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

BULLETIN NO. 7

GEOCHEMICAL PROSPECTING BY SOIL ANALYSIS IN MONTANA

by FORBES ROBERTSON

With chapter on

CHEMICAL METHODS USEFUL IN PROSPECTING

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

Chemical analyses by
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X-ray spectographic analyses by
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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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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 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.

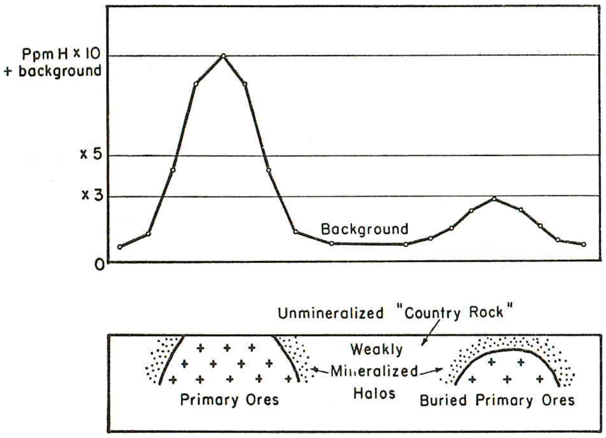

Figure 1. IDEALIZED GEOCHEMICAL HIGH (ANOMALY) OVER EXPOSED AND BURIED ORE

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.

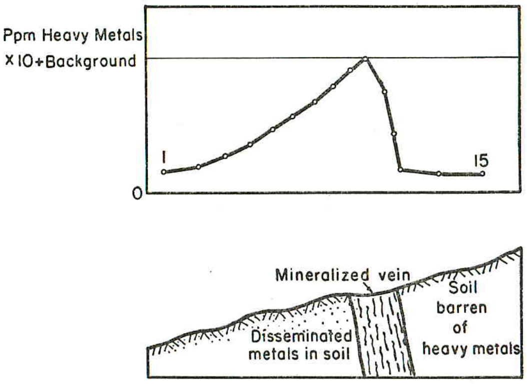

Figure 2. IDEALIZED GEOCHEMICAL HIGH (ANOMALY) OVER MINERALIZED VEIN ON HILLSIDE

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 geochemical 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.

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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.

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 insoluble, 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

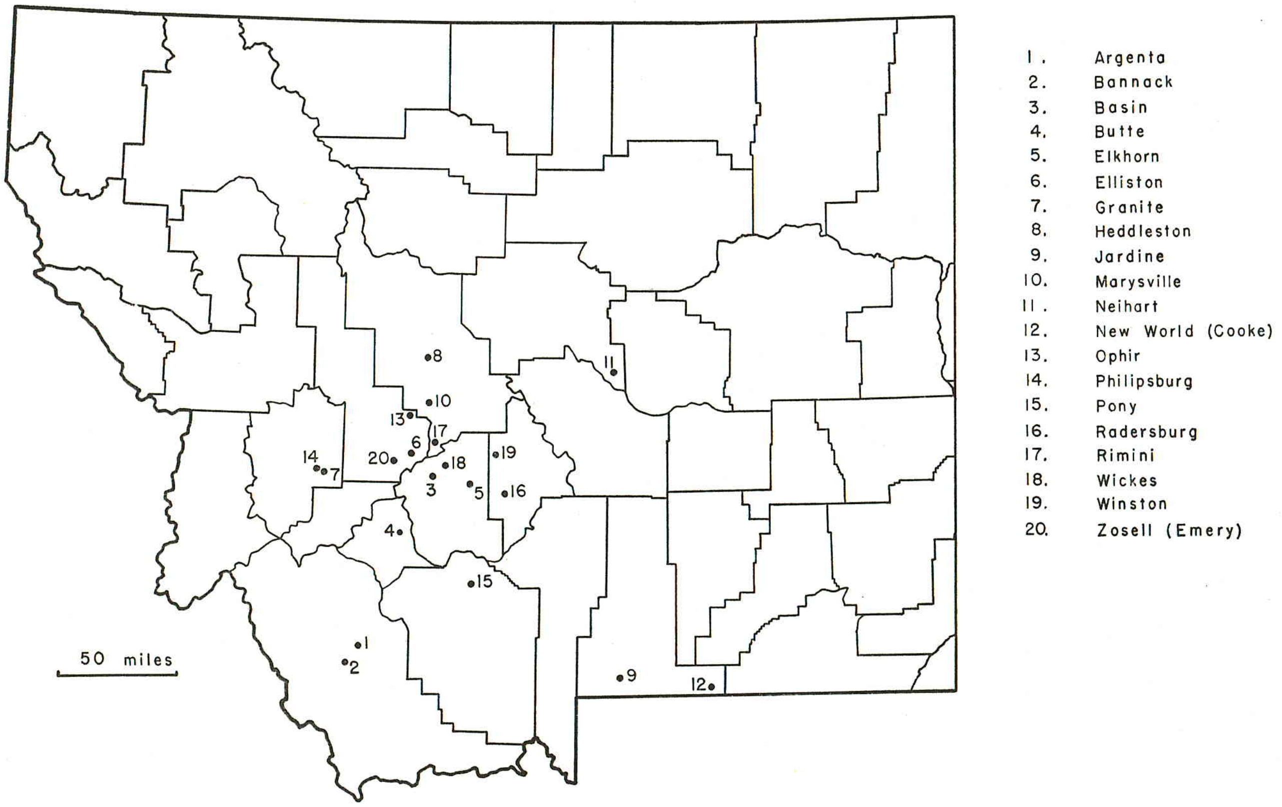


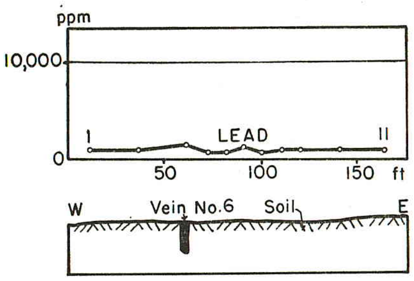
Figure 3 . MINING DISTRICTS IN WHICH GEOCHEMICAL SOIL SAMPLING WAS CONDUCTED FOR THIS INVESTIGATION

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.

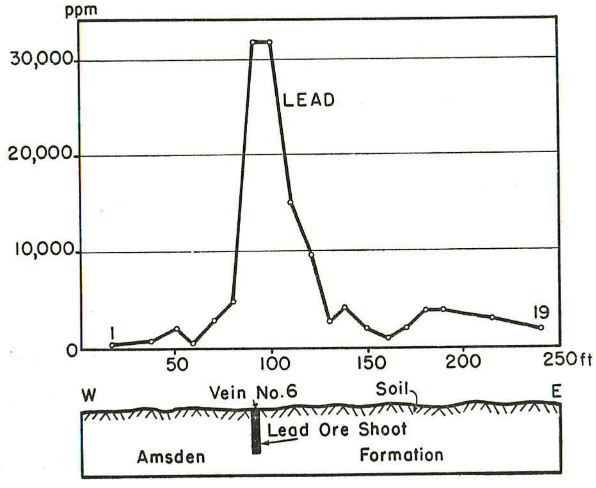
A considerable amount of geochemical work was done at the Hand mine. In addition, two geochemical traverses were made at the Governor Tilden claim, about 2 miles north of the Hand mine.

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.



Barren zone in vein



Ore Shoot in vein

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 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.

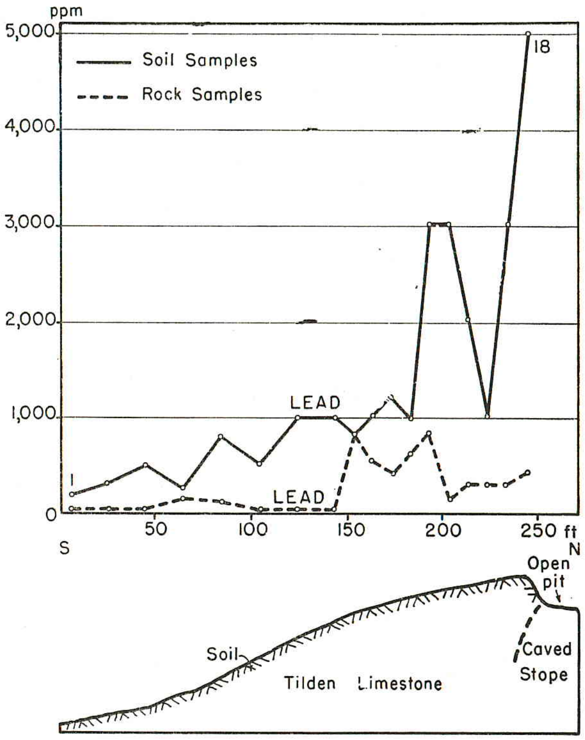


Figure 5. GOVERNOR TILDEN CLAIM ADJACENT TO ORE SHOOT, ARGENTA

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-

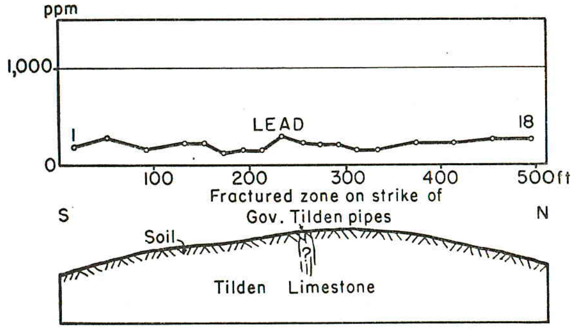


Figure 6. GOVERNOR TILDEN CLAIM OVER BARREN ZONE, ARGENTA

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.

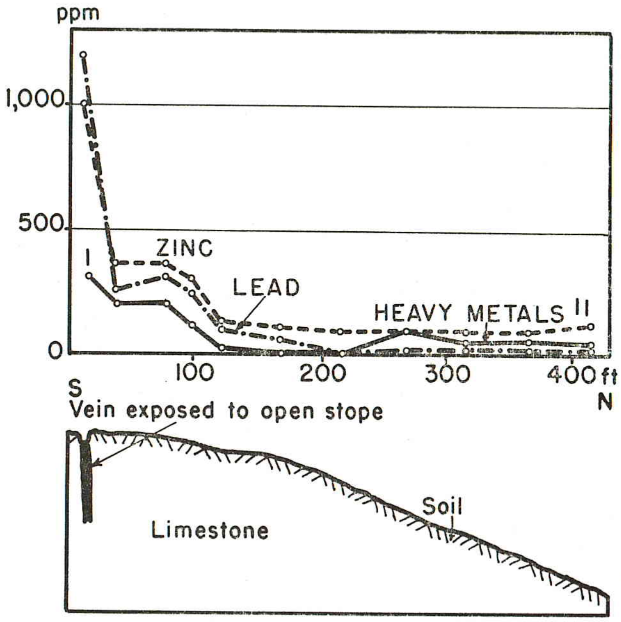


Figure 7. POMEROY VEIN, BANNACK

Table 3—Pomeroy Vein, Bannack

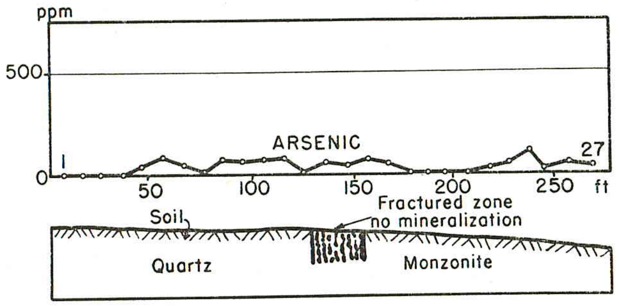
Chemical analyses of grass root soils collected from north edge of open stope on the Pomeroy Vein Sample interval 20 ft. Strike of vein No. 85° E. dips 75° N., traverse bearing N. 10° E., slope variable to 25° as shown in Figure 7. Thick soils support a small stand of Lodgepole pine.

