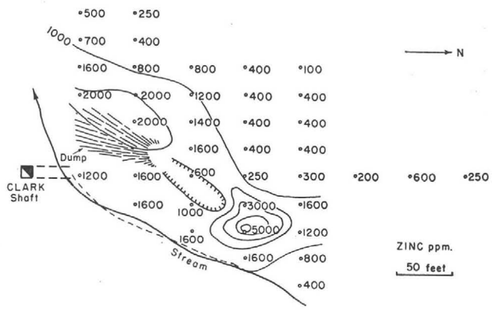


Figure 15. GRID SAMPLE LAYOUT AT THE CLARK MINE, ELLISTON

Replacement Lodes in Sediments, Silver Hill Formation.—On West Algonquin hill a specific bed in the Silver Hill formation has been replaced along the intersection of the narrow east-west Bernard vein. The zone has been mined and extensively prospected on the south side of the hill. Geochemical sample traverse was made just west of a stoped area across the zone in an area that had been extensively explored by bulldozer cuts, which revealed the vein and the replaced beds in the Silver Hill formation. It is not possible to locate the traverse at right angles to the structure. The traverse bears S. 20° E. on about a 20° hillslope, which is parallel to the structure. The soil averages from 8 to 10 in. deep and includes large blocky float boulders of hornfelsed shales. Samples were collected every 10 ft. for 170 ft. across the vein. Figure 33 shows a strong, definite manmanese anomaly; as shown in Table 31, lead and zinc each show an anomaly related closely to the narrow vein structure. Note that the lead and zinc anomalies are displaced by about 10 ft.

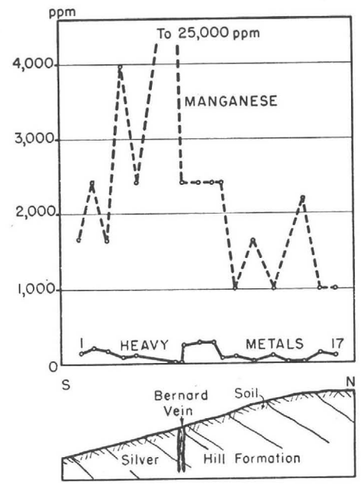


Figure 33. WEST ALGONQUIN, REPLACEMENT LODE, PHILIPSBURG

Table 31—West Algonquin Mine, Philipsburg

Chemical analyses of soil samples collected across Bernard vein, west of West Algonquin mine. Sample interval 10 ft. on bearing S. 20° E. about at right angles to the mineralized structure. Slope variable from 0° to 27° as shown in Figure 33. Soil averages 80 to 10 in. with much blocky float.

Sample No.	Location of Sample	Lead ppm	Zinc ppm	Manganese ppm	Heavy Metals ppm	Remarks
1	65 ft. S of vein	70	150	1,600	125	
2	55 " " " "	250	350	2,400	200	
3	45 " " " "	250	350	1,600	175	
4	35 " " " "	70	200	4,000	100	
5	25 " " " "	500	300	2,400	100	
6	S side of vein	20	30	25,000	0	Center bulldozer cut, very
7	N side of vein	130	250	2,400	0	thin soil.
8	10 ft. N of vein	500	600	2,400	250	
9	20 " " " "	500	600	2,400	300	
10	30 " " " "	200	250	2,400	75	
11	40 " " " "	200	250	1,000	100	
12	50 " " " "	150	100	1,600	25	
13	60 " " " "	150	300	1,000	100	
14	70 " " " "	30	50	600	25	
15	80 " " " "	250	100	2,400	25	
16	90 " " " "	250	200	1,000	150	
17	100 " " " "	200	200	1,000	100	

small rock chips; yet it supports a fairly heavy timber cover. Sampling was done at 20-ft. intervals for 80 ft. to the northwest and 260 ft. to the southeast. Two small structures were encountered east of the principal Galt lode. Samples from the Galt No. 2 adit indicate maganiferous oxide with some iron oxide and barite in a brecciated zone. Some galena was noted, but no other sulfides are present in the oxidized material. Figure 20 shows the lead and zinc anomalies over the Galt vein and one of the structures to the east. Figure 20 and Table 21a indicate an anomaly at the location of the second vein east of the Galt vein.

A second traverse was made on the north side of a bulldozer cut in disintegrated Pinto porphyry about 250 to 300 ft. north of the Galt No. 2 adit. Just below grass roots, the bulldozer cut exposes a small drift, which exposes a rather barren-looking fracture zone. The fracture zone is about 4 ft. wide, strikes N. 20°E. and dips 75° to 80° W. Soil samples for geochemical analysis were taken at 20-ft. intervals along the north side of the cut for 80 ft. to the west and 80 ft. to the east of the vein. The sample line is about on contour, the east end approximately ten feet lower than the west end of the traverse. The soil is thin, averaging from 3 to 4 in., below which are several feet of small rock chips. Sparse timber covers the hillslope above the bulldozer cut.

Table 21a—Galt Vein, Neihart

Chemical analyses of soil samples collected across stoped area of Galt vein, and two other veins, in syenite gneiss and biotite schist country rock. Sample interval 20 ft. Strike of vein N. 20° E., course of traverse N. 60° W., approximately on contour. Slope of hillside 25°. Thin soils with many small rock chips.

Sample No.	Location of Sample	Lead ppm	Zinc ppm	Remarks
1	80 ft. NW of Galt vein	150	600	
2	60 " " " " "	300	1200	
3	40 " " " " "	250	1400	
4	20 " " " " "	400	1600	
5	Over Galt vein	600	2000	Galt vein
6	20 ft. SE of Galt vein	400	1600	
7	40 " " " " "	130	400	
8	60 " " " " "	70	400	
9	80 " " " " "	100	600	
10	100 " " " " "	150	600	
11	120 " " " " "	3000	2000)	Vein in caved adit
12	140 " " " " "	2000	3000)	
13	160 " " " " "	300	800	
14*	180 " " " " "	70	400	
15*	200 " " " " "	300	800	
16*	220 " " " " "	3000	1600	Caved adit
17*	240 " " " " "	800	1200	
18*	260 " " " " "	300	400	

*Not shown in Figure 20.

Table 21b—Galt Vein, Neihart

Chemical analyses of soil samples collected across 4-ft. wide barren zone in Galt vein exposed in small adit in Pinto Diorite about 250 to 300 ft. north of Galt No. 2 adit. Vein structure strikes N. 20° E., dips 75° to 80° W. Sample interval 20 ft. collected along contour. Slope 15° to 20°. Three to four inch soils with abundant rock chips. Grass covered.

Sample No.	Location of Sample	Lead ppm	Zinc ppm	Remarks
1	80 ft. W of vein	70	400	
2	60 " " " "	120	1000	
3	40 " " " "	250	2000	
4	20 " " " "	250	2000	
5	Over vein	1000	3000	Vein structure
6	20 ft. E of vein	300	600	
7	40 " " " "	150	1000	
8	60 " " " "	200	600	
9	80 " " " "	70	400	

The geochemical traverse across the Galt vein structure in the Pinto diorite, at a locality where no commercial ore is known, shows a strong geochemical anomaly, as recorded in Figure 20. This strong anomaly suggests that metal-bearing solutions passed through the vein structure but that insufficient amounts were deposited to produce an ore shoot.

The principal workings in the district are in steep ravines on the mountain slopes just north of the town of Neihart. So abundant are the dumps and that application of geochemical prospecting within the main part of the district may be limited. On the other hand, the forested area south and north of Carpenter Creek, as well as the area south of Neihart, may be considered favorable areas for geochemical exploration. The data from this district suggest that it may be possible to trace vein structures even in relatively barren zones, which would be of great value in the solution of structural problems in the heavily forested areas.

NEW WORLD (Cooke City) DISTRICT

The New World (Cooke City) mining district is in Park County just northeast of Yellowstone National Park in a region remote from rail transportation. Mineral deposits crop out at elevations from about 7,500 to over 10,000 ft. in the Beartooth Mountains. At the lower elevations this region is heavily timbered, but in the higher country, the timber is sparse and soil cover very thin. The total value of the production of the district to date is probably not over one million dollars.

General Geology.—Pre-Cambrian rocks crop out over a wide area and include high-grade schists, gneisses, and granites, all of which are unconformably overlain by lower Paleozoic sediments, except where the sediments have been stripped off by subsequent erosion. During Laramide time, the region was bowed into a gentle anticline and subjected to erosion, which removed the sedimentary cover over a large area. Tertiary volcanics and their derived sediments were deposited onto the erosion surface. Tertiary intrusives include a large laccolithic intrusion and stocks of monzonite porphyry, and sills and dikes of gabbro, quartz monzonite, and syenite. Sills of monzonite porphyry are abundant in the sedimentary rocks throughout the region. The mineralization in the district is thought to be related to the Tertiary intrusives.

The lower Paleozoic formations include a considerable amount of limestone with interbedded shale. The limestones are particularly susceptible to replacement. The lower Gallatin formation, a massive, oolitic limestone from 130 to 150 ft. thick, is locally known as the "Republic reef." According to Lovering, "The massive lower limestone is little affected by contact metamorphism but is the favorite horizon for ore deposits of the vein and replacement type and contains the most promising lead-silver-zinc ores of the district." (Lovering 1921:23). The Bighorn dolomite of Ordovician age is likewise the host to some replacement mineral deposits.

Mineral Deposits. — In the district are found varied mineral occurrences, including magmatic segregation deposits of copper-gold-platinum; contact copper deposits; high-temperature, pyritic-copper fissure veins; and fissure veins and lode replacements of lead-silver in limestone. The lead-silver replacements and veins in limestone, and the contact copper deposits have been responsible for the principal production. (Lovering 1921).

Geochemical Investigations.—Geochemically, the Cooke region is one of the more favorable districts for this type of prospecting. Several deposits were tested with generally promising results. The thick soil cover on the forested hillslopes offers especially favorable conditions for this method.

Copper King.—(Magmatic Segregation). The Copper King property includes a group of patented claims at the north end of Goose Lake in the extreme northern end of the district. The deposit is at about 10,000 ft. elevation. The country rocks include pre-Cambrian granite, schist, and gneiss which have been intruded by Tertiary gabbro, granodiorite, and syenite. The deposit is reported to be associated with coarse-grained syenite. No outcroppings of mineralized syenite were seen at the property. The attitude of the deposit could not be ascertained. A 75-ft. trench is reported to have exposed ore minerals which assayed 20 per cent copper, 2.85 ounces silver, and 0.1 ounce platinum per ton. (Lovering 1929:60).

Two traverses were run on the property, and the soil samples assayed for copper. The soil is several inches thick, underlain by disintegrated rock fragments. The mine workings are on the flat valley floor, which is littered with glacial debris.

One traverse line was run on a north-south trend about 150 ft. east of the main shaft, and roughly parallel to a trench which may be the one to which Lovering referred. The copper content in the soils varies from 100 ppm at the extreme south end of the traverse to 800 ppm just north of the cut. Along the cut, 500 and 600 ppm analyses were obtained.

The second traverse was made immediately north of the shaft, in a N. 60° E. direction for 125 ft. west of the shaft to 150 ft. east. The copper content of the soil samples ranges from 100 to 500 ppm, the average of all samples collected being about 335 ppm. These are the highest consistent copper analyses encountered in this investigation.

From the very limited amount of sampling done at the property, because of the fact that the region did not at first appear to be favorable for geochemical prospecting, it now seems probable that a systematic grid would serve to focus attention on the most promising areas for prospecting.

True Fissure.—The True Fissure vein extends into the granodiorite of the batholith east of the Horton vein. A single traverse was made across the vein east (uphill) from the True Fissure shaft. The soils are quite deep by rocky, and the steep hillslope heavily timbered with lodgepole pine. A conspicuous anomaly was recorded in the zinc assays across the vein. Lead and heavy-metal determinations failed to indicate the position of the structure. Figure 32 shows the nature of the anomaly, revealing a rather broad spread, which may be due, in part, to fanning out of zinc in the soils from the weathering of the vein farther uphill.

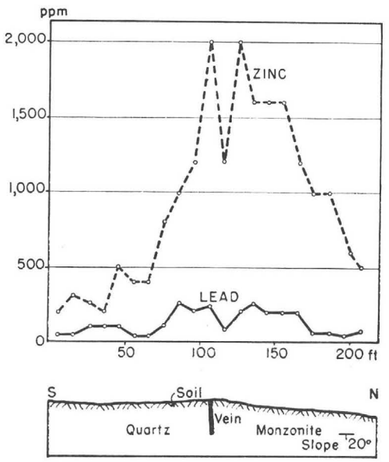


Figure 32. TRUE FISSURE VEIN EAST OF SHAFT, PHILIPSBURG

Table 30—True Fissure Vein, Philipsburg

Chemical analyses of soil samples collected across True Fissue vein 50 ft. east of adit which exposes vein uphill and east of shaft. Sample interval 10 ft. on bearing N. 5° W. over vein which strikes N. 85° to 90° E. Slope of traverse nearly on contour on steep hillslope of 20°. Traverse through lodgepole pine forest. Soils moderately thick.

Sample No.	Location of Sample	Lead ppm	Zinc ppm	Heavy Metals ppm	Remarks
1	100 ft. S of vein	80	500	400	
2	90 " " " "	50	600	400	
3	80 " " " "	50	1000	400	
4	70 " " " "	200	1200	400	
5	60 " " " "	200	1200	400	
6	50 " " " "	200	1600	400	
7	40 " " " "	200	1600	400	
8	30 " " " "	250	1600	400	
9	20 " " " "	200	2000	250	
10	10 " " " "	100	1200	400	
11	Over vein	250	2000	400	Adit exposes vein.
12	10 ft. N of vein	200	1200	600	
13	20 " " " "	250	1000	400	
14	30 " " " "	100	800	400	Small stringers on same bearing as True Fissure vein exposed in small shaft.
15	40 " " " "	30	400	200	
16	50 " " " "	30	400	400	
17	60 " " " "	100	500	500	
18	70 " " " "	100	200	200	
19	80 " " " "	100	250	200	
20	90 " " " "	50	300	300	
21	100 " " " "	50	200	200	

Horton Vein.—In the early days of the Philipsburg district, the Horton vein was one of the important producers. It is in the Hasmark formation west of the contact of the batholith. Because of the extensive mine dumps below the vein, the downhill traverse below the vein is short, as shown in Figure 31. Table 29 lists analyses for lead, zinc, and heavy metals. The heavy-metal determinations were made first, and it was very surprising to the writer that the anomaly for the vein structure was so poorly demonstrated. Lead and zinc analyses proved to be much more satisfactroy.

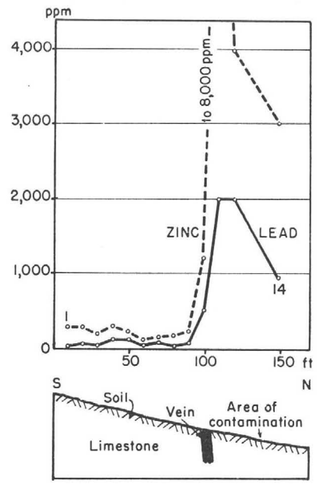


Figure 31. HORTON VEIN, PHILIPSBURG

Table 29—Horton Vein, Philipsburg

Chemical analysis of soil samples collected across Horton vein which strike approximately N. 80° E. Traverse line N. 15° W. from point uphill from vein. Sample interval 10 ft. and variable as shown in Figure 31. Slope about 27° parallel to traverse line. Soils thick, 12 to 16 in. Dense cover of underbrush.

Sample No.	Location of Sample	Lead ppm	Zinc ppm	Heavy Metals ppm	Remarks
1	100 ft. uphill from vein	250	600	400	
2	90 " " " "	50	300	350	
3	80 " " " "	70	300	250	
4	70 " " " "	50	200	300	
5	60 " " " "	150	300	250	
6	50 " " " "	130	250	300	
7	40 " " " "	50	150	200	
8	30 " " " "	80	120	300	
9	20 " " " "	500	1,200	400	
10	10 " " " "	1,200	8,000	400	
11	Over vein	2,000	4,000	300	
12	10 ft. downhill from vein	6,000	25,000	300	
13	20 " " " "	1,000	3,000	300	
14	60 " " " "	5,000	25,000	300	Probable contamination, Dumps below.

McClaren Mine (Estelle and New Year's Gift Claims)—(Contact Metamorphic).—The McClaren open-pit copper mine is on the northwest side of Henderson Mountain at an elevation of about 9600 ft. The deposit is along a contact zone between a fine-grained intrusive monzonite porphyry, in large part sericitized, and Cambrian sediments which metamorphosed, in part, to lime silicate hornfelses. Chalcopyrite and pyrite occur as replacement stringers and pods in the metamorphosed sediments, and fine-grained disseminations in the monzonite porphyry.

A series of soil samples was collected at about 50-ft. intervals for 17,500 ft. along the west side of Henderson Mountain above the highest workings. Figure 21 shows the traverse line and the conspicuous geochemical anomaly which was found above the pit area. The soil consists of thin gravel and disintegrated country rock of coarse and particle size. Table 22 lists the analyses.