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	

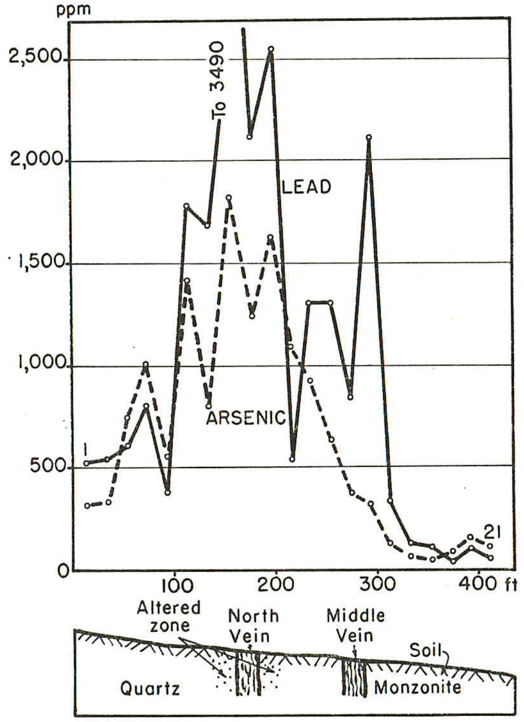
BASIN DISTRICT

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.



Barren zone in Gray Eagle structure



Mineralized zone in Comet structure

Figure 8. GRAY EAGLE-COMET STRUCTURE, BASIN

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

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

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.

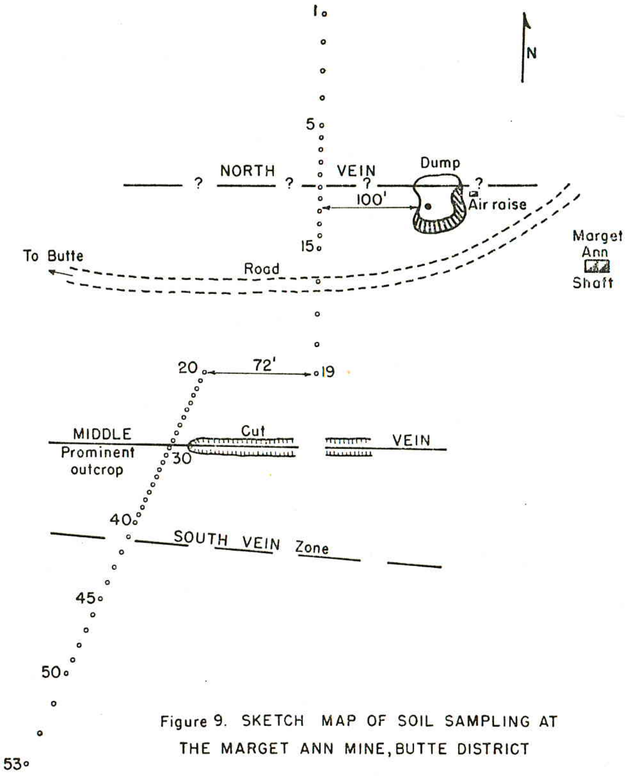


Figure 9. SKETCH MAP OF SOIL SAMPLING AT THE MARGET ANN MINE, BUTTE DISTRICT

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

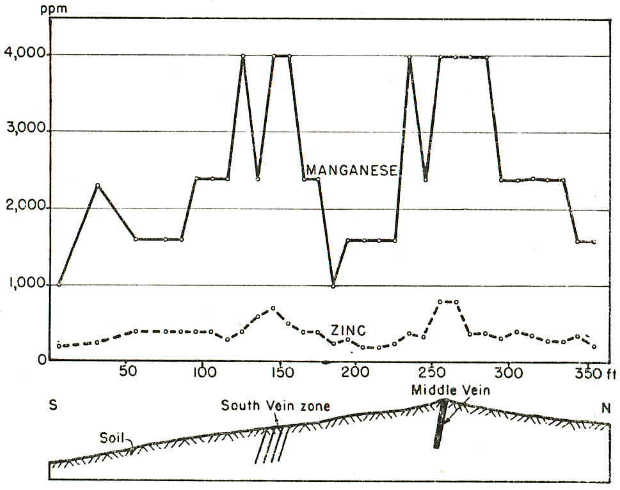


Figure 10 SAMPLE PROFILE, MARGET ANN MINE, BUTTE DISTRICT

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	
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,

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*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)		Zinc, ppm (a)		Remarks
		Original Analysis	Check Analysis	Original Analysis	Check Analysis	
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 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

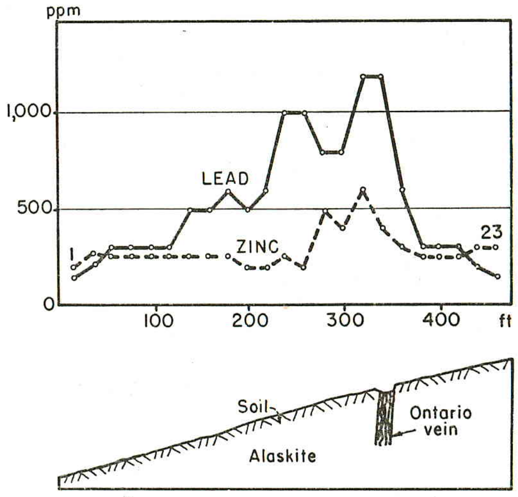


Figure II ONTARIO MINE, ELLISTON

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, 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.

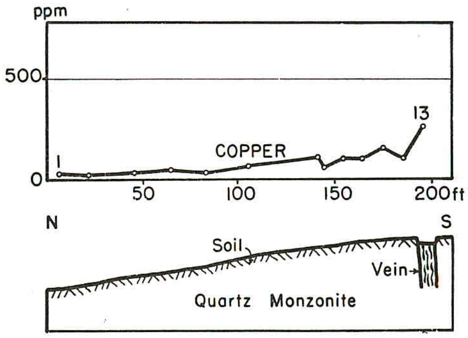


Figure 12. COPPER KING CLAIM, ELLISTON

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

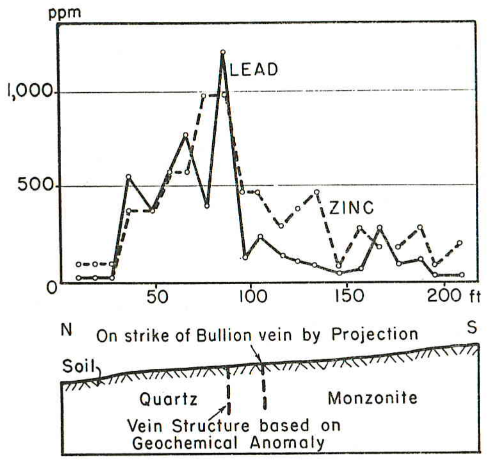


Figure 13. BULLION VEIN, ELLISTON

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.

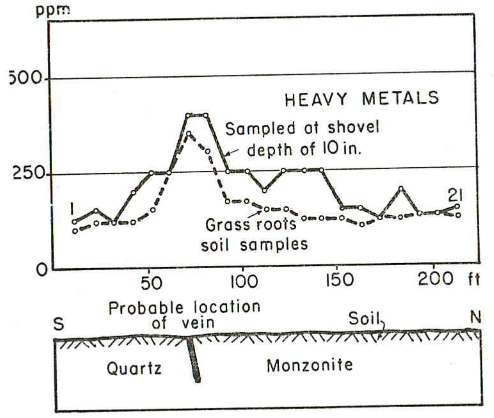


Figure 14. BULLION VEIN, ELLISTON

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-

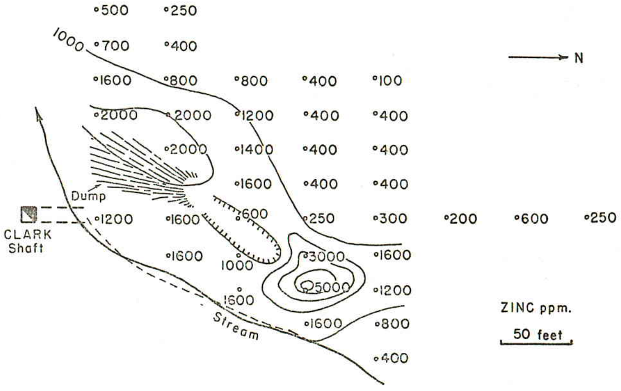


Figure 15. GRID SAMPLE LAYOUT AT THE CLARK MINE, ELLISTON

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 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.

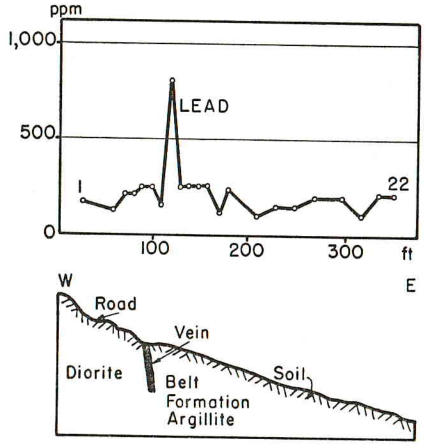


Figure 16. MIKE HORSE MINE, HEDDLESTON

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

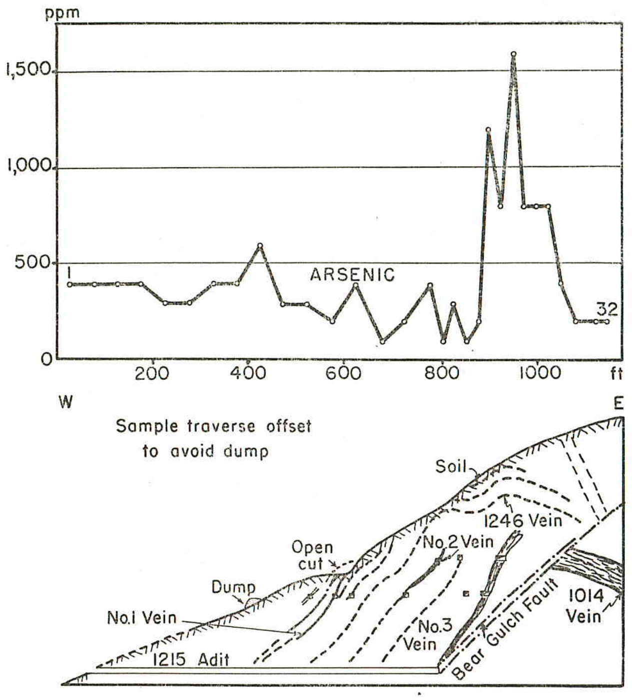


Figure 17. JARDINE MINE, JARDINE

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.

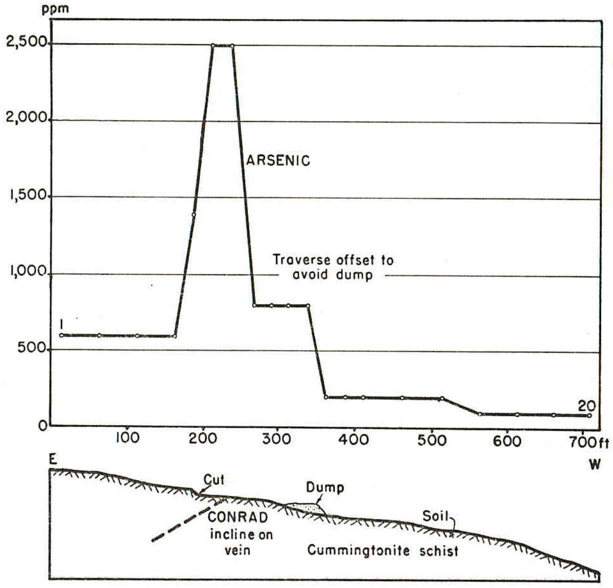


Figure 18. CONRAD INCLINE, CREVASSE MOUNTAIN

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

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.