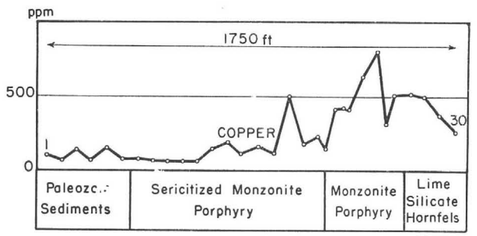


Figure 21. McCLAREN MINE, NEW WORLD

Table 22—McClaren Mine, Cooke City

Chemical analyses of grass-root soil samples collected on hillside above open pit at McClaren Mine. Approximate position of traverse line shown in Figure 21. Soil consists of gravel of granitic and metamorphic rocks. Sample traverse about on contour, hillslope variable to 30°.

Sample No.	Location of Sample	Copper ppm	Remarks
1	1000 ft. NW McClaren pit	40*	Paleozoic sediments
2	950 " " " "	20*	" "
3	900 " " " "	150*	" "
4	850 " " " "	70*	" "
5	800 " " " "	70	" "
6	750 " " " "	70	" "
7	700 " " " "	30	" "
8	650 " " " "	70	" "
9	600 " " " "	70	" "
10	550 " " " "	70	" "
11	500 " " " "	70	Sericitized monzonite porphyry
12	450 " " " "	70	" " "
13	400 " " " "	50	" " "
14	350 " " " "	130	" " "
15	300 " " " "	70	" " "
16	250 " " " "	180	" " "
17	200 " " " "	180	" " "
18	150 " " " "	70	" " "
19	100 " " " "	100	" " "
20	50 " " " "	500	" " "
21	Above edge of pit	50	" " "
22	" " " "	70	" " "
23	" " " "	180	" " "
24	" " " "	130	Monzonite porphyry
25	" " " "	400	" "
26	" " " "	400	" "
27	" " " "	600	" "
28	50 ft. SE of pit	700	" "
29	100 " " " "	800	" "
30	150 " " " "	300	" "
31	150 " " " "	500	" "
32	250 " " " "	500	Lime silicate hernfels (Metamorphosed
33	300 " " " "	500	Paleozoic sediments)
34	350 " " " "	400	" "
35	400 " " " "	250	" "

*Not shown in Figure 21.

The fact that anomalies of about 20 times background were obtained over this porphyry-type deposit from very immature soils suggests that similar areas above timber line may be successfully explored by this method.

Glengarry Mine. (Contact Metamorphic).—The Glengarry properties include a number of claims near the headwaters of Clark Fork of the Yellowstone River between Red and Scotch Bonnet Mountains. A group of trenches on the east side of Red Mountain are along a contact zone between fine-grained, sericitized monzonite porphyry and metamorphosed Cambrian sediments. Some evidence of quartz-pyrite mineralization was noted in development workings, and some massive limonite gossan was observevd, but indications of extensive mineralization are sparse.

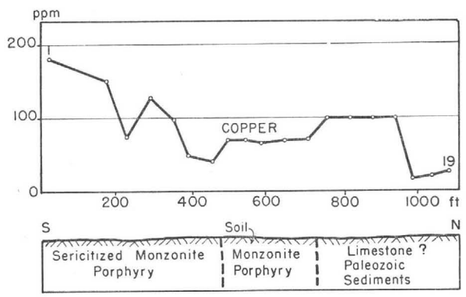


Figure 22. GLENGARRY PROSPECT, NEW WORLD

One line of samples was run on the south side of the valley from a small cabin near the divide northwest of the workings across and above the workings, as shown in Figure 22. Note that in the sedimentary rocks, the background for copper is low, from 20 to 30 ppm; but as the contact is approached, the copper content increases 4 to 5 times. The copper content in the soils over the altered monzonite porphyry is erratic but somewhat higher, but in no case reaches the copper content found at the McClaren mine. These data are given in Table 23. The soils consist of disintegrated rock fragments a few inches in thickness. Sampling conditions are similar to those found at the McClaren mine.

A second traverse was made on the north side of the valley, north of the open-pit area of the Glengarry prospect across a zone of reported higher-temperature quartz-pyrite veins. No anomaly was found along the traverse to indicate the position of the veins. Seventeen samples collected at 50-ft. intervals across this mineralized zone average 50 ppm with analyses from 30 to 150 ppm in no pattern obviously controlled by the geology.

Table 23—Glengarry Mine, Cooke City

Chemical analyses of soil samples collected above open-pit workings at Glengarry prospect. Sample interval 50 ft. and variable as shown in Figure 22. Traverse line approximately SE from rear of log cabin on divide NW of workings. Soils thin, immature, composed of gravel of rock and mineral fragments. No vegetational cover.

Sample No.	Location of Sample	Copper ppm	Remarks
1	950 ft. SE of cabin	180	Seriticized monzonite porphyry
2	850 " " " "	150	" " "
3	800 " " " "	70	" " "
4	750 " " " "	130	" " "
5	700 " " " "	100	" " "
6	650 " " " "	50	" " "
7	600 " " " "	40	" " "
8	550 " " " "	70	Monzonite porphyry
9	500 " " " "	70	" "
10	450 " " " "	70	" "
11	400 " " " "	70	" "
12	350 " " " "	70	" "
13	300 " " " "	100	Paleozoic sediments
14	250 " " " "	100	" "
15	200 " " " "	100	" "
16	150 " " " "	100	" "
17	100 " " " "	20	" "
18	50 " " " "	20	" "
19	Above cabin	30	" "

anomaly. Tables 27 and 28 list the analytical data for Figures 29 and 30. Note how the combined heavy-metal analyses do not increase proportionately to lead and zinc analyses. Manganese, which is probably present as a carbonate gangue mineral in the vein, shows a widespread anomaly on both sides of the vein. This occurrence could represent, in part, the spread of manganese from uphill sources, with the manganese fanning out from the vein at elevations higher on the hillslope.

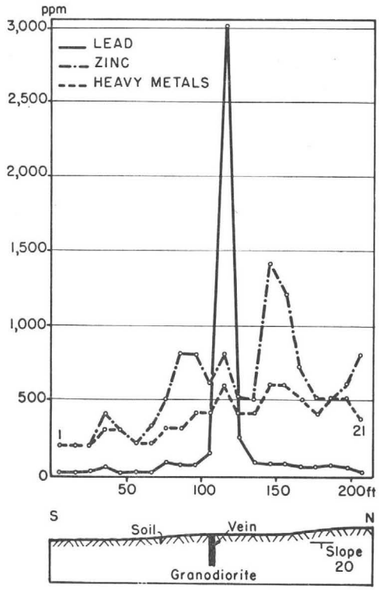


Figure 30. PEARL VEIN EAST OF SHAFT, PHILIPSBURG

Table 28—Pearl Vein, Philipsburg

Chemical analyses of soil samples collected across Pearl vein 400 ft. uphill from lower traverse. Sample interval 10 ft. on bearing N. 10° W. about at right angles to the vein. Hillslope about 20°, but the traverse line practically on contact. Soils 10 to 12 in. in area of lodgepole pine.

Sample No.	Location of Sample	Lead ppm	Zinc ppm	Manganese ppm	Heavy Metals ppm	Remarks
1	100 ft. S of vein	30	20	600	200	
2	90 " " " "	20	200	200	200	
3	80 " " " "	20	200	200	200	
4	70 " " " "	50	400	600	300	
5	60 " " " "	30	300	600	300	
6	50 " " " "	20	200	200	200	
7	40 " " " "	20	300	200	200	
8	30 " " " "	80	500	600	300	
9	20 " " " "	60	800	600	300	
10	10 " " " "	60	800	600	400	
11	Over vein	130	600	200	400	
12	10 ft. N of vein	3000	800	200	600	
13	20 " " " "	250	500	600	400	
14	30 " " " "	70	500	200	400	
15	40 " " " "	70	1400	200	600	Subsidiary strike?
16	50 " " " "	60	1200	200	600	
17	60 " " " "	50	700	200	500	
18	70 " " " "	50	500	200	400	
19	80 " " " "	50	500	200	500	
20	90 " " " "	50	600	200	500	
21	100 " " " "	20	800	200	400	

Table 27—Pearl Vein, Philipsburg

Analyses of soil samples collected across caved stope on vein. Sample interval 10 ft. on contour in area of 20° slope. Vein strike N. 80° E. Traverse bearing S. 10° E. Soils moderately thick. Area of traverse in lodgepole pine.

(a) Chemical analysis.

(b) X-ray spectrographic analyses.

Sample No.	Location of Sample	Lead ppm (a)	Zinc ppm (a)	Manganese ppm (a)	Lead ppm (b)	Zinc ppm (b)	Manganese ppm (b)	Copper ppm (b)
1	110 ft. S of vein	30	150	200	55	65	636	230
2	100 " " " "	50	200	200	75	99	710	210
3	90 " " " "	20	150	600	55	79	726	240
4	80 " " " "	30	150	200	30	45	1045	80
5	70 " " " "	30	100	200	40	0*	673	250
6	60 " " " "	30	100	200	75	0*	795	250
7	50 " " " "	20	100	200	10	0*	700	400
8	40 " " " "	40	300	200	75	68	820	85
9	30 " " " "	50	200	200	90	52	633	330
10	20 " " " "	50	300	300	100	127	733	150
11	10 " " " "	100	250	200	150	223	543	240
12	Over vein	20	1200	200	55	1225	726	180
13	10 ft. N of vein	50	1000	600	35	990	1080	310
14	20 " " " "	50	800	200	105	647	616	0*
15	30 " " " "	50	800	200	105	676	560	210
16	40 " " " "	50	600	200	75	462	536	0*
17	50 " " " "	50	700	200	165	676	800	260
18	60 " " " "	50	600	200	140	450	610	80
19	70 " " " "	50	600	600	270	540	1170	180
20	80 " " " "	130	800	200	250	508	783	285
21	90 " " " "	70	400	200	190	185	580	330

*Below level of detection.

Pearl Mine.—Two geochemical samples traverses were made across the Pearl vein, one east of the Algonquin shaft low in the valley and a second well up on the hill above the uppermost workings. Figure 29 shows a traverse which began about 20 ft. uphill from a caved stope, exposing the vein (one to two feet wide), which strikes S. 80° W. and dips nearly vertical. Samples were collected from an initial point nearly over the vein at 10-ft. intervals 100 ft. southeast and northwest. Lodgepole pine and somewhat grassy areas free from underbrush comprise the vegetation along the traverse, the slope of which is indicated in Figure 29. Between 30 and 70 ft. north of the vein, some contamination may be expected as a result of dumps above the traverse line. A strong anomaly is reported in the zinc and heavy-metal analyses. The zinc anomaly is conspicuous for more than 100 ft. downhill from the vein; a lead anomaly is also suggested. Table 27 lists assays for lead, zinc, manganese, and "heavy metals."

The analyses of the second traverse line are shown in Figure 30 and record a conspicuous zinc

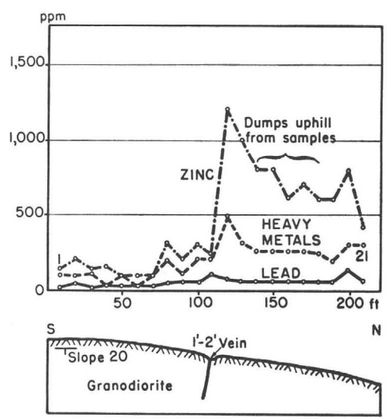


Figure 29. PEARL VEIN EAST OF TROUT MINE, PHILIPSBURG

Duke and Big Blue Claims. (Lead-silver fissures and replacements in limestone).—These adjoining claims on the south slope of Miller Mountain are about ¾ miles northwest of Cooke at an elevation of about 8300 ft. They lie on a relatively steep hillslope, which is heavily timbered and covered with thick soil and rock mantle. A number of old mine workings and prospect pits were found, representing the exploration for veins and replacement bodies in the Bighorn dolomite. Because of the complex faulted structures, and the scarcity of outcrops, the stratigraphy has not been worked out in detail. The sedimentary rocks are intruded by monzonite porphyry sills. The mineral deposits may be closely related to them.

The soil samples collected from a single traverse in the summer of 1953 reveal high concentrations of lead and total heavy metals throughout the line of traverse, and conspicuous anomalies associated with prospects, especially those on north-south vein structures. As the area is so heavily timbered and there are virtually no outcrops, a systematic soil-sampling program on a 100-ft. center grid was laid out.

A plane-table survey was made along the road, and the position of each 100-ft. traverse line was indicated. From these points, the location of the sample points was determined by pace-and-compass traverse. Figures 23 to 26 show the grid sample layout, with analytical data generalized by contour lines for lead, zinc, copper, and manganese. (See pages 38 and 39.)

There is a rather close correspondence of lead and zinc concentrations, with distinct anomalies related to the known mineralization, as shown in Figures 23 and 24. One of the strongest anomalies, however, is in a timbered area with no prospect pits. The strong copper anomaly has a conspicuous north-south trend and corresponds to some degree with the westernmost lead anomaly. (See Figure 25.) In the area of the most active lead exploration, no copper anomaly occurs. The increase in copper south of the Big Blue prospect is of interest, indicating a possible separation of copper and lead mineralization.

Manganese appears to be dispersed over the lead, zinc, and copper anomaly areas. The strongest anomaly is in the extreme western part of the area and does not correspond to any base-metal anomaly, as shown in Figure 26.

The geology is not known in sufficient detail to explain adequately the metal anomalies found. The south slope of Miller Mountain, on which the claims are located, is intensely faulted, and the stratigraphy is not known in any detail. Monzonite porphyry sills occur in the section, and fissure veins and replacement deposits occur in favorable host rocks. Careful geological mapping might well indicate the primary control for geochemical anomalies and aid in further prospecting and developing in this area.

Republic Mine. (Lead-silver fissures and replacements in limestone.)—The Republic mine consists of fissure veins and replacements of argentiferous galena and manganiferous carbonate in the lower Gallatin limestone formation about a mile south of Cooke City. One soil-sample traverse line was made across the vein at a locality

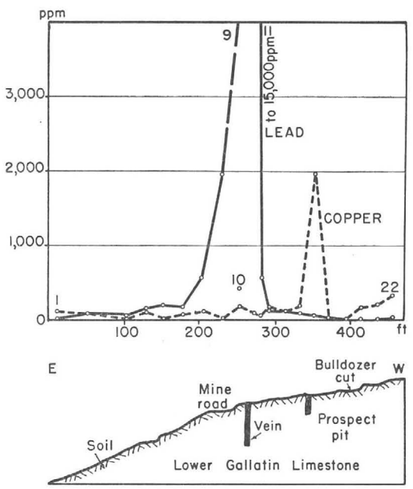


Figure 27. REPUBLIC MINE, COOKE CITY

where the vein minerals had been mined to the surface. North across the mine road, the hillslope is very steep, about 30°, and covered with dense jungle of small lodgepole pine. Figure 27 shows the strong anomaly recorded over the vein and likewise illustrates how the anomaly disappears 100 ft. downhill from the vein on a steep hillslope. Table 24 lists the assays for lead and manganese obtained from the soil samples.

Note a close correspondence in the lead and manganese assays. At the Big Blue and Duke claims it is indicated that manganese and lead may show similar anomalies—yet lead does not necessarily go with manganese, as shown in Figure 26.

The soils in this area are nearly a foot deep, but contain abundant float pebbles and cobbles. In the mine area, the soils are somewhat thinner.

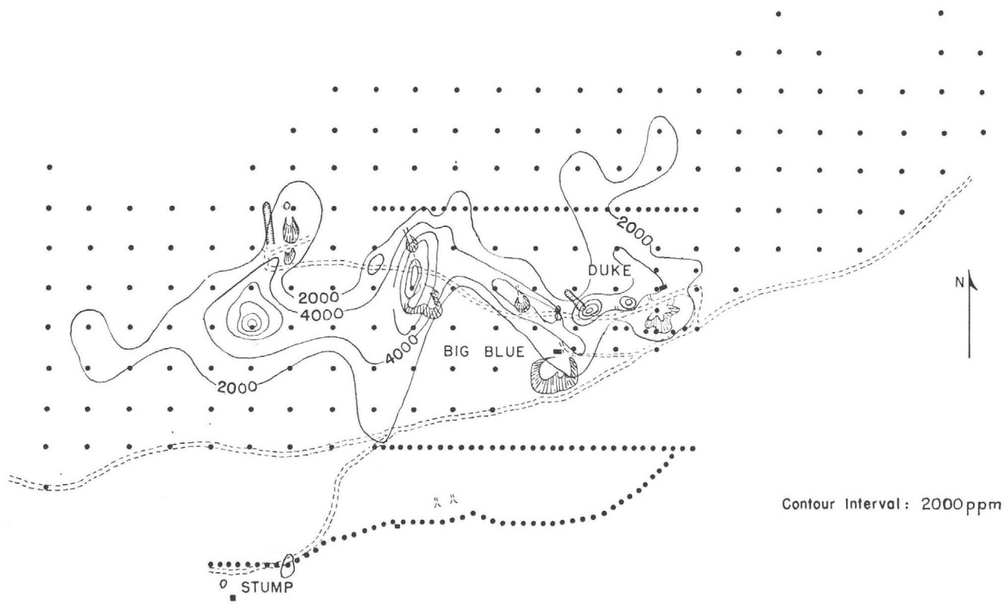


Figure 23. LEAD ANOMALIES ON BIG BLUE AND DUKE CLAIMS, NEW WORLD

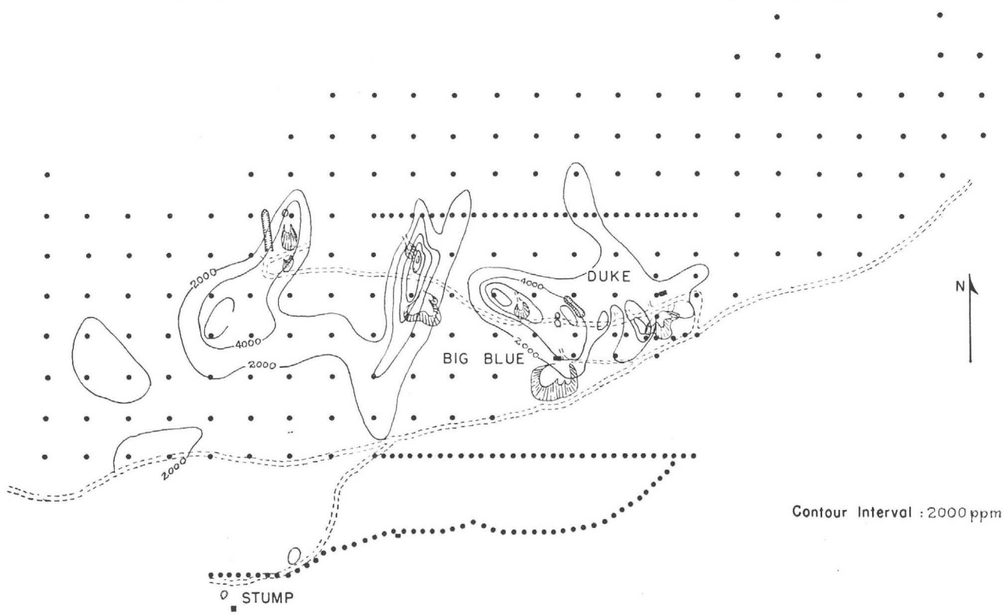


Figure 24. ZINC ANOMALIES ON BIG BLUE AND DUKE CLAIMS, NEW WORLD

the traverse range from 5° to 10° to the south. A conspicuous anomaly was noted both in heavy-metal and manganese analyses; however, the anomaly does not persist more than 60 ft. downhill from the vein. Table 26 lists assays for heavy-metals and manganese, as well as for lead and zinc.

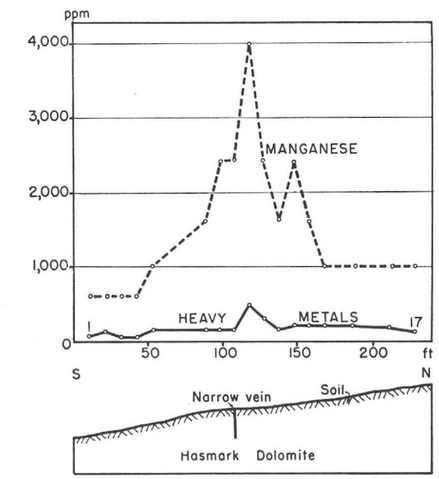


Figure 28. ALGONQUIN VEIN WEST OF MAIN WORKINGS, TROUT MINE, PHILIPSBURG

Table 26—Algonquin Vein, Philipsburg

Chemical analyses of soil samples collected across the Algonquin vein which strikes N. 88° E. Sample interval 10 and 20 ft. as shown in Figure 28. Traverse bearing N. 2° W. Slope 5° to 10° parallel to traverse. Soil averaged 8 to 10 in. with small pebbles of float. Open park and small fir and cedar.

Sample No.	Location of Sample	Lead ppm	Zinc ppm	Manganese ppm	Heavy Metals ppm
1	100 ft. downhill from vein	70	200	600	100
2	90 " " " "	70	150	600	100
3	80 " " " "	20	100	600	50
4	70 " " " "	30	100	600	50
5	60 " " " "	20	300	1000	150
6	30 " " " "	130	400	1600	150
7	20 " " " "	200	400	2400	150
8	10 " " " "	250	600	2400	150
9	Over vein	1000	1600	4000	500
10	10 ft. uphill from vein	600	1400	2400	300
11	20 " " " "	130	400	1600	150
12	30 " " " "	250	800	2400	300
13	40 " " " "	100	600	1600	200
14	50 " " " "	100	600	1000	200
15	70 " " " "	250	700	1000	200
16	90 " " " "	150	500	1000	150
17	110 " " " "	200	500	1000	125

lying the Flathead is the Silver Hill formation, about 320 ft. in thickness, composed of thinly bedded, nearly pure, limestone, with alternate layers of brown silty shales. Near the contact with the granodiorite, the limestone beds have been marbleized, and the shale bands have been altered to calc-hornfels rocks composed principally of diopside, epidote, and garnet. Ranging from 800 to 1200 ft. in thickness, the Hasmark dolomite overlies the Silver Hill formation. Where not metamorphosed, the formation is a bluish-gray, medium-to-fine-grained dolomitic limestone; but in the ore-producing area and adjacent to the contact of the batholith, the rocks are metamorphosed to a medium-grained, white-to-buff marble. A discontinuous shale layer is sometimes found near the middle of the formation. Overlying the Hasmark is the Red Lion formation, which is from 225 to 350 feet thick. This formation is composed chiefly of thinly bedded shaly limestone, with wavy discontinuous bands of yellowish shale. Shale bands, from a fraction of an inch to an inch apart, are more abundant in the lower part of the formation and decrease upward to a massive gray limestone. The upper 2 to 8 ft. of the formation resembles the Hasmark dolomite. The Red Lion formation is commonly metamorphosed to banded calc-hornfels somewhat similar to the Silver Hill formation. Possibly Silurian in age, the Maywood formation is from 210 to 490 ft. in thickness, and is composed of fine-grained, marbly, thin-bedded sandy limestone, which is greenish to brownish gray when fresh and weathers to a brownish soil. At the base of the formation is a 5-ft. banded, white-and-greenish-gray shale, which metamorphose to a fine-grained siliceous hornfels near the contact.

Of special importance is the "Headlight bed," a stratigraphic unit probably in the Red Lion formation immediately adjacent to the Maywood formation. This is the most important zone for replacement ore bodies. Overlying the Maywood formation is the Jefferson formation of Devonian age; of from 1,000 to 1,300 ft. in thickness and composed of massive blue-gray limestone with some chert near the top of the formation. In the metamorphosed area, it alters to a white, medium-grained marble, which is yellowish to buff colored on weathered surfaces.

The granodiorite of the Philipsburg batholith intruded the sedimentary rocks on the east side of the anticline. The contact of the batholith dips to the east, presumably at an angle somewhat steeper than the sedimentary beds, although in some localities it is though to be very nearly concordant. The attitude of the contact has been determined from the underground workings at the True Fissure and the Algonquin mines.

The ore deposits are found in east-west, and to a lesser extent, northwest striking fissure veins, which are quite abundant in the district, but many of which are very small. The veins are very steep, but the dip is variable at depth as the veins intersect the different sedimentary horizons. The east-west fissures in the sedimentary beds have yielded important amounts of battery-grade manganese oxides in the oxidized zone, and manganese carbonate in the primary zone, as well as silver and zinc. Some lead is associated with these deposits. In the granitic rocks the east-west veins rarely make commercial ores, although traces of silver, lead, and zinc are common. This situation is somewhat in contrast to the large important veins which made ore in the Granite district southeast of Philipsburg.

At the intersection of favorable horizons in the sedimentary series and the vertical fissures, manganese deposits carry minor amounts of zinc and silver, in contrast to the mineralogy of the east-west fissures. In some areas even small veins have produced good ore shoots at their intersection with favorable horizons in the sedimentary rock. In addition to the favorable beds in the sedimentary rocks, the Jefferson formation at the contact with the granodiorite has localized mineral deposits in the eastern part of the camp.

Geochemical Sampling. — The objective of the geochemical sampling in this district was to test the method over different types of structures which have localized ore deposits. The Algonquin vein, a strong east-west fissure in the sedimentary rocks in the southern part of the district, was traversed, as well as the Pearl vein in the granite east of the Algonquin. The intersection of a vein and a favorable horizon in the Silver Hill formation on west Algonquin Hill was sampled. Traversed also was the Headlight bed adjacent to a productive area at the Headlight workings and near the Two Percent workings at a place which has not been mined and which is considered of no economic significance. The contact between the Jefferson dolomite and the intrusive granodiorite was sampled at three localities: one near a glory hole, from which manganese was produced at the Scratch All property; a second at a locality north of the True Fissure shaft, where no commercial ore is known; and a third along the ridge north of the San Francisco mine.

Algonquin Mine. — The Algonquin vein was traversed, and a series of soil samples taken just west of the Algonquin shaft between two glory holes which indicate that an ore shoot along the vein was stoped through to the surface. Veins exposed in the open stopes strike N. 88° E. and are in the Hasmark dolomite. Samples were collected at 10-ft. intervals north and south of the vein on a bearing S. 2° E. for 100 ft. and N. 2° W. for 120 ft. The soil, generally free from dolomite float, averaged from 8 to 10 inches in depth. Small stands of fir and cedar cover part of the area, whereas other parts traversed are open grassy slopes. As indicated in Figure 28, the slopes of

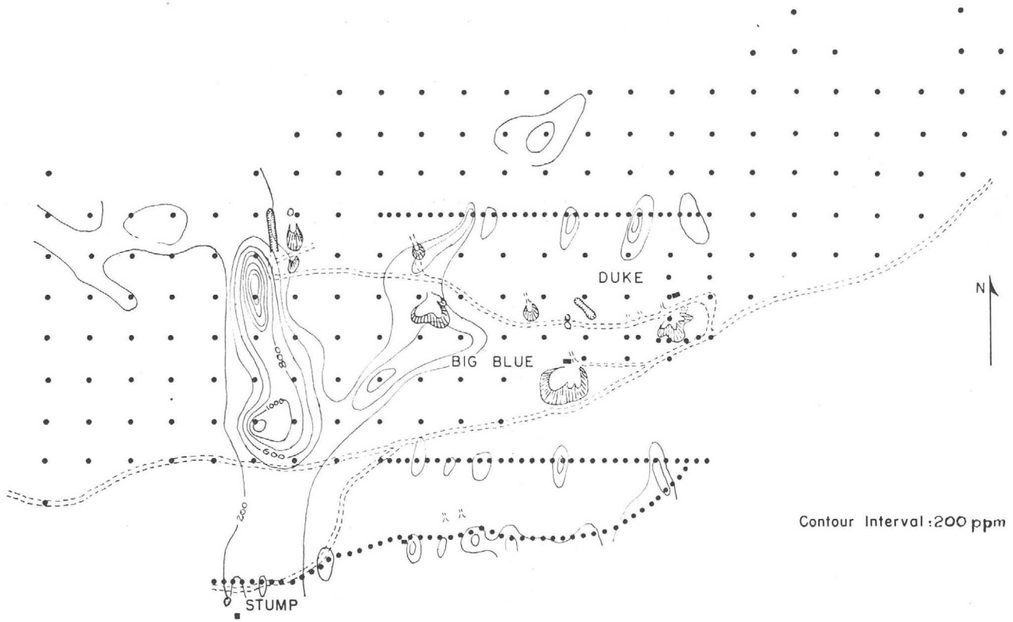


Figure 25. COPPER ANOMALIES ON BIG BLUE AND DUKE CLAIMS, NEW WORLD

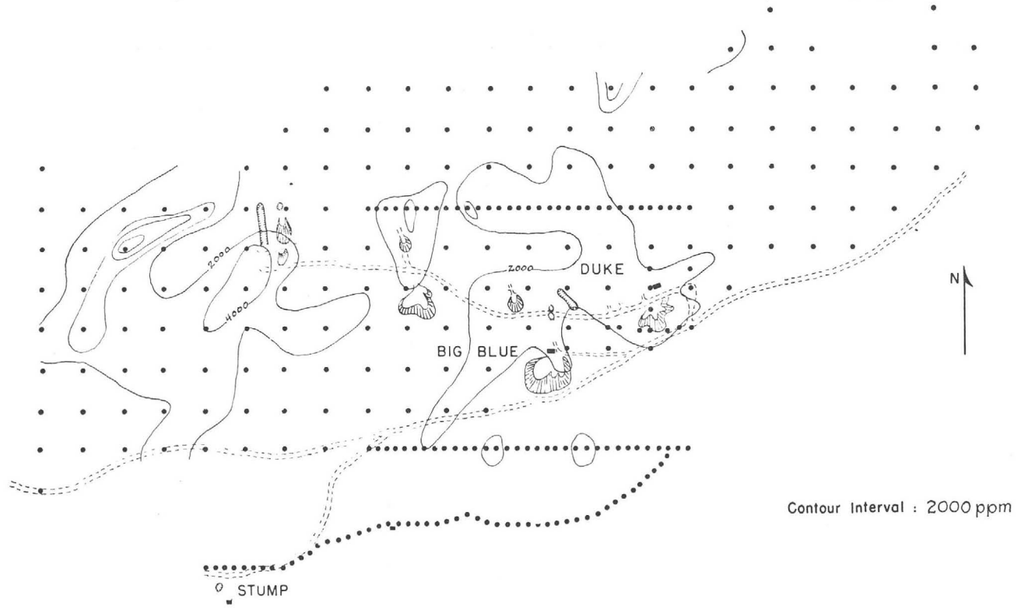


Figure 26. MANGANESE ANOMALIES ON BIG BLUE AND DUKE CLAIMS, NEW WORLD

Table 24—Republic Mine, Cooke City

Analyses of soil samples collected across ore shoot on vein at Republic mine. Sample interval 20 and 50 feet as shown in Figure 26. Slope variable, above vein approximately 10°, below wood, 30° in dense jungle of lodgepole pine.

(a) Chemical analyses
(b) X-ray spectrographic analyses

Sample No.	Location of Sample	Lead ppm (a)	Manganese ppm (b)	Remarks
1	260 ft. below vein	20	200	
2	210 " " "	50	600	
3	160 " " "	100	600	
4	140 " " "	150	600	
5	120 " " "	250	600	
6	100 " " "	200	600	
7	80 " " "	600	600	
8	60 " " "	2,000	1,000	
9	40 " " "	30,000	45,000	Contamination at roadside
10	20 " " "	600	1,000	In wood—not soil sample
11	Over vein	15,000	12,000	
12	20 ft. above vein	600	1,000	
13	40 " " "	150	1,000	
14	60 " " "	130	1,000	
15	80 " " "	130	600	
16	100 " " "	100	200	
17	120 " " "	70	600	
18	140 " " "	50	600	
19	160 " " "	50	200	
20	180 " " "	20	600	
21	200 " " "	20	200	

Table 24 (Continued)

Sample No.	Location of Sample	Lead ppm (b)	Zinc ppm (b)	Manganese ppm (b)	Arsenic ppm (b)	Copper ppm (b)	Remarks
1	260 ft. below vein	5	1,770	1,160	234	130	
2	210 " " "	0*	381	854	225	80	
3	160 " " "	50	330	1,110	288	170	
4	140 " " "	150	428	1,400	378	47	
5	120 " " "	260	415	1,530	324	12	
6	100 " " "	460	566	1,430	441	240	
7	80 " " "	440	474	1,700	243	58	
8	60 " " "	445	440	1,370	306	140	
9	40 " " "	19,550	9,710	15,960	2,763	160	Contam. at roadside
10	20 " " "	10,200	4,280	5,440	1,134	0*	In wood—not sample
11	Over vein	6,725	2,435	3,990	981	190	
12	20 ft. above vein	615	268	1,498	243	90	
13	40 " " "	150	202	1,703	288	280	
14	60 " " "	150	195	1,122	321	170	
15	80 " " "	130	177	759	126	200	
16	100 " " "	105	216	858	279	1,960	Prospect pit
17	120 " " "	105	167	841	243	80	
18	140 " " "	55	194	851	423	60	
19	160 " " "	40	233	927	414	210	
20	180 " " "	60	172	798	306	210	
21	200 " " "	70	143	947	198	320	

*Below limit of detection.

Bunker Hill Claim. (Lead-silver fissures and replacements in limestone.)—The Bunker Hill claim is on the southeast slope of Miller Mountain uphill from the Big Blue claim. Seven samples were collected from a point uphill from two prospect pits, in which mineralization was noted, across the presumed strike of a lead- and zinc-bearing structure downhill for about 135 ft. Distinct anomalies are shown for lead and zinc across this structure. Downhill 100 ft. from the deposit, the lead anomaly is gone. However, the limit of high-zinc concentrations in the soils was not reached.

Table 25—Bunker Hill Claim, Cooke City

Chemical analyses of grass-root soil samples collected across vein structure at Bunker Hill claim. Sample interval 25 ft. Bearing of traverse N. 55° E., approximately at right angles to mineralized structure. Slope variable 15° to 25°. Soil averaged 18 in., samples taken at 10 to 12 in.

Sample No.	Location of Sample	Lead ppm	Zinc ppm	Remarks
1	50 ft. uphill	300	600	
2	25 ft. uphill	300	600	
3	uphill side of vein?	400	2000	
4	25 ft. downhill from vein	500	4000	
5	50 " " " "	400	4000	
6	75 " " " "	150	1200	
7	100 " " " "	150	1200	
8	125 " " " "	150	800	5 ft. SW of road

OPHIR DISTRICT

The Ophir district lies northeast of Avon and about 25 miles west-northwest of Helena. Minor amounts of copper with gold have been produced from veins and numerous placers. Recent attention has been given to the district because of the discovery of scheelite in a tactite (contact lime silicate rock) zone at the contact between Paleozoic limestones and an intrusive quartz diorite.