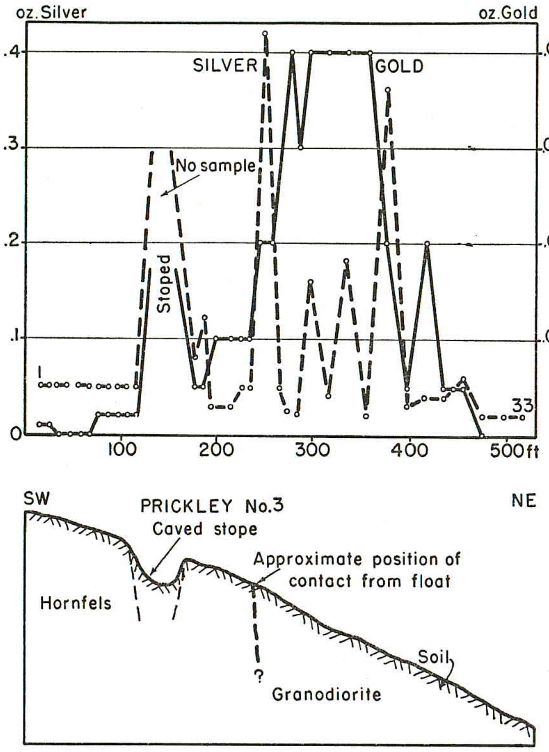


Figure 19. DRUMLUMMON MINE, MARYSVILLE

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 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	

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

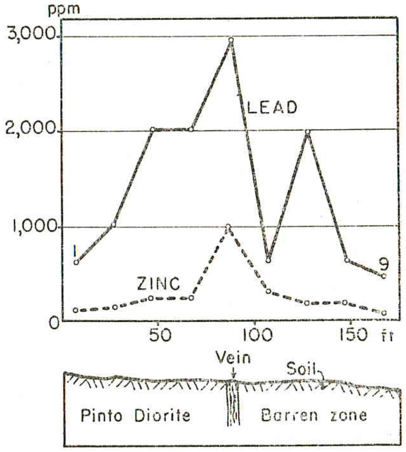
The Neihart mining district is in the central part of the Little Belt Mountains on the headwaters of Belt Creek in Cascade County, Montana. The region is mountainous and the veins crop out at elevations between 4,000 and 7,000 ft. on steep, timber-covered slopes. Though the district was developed principally 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.

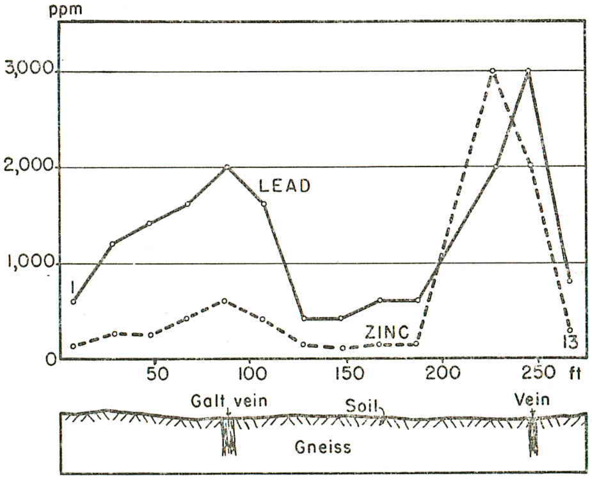
Early Tertiary (?) dikes, sills, and laccoliths cut the pre-Cambrian rocks. The Snow Creek porphyry occurs in dikes, which are frequently encountered in the principal mines. The Carpenter Creek porphyry is a granite porphyry, which occurs in a large number of dikes. Schafer (1935) has described the geology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

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.

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.

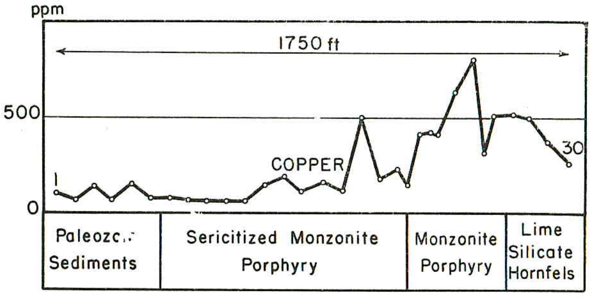


Figure 21. McCLAREN MINE, NEW WORLD

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 Paleozoic sediments)
33	300 " " " "	500	" "
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.

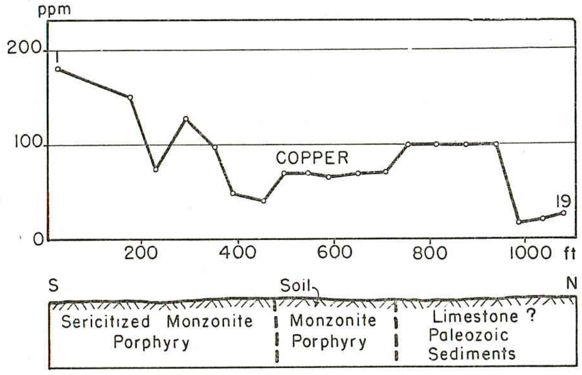


Figure 22. GLENGARRY PROSPECT, NEW WORLD

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	" "

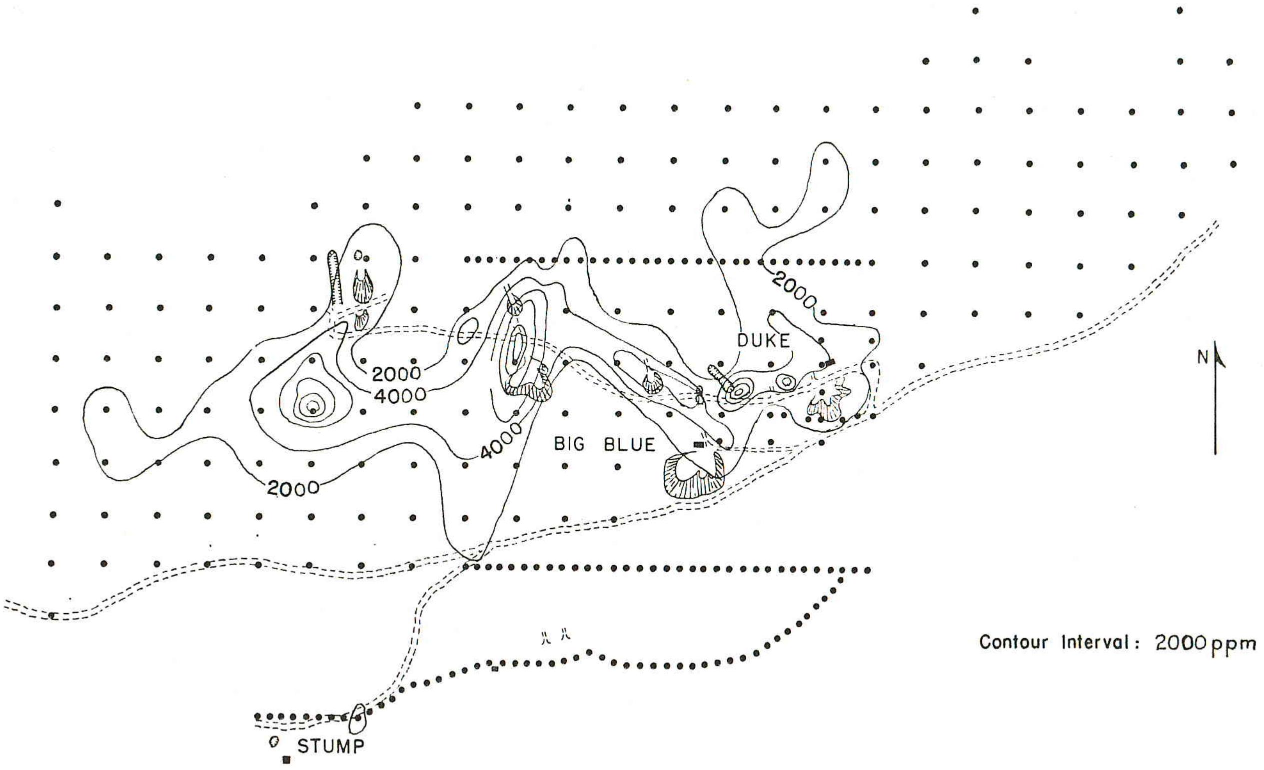


Figure 23. LEAD ANOMALIES ON BIG BLUE AND DUKE CLAIMS, NEW WORLD

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

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 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.

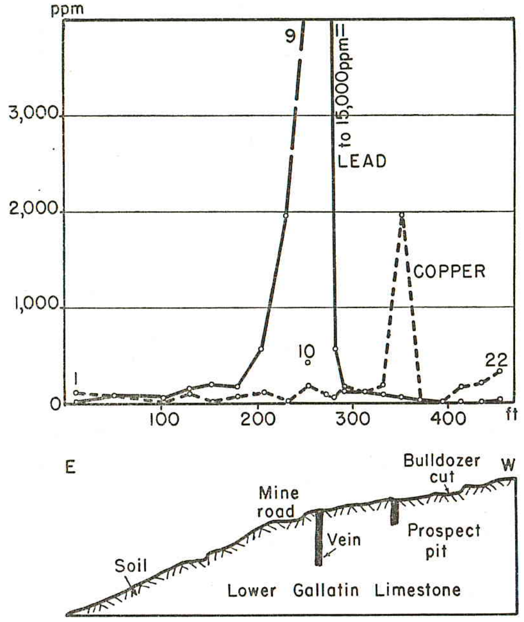
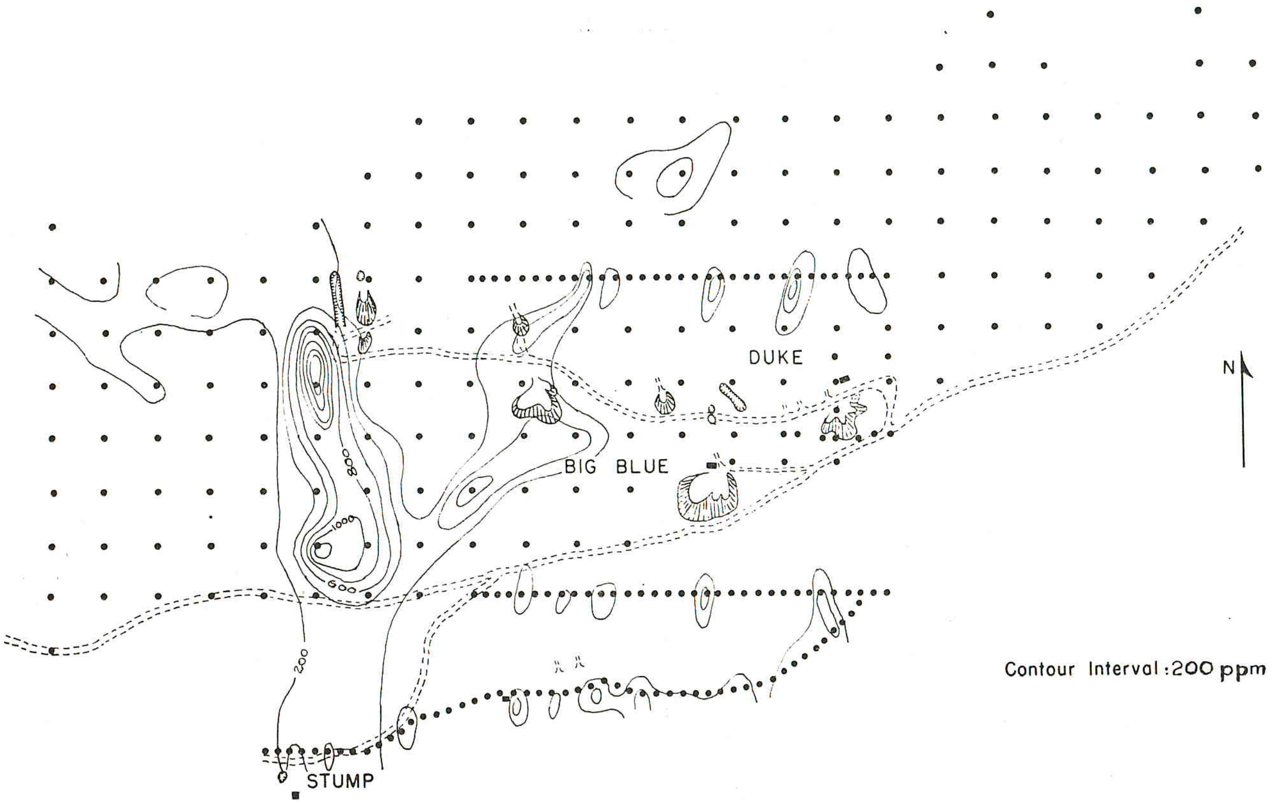


Figure 27. REPUBLIC MINE, COOKE CITY

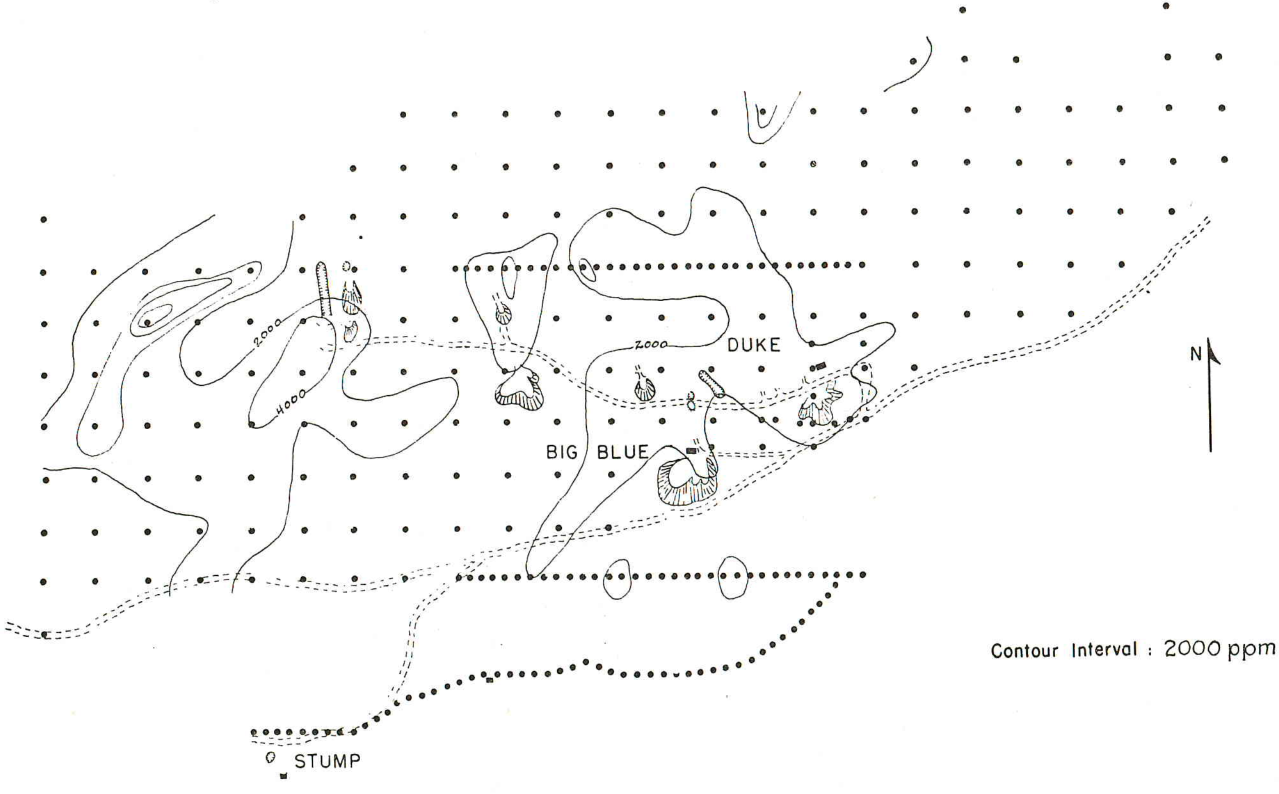
Note a close correspondence in the lead and manganese assays. At the Big Blue and Duke claims it is indicated that manganese and lead may show similar anomalies—yet lead does not necessarily go with manganese, as shown in Figure 26.

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.



Contour Interval:200 ppm

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



Contour Interval : 2000 ppm

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. Overlying 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 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.

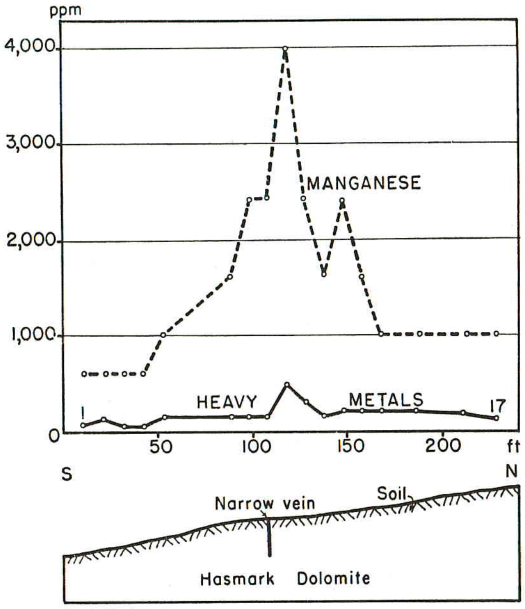


Figure 28. ALGONQUIN VEIN WEST OF MAIN WORKINGS, TROUT MINE, PHILIPSBURG

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

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

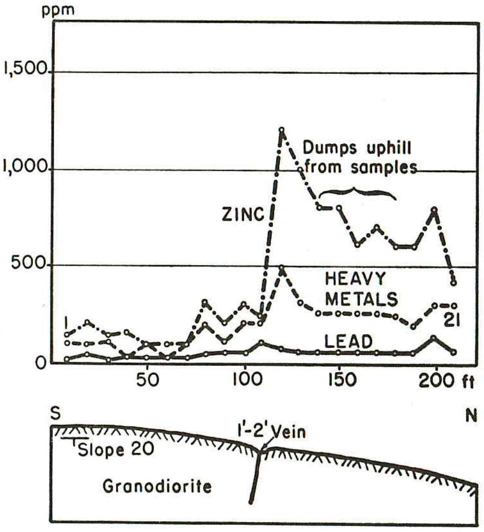


Figure 29. PEARL VEIN EAST OF TROUT MINE, PHILIPSBURG

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.

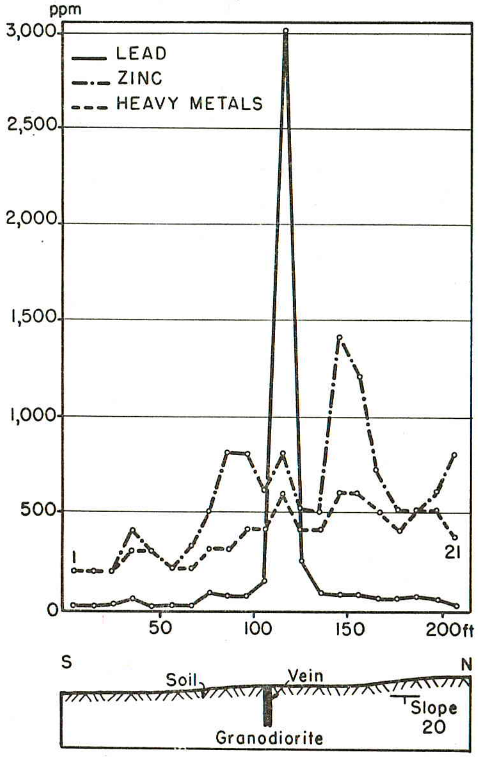


Figure 30. PEARL VEIN EAST OF SHAFT, PHILIPSBURG

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	

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.

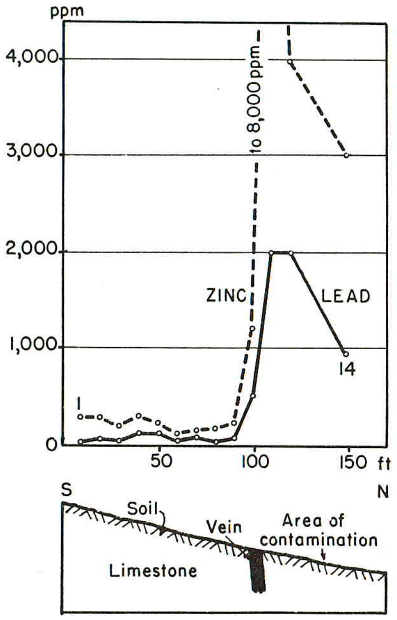


Figure 31. HORTON VEIN, PHILIPSBURG

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.

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.

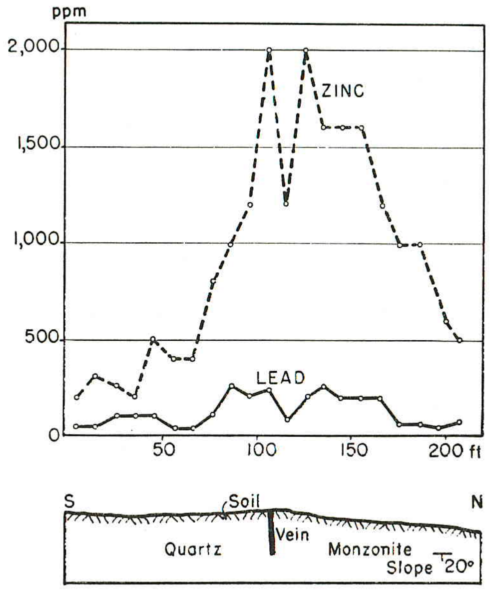


Figure 32. TRUE FISSURE VEIN EAST OF SHAFT, PHILIPSBURG

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	

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° hill-slope, 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.

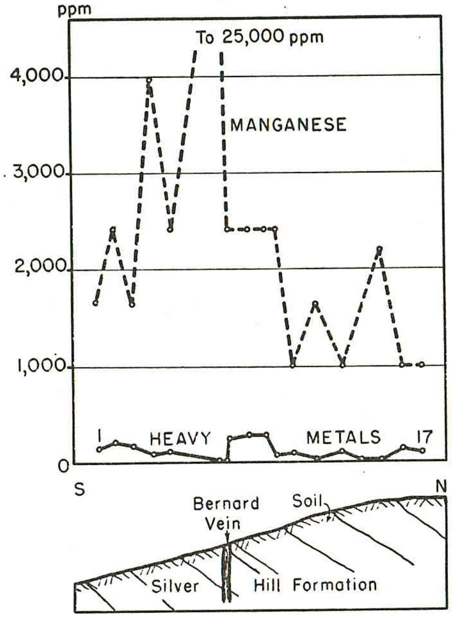


Figure 33. WEST ALGONQUIN, REPLACEMENT LODE, PHILIPSBURG

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 thin soil.
7	N side of vein	130	250	2,400	0	
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	

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.