One traverse was made at the Arnold mine across two vein structures, one of which is approximately parallel to the quartz diorite-limestone contact, and the second just east of the contact. The purpose of the traverse was to determine whether it is possible to detect the presence of tungsten by geochemical methods and also to determine the copper content in these soils over the veins.

The soil-sample traverse was made on a fairly steep hillslope, which is sparesly timbered with lodgepole pine and fir. The soil is deeper than average, ranging from 12 to 16 in.

The copper background is from 10 to 30 ppm. Along the line of traverse, individual spot analyses of from 150 to 250 ppm copper were noted, with an isolated 600-ppm assay directly over the vein at the portal of the main workings. The 600-ppm assay is flanked 10 ft. to the west by a 40-ppm analysis, and 10 ft. to the east by a 10-ppm analysis. The very erratic nature of the copper anomalies suggests only spotty concentrations of copper minerals. The results at this property suggest, however, that such limestone areas may be successfully prospected by geochemical methods.

Thirty-two tungsten analyses were run, with negative results throughout. No tungsten was detected over the portal of the mine tunnel on the structure.

PHILIPSBURG MINING DISTRICT

East of the town of Philipsburg is the Philipsburg mining district, in the mountains on the west side of the Philipsburg batholith. The principal deposits lie near the contact of the batholith in the Paleozoic sedimentary rocks in veins and favorable limestone beds. A mountainous region with sharp relief, the principal mines in the district are at an elevation of about 6,000 ft. The soils are uniformly rather thin and immature. The dominant vegetational cover is lodgepole pine.

Geologic Setting. The geology of the region is described by Emmons and Calkins (1913). The most recent geological map of the district is by Goddard (1940). Sedimentary rocks from the Belt series of pre-Cambrian age, to Jefferson limestone of Devonian age, are folded into a north-plunging anticline, which has been subsequently intruded by the Philipsburg batholith. The granodiorite of the batholith altered the sedimentary rocks to hornfels. The region has been cut by east-west striking fissures, in which ore deposits are found. Replacement lodes are localized where veins intersect the favorable horizons in the sedimentary rocks.

The Spokane formation (Belt series) is characterized by red argillites, which frequently show conspicuous ripple marks and mud-cracks. The Flathead quartzite of Upper Cambrian age rests disconformably upon the Spokane formation. Over-

Gregory Vein.—The Gregory vein is at the north end of the district. It is a strong, nearly east-west vein in which lead and zinc occur with quartz and pyrite in intensely altered andesite.

A geochemical traverse was made across the vein in an area that had been mined underground. The traverse is east of the eastern-most principal mine dump and on the south side of a transverse east-west valley. Figure 47 shows strong lead and zinc anomalies in contrast to the rather inconspicuous heavy-metal anomaly. Table 45 lists analyses for copper, arsenic, manganese, lead, zinc, and heavy metals.

It is of interest to note that some copper is present in the soils but that the copper anomaly does not correspond with the lead-zinc anomalies. The manganese and arsenic anomalies show correspondence but do not follow the base metals.

A much more detailed investigation of the metals and their distribution with regard to mapped geologic structures would be valuable in piecing together the history of metalization in the large complex veins in the Boulder batholith.

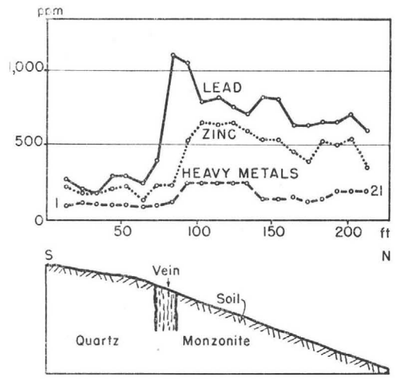


Figure 47. GREGORY VEIN, WICKES

Table 45—Gregory Mine, Wickes

Analyses of soil samples collected across vein about 800 ft. east of vein shaft but in area which apparently was stoped to the surface. Sample interval 10 ft. on bearing S. 10° E., approximately at right angles to the vein structure. Slope 25° in area of dense fir and juniper. Soil approximately 6-12 in.

(a) Chemical analyses.

(b) X-ray spectrographic analyses.

Sample No.	Location of Sample	Lead ppm (b)	Zinc ppm (b)	Copper ppm (b)	Arsenic ppm (b)	Manganese ppm (b)	Heavy Metals ppm (a)
1	60 ft. S of vein	280	214	0	0	1082	100
2	50 " " " "	192	192	0	0	805	100
3	40 " " " "	192	198	95	0	902	100
4	30 " " " "	315	216	0	38	875	100
5	20 " " " "	308	227	85	20	825	100
6	10 " " " "	250	130	0	0	567	100
7	S side of vein	407	229	0	38	601	100
8	N side of vein	1020	257	0	0	454	125
9	10 ft. N of vein	1065	545	85	61	755	250
10	20 " " " "	800	673	120	0	783	250
11	30 " " " "	838	666	0	85	1062	250
12	40 " " " "	774	673	0	38	1280	250
13	50 " " " "	708	600	0	70	1280	250
14	60 " " " "	842	551	0	100	1390	150
15	70 " " " "	823	551	0	61	1730	150
16	80 " " " "	646	457	0	46	896	150
17	90 " " " "	646	394	0	0	784	150
18	100 " " " "	689	535	0	23	1110	150
19	110 " " " "	685	509	0	0	1378	200
20	120 " " " "	731	570	0	246	1545	200
21	130 " " " "	604	321	0	0	1405	200

Replacement Lodes in Sediments, Headlight Bed.—The Headlight bed had been extensively stoped in the area north of the Norton vein at the Headlight mine. A long traverse was run from 150 ft. uphill above the Headlight bed for about 700 ft. on the slope to about 550 ft. below the vein. The soil is from 12 to 16 in. deep, free of pebbles near the start of the traverse at the top of the hill, but contains many rock chips in shallow soils downhill. The traverse at the north end is nearly flat, with the slope increasing to 27° near the south end of the traverse. Figure 34 shows a strong "heavy-metal" anomaly. Assays for lead and zinc would undoubtedly be very large; as shown in Table 32, manganese is very large in amount. It is, however, present in such discrete mineral particles that its use in geochemical work is probably limited at such a locality.

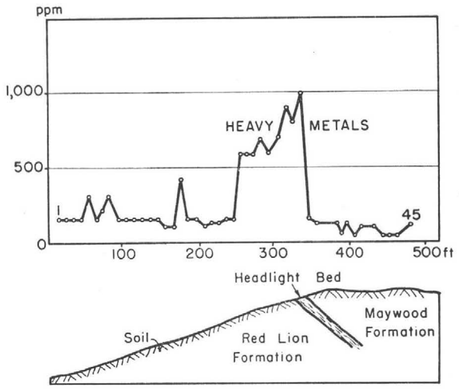


Figure 34. HEADLIGHT BED IN MINERALIZED ZONE AT HEADLIGHT MINE, PHILIPSBURG

Table 32—Headlight Bed (near Headlight Mine), Philipsburg

Chemical analyses of soil samples collected across Headlight Bed near Headlight Mine. Samples collected on bearing S. 25° W. approximately at right angles to mineralized bed which dips approximately 40° NE. Sample interval 10 and 20 ft. Soils thin and rocky.

Sample No.	Location of Sample	Heavy Metals ppm	Manganese ppm	Remarks
1	300 ft. below Headlight Bed	150	1600	Red Lion Formation
2	290 " " " "	150	1600	" " "
3	280 " " " "	150	1600	" " "
4	270 " " " "	300	1600	" " "
5	260 " " " "	300	1600	" " "
6	250 " " " "	150	2400	" " "
7	240 " " " "	200	1000	" " "
8	230 " " " "	200	2400	" " "
9	220 " " " "	150	4000	" " "
10	210 " " " "	150	2400	" " "
11	200 " " " "	150	2400	" " "
12	190 " " " "	150	1600	" " "
13	180 " " " "	150	4000	" " "
14	170 " " " "	150	1000	" " "
15	160 " " " "	100	1000	" " "
16	150 " " " "	100	1600	" " "
17	140 " " " "	400	2400	" " "
18	130 " " " "	150	2400	" " "
19	120 " " " "	150	1600	" " "
20	110 " " " "	100	1600	" " "
21	100 " " " "	125	2400	" " "
22	90 " " " "	125	2400	" " "
23	80 " " " "	150	2400	" " "
24	70 " " " "	150	1600	" " "
25	60 " " " "	600	2400	" " "
26	50 " " " "	600	2400	" " "
27	40 " " " "	600	2400	" " "
28	30 " " " "	700	4000	" " "
29	20 " " " "	600	2400	" " "
30	10 " " " "	700	5000	" " "

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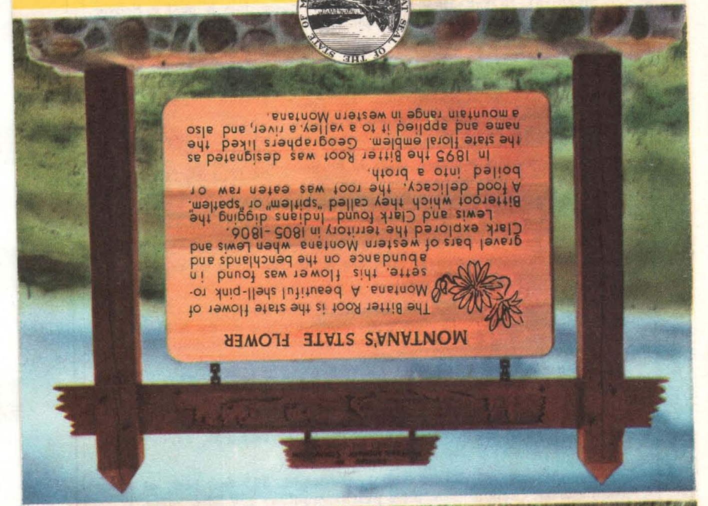


1953 Montana HIGHWAY MAP

WELCOME . . . to the Land of Shining Mountains

Governor J. Hugo Aronson

As governor of Montana, the Treasure State, I am pleased to extend a warm welcome to all visitors to our state. It is our hope that this map will aid you in the enjoyment of the many scenic, historic and recreational attractions to be found in the Land of Shining Mountains.

Montana is a western state with western atmosphere. Our brand of entertainment includes rodeos, Indian ceremonials, dude ranch life, sight seeing and plenty of hunting and fishing.

Our far-reaching system of black topped highways will lead you to the many vacation areas. In addition, Montana maintains nine port of entry greeter stations to supply the tourist with needed information, and the state's 109 roadside historical markers will give you Montana's history in capsule form.

Enjoy yourself while in Montana and come back again often.

Sincerely yours,

J. Hugo Aronson

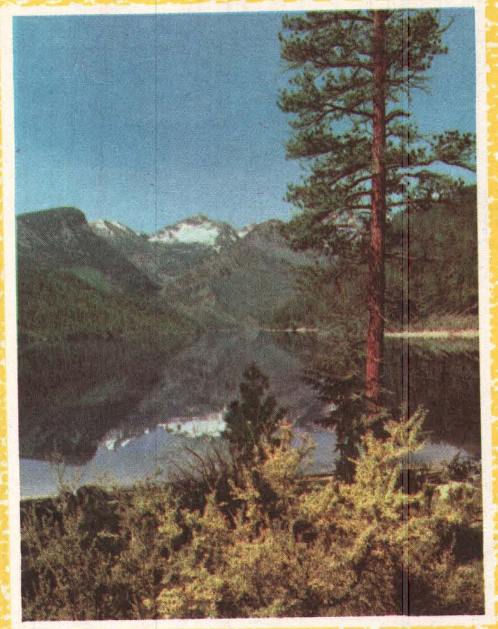
J. Hugo Aronson
Governor of Montana

TRAFFIC REGULATIONS AND SAFETY RULES

1. Montana speed limits: reasonable and prudent to existing conditions in the day time; 55 miles per hour during the hours when lights are required; except where zoned and posted for lower speeds. No truck shall be operated at a speed greater than 45 miles per hour.
2. Vehicles entering main highways from side road or drive must come to complete stop before entering highway and yield right-of-way to vehicles traveling main highway.
3. Vehicles must drive to right of center line at all times except when passing another car. Never pass on hills or curves. Be sure you can see far enough ahead to make a safe passing before you try to do so.
4. Proper signal must be given when passing another vehicle, changing direction, stopping or slowing down on the highway. Blow horn to warn the car ahead you are going to pass—Left turn, left hand and arm extended horizontally; Right turn, left hand and arm extended upward; Stop or Slow Down, left arm extended downward.
5. Observe and obey all warning signs, such as School Zone, Stop, Slow, Danger, Curve, etc. They are placed there at considerable expense for your protection.
6. Never drive at a speed greater than that at which you can stop in the clear road visible ahead. Slow down at night or when the road is wet or icy.
7. When meeting at night or passing from the rear, dim your lights. Don't be afraid to dim first (courtesy promotes safety).
8. Slow down when approaching any child, pedestrian, bicycle, livestock, parked car, or other obstruction on the highway. Be prepared for the unexpected.
9. Don't stop or park on the main traveled portion of the highway, especially on hills or curves. Pull out on the shoulder. It's safer for you and other cars.
10. Report all accidents resulting in death, personal injury or property damage of an apparent extent of $25.00 or more to the Highway Patrol.
11. Be careful. An alert, careful driver is the best insurance against all accidents.
12. PREVENT FOREST FIRES—USE YOUR ASH TRAY.

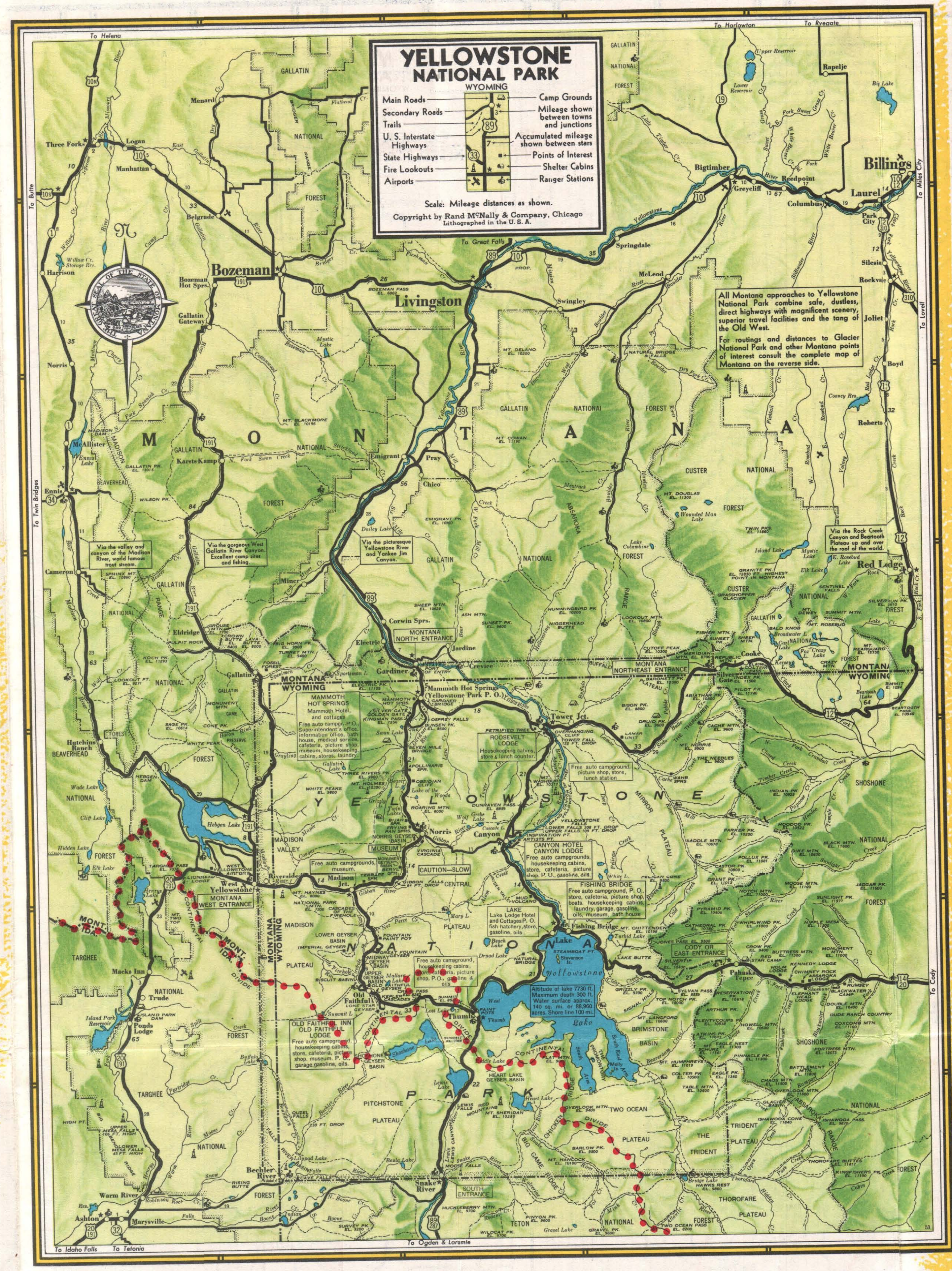
OLD FAITHFUL The world's most famous geyser is a top attraction in the largest and oldest of all national parks—Yellowstone. Three entrances to Yellowstone are by way of Montana at Cooke City, Gardiner and West Yellowstone. Within Yellowstone's forested plateau of 3472 square miles are 10,000 geysers and thermal leaks, paint pots, fossil forests, huge Yellowstone lake, colorful grand canyon of the Yellowstone, and one of the largest game sanctuaries in the country abounding in bear, deer, elk, moose and other wild animals.