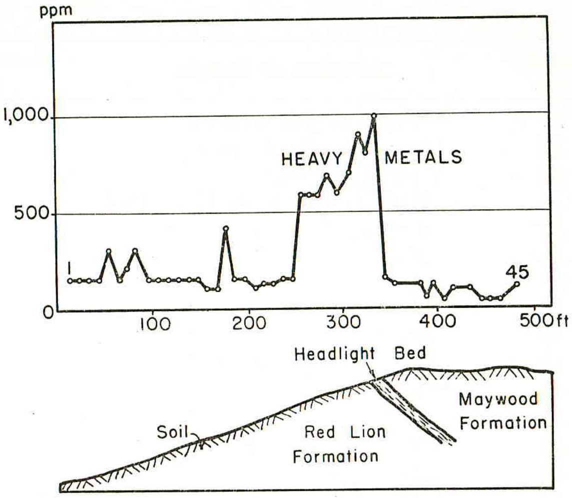


Figure 34. HEADLIGHT BED IN MINERALIZED ZONE AT HEADLIGHT MINE, PHILIPSBURG

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	" " "

Table 32 (Continued)

Sample No.	Location of Sample	Heavy Metals ppm	Manganese ppm	Remarks
31	Downhill side of Bed	900	2400	Headlight Bed
32	Over Headlight Bed	800	8000	" "
33	Uphill side of Bed	1000	8000	" "
34	10 ft. uphill from Hdlt Bed	150	4000	Maywood Formation
35	20 " " " " "	125	4000	" "
36	50 " " " " "	125	4000	" "
37	60 " " " " "	125	4000	" "
38	70 " " " " "	50	1000	" "
39	80 " " " " "	125	2400	" "
40	90 " " " " "	50	1600	" "
41	100 " " " " "	100	8000	" "
42	110 " " " " "	100	1600	" "
43	120 " " " " "	100	2400	" "
44	130 " " " " "	50	1600	" "
45	150 " " " " "	50	1600	" "

A second traverse was made across a barren zone of the "Headlight bed," southeast of the Two Percent workings. The stratigraphic position of the "Headlight bed" is not obvious from the surface float. A 300-ft. traverse line on a 20° slope through a small stand of fir and cedar gave an anomaly which demonstrated the position of the Headlight bed, as shown in Figure 35. The heavy-metal analyses did not reveal the structure, but manganese did. Table 33 lists manganese and heavy-metal analyses. The fact that the Headlight bed can be picked out by geochemical methods may be important in the solution of stratigraphic and structural proglems in regions where outcrops are few.

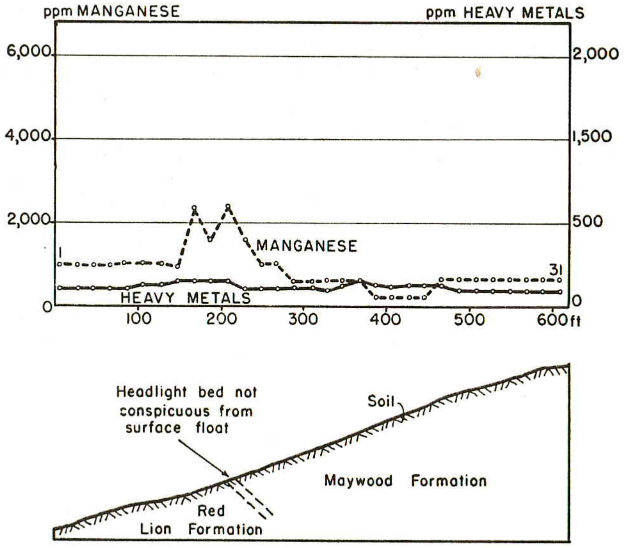


Figure 35. HEADLIGHT BED IN BARREN ZONE EAST OF TWO PERCENT MINE, PHILIPSBURG

Table 33—Headlight Bed (near Two Percent Mine), Philipsburg

Chemical analyses of soil samples collected across a barren zone of the Headlight bed about 500 ft. NE. of Two Percent Shaft. Sample interval 20 ft. on bearing N. 70° W. approximately at right angles to the strike of the sedimentary rocks which dip about 45° NE. Slope 19° to 21°. Thin soils support stands of small fir and cedar.

Sample No.	Location of Sample	Heavy Metals ppm	Manganese ppm	Remarks
1	600 ft. from start of traverse	100	1000	Red Lion Formation
2	580 " " " " "	100	1000	" " "
3	560 " " " " "	100	1000	" " "
4	540 " " " " "	100	1000	" " "
5	520 " " " " "	100	1000	" " "
6	500 " " " " "	125	1000	" " "
7	480 " " " " "	125	1000	" " "

Table 33 (Continued)

Sample No.	Location of Sample	Heavy Metals ppm	Manganese ppm	Remarks
8	460 " " " " "	150	1000	" " "
9	440 " " " " "	150	2400	" " "
10	420 " " " " "	150	1600	Probable position Headlight bed
11	400 " " " " "	150	2400	" " " "
12	380 " " " " "	150	1600	Maywood Formation
13	360 " " " " "	100	1000	" "
14	340 " " " " "	100	1000	" "
15	320 " " " " "	100	600	" "
16	300 " " " " "	100	600	" "
17	280 " " " " "	100	600	" "
18	260 " " " " "	125	600	" "
19	240 " " " " "	150	600	" "
20	220 " " " " "	125	200	" "
21	200 " " " " "	100	200	" "
22	180 " " " " "	125	200	" "
23	160 " " " " "	125	200	" "
24	140 " " " " "	125	600	" "
25	120 " " " " "	100	600	" "
26	100 " " " " "	100	600	" "
27	80 " " " " "	100	600	" "
28	60 " " " " "	100	600	" "
29	40 " " " " "	100	600	" "
30	20 " " " " "	100	600	" "
31	Start of traverse	100	600	" "

Jefferson Limestone-Granodiorite Contact.—Three traverses were made across the granodiorite-Jefferson formation contact: one at the Scratch All mine, another in a presumably barren region north of the True Fissure vein, and a third farther north on the ridge north of the San Francisco mine.

At the Scratch All mine, the geochemical traverse is south of a large "glory hole," which was mined through to the surface for manganese oxide ores. The traverse is 295 ft. on a steep hillslope Several jogs in the trend of the traverse were required to avoid dumps and surface workings. The line of traverse is densely wooded with small fir trees, the soil averaging from 12 to 14 in. in depth. As in other traverses in this district, no strong "heavy-metal" anomaly marks the contact, but an unusually high background was recorded across the entire traverse. A similar situation occurs with manganese, likewise unusually high over the entire area, with two very conspicuous single-point anomalies which could be interpreted as the contact. The position of the contact is best indicated by lead and zinc analyses, as shown in Figure 36. From the physiographic evidence, the contact would probably be drawn at the drainage, about 150 ft. west of the contact. Granodiorite float is found in the hillslope east of the drainage, a fact which serves to corroborate the geochemical contact. Table 34 gives additional analytical data.

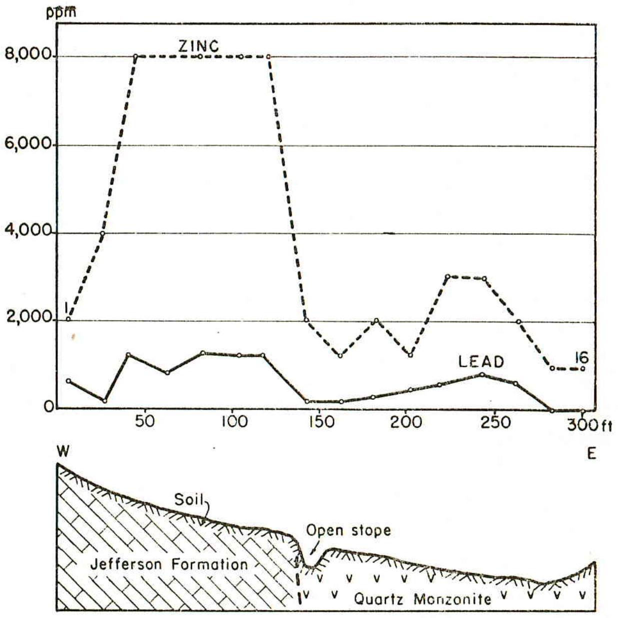


Figure 36. CONTACT AT SCRATCH ALL MINE, PHILIPSBURG

Table 34—Contact at Scratch All Mine, Philipsburg

Chemical analyses of soil samples collected across contact between the Jefferson limestone and the intrusive granodiorite of the Philipsburg batholith at Scratch All mine. Strong manganese mineralization in limestone at or near contact of the granodiorite. Sample interval 20 ft. on line of traverse, about N. 70° E. from a point about 350 ft. NE of Scratch All shaft. Sample interval 20 ft. Soil averages 12 in. Slope variable as shown in Figure 36.

Sample No.	Location of Sample	Lead ppm	Zinc ppm	Manganese ppm	Heavy Metals ppm	Remarks
1	140 ft. W of stope	600	2000	400	800	Jefferson formation
2	120 " " " "	200	4000	1600	800	" "
3	100 " " " "	1200	8000	4000	800	" "
4	80 " " " "	1000	8000	2400	800	" "
5	60 " " " "	1200	8000	2400	800	" "
6	40 " " " "	1200	8000	2400	600	" "
7	25 " " " "	2000	8000	2400	800	" "
8	West side of stope	200	2000	1600	700	Contact between
9	East side of stope	600	2000	9000	800	limestone and
10	20 ft. E of stope	20	1000	200	400	granodiorite (?)
11	40 " " " "	20	1000	200	400	Granodiorite
12	60 " " " "	200	1600	12000	300	"
13	80 " " " "	250	2000	2400	400	"
14	100 " " " "	300	1600	2400	400	"
15	120 " " " "	500	3000	1600	500	"
16	140 " " " "	800	3000	4000	600	"

South of the San Francisco mine and north of the True Fissure mine, an east-west line of soil samples was taken across the contact, in an area where the contact could not be located within a distance of about 200 ft. on a gentle open grassy hillslope. (Note Figure 37.) The soil averaged from 12 to 18 in. in depth, with large blocky float boulders of Jefferson marble throughout the line of samples. As no igneous rock float was found anywhere along the traverse, the writer is convinced that the contact is conspicuously pinpointed as a result of the geochemical sampling as illustrated in Figure 38. The anomaly is marked by lead and zinc and to a less conclusive extent by manganese, as shown in Table 35. An assay for total heavy metals revealed only a high metal background across the entire area. The zinc anomaly is especially high, possibly warranting some exploration at this locality.

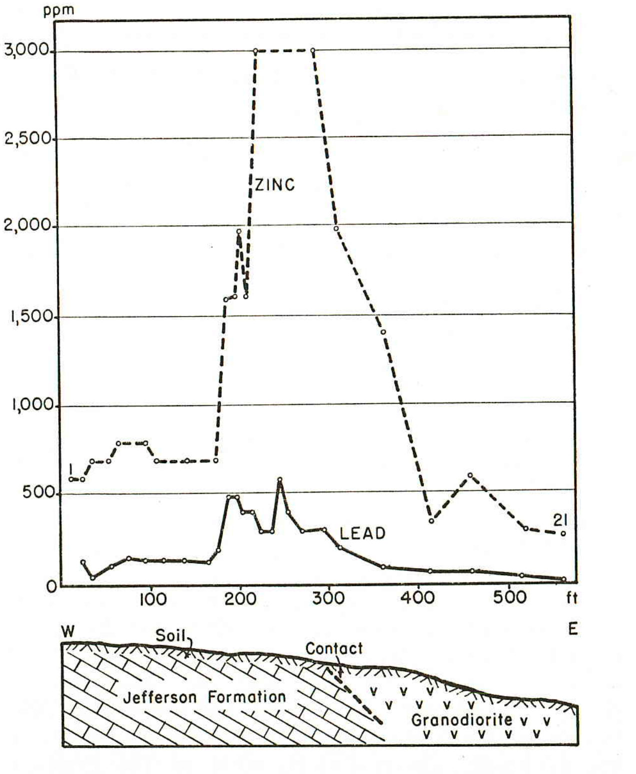


Figure 38. CONTACT BETWEEN TRUE FISSURE AND SAN FRANCISCO MINE, PHILIPSBURG

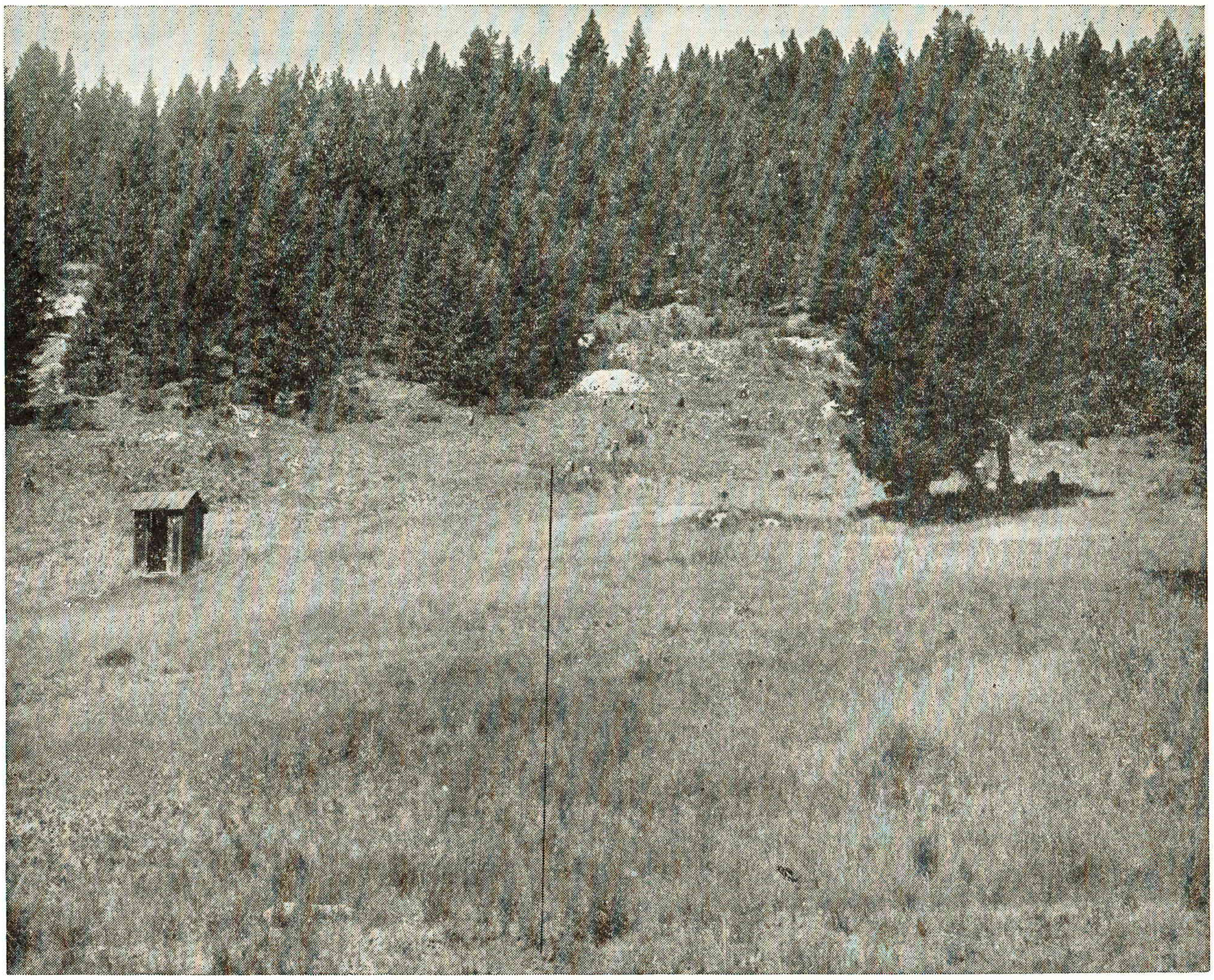


Fig. 37—Grassy slope underlain by contact between granodiorite and limestone, north of True Fissure mine, Philipsburg.

Table 35—Contact between True Fissure and San Francisco Mine, Philipsburg

Chemical analyses of soil samples collected across contact between the Jefferson limestone and the intrusive granodiorite of the Philipsburg batholith at a locality where the contact is not exposed but which is under a grass-covered hill-slope. Sample interval 10, 20 and 50 ft. as shown in Figure 37. Traverse bearing due east on grassy hillslope. Slope angle 5° to 10°, soil averages 12 to 18 in.

Sample No.	Location of Sample	Lead ppm	Zinc ppm	Manganese ppm	Heavy Metals ppm	Remarks
1	West end of traverse	100	800	2400	500	Jefferson Formation
2	20 ft. E of traverse	100	500	1000	500	" "
3	40 " " " "	200	600	1000	500	" "
4	60 " " " "	250	1200	1000	500	" "
5	80 " " " "	100	1400	1600	500	" "
6	100 " " " "	130	600	1600	500	" "
7	120 " " " "	130	600	1600	500	" "
8	140 " " " "	50	700	1000	500	" "
9	160 " " " "	100	700	1000	500	" "
10	180 " " " "	100	700	2400	400	" "

Table 35 (Continued)

Sample No.	Location of Sample	Lead ppm	Zinc ppm	Manganese ppm	Heavy Metals ppm	Remarks
11	200 " " " "	130	800	1600	250	" "
12	220 " " " "	150	800	1600	250	" "
13	240 " " " "	150	800	1600	200	" "
14	260 " " " "	150	800	600	250	" "
15	280 " " " "	130	700	600	250	" "
16	300 " " " "	130	700	1600	250	" "
17	320 " " " "	130	700	1600	250	" "
18	340 " " " "	130	700	1000	250	" "
19	360 " " " "	130	700	1000	250	" "
20	380 " " " "	130	700	1000	250	" "
21	400 " " " "	130	700	1000	250	" "
22	410 " " " "	200	700	1000	200	" "
23	420 " " " "	500	1600	1000	200	" "
24	430 " " " "	500	1600	1000	250	" "
25	440 " " " "	400	2000	1000	300	" "
26	450 " " " "	400	1600	2400	250	" "
27	460 " " " "	300	3000	1000	250	" "
28	470 " " " "	300	3000	1600	250	" "
29	480 " " " "	600	3000	1600	200	" "
30	490 " " " "	400	3000	1000	200	" "
31	500 " " " "	300	3000	2400	250	" "
32	520 " " " "	300	3000	2400	250	" "
33	540 " " " "	200	2000	1600	500	Contact ?
34	590 " " " "	100	1400	1600		Granodiorite
35	640 " " " "	70	350	1600		"
36	690 " " " "	70	600	1600		"
37	740 " " " "	50	300	1000		"
38	790 " " " "	20	300	1000		"

A third series of soil samples was taken across the contact on the ridge north of the San Francisco shaft, in what was hoped to be a completely barren zone. Again, the location of the contact could not be pinpointed on the surface within a hundred feet of the contact. The geochemical anomaly reported in Figure 39 is not broad, but it is definite. Additional analytical data are given in Table 36. From these data, it appears probable that the contact between the granodiorite and the sedimentary rocks can be picked by geochemical sampling, and a systematic sampling of the contact zone may reveal locations for further exploration leading to development of individual ore shoots. These data have structural as well as possibly direct economic significance.

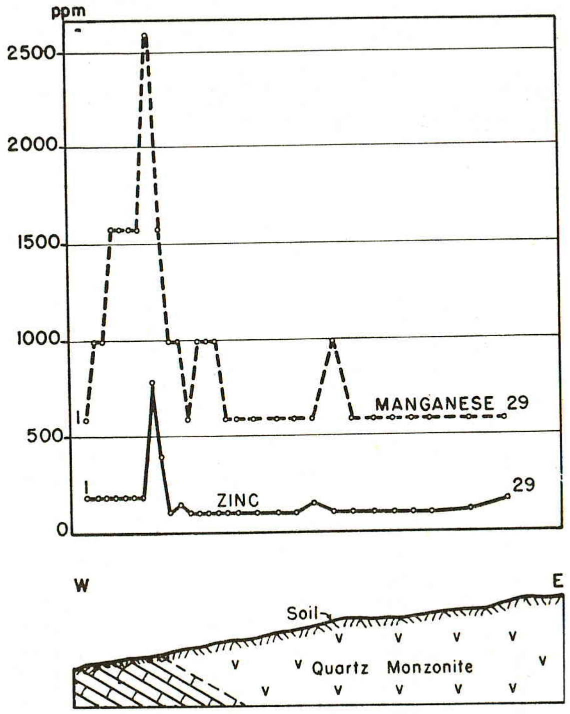


Figure 39. CONTACT ON RIDGE NORTH OF SAN FRANCISCO MINE, PHILIPSBURG

Table 36—Contact on Ridge North of San Francisco Mine, Philipsburg

Chemical analyses of soil samples collected across contact between the Jefferson limestone and the intrusive granodiorite of the Philipsburg batholith in an area presumed to be barren of mineralization, on a ridge north of the San Francisco mine. Sample interval 25, 50 and 100 ft. as shown in Figure 39. The contact is not exposed on the gentle, forested hillslopes of 5° to 10°. Soils thick.

Sample No.	Location of Sample	Lead ppm	Zinc ppm	Manganese ppm	Remarks
1	West end of traverse	10	200	600	Jefferson Formation
2	25 ft. east of traverse	10	200	1000	" "
3	50 " " " "	100	200	1000	" "
4	75 " " " "	20	200	1600	" "
5	100 " " " "	20	200	1600	" "
6	125 " " " "	20	200	1600	" "
7	150 " " " "	20	200	1600	" "
8	175 " " " "	200	800	2400	Contact zone
9	200 " " " "	200	400	1600	Contact zone W end of wood
10	225 " " " "	20	100	1000	Granodiorite
11	250 " " " "	200	150	1000	"
12	275 " " " "	20	100	600	"
13	300 " " " "	20	100	1000	"
14	325 " " " "	20	100	1000	"
15	350 " " " "	20	100	1000	"
16	375 " " " "	20	100	600	"
17	400 " " " "	20	100	600	"
18	450 " " " "	20	100	600	"
19	500 " " " "	20	100	600	"
20	550 " " " "	20	100	600	"
21	600 " " " "	20	150	600	"
22	650 " " " "	20	100	1000	"
23	700 " " " "	10	100	600	"
24	750 " " " "	10	100	600	"
25	800 " " " "	10	100	600	"
26	850 " " " "	10	100	600	"
27	900 " " " "	10	100	600	"
28	1000 " " " "	10	100	600	"
29	1100 " " " "	10	150	600	"
30	1200 " " " "	20	1600	1000	"
31	1300 " " " "	10	250	1000	"

PONY DISTRICT

The Pony district is located about 40 miles southeast of Butte, in the mountains. The rocks of the district include pre-Cambrian schists and gneisses of the Pony series. These have been intruded by quartz monzonite bodies. Gold deposits were developed in the early days of mining. The more recent tungsten discoveries at the Strawberry mine led to the taking of a series of soil samples at the mine for geochemical tests. The geology of the mine is described by Meyer (1954) in an unpublished thesis.

Samples were collected at 10-ft. intervals across the 2½ ft. zone in the schists in which scheelite is exposed in a prospect pit. Tungsten was recorded in the soil samples as shown in Table 37; however, the largest tungsten assays are from soils uphill from the pits in which scheelite is exposed.