THE "HIGH ROAD" Most spectacular entrance or exit of Yellowstone Park is the Red Lodge-Cooke City highway that follows one of the oldest Indian trails in the state. The Red Men called it "the path above the eagles" because it winds in three gigantic switchbacks up and over the Beartooth plateau at an elevation of 10,943 feet. From this top of the world highway may be seen the highest peaks of Montana, eternally snow-capped. Lakes are alongside and the road runs through a carpet of alpine flowers such as dryad, fireweed, Rocky Mountain laurel, columbine, daisies and asters.



LAKE COMO Located in the Bitterroot valley, this is a typical Montana mountain lake. Altogether there are over 1,200 lakes in the Treasure State and they provide any angler with a diversity of fine fishing.

OLD WEST REVIVED In Virginia City, they've turned the clock back almost 90 years—back to the roaring 1860's when this gold rush camp was Montana's second territorial capital. All around are evidences of the fierce struggle between Vigilantes and Road Agents—Boot Hill cemetery, Hangmans House. Among the old buildings restored are Wells, Fargo Express Station, Bale of Hay saloon, and Old Stone Barn Playhouse.



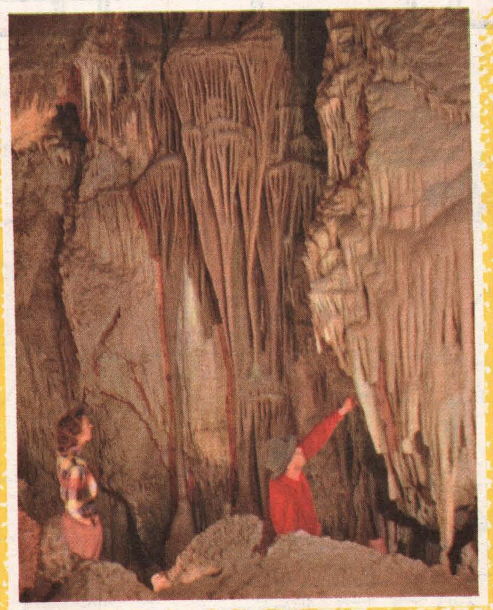
MONTANA MILEAGE TABLE

The mileage between two points is found at the intersection of the vertical column of figures under the name of one point, and the horizontal line of figures opposite the name of the other point.

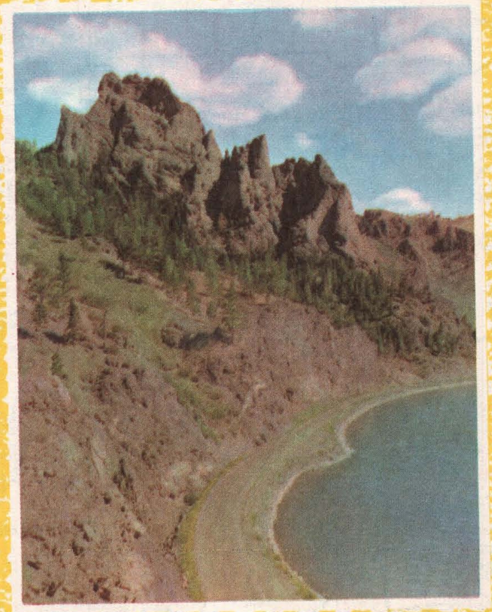
All distances are computed by way of trunk lines. Some may be materially shortened by use of secondary or county roads. Inquire locally.

APPROXIMATE MILEAGE

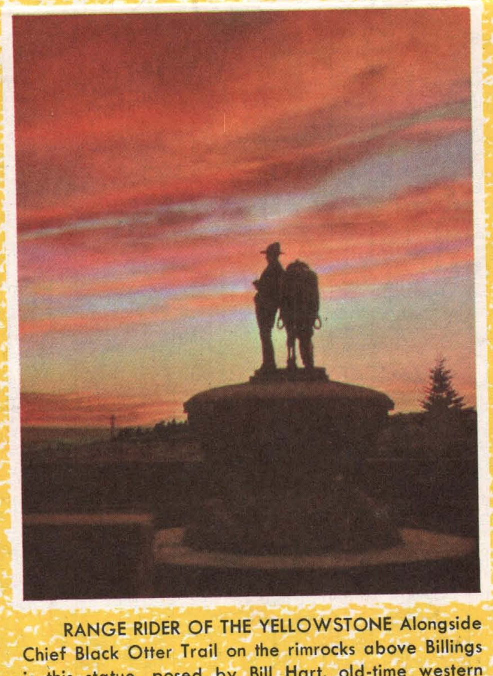
	Anaconda	Billings	Bozeman	Butte	Glasgow	Gt. Falls	Havre	Helena	Kalispell	Lewistown	Livingston	Miles City	Missoula
Atlanta, Ga.	2167	1907	2077	2273	2049	2243	2355	2150	2387	2032	2023	1837	2267
Chicago, Ill.	1532	1269	1411	1507	1266	1442	1427	1470	1672	1335	1385	1120	1588
Dallas, Texas	1534	1271	1413	1509	1579	1507	1619	1619	1737	1400	1387	1347	1631
Denver, Colo.	858	595	737	833	903	831	943	838	1061	724	711	671	955
New Orleans, La.	2142	1879	2021	2117	2187	2115	2227	2122	2345	2008	1995	1955	2239
New York, N. Y.	2361	2098	2240	2336	2095	2271	2256	2299	2501	2164	2214	1949	2417
Salt Lake City, Utah	465	527	404	449	862	589	701	496	683	558	422	687	563
San Francisco, Calif.	1090	1273	1131	1074	1506	1233	1345	1140	1308	1287	1157	1422	1188
Seattle, Wash.	611	862	720	626	919	712	758	619	493	810	746	969	502
St. Louis, Mo.	1592	1332	1474	1570	1474	1564	1635	1575	1794	1457	1448	1242	1692
Washington, D. C.	2223	1960	2102	2198	1957	2133	2118	2161	2363	2026	2076	1811	2279
Edmonton	694	765	717	682	706	529	545	616	501	636	702	851	621
Dawson Cr.	1170	1241	1193	1158	1182	1005	1021	1092	977	1112	1178	1327	1097
White Horse	2064	2135	2087	2052	2076	1899	1915	1986	1871	2006	2072	2221	1991
Fairbanks	2687	2758	2710	2675	2699	2522	2538	2609	2494	2629	2695	2844	2614



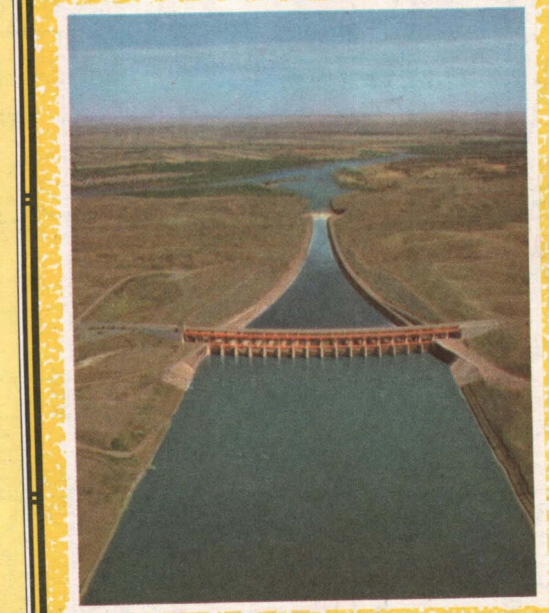
LEWIS AND CLARK CAVERN A state park, this cavern is the largest in the Pacific Northwest. Beautifully lighted, it features two main rooms with multi-colored stalagmites, stalactites, clusterites, flowstone and other formations. Guided tours from May to November. The Cavern tour takes 1½ hours.



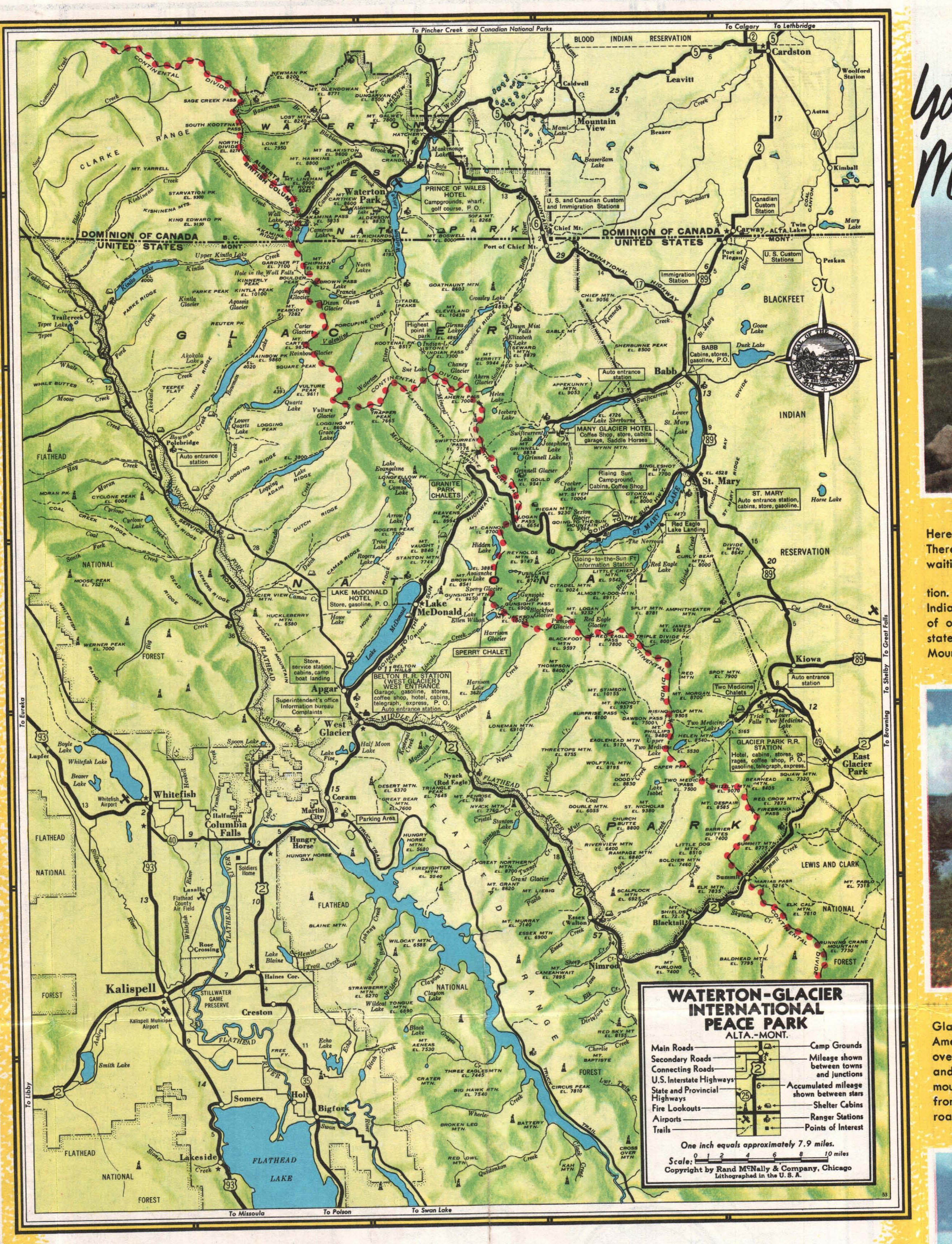
MISSOURI RIVER CANYON Between Helena and Great Falls U. S. Highway 91 winds along the Missouri river following an old Indian road. Walls of the canyon are mottled with tints of red, moss green and yellow, and weird formations of all shapes and sizes tower above the highway.



RANGE RIDER OF THE YELLOWSTONE Alongside Chief Black Otter Trail on the rimrocks above Billings is this statue, posed by Bill Hart, old-time western movie star. Other points of interest on the trail include Boothill cemetery, and graves of Chief Black Otter and Indian Scout Yellowstone Kelly.



FORT PECK DAM Largest earth fill dam in the world, Fort Peck has tamed the mighty Mo by impounding the Missouri for a distance of 175 miles. Nearly four miles long, the dam measures 21,026 feet in length with a height of 250 feet, and has a concrete spillway a mile long. Fort Peck lake has a shore line of 1600 miles and boasts a great variety of fine fishing.



THE ALASKA HIGHWAY

The Alaska Highway, extending from Dawson Creek, B. C. to Fairbanks, Alaska, is 1,523 miles long and is kept open to traffic throughout the year. Permits to travel on the highway are not required, but arrangements for accommodations should be made in advance.

Restrictions on travel may be made on short notice at any time by highway maintenance authorities because of flood conditions or damage to bridges.

Roadside facilities, overnight accommodations, and automobile repairs and services are limited along the highway. Among centers offering the most complete overnight accommodations are Dawson Creek, Fort St. John, Fort Nelson, Lower Post, Teslin, Whitehorse, Burwash Landing, and Fairbanks. Public camp-grounds are maintained at several locations in the Yukon Territory for the convenience of travelers equipped for camping and carrying their own food and supplies.

Automobiles should be in first class mechanical condition, with travelers carrying sufficient car tools, spare tires, tubes, etc., for their own needs. Assistance in matters of automotive repairs, food and shelter cannot be expected from Northwest Highway System maintenance camps.

The use of trailers and cabin trailers is permissible on the highway but heavy trailers in conjunction with passenger cars is not recommended, owing to difficulties which might be encountered on some of the longer grades.

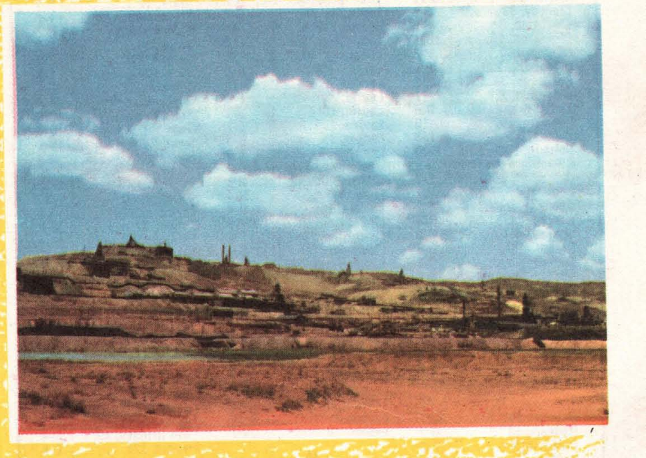
U. S. citizens passing through Canada to Alaska do not require passports, and as a general rule will experience no difficulty or delay at the border. They should, however, possess ample means of personal identification.

You Will See More in Montana

In majestic Montana you will discover an ideal vacationland. Here nights are cool and days are zestful with plenty of sunshine. There is no crowding. Nearly 6,000 miles of surfaced highways are waiting to lead you into this vast playland.

Montana offers a variety vacation program of fun and relaxation. Sight seeing tops the list. There are rodeos, dude ranches, Indian ceremonials, battlefields, bison ranges (above) and all kinds of outdoor recreational activities. Don't hurry through—it's a big state, take a day or two extra and really see the Land of Shining Mountains.

GLACIER NATIONAL PARK Established as the Waterton-Glacier International Peace Park, this mountain country is one of America's great playgrounds. Astride the Continental divide, it has over 60 living glaciers, 200 sparkling lakes, waterfalls by the score and wildlife of all kinds. Picture takers rave about Glacier's towering mountains and masses of alpine flowers. Going-to-the-Sun highway from Lake McDonald to St. Mary's lake is one of the most scenic roads to be found anywhere.



RICHEST HILL ON EARTH By yielding over four billion dollars worth of metallic and non-metallic products this hill at Butte rightfully has earned its title. Copper, zinc, lead and manganese are its principal metals. Known as the mile high and mile deep city, Butte is built at a mile high altitude in a bend of the Continental divide, and its mine workings extend to a depth of a mile below.

FLATHEAD LAKE Located in northwestern Montana, this is one of the largest bodies of fresh water west of the Great Lakes. It is 30 miles long, 10 miles wide and has an average depth of 220 feet. Black-topped highways encircle the lake. On the east shore are sweet cherry orchards and from the west shore can be seen the beautiful Mission and Swan mountain ranges. Boating and fishing for silver salmon, Dolly Varden trout, whitefish and bass are popular pastimes in this lake region.