Table 37—Strawberry Mine, Pony

Chemical analyses of soil samples collected across 2½ ft. zone of scheelite mineralization. Sample traverse bearing N. 10° E., approximately at right angles to the mineralized zone which dips 60° N. Sample interval 10 and 20 ft. Slope variable at about 15° parallel to the line of traverse. Traverse in open grass and sage-covered slopes. Initial point 50 ft. upslope from new prospect pit. Sample traverse made by Meyer.

Sample No.	Location of Sample	Tungsten ppm	Remarks
1	Start of Traverse	40	
2	10 ft. N	40	
3	20 " "	20	
4	30 " "	20	
5	40 " "	20	Pits with scheelite exposed
6	50 " "	20	
7	60 " "	20	
8	70 " "	20	
9	80 " "	20	
10	90 " "	0	
11	100 " "	0	
12	110 " "	0	
13	120 " "	0	
14	130 " "	0	
15	140 " "	0	
16	160 " "	20	
17	180 " "	0	
18	200 " "	0	
19	220 " "	0	
20	240 " "	0	

RADERSBURG DISTRICT

Geological Setting.—The Radersburg district, also known as the Cedar Plains district, is on the east side of the Elkhorn Mountains just west of the town of Radersburg. Paleozoic and Mesozoic sedimentary rocks are overlain by Upper Cretaceous pyroclastic volcanic rocks. Hornblende-diorite and hornblende-quartz monzonite intrude the older rocks south of Radersburg. Although the principal production has been gold, some rather rich silver-bearing lead deposits occur in favorable limestone beds in small breccia zones and replacement bodies along east-west faults. Typical are the Jo Dandy and Santa Anita deposits. Specific limestone beds in the Quadrant formation are the sites of replacement lodes. The geology of the district is briefly described by Pardee and Schrader (1933). The results of recent work of the U. S. Geological Survey are available in open-file reports on file in the library of Montana School of Mines.

Jo Dandy and Santa Anita Claims.—Three geochemical traverses were made in the district after a successful geochemical traverse had been reported by Klepper of the U. S. Geological Survey. One traverse was made in an east-west direction across the Jo Dandy claim, the results of which are shown in Figure 40. A very strong anomaly for lead shows up at the sites of the workings at the Jo Dandy property. Table 38 gives the pertinent analytical data.

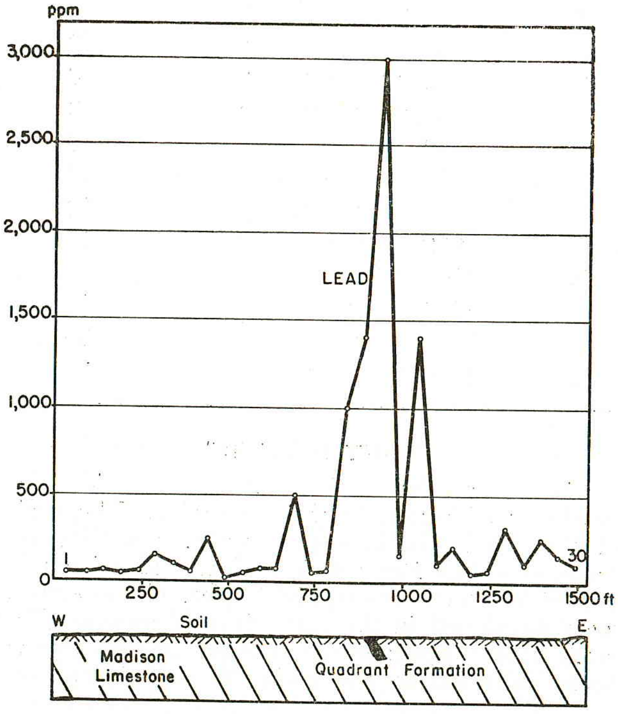


Figure 40 JO DANDY MINE, RADERSBURG

Table 38—Jo Dandy Mine, Radersburg

Chemical analyses of grass-root soil samples collected across the Jo Dandy workings along trail which is more or less parallel to the east-west fracture zone which localized the ore shoots in the Quadrant formation. Traverse bearing approximately east from initial point in Madison formation. Sample interval 25 ft. Soils thin, slope variable but not great.

Sample No.	Location of Sample	Lead ppm	Remarks
1	W end of traverse	50	Madison formation
2	25 ft. E	50	" "
3	50 " "	70	" "
4	75 " "	50	" "
5	100 " "	70	" "
6	125 " "	150	" "
7	150 " "	100	" "
8	175 " "	50	" "
9	200 " "	250	" "
10	225 " "	20	" "
11	250 " "	50	" "
12	275 " "	70	Quadrant formation?
13	300 " "	500	" "
14	325 " "	500	" "
15	350 " "	50	Quartzite
16	375 " "	70	"
17	400 " "	1000	Open stopes to north
18	425 " "	1400	" " " "
19	450 " "	3000	" " " "
20	475 " "	150	Quartzite
21	500 " "	1400	Open stopes to north
22	525 " "	100	Quadrant formation
23	550 " "	200	" "
24	575 " "	50	" "
25	600 " "	70	" "
26	625 " "	300	" "
27	650 " "	100	" "
28	675 " "	250	" "
29	700 " "	150	Igneous sill in Quadrant formation
30	E end of traverse	70	Quadrant formation

Table 39—Jo Dandy and Santa Anita Mines, Radersburg

Chemical analyses of grass-root soil samples collected from the Jo Dandy to Santa Anita mines. Mineralization is localized in limestone members of the Quadrant formation on each side of quartzite bed. Table 39a, analyses of soils from limestone member are foot below base of massive quartzite. Table 39b, analyses of soils from limestone member above massive quartzite. Traverse line approximately north, but sample location controlled by stratigraphic position. Sample interval variable. Slope variable. Soils thin. The data are combined in Figure 41.

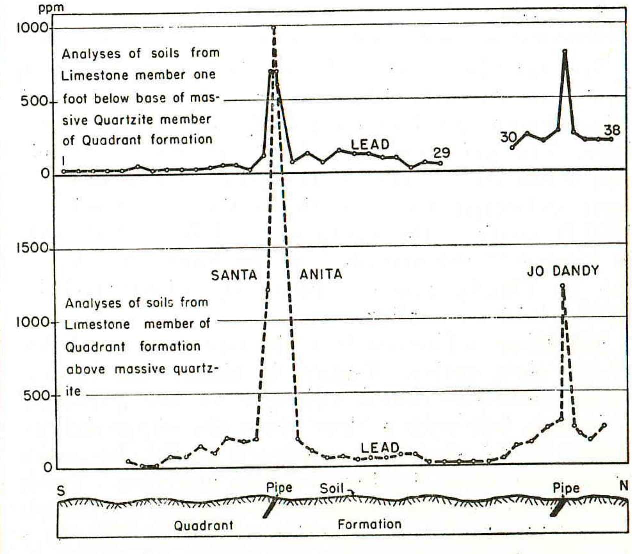


Figure 41 SANTA ANITA - JO DANDY CLAIMS, RADERSBURG

Table 39a

Sample No.	Location of Sample	Lead ppm	Remarks
1	700 ft. S of Santa Anita	20	
2	650 " " " " "	20	
3	600 " " " " "	20	
4	550 " " " " "	20	
5	500 " " " " "	20	Fault zone
6	450 " " " " "	20	
7	400 " " " " "	50	
8	350 " " " " "	20	
9	300 " " " " "	20	
10	250 " " " " "	20	
11	200 " " " " "	20	
12	150 " " " " "	50	
13	100 " " " " "	50	
14	50 " " " " "	20	
15	25 " " " " "	130	
16	Santa Anita workings	700	
17	" " "	700	
18	" " "	600	
19	50 ft. N of Santa Anita	70	
20	100 " " " " "	130	
21	150 " " " " "	70	
22	200 " " " " "	150	
23	250 " " " " "	130	
24	300 " " " " "	130	
25	350 " " " " "	100	Fault zone
26	400 " " " " "	100	
27	450 " " " " "	20	
28	500 " " " " "	70	Fault zone
29	550 " " " " "	50	
30	175 ft. S of Jo Dandy	150	
31	125 " " " " "	250	
32	75 " " " " "	200	
33	25 " " " " "	250	
34	Jo Dandy workings	800	
35	25 ft. N of Jo Dandy	250	
36	50 " " " " "	200	
37	75 " " " " "	200	
38	100 " " " " "	200	

Table 39b

Sample No.	Location of Sample	Lead ppm	Remarks
1	500 ft. S of Santa Anita	50	Fault zone
2	450 " " " " "	20	
3	400 " " " " "	20	
4	350 " " " " "	70	
5	300 " " " " "	70	
6	250 " " " " "	150	
7	200 " " " " "	100	
8	150 " " " " "	200	
9	100 " " " " "	180	
10	50 " " " " "	180	
11	25 " " " " "	1200	
12	Santa Anita workings	3000	
13	50 ft. N of Santa Anita	800	
14	100 " " " " "	150	
15	150 " " " " "	100	
16	200 " " " " "	50	
17	250 " " " " "	70	
18	300 " " " " "	50	
19	350 " " " " "	50	
20	400 " " " " "	50	Fault zone
21	450 " " " " "	70	
22	500 " " " " "	70	Fault zone
23	500 ft. S of Jo Dandy	20	
24	450 " " " " "	20	
25	400 " " " " "	20	
26	350 " " " " "	20	
27	300 " " " " "	20	
28	250 " " " " "	50	
29	200 " " " " "	130	
30	150 " " " " "	150	
31	100 " " " " "	250	
32	50 " " " " "	300	
33	Jo Dandy workings	1200	
34	25 ft. N of Jo Dandy	400	
35	50 " " " " "	200	
36	75 " " " " "	150	
37	100 " " " " "	250	

Soil samples were collected from two limestone beds, one on each side of a massive quartzite bed, which crops out just west of the Jo Dandy workings. The principal ore shoots at the Jo Dandy and Santa Anita occur in these beds. The samples were collected from north of the Jo Dandy to 1500 ft. south of the Santa Anita claims. Note that in Figure 41 the structure at the Santa Anita and the Jo Dandy are conspicuously illustrated by strong lead anomalies.

Ida Mine.—The Ida is in the Greyson formation of the Belt series. Figure 42 shows the heavy-metal anomaly found adjacent to the principal workings, but with a "low" over the supposed ore shoot. Lead and zinc analyses might be more significant than the heavy-metal analyses. Table 40a lists the analyses of the soils over the ore shoot; no heavy-metal concentration was recorded in a traverse made across the vein trend about 500 ft. north in a barren zone (see Table 40b), and only relatively low concentrations of heavy metals were obtained from a series of samples collected along the strike of the vein from the stope to the barren zone traverse, with analyses from 250 to 50 ppm.

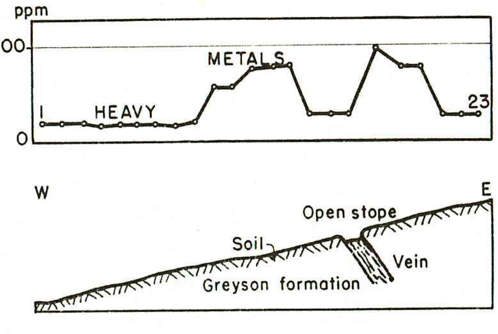


Figure 42. IDA CLAIM, RADERSBURG

Table 40—Ida Mine, Radersburg

Chemical analyses of grass-root soil samples collected at the Ida mnie. Table 40a represents samples collected across mineralized zone, and Table 40b across barren zone, 500 ft. north of the open stope. Table 40a, samples collected on traverse bearing S. 85° W. approximately at right angles to the strike of the Ida vein. Sample interval 10 ft. on slope of about 15°. Thin, rocky soils, grass and sagebrush cover. Table 40b, samples collected on traverse line S. 78° W., sample interval 20 ft. Slope variable 0° to 10°. Same sampling conditions as at traverse 40a.