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Population: 591,024 (1950 Census) Area: 146,131 sq. miles
Capital: Helena

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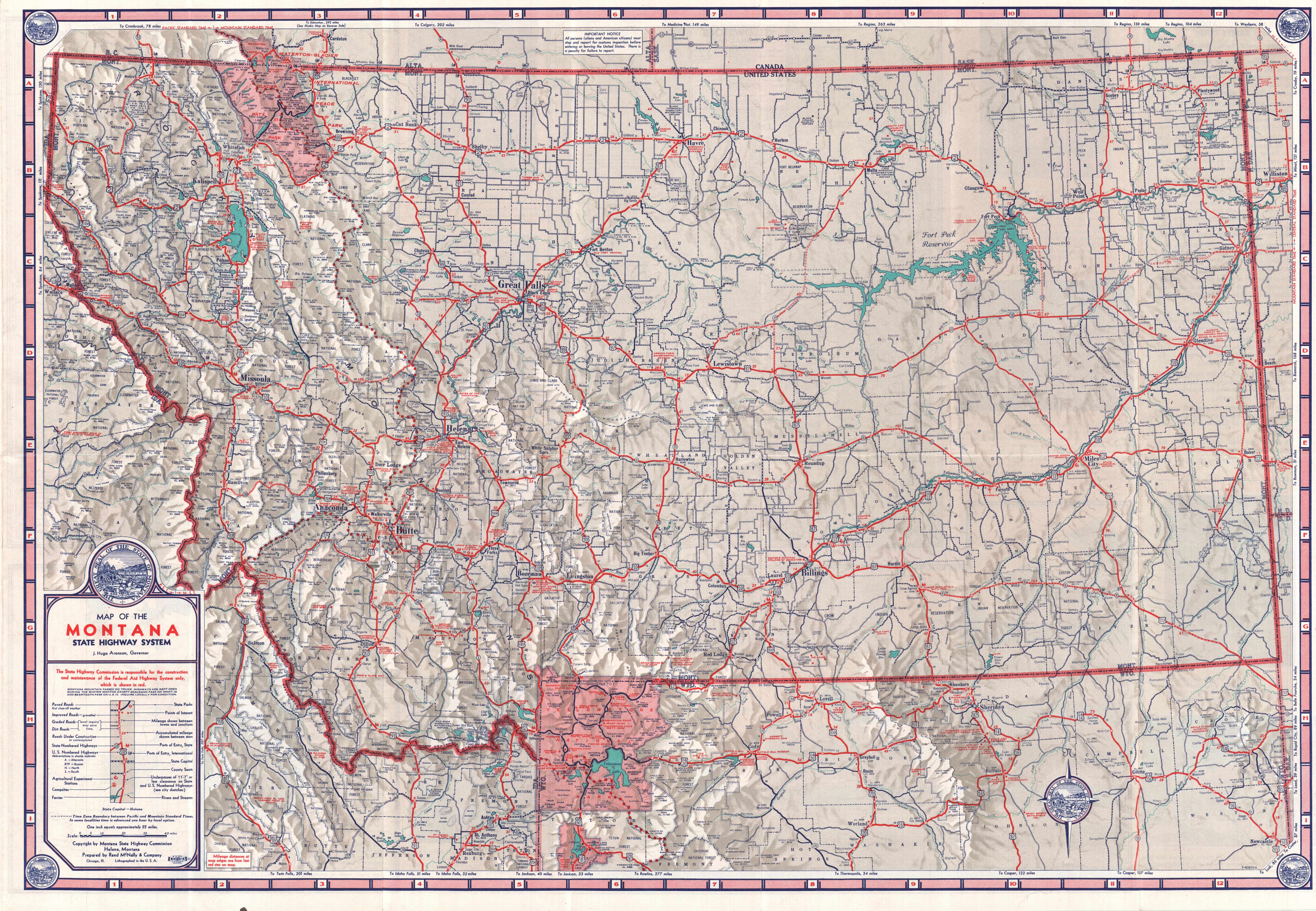


POINTS OF INTEREST
(From West to East)

Along U. S. Highway 2: KOOTENAI CANYON and FALLS (B-1) Scenic drive along Kootenai river, near Troy.

LAKES DRIVE (B-2-1) Through magnificent stands of fir, pine, larch; past Thompson and McGregor lakes from Libby to Kalispell.

HUNGRY HORSE DAM (B-2) Hungry Horse dam is next to Hoover and Shasta in height (564 feet high), and fourth largest concrete dam in the world. Vista point.

GLACIER - WATERTON INTERNATIONAL PEACE PARK (A-2-3) Over 60 living glaciers, lakes and majestic mountains atop the Continental divide. Traversed by world-famous Going-to-the-Sun highway.

PLAINS INDIAN MUSEUM (B-3) At Browning—an outstanding Indian museum containing dioramas of Indian life, and a fine collection of Indian weapons and clothing.

BEARS PAW BATTLEFIELD (B-7) 30 miles south of Chinook. Site of Nez Perce Chief Joseph's surrender after one of the last great Indian battles in 1877.

FORT PECK DAM AND LAKE (B-10) 18 miles southeast of Glasgow on Mont. 24. Largest earth-fill dam in the world, backing up the Missouri river into a 175 mile long lake. Fishing. Eastern approach via Nashua.

Along U. S. 10-A: CABINET GORGE DAM (B-1) Hydro-electric dam one-half mile from Montana-Idaho border. Vista point.

THOMPSON FALLS (C-1) Hydro-electric dam at site of natural falls in Clarks Fork of Columbia River. Named for David Thompson, explorer and surveyor.

LARGEST SMOKE STACK (F-3) in the world, 585 feet high, at Anaconda smelter. Chain of lakes drive past Georgetown and Silver lakes.

Along U. S. 10: SMOKE JUMPERS of U. S. Forest Service headquarters at Missoula (D-2). Site of Montana University with Mount Sentinel on campus.

COPPER MINING at Butte (F-3), the "richest hill on earth." Known as the city that is a mile high and a mile deep; it has 2,200 miles of mine level workings and 5,200 miles of stope workings honeycombed underneath.

LEWIS AND CLARK CAVERN STATE PARK (F-4) Located midway between Butte and Bozeman, this cavern is 3.2 miles off U. S. 10-S. Guided tours available at intervals through this largest limestone cavern in the Pacific Northwest. Scenic, open-air narrow gauge railroad ride to cave entrance.

STATE CAPITOL BUILDING at Helena (E-4). This is on U. S. 10-N. Museum and state historical library. Early-day discovery of gold made in Last Chance Gulch.

GATEWAY TO YELLOWSTONE PARK through Bozeman (G-5) up Gallatin river canyon to West Yellowstone. Montana State college located at Bozeman.

GATEWAY TO YELLOWSTONE PARK through Livingston-Gardiner (G-6) by way of Yankee Jim canyon. Dude ranch country.

BOOTHILL CEMETERY (F-8) along Black Otter trail on the rimrocks overlooking Billings, Bill Hart range rider statue, graves of Yellowstone Kelly, famous scout and Chief Black Otter. Oil refineries.

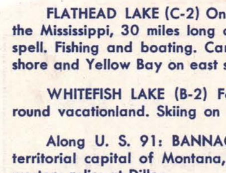
POMPEYS PILLAR (F-8) An isolated rock 200 feet high on the bank of the Yellowstone river to the left going east. First climbed by Capt. William Clark July 25, 1806. Named for Pomp, Sacajawea's son.

RANGE RIDERS MUSEUM (E-11) at Miles City's western outskirts. Fine collection of relics of the days of the unfenced range. Historic Fort Keogh nearby.

BADLANDS (D-12) of Maco Sica state park just east of Glendive. Other badlands found near Jordan (D-10) and Havre (B-7).

(From South to North)

Along U. S. 93: ST. MARY'S MISSION (E-2) Oldest mission in Montana, established in 1841 near Stevensville by Father DeSmet, Jesuit priest. Old Fort Owens nearby.



NATIONAL BISON RANGE (D-2) About 500 buffalo graze in an 18,000 acre preserve. Among them is an albino buffalo, regarded as sacred by the Indians.

MISSION MOUNTAINS (C-2) One of the many majestic mountain ranges to be found in Montana. At St. Ignatius is Catholic mission with beautiful murals. East of Ronan is lofty Mount McDonald (9,800 feet altitude).

FLATHEAD LAKE (C-2) One of the largest bodies of fresh water west of the Mississippi, 30 miles long and 10 miles wide. Between Polson and Kalispell. Fishing and boating. Campgrounds at Goose Bay state park on west shore and Yellow Bay on east shore.

WHITEFISH LAKE (B-2) Famous for mackinaw trout fishing. All year-round vacationland. Skiing on Big Mountain. Summer operation of chair lift.

Along U. S. 91: BANNACK (G-3) 25 miles southwest of Dillon. First territorial capital of Montana, now a ghost gold mining camp. Museum of western relics at Dillon.

GATES OF THE MOUNTAINS (D-4) 20 miles northeast of Helena. Deep gorge of Missouri river. So-named by Lewis and Clark because of huge stone that seems to block river. Cruise boats available during summer.

GIANT SPRINGS (C-5) Phenomenal spring flowing 388,800,000 gallons of water every 24 hours—along river drive at Great Falls. Series of falls and hydro-electric plants along Missouri river.

CHARLIE RUSSELL STUDIO (C-5) Studio of famous cowboy artist. 1217 Fourth Ave. North, Great Falls. Open from 2 to 8 p.m. July 1st to Sept. 1st.

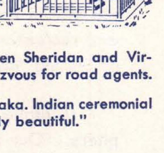
Along U. S. 12: GRASSHOPPER GLACIER (G-6) 14 miles north by trail from Cooke City. Millions of grasshoppers frozen into the face of an 80-foot cliff of ice.

RED LODGE-COOKE CITY HIGHWAY (G-7) Most spectacular approach to Yellowstone National Park. Called the "high road" it reaches an elevation of almost 11,000 feet. Rugged mountain scenery, alpine flowers.

Along U. S. 87: CUSTER BATTLEFIELD NATIONAL CEMETERY (F-9) Site of Custer's famed Last Stand, near Crow Agency. Sandstone obelisk monument, 209 marble gravestones, markers. Gen. Custer and Crow Indian museum.

BIG SPRING (D-7) Near Lewistown. This spring discharges 62,700 gallons of water a minute, forming an excellent trout stream, Big Springs creek.

BIG HOLE BATTLEFIELD NATIONAL MONUMENT (F-2) Near Wisdom. Site of battle between Chief Joseph's Nez Perce Indians and U. S. soldiers on August 9, 1877. Rifle pits, bullet scarred trees, monuments.



VIRGINIA CITY (G-4) On Montana 34. Colorful gold mining camp up Alder Gulch that produced over $100,000,000 in gold. Now restored to 1865 vintage with stage station, saloons, blacksmith shop, first Montana newspaper, museum and other historic buildings.

ROBBERS ROOST (G-4) On Montana 34, between Sheridan and Virginia City. Large log structure that was early-day rendezvous for road agents.

MEDICINE ROCKS (F-12) On Montana 7 near Ekalaka. Indian ceremonial grounds. Described by Teddy Roosevelt as "fantastically beautiful."

MONTANA ROADS OPEN FOR WINTER TRAVEL

Modern maintenance equipment enables Montana to keep all primary roads (shown in red) open during winter months except for very short periods during or immediately after a severe storm. Inquiries should be made regarding local conditions during storms. Chains and a shovel are recommended.

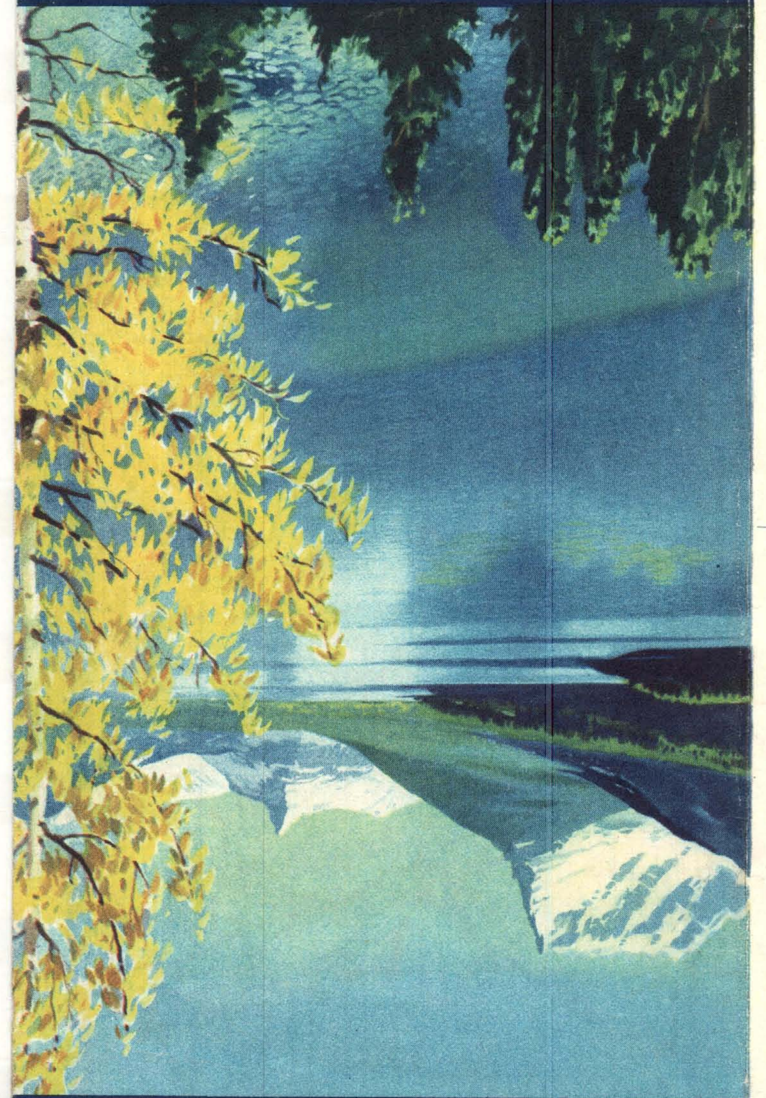
All main highway passes are kept open during the winter. Passes that are closed to wheel traffic for several months are:

- Red Lodge-Cooke City highway to Yellowstone Park on U. S. 12. From 12 miles south of Red Lodge over Beartooth plateau.
- Skalkaho pass on Montana 38 between Anaconda and Hamilton.
- Gibbons pass on Montana 43 from 2 miles north of Wisdom to U. S. 93.
- Logan pass in Glacier National park. Closed from approximately Oct. 15 to June 1.
- Yellowstone National park roads subject to closure after Oct. 15 except for Gardiner—Cooke City via Mammoth which remains open year round.

As part of Montana's winter maintenance program, hills and curves are sanded. Reduced speeds are recommended for winter highway travel.

Montana's snow removal program is one of the finest.

RPM MOTOR OIL
100% PURE PARAFFIN BASE
CHEVRON SUPREME GASOLINE



POINTS OF INTEREST AND TOURING MAP

MONTANA

TRAVEL TIPS

FOR MOTORISTS SEEING THE WEST

How to avoid roadside grief—Cheerful attendants at independent Chevron Gas Stations will be glad to check your tires, battery, radiator. They're specially trained to watch for hidden troubles, warn you before a failure.

Protect your car with the *only* real insurance against breakdowns. Let experts take over your car cares.

Good local information—These men know their communities . . . restaurants, accommodations, recreation, sights. They'll give you a neighborly steer in the right direction.

Want that "New Car Feeling?"—Fill the tank with CHEVRON Supreme Gasoline. It's *super-refined* to eliminate harmful gum, coax extra power and thriftier mileage out of your engine.

For complete engine protection depend on RPM Motor Oil. Compounded "RPM" sticks to hot spots other oils leave bare. Look for the "RPM" trade-mark.

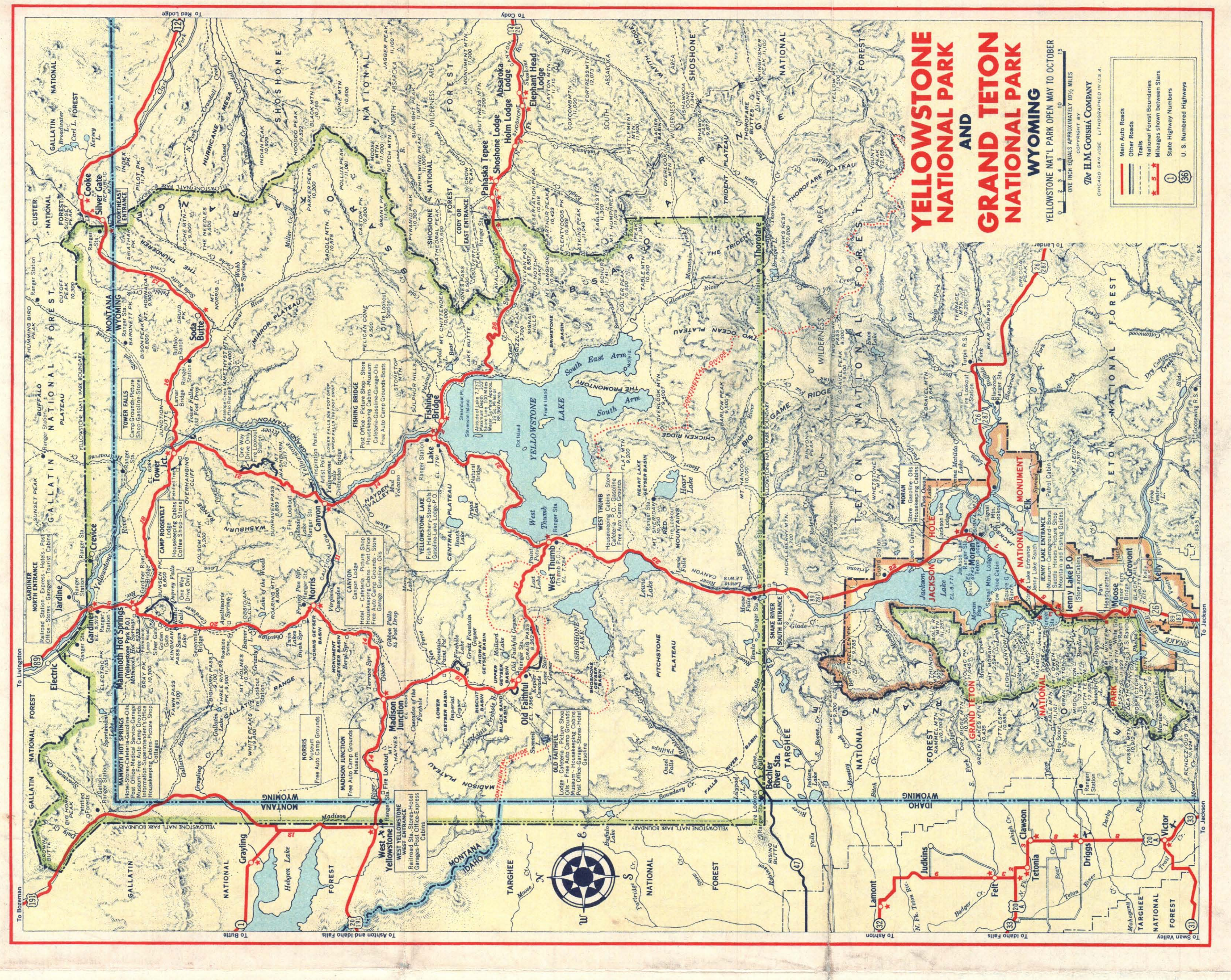
Note—for your convenience—You'll find clean rest rooms, cool drinking water, free maps of states and principal Western cities at independent Chevron Gas Stations.

Handy to take along—A CHEVRON National Credit Card, honored from coast to coast and in Canada, is your introduction to friendly, courteous service wherever you drive.

Make it a habit when you travel Western highways to look for the signs of independent Chevron Gas Stations where they say and mean . . .

WE TAKE BETTER CARE OF YOUR CAR

CHEVRON GAS STATION



TRANSCONTINENTAL MILEAGE CHART

RPM MOTOR OIL

	AKRON, OHIO	ATLANTA, GA.	BOSTON, MASS.	BUFFALO, N. Y.	CHICAGO, ILL.	CINCINNATI, OHIO	CLEVELAND, OHIO	COLORADO SPRS., COLO.	COLUMBUS, OHIO	DALLAS, TEX.	DAVENPORT, IOWA	DENVER, COLO.	DES MOINES, IOWA	DETROIT, MICH.	DULUTH, MINN.	EL PASO, TEX.	GRAND RAPIDS, MICH.	HOUSTON, TEX.	INDIANAPOLIS, IND.	JACKSONVILLE, FLA.
AKRON, OHIO	●	697	678	224	357	232	35	1417	123	1217	509	1381	686	177	852	1777	295	1335	297	1001
ATLANTA, GA.	697	●	1129	907	724	481	718	1449	574	826	783	1464	933	733	1199	1471	790	875	557	325
BISMARCK, N. DAK.	1228	1569	1850	1396	871	1172	1220	782	1187	1294	780	710	725	1144	461	1454	1054	1538	1062	1898
BOSTON, MASS.	678	1129	●	454	979	879	643	2068	774	1868	1137	2008	1313	706	1474	2428	833	1961	948	1228
BUFFALO, N. Y.	224	907	454	●	525	430	189	1614	333	1414	683	1554	859	252	1020	1974	379	1545	494	1142
CARLSBAD CAVERNS NAT'L PK.	1680	1319	2331	1872	1422	1493	1688	563	1557	493	1287	635	1126	1657	1545	160	1586	684	1383	1594
CHICAGO, ILL.	357	724	979	525	●	301	349	1115	316	976	171	1043	348	273	495	1519	183	1113	191	1049
CINCINNATI, OHIO	232	481	879	430	301	●	241	1230	109	1007	427	1245	582	252	796	1590	309	1115	110	806
CLEVELAND, OHIO	35	718	643	189	349	241	●	1425	144	1225	501	1373	678	166	844	1785	284	1356	305	1028
COLO. SPRS. COLO.	1417	1449	2068	1614	1115	1230	1425	●	1294	733	944	72	767	1374	1137	672	1288	977	1120	1774
COLUMBUS, OHIO	123	574	774	333	316	109	144	1294	●	1094	463	1309	640	180	811	1654	289	1212	174	899
DALLAS, TEX.	1217	826	1868	1414	976	1007	1225	733	1094	●	860	805	718	1194	1147	645	1140	244	920	1101
DAVENPORT, IOWA	509	783	1137	683	171	427	501	944	463	860	●	872	177	431	454	1384	344	1058	317	1108
DENVER, COLO.	1381	1464	2008	1554	1043	1245	1373	72	1309	805	872	●	695	1302	1065	679	1216	1049	1064	1789
DES MOINES, IOWA	686	933	1313	859	348	582	678	767	640	718	177	695	●	607	429	1223	521	962	472	1258
DETROIT, MICH.	177	733	706	252	273	252	166	1374	180	1194	431	1302	607	●	768	1754	143	1326	274	1058
DUBUQUE, IOWA	539	857	1161	707	182	483	531	958	498	909	74	886	191	455	380	1414	365	1062	373	1182
DULUTH, MINN.	852	1199	1474	1020	495	796	844	1137	811	1147	454	1065	429	768	●	1642	667	1391	686	1524
EL PASO, TEX.	1777	1471	2428	1974	1519	1590	1785	672	1654	645	1384	679	1223	1754	1642	●	1683	762	1480	1722
FT. WAYNE, IND.	210	635	848	394	161	154	205	1227	155	1035	308	1180	485	160	656	1595	155	1167	115	960
GLACIER NAT'L PK.	1996	2378	2618	2164	1639	1940	1988	1110	1955	1843	1648	987	1533	1912	1193	1592	1822	2087	1830	2703
GRAND CANYON NAT'L PK.	2067	1884	2718	2264	1807	1880	2075	920	1944	1068	1669	785	1492	2044	1843	581	1971	1291	1770	2169
HOUSTON, TEX.	1335	875	1961	1545	1113	1115	1356	977	1212	244	1058	1049	962	1326	1391	762	1277	●	1052	960
INDIANAPOLIS, IND.	297	557	948	494	191	110	305	1120	174	920	317	1064	472	274	686	1480	246	1052	●	882
JACKSONVILLE, FLA.	1001	325	1228	1142	1049	806	1028	1774	899	1101	1108	1789	1258	1058	1524	1722	1115	960	882	●
JEFFERSON CITY, MO.	667	699	1318	864	386	480	675	773	544	582	278	788	266	636	658	1142	550	826	370	1034
KANSAS CITY, MO.	791	823	1442	988	504	604	799	626	668	510	369	641	208	752	637	1015	668	754	494	1148
LITTLE ROCK, ARK.	883	560	1530	1093	661	631	904	958	760	344	606	1029	587	874	1016	989	825	452	566	811
LOS ANGELES, CALIF.	2479	2288	3130	2676	2189	2292	2487	1228	2356	1462	2018	1197	1841	2448	2192	817	2362	1579	2182	2539
LOUISVILLE, KY.	343	439	989	541	309	111	352	1152	220	896	438	1167	590	363	804	1512	364	1004	118	764
MADISON, WIS.	500	847	1122	668	143	444	492	1054	459	1005	170	982	287	416	352	1510	326	1185	334	1172
MEMPHIS, TENN.	742	419	1389	952	562	492	763	1040	619	485	550	1109	637	751	1004	1130	723	593	453	672
MIAMI, FLA.	1338	662	1565	1479	1386	1143	1365	2111	1236	1447	1445	2126	1595	1395	1861	2068	1452	1306	1219	337
MPLS.-ST. PAUL, MINN.	777	1124	1399	945	420	721	769	978	736	988	329	855	270	693	159	1483	603	1232	611	1449
MONTREAL, QUE.	613	1296	338	389	854	819	578	1955	722	1775	1012	1883	1188	581	1074	2335	700	1907	855	1395
NASHVILLE, TENN.	521	259	1168	731	465	301	542	1190	398	706	524	1205	674	553	940	1351	554	814	308	584
NEW ORLEANS, LA.	1111	532	1625	1321	977	846	1132	1242	988	509	965	1314	1056	1143	1419	1130	1138	368	845	603
NEW YORK, N. Y.	493	910	219	380	841	660	502	1847	555	1649	988	1852	1165	632	1336	2209	759	1742	729	1009
NORTH PLATTE, NEBR.	1109	1268	1736	1282	771	987	1101	344	1051	782	600	272	423	1030	793	1016	944	1026	877	1593
OMAHA, NEBR.	824	1024	1451	997	486	702	816	629	766	693	315	557	138	745	538	1104	659	937	592	1349
PEORIA, ILL.	450	674	1091	646	157	327	457	979	391	844	100	932	255	405	554	1368	319	993	217	999
PHILADELPHIA, PA.	411	816	313	365	759	578	425	1767	473	1561	906	1770	1083	588	1254	2127	700	1648	647	915
PHOENIX, ARIZ.	2095	1894	2746	2292	1837	1908	2103	865	1972	1068	1702	937	1541	2072	1960	423	2001	1185	1798	2145
PITTSBURGH, PA.	117	727	595	218	465	293	131	1482	188	1282	612	1476	789	294	960	1842	406	1396	362	924
PORTLAND, OREG.	2607	2776	3229	2775	2250	2495	2599	1437	2559	2145	2108	1365	1931	2523	1840	1745	2433	2368	2385	3101
PUEBLO, COLO.	1435	1415	2086	1632	1148	1248	1443	44	1312	689	988	116	811	1396	1181	628	1312	933	1138	1734
QUEBEC, QUE.	785	1468	388	561	1026	991	750	2127	894	1947	1184	2055	1360	753	1246	2507	872	2079	1027	1567
ROCKFORD, ILL.	446	779	1068	614	89	390	438	1044	405	970	110	972	277	362	420	1494	272	1117	280	1104
ST. LOUIS, MO.	537	569	1188	734	296	350	545	880	414	680	241	895	364	514	695	1240	460	817	240	904
SALT LAKE CITY, UTAH	1804	1959	2431	1977	1466	1682	1796	593	1746	1285	1295	521	1118	1725	1469	885	1639	1508	1572	2284
SAN ANTONIO, TEX.	1467	1022	2108	1677	1245	1247	1488	903	1344	278	1120	975	996	1458	1425	571	1409	196	1184	1166
SAN FRANCISCO, CALIF.	2571	2607	3198	2744	2233	2449	2563	1360	2513	1791	2062	1288	1885	2492	2155	1222	2406	1984	2339	2892
SEATTLE, WASH.	2541	2807	3163	2709	2184	2485	2533	1514	2500	2222	2093	1442	1962	2457	1774	1822	2367	2445	2375	3132
SOUTH BEND, IND.	271	696	889	435	90	230	260	1192	231	1044	248	1120	425	183	585	1587	117	1181	139	1021
SPOKANE, WASH.	2235	2501	2857	2403	1878	2179	2227	1229	2194	1962	1787	1157	1656	2151	1468	1643	2061	2206	2069	2826
SPRINGFIELD, ILL.	488	620	1138	684	193	302	495	937	366	783	163	952	301	443	617	1326	357	920	192	945
TAMPA, FLA.	1188	465	1427	1341	1215	972	1209	1988	1065	1186	1274	1933	1424	1224	1690	1807	1281	1045	1048	199
TERRE HAUTE, IND.	367	537	1018	564	185	187	375	1050	244	850	283	1065	438	344	680	1410	321	987	70	862
TOLEDO, OHIO	124	680	756	302	237	199	113	1334	127	1142	395	1267	572	53	732	1702	171	1274	222	1005
TORONTO, ONT.	339	963	569	115	503	482	304	1604	430	1424	661	1532	837	230	935	1984	349	1556	504	1257
TULSA, OKLA.	976	853	1627	1173	735	789	984	665	853	285	618	736	477	953	906	801	899	529	679	1172
WASHINGTON, D.C.	348	669	460	379	696	503	362	1692	398	1414	843	1707	1061	525	1191	2052	637	1501	572	768
WICHITA, KANS.	1015	980	1682	1212	728	828	1023	479	892	393	593	519	432	976	851	791	892	637	718	1299
WILMINGTON, N. C.	706	437	828	755	974	696	720	1817	669	1257	1099	1832	1255	849	1469	1902	958	1305	783	428
YELLOWSTONE NAT'L PK.	1794	1953	2421	1967	1456	1672	1688	648	1736	1381	1285	539	1108	1614	1031	1209	1629	1625	1562	2278

	KANSAS CITY, MO.	LITTLE ROCK, ARK.	LOS ANGELES, CALIF.	LOUISVILLE, KY.	MEMPHIS, TENN.	MILWAUKEE, WIS.	MPLS.-ST. PAUL, MINN.	MONTREAL, QUE.	NASHVILLE, TENN.	NEW ORLEANS, LA.	NEW YORK, N. Y.	OMAHA, NEBR.	PHILADELPHIA, PA.	PITTSBURGH, PA.	PORTLAND, OREG.	PUEBLO, COLO.	QUEBEC, QUE.	ST. LOUIS, MO.	SALT LAKE CITY, UTAH	SAN ANTONIO, TEX.	SAN FRANCISCO, CALIF.	SEATTLE, WASH.	SPOKANE, WASH.	TAMPA, FLA.	TOLEDO, OHIO	TORONTO, ONT.	TULSA, OKLA.	WASHINGTON, D.C.
AKRON, OHIO	791	883	2479	343	742	447	777	613	521	1111	493	824	411	117	2607	1435	785	537	1804	1467	2571	2541	2235	1188	124	339	976	348
ATLANTA, GA.	823	560	2288	439	419	814	1124	1296	259	532	910	1024	816	727	2776	1415	1468	569	1959	1022	2607	2807	2501	465	680	963	853	669
BISMARCK, N. DAK.	838	1256	1723	1180	1306	792	451	1535	1310	1721	1712	616	1630	1336	1379	826	1707	1006	1000	1514	1767	1313	1007	2054	1108	1374	1044	1567
BOSTON, MASS.	1442	1530	3130	989	1389	1069	1399	338	1168	1625	219	1451	313	595	3229	2086	388	1188	2431	2108	3198	3163	2857	1427	756	569	1627	460
BUFFALO, N. Y.	988	1093	2676	541	952	615	945	389	731	1321	380	997	365	218	2775	1632	561	734	1977	1677	2744	2709	2403	1341	302	115	1173	379
CARLSBAD CAVERNS NAT'L PK.	918	837	977	1415	973	1496	1386	2238	1199	1002	2112	1007	2030	1745	1805	519	2410	1143	945	493	1382	1882	1703	1679	1605	1887	704	1955
CHICAGO, ILL.	504	661	2189	309	562	90	420	854	465	977	841	486	759	465	2250	1148	1026	296	1466	1245	2233	2184	1878	1215	237	503	735	696
CINCINNATI, OHIO	604	631	2292	111	492	391	721	819	301	846	660	702	578	293	2495	1248	991	350	1682	1247	2449	2485	2179	972	199	482	789	503
CLEVELAND, OHIO	799	904	2487	352	763	439	769	578	542	1132	502	816	425	131	2599	1443	750	545	1796	1488	2563	2533	2227	1209	113	304	984	362
COLO. SPRS. COLO.	626	958	1228	1152	1040	1131	978	1955	1190	1242	1847	629	1767	1482	1437	44	2127	880	593	903	1360	1514	1229	1988	1334	1604	665	1692
COLUMBUS, OHIO	668	760	2356	220	619	406	736	722	398	988	555	766	473	188	2559	1312	894	414	1746	1344	2513	2500	2194	1065	127	430	853	398
DALLAS, TEX.	510	344	1462	896	485	1054	988	1775	706	509	1649	693	1561	1282	2145	689	1947	680	1285	278	1791	2222	1962	1186	1142	1424	285	1414
DAVENPORT, IOWA	369	606	2018	438	550	190	329	1012	524	965	988	315	906	612	2108	988	1184	241	1295	1120	2062	2093	1787	1274	395	661	618	843
DENVER, COLO.	641	1029	1197	1167	1109	1059	855	1883	1205	1314	1852	557	1770	1476	1365	116	2055	895	521	975	1288	1442	1157	1933	1267	1532	736	1707
DES MOINES, IOWA	208	587	1841	590	637	364	270	1188	674	1056	1165	138	1083	789	1931	811	1360	364	1118	996	1885	1962	1656	1424	572	837	477	1061
DETROIT, MICH.	752	874	2448	363	751	363	693	581	553	1143	632	745	588	294	2523	1396	753	514	1725	1458	2492	2457	2151	1224	53	230	953	525
DUBUQUE, IOWA	399	680	2032	491	624	176	255	1036	598	1039	1023	329	949	647	2085	1002	1208	315	1309	1187	2076	2019	1713	1348	419	685	668	878
DULUTH, MINN.	637	1016	2192	804	1004	416	159	1074	940	1419	1336	538	1254	960	1840	1181	1246	695	1469	1425	2155	1774	1468	1690	732	935	906	1191
EL PASO, TEX.	1015	989	817	1512	1130	1587	1483	2335	1351	1130	2209	1104	2127	1842	1745	628	2507	1240	885	571	1222	1822	1643	1807	1702	1984	801	2052
FT. WAYNE, IND.	601	715	2297	217	592	251	581	741	407	997	707	613	648	354	2411	1245	913	355	1603	1299	2370	2345	2039	1126	107	390	794	585
GLACIER NAT'L PK.	1500	1973	1449	1948	2023	1560	1141	2267	2119	2352	2480	1291	2398	2104	673	1154	2439	1809	707	2013	1257	581	290	2847	1876	2128	1774	2335
GRAND CANYON NAT'L PK.	1303	1322	530	1802	1463	1856	1684	2625	1684	1577	2499	1354	2417	2132	1253	772	2797	1530	393	1147	841	1330	1151	2159	1992	2274	1091	2340
HOUSTON, TEX.	754	452	1579	1004	593	1191	1232	1907	814	368	1742	937	1648	1396	2368	933	2079	817	1508	196	1984	2445	2206	1045	1274	1556	529	1501
INDIANAPOLIS, IND.	494	566	2182	118	453	281	611	855	308	845	729	592	647	362	2385	1138	1027	240	1572	1184	2339	2375	2069	1048	222	504	679	572
JACKSONVILLE, FLA.	1148	811	2539	764	672	1179	1449	1395	584	603	1009	1349	915	924	3101	1734	1567	904	2284	1166	2892	3132	2826	199	1005	1257	1172	768
JEFFERSON CITY, MO.	147	381	1814	402	358	470	499	1217	440	773	1099	359	1017	732	2100	780	1389	130	1283	860	2050	2131	1825	1190	590	866	341	942
KANSAS CITY, MO.	●	418	1631	526	468	572	478	1333	564	887	1223	212	1141	856	1953	644	1505	254	1136	788	1903	1984	1678	1292	708	982	269	1066
LITTLE ROCK, ARK.	418	●	1736	552	141	739	857	1455	362	469	1311	630	1217	944	2371	914	1627	365	1518	584	2047	2402	2096	965	822	1104	293	1070
LOS ANGELES, CALIF.	1631	1736	●	2214	1877	2205	2033	3029	2098	1947	2911	1703	2829	2544	1019	1264	3201	1942	742	1388	405	1207	1265	2624	2404	2678	1473	2754
LOUISVILLE, KY.	526	552	2214	●	383	399	729	930	190	737	771	710	689	404	2479	1170	1102	272	1662	1136	2433	2493	2187	930	310	593	711	614
MADISON, WIS.	495	733	2128	452	639	80	277	997	588	1054	984	425	902	608	2107	1098	1169	368	1405	1283	2172	2041	1735	1338	380	646	764	839
MEMPHIS, TENN.	468	141	1877	383	●	652	864	1332	221	415	1170	680	1076	803	2421	996	1504	309	1600	725	2188	2452	2146	782	699	981	434	929
MIAMI, FLA.	1485	1157	2885	1101	1018	1476	1786	1732	921	895	1346	1686	1252	1261	3236	2076	1904	1231	2621	1512	3238	3469	3163	264	1342	1594	1514	1105
MPLS.-ST. PAUL, MINN.	478	857	2033	729	864	341	●	1194	865	1279	1261	339	1179	885	1830	1022	1366	555	1310	1266	2077	1764	1458	1615	657	923	747	1116
MONTREAL, QUE.	1333	1455	3029	930	1332	944	1194	●	1120	1710	391	1326	480	607	2914	1977	172	1095	2306	2039	3073	2848	2542	1594	634	351	1534	627
NASHVILLE, TENN.	564	362	2098	190	221	555	865	1120	●	549	949	756	855	582	2517	1208	1292	310	1700	946	2409	2548	2242	750	500	783	655	708
NEW ORLEANS, LA.	887	469	1947	737	415	1067	1279	1710	549	●	1406	1099	1312	1172	2654	1198	1882	724	1794	574	2300	2731	2471	650	1090	1373	762	1165
NEW YORK, N. Y.	1223	1311	2911	771	1170	931	1261	391	949	1406	●	1295	94	376	3088	1867	563	969	2275	1889	3042	3025	2719	1208	611	495	1408	241
NORTH PLATTE, NEBR.	445	863	1418	971	913	787	589	1611	1009	1332	1580	285	1498	1204	1508	388	1783	699	695	1060	1462	1539	1233	1737	995	1270	575	1445
OMAHA, NEBR.	212	630	1703	710	680	502	379	1326	765	1099	1295	●	1213	919	1793	673	1498	455	980	971	1747	1824	1518	1504	710	975	408	1150
PEORIA, ILL.	353	541	2070	338	461	216	429	986	415	876	920	375	838	544	2168	997	1158	176	1355	1122	2122	2199	1893	1165	359	635	603	775
PHILADELPHIA, PA.	1141	1217	2829	689	1076	849	1179	480	855	1312	94	1213	●	294	3006	1785	652	887	2193	1795	2960	2943	2637	1114	529	480	1326	139
PHOENIX, ARIZ.	1333	1352	394	1830	1493	1905	1678	2653	1714	1553	2527	1343	2445	2160	1413	821	2825	1558	689	994	799	1601	1468	2230	2020	2302	1119	2370
PITTSBURGH, PA.	856	944	2544	404	803	555	885	607	582	1172	376	919	294	●	2712	1500	779	602	1899	1528	2666	2649	2343	1123	235	333	1041	231
PORTLAND, OREG.	1953	2371	1019	2479	2421	2171	1830	2914	2517	2654	3088	1793	3006	2712	●	1464	3086	2207	860	2224	700	188	372	3245	2487	2753	2085	2943
PUEBLO, COLO.	644	914	1264	1170	996	1175	1022	1977	1208	1198	1867	673	1785	1500	1464	●	2149	898	604	859	1371	1541	1262	1824	1352	1626	621	1710
QUEBEC, QUE.	1505	1627	3201	1102	1504	1116	1366	172	1292	1882	563	1498	652	779	3086	2149	●	1267	2478	2211	3245	3020	2714	1766	806	523	1706	799
ROCKFORD, ILL.	479	665	2118	398	571	80	345	943	520	986	930	415	848	554	2175	1088	1115	300	1395	1230	2162	2109	1803	1270	326	592	728	785
ST. LOUIS, MO.	254	365	1942	272	309	374	555	1095	310	724	969	455	887	602	2207	898	1267	●	1390	949	2157	2238	1932	1060	462	744	439	812
SALT LAKE CITY, UTAH	1136	1518	742	1662	1600	1482	1310	2306	1700	1794	2275	980	2193	1899	860	604	2478	1390	●	1364	767	937	758	2424	1690	1955	1225	2130
SAN ANTONIO, TEX.	788	584	1388	1136	725	1323	1266	2039	946	574	1889	971	1795	1528	2224	859	2211	949	1364	●	1793	2301	2122	1251	1406	1688	563	1648
SAN FRANCISCO, CALIF.	1903	2047	405	2433	2188	2249	2077	3073	2409	2300	3042	1747	2960	2666	700	1371	3245	2157	767	1793	●	888	927	2977	2457	2722	1814	2897
SEATTLE, WASH.	1984	2402	1207	2493	2452	2105	1764	2848	2548	2731	3025	1824	2943	2649	188	1541	3020	2238	937	2301	888	●	293	3276	2421	2687	2162	2880
SOUTH BEND, IND.	587	729	2226	261	616	180	510	764	447	1031	746	563	664	370	2340	1216	936	364	1543	1313	2310	2274	1968	1187	147	413	803	601
SPOKANE, WASH.	1678	2096	1265	2187	2146	1799	1458	2542	2242	2471	2719	1518	2637	2343	372	1262	2714	1932	758	2122	927	293	●	2970	2115	2381	1893	2574
SPRINGFIELD, ILL.	311	468	2028	286	388	277	492	1024	361	803	921	421	839	554	2214	955	1196	103	1401	1052	2168	2245	1939	1111	397	673	542	785
TAMPA, FLA.	1292	965	2694	930	782	1305	1615	1594	750	650	1208	1504	1114	1123	3245	1824	1766	1060	2424	1251	2977	3276	2970	●	1171	1456	1258	967
TERRE HAUTE, IND.	424	535	2112	155	419	275	605	925	278	834	799	558	717	432	2351	1068	1097	170	1538	1119	2305	2369	2063	1028	292	574	609	642
TOLEDO, OHIO	708	822	2404	310	699	327	657	634	500	1090	611	710	529	235	2487	1352	806	462	1690	1406	2457	2421	2115	1171	●	283	901	466
TORONTO, ONT.	982	1104	2678	593	981	593	923	351	783	1373	495	975	480	333	2753	1626	523	744	1955	1688	2722	2687	2381	1456	283	●	1183	494
TULSA, OKLA.	269	293	1473	711	434	808	747	1534	655	762	1408	408	1326	1041	2085	621	1706	439	1225	563	1814	2162	1893	1258	901	1183	●	1251
WASHINGTON, D.C.	1066	1070	2754	614	929	786	1116	627	708	1165	241	1150	139	231	2943	1710	799	812	2130	1648	2897	2880	2574	967	466	494	1251	●
WICHITA, KANS.	224	479	1493	750	561	796	692	1557	733	902	1447	561	1365	1080	1899	435	1729	478	1039	661	1806	1976	1707	1385	932	1206	186	1290
WILMINGTON, N. C.	1191	991	2719	665	850	1064	1394	995	629	948	609	1375	515	589	3144	1835	1167	937	2327	1511	3048	3158	2852	627	776	870	1284	368
YELLOWSTONE NAT'L PK.	1085	1548	1065	1656	1570	1451	1110	2089	1694	1890	2265	905	2183	1889	871	692	2366	1343	320	1477	978	781	488	2422	1680	1945	1312	2120

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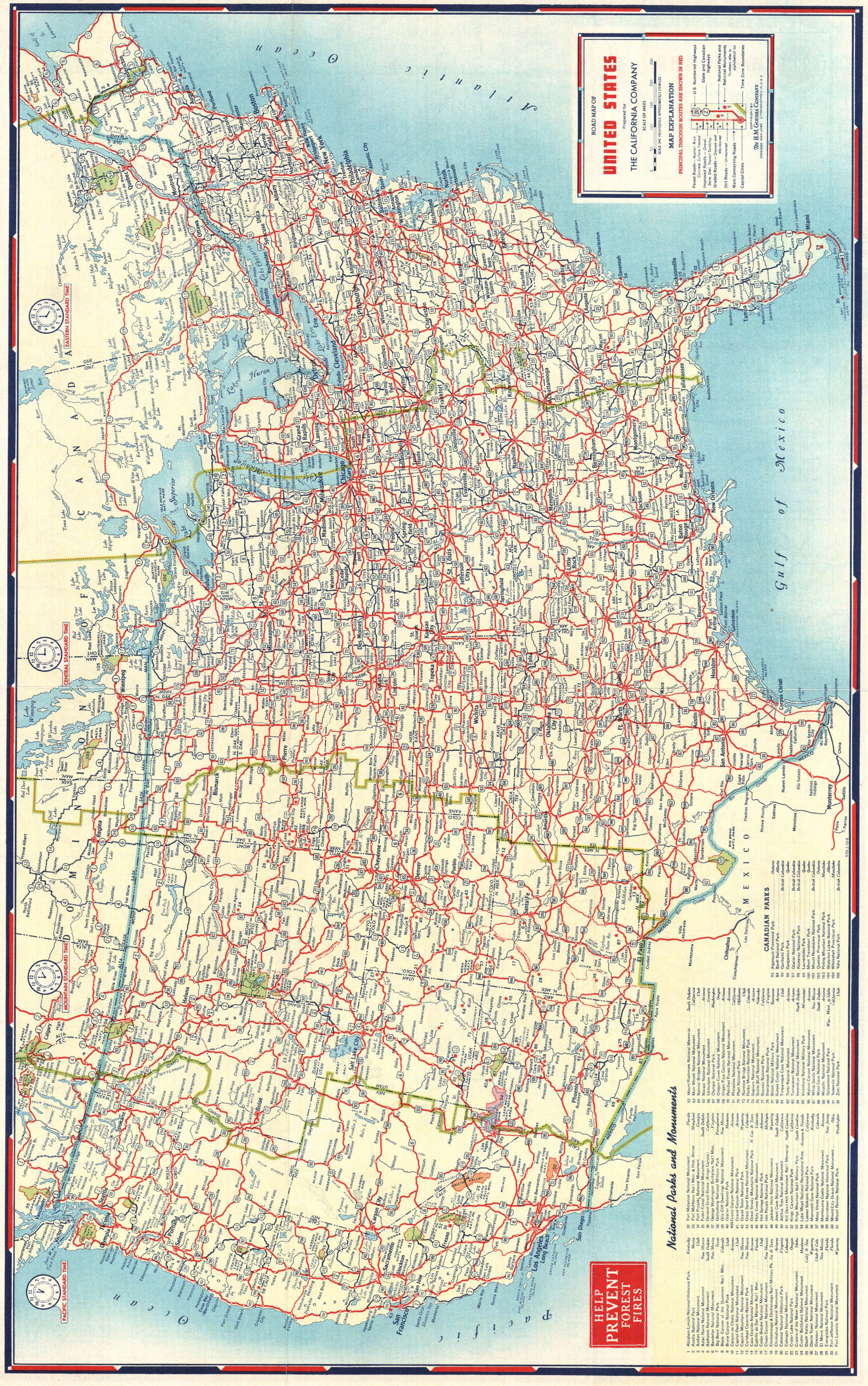
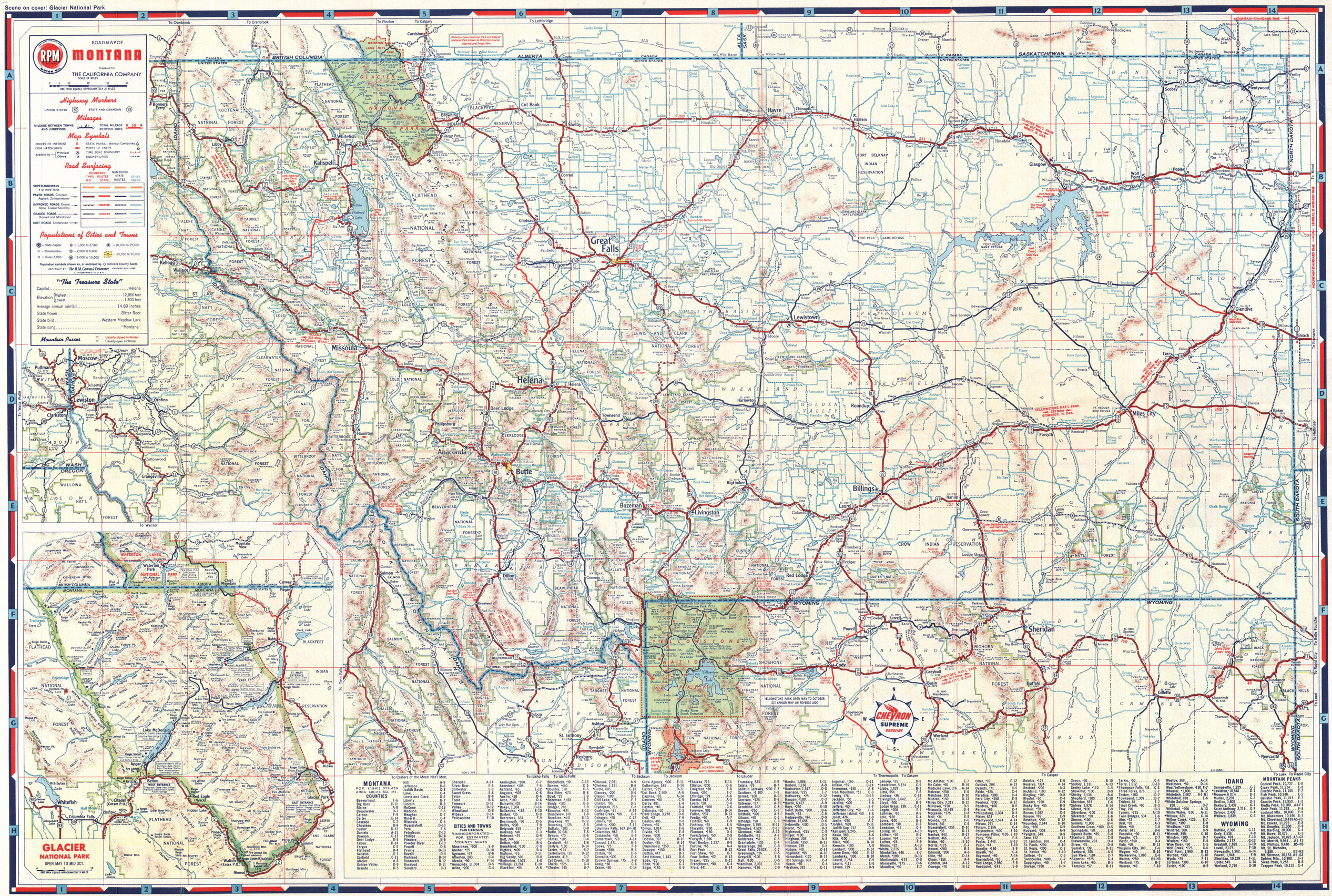
Scene on cover: Glacier National Park