Table 40a

Sample No.	Location of Sample	Heavy Metals ppm	Remarks
1	160 ft. W of stope	100	Bottom of drainage
2	150 " " " "	100	
3	140 " " " "	100	
4	130 " " " "	100	
5	120 " " " "	100	
6	110 " " " "	100	
7	100 " " " "	100	
8	90 " " " "	100	
9	80 " " " "	100	
10	70 " " " "	300	
11	60 " " " "	300	
12	50 " " " "	400	
13	40 " " " "	400	
14	30 " " " "	400	
15	20 " " " "	150	In part dump
16	10 " " " "	150	" " "
17	W side of stope	150	" " "
18	10 ft. E of stope	500	
19	20 " " " "	400	
20	30 " " " "	400	
21	40 " " " "	150	
22	50 " " " "	150	
23	60 " " " "	150	

Table 40b

Sample No.	Location of Sample	Heavy Metals ppm
1	100 ft. above vein	100
2	80 " " "	100
3	60 " " "	100
4	40 " " "	100
5	20 " " "	100
6	Over vein	125
7	20 " " "	100
8	40 " " "	100
9	60 " " "	100
10	80 " " "	100
11	100 " " "	100

Ruby Claim.—The mineralization of the Ruby claim apparently occures in a favorable bed in the Madison limestone. Samples were collected on a bearing No. 80° E. at 10-ft. intervals from a point 30 ft. north and from 30 to 40 ft. west of the raise in which mineralization extended to surface. The soils are quite thick and free from float pebbles. Grass-root samples were collected. No conspicuous anomaly was recorded by the heavy-metal analysis, but the soils contain a high metal content from 400 to 1200 ppm. Lead analyses might well pinpoint the deposit.

RIMINI DISTRICT

The Rimini district is about 14 miles southwest of Helena in the northern part of the Boulder batholith. In this area the Lee Mountain lode is the only one sampled for geochemical studies. The geology of the district is described by Pardee and Schrader (1933, pp. 246-264). The results of recent work of the U. S. Geological Survey are not yet available. The mineral deposits at Lee Mountain occur in a shear zone 60 ft. wide, which strikes 60° E. and dips 80° S. Quartz, tourmaline, and pyrite are the principal minerals in the structure. The quartz monzonite wallrock is intensively sericitized. A considarable amount of gold is reported to have been taken from the mine in the immediate area of the traverse.

The soil is relatively thick along the traverse, which is in a saddle near the crest of the mountain west of the main workings on the west side of the valley. Initial geo-

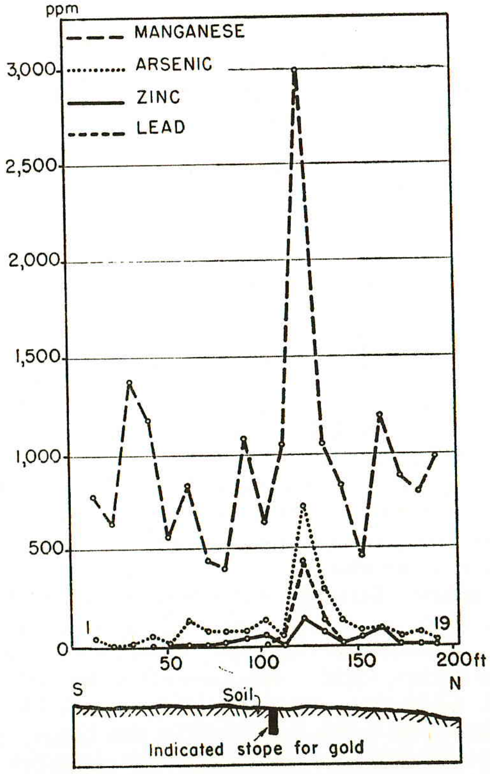


Figure 43. LEE MOUNTAIN MINE, RIMINI

chemical work, with total heavy-metals, was completely negative. Detailed analyses by X-ray spectrographic methods indicate a distinct anomaly for lead, zinc, arsenic, and manganese about 20 ft. north of the indicated position of the gold ore shoot. It appears possible that the heavy metals are concentrated at the north margin of the vein. Commonly, the base-metal ore shoots are found at one wall of the large quartz-pyrite veins; they are not pervasive throughout the vein structures. Figure 43 shows the base-metal anomaly at the property; the analytical data are given in Table 41. In this instance, striking anomalies are manifest in all of the metals tested.

Table 41 is especially interesting, in that, in this instance, it demonstrates the insensitivity of the combined heavy-metals chemical test. The combined heavy-metals test is reported to give good results in certain localities; however, in others, such as west of western Montana (based on the experience of this investigation), the method lacks the sensitivity normally required to pinpoint an anomaly. For example, Sample 2 has a combined lead-zinc X-ray spectrographic analyses value of zero ppm, (less than sensitivity of instrument), whereas the combined heavy metals is 150 ppm. Sample 12 has a 585 ppm lead-zinc by X-ray spectrographic analysis, where the heavy-metal chemical is reported as zero. We do not have a satisfactory explanation for this extremely erratic result.

Table 41—Lee Mountain Mine, Rimini

Analyses of soil samples collected across stoped area on vein at Lee Mountain mine, (a) chemical analyses, (b) X-ray spectrographic analyses. Traverse bearing N. 15° W. across vein, 35 ft. E. of raise on vein which strikes N. 50°-60° E. Sample interval 10 ft. Soils 6-12 in. with small pebbles. Slope 5° in area of lodgepole pine.

Sample No.	Location of Sample	Lead ppm (b)	Zinc ppm (b)	Manganese ppm (b)	Arsenic ppm (b)	Heavy Metals ppm (a)
1	90 ft. S of stope	0	10	798	69	50
2	80 “ “ “ “	0	0	643	16	150
3	70 “ “ “ “	8	94	1380	23	150
4	60 “ “ “ “	12	13	1190	77	100
5	50 “ “ “ “	0	0	580	28	150
6	40 “ “ “ “	8	27	840	131	50
7	30 “ “ “ “	0	0	434	77	140
8	20 “ “ “ “	0	12	413	85	150
9	10 “ “ “ “	92	28	1090	169	0
10	S side of caved stope	0	45	658	131	150
11	10 ft. N of stope	35	0	1060	54	0
12	20 “ “ “ “	442	143	3080	732	0
13	30 “ “ “ “	131	80	1050	308	0
14	40 “ “ “ “	0	0	812	115	0
15	50 “ “ “ “	42	39	469	77	0
16	60 “ “ “ “	0	96	1190	100	250
17	70 “ “ “ “	35	0	867	62	300
18	80 “ “ “ “	0	0	798	77	50
19	90 “ “ “ “	0	0	980	31	150

WICKES DISTRICT

The Wickes district is one of the important districts in the northern part of the Boulder batholith. Lying about 20 miles south of Helena, it has produced important amounts of silver, gold, lead, and some zinc.

Geological Setting. — Pre-batholithic andesitic rocks occur as a roof pendant surrounded by quartz monzonite of the Boulder batholith. Quartz veins and replacement lodes cut the altered andesites and contain the principal ore deposits. The veins extend into the quartz monzonite, but are not generally so productive in the granite rocks as in the volcanic rocks. Aplite is abundant, particularly on the east side of the pendant adjacent to the andesite-quartz monzonite contact. The andesites are locally altered to dense felsites near the contact. Dacite flows, tuffs, and dikes occur in the central part of the district, their location probably controlled by an early Tertiary drainage. The dikes trend northeasterly.

The geology is described by Pardee and Schrader (1933:232-245). The district has recently been mapped in detail by Klepper and others, but the results of their work are not yet available. Geochemical traverses were made on the Mount Washington-Bluebird vein system, the Gregory vein, and across a series of veins in the western part of the district which show no significant mineralization but which are strong structures. In addition, a considerable amount of sampling was done to determine "background" and the heavy-metal distribution in the intensely hydrothermally altered andesite in this district.

Mount Washington-Bluebird Structure. — The Mount Washington vein system, more than 12,000 ft. long, has been explored to a depth of 1050 ft. at the Mount Washington shaft. Over much of its length, the structure is a composite vein, whose strike is almost due east, with the dip about 80° N., the width ranging from about 10 ft. up to 20 or 25 ft. in individual shoots. The principal vein minerals include pyrite, galena, sphalerite, chalcopyrite, tetrahedrite, and arsenopyrite. Quartz and calcite occur as gangue minerals along with crushed and altered andesite wall rock. The geochemical traverse at the Mount Washington vein was made near the shaft across a stoped area which reached the surface. A strong geochemical anomaly was recorded for lead and zinc, as shown in Figure 44. The entire vein zone appears to have heavy metals in more than normal amounts. Table 42 lists the analyses for lead, zinc, and heavy metals.

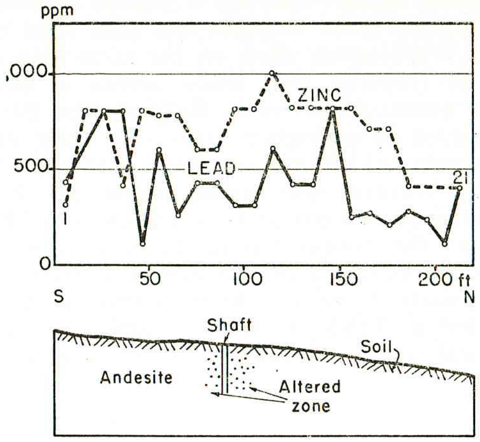


Figure 44. MOUNT WASHINGTON MINE, WICKES

Table 42—Mount Washington Mine, Wickes

Chemical analyses of soil samples collected across vein structure close to the shaft at the Mount Washington mine. Vein strike N. 70° W. Samples collected at 10 and 20 ft. intervals on bearing S. 20° E. on grassy slope of 0 to 5°. The soils average 6-8 in. in depth with a large amount of small pebbles.

Sample No.	Location of Sample	Lead ppm	Zinc ppm	Heavy Metals ppm	Remarks
1	150 ft. S of shaft	400	300	200	
2	140 “ “ “ “	600	800	350	
3	120 “ “ “ “	800	800	500	
4	100 “ “ “ “	800	400	600	
5	90 “ “ “ “	400	400	200	
6	80 “ “ “ “	100	400	200	
7	70 “ “ “ “	250	400	400	
8	60 “ “ “ “	300	700	400	
9	50 “ “ “ “	200	700	500	
10	40 “ “ “ “	250	700	500	
11	30 “ “ “ “	250	800	500	
12	20 “ “ “ “	600	800	600	Altered zone
13	10 “ “ “ “	800	800	1000	“ “
14	Beside shaft	400	800	500	“ “
15	10 ft. N of shaft	400	800	600	“ “
16	20 “ “ “ “	500	800	600	“ “
17	30 “ “ “ “	600	800	600	“ “
18	40 “ “ “ “	1600?	300	800	“ “
19	50 “ “ “ “	300	800	800	
20	60 “ “ “ “	300	600	400	
21	70 “ “ “ “	400	600	400	
22	80 “ “ “ “	400	600	400	
23	90 “ “ “ “	250	800	400	
24	100 “ “ “ “	500	800	400	
25	120 “ “ “ “	600	800	400	
26	140 “ “ “ “	100	800	300	
27	160 “ “ “ “	300	700	400	

Bluebird Mine.—Having a similar mineralogy, the Bluebird mine is about one mile west of the Mount Washington shaft on the same vein structure. A traverse was made across a strongly altered quartz-pyrite vein. Between the Bluebird and Mount Washington veins is a long stretch of the vein which has not been fully developed. Another traverse was made across the vein in what was considered to be a barren zone. Figure 45 shows the anomaly over the main vein structure at the Bluebird vein; however, a distinct copper anomaly is shown 30 ft. south of the vein. As listed in Table 43, a considerable amount of analytical work was done on this traverse.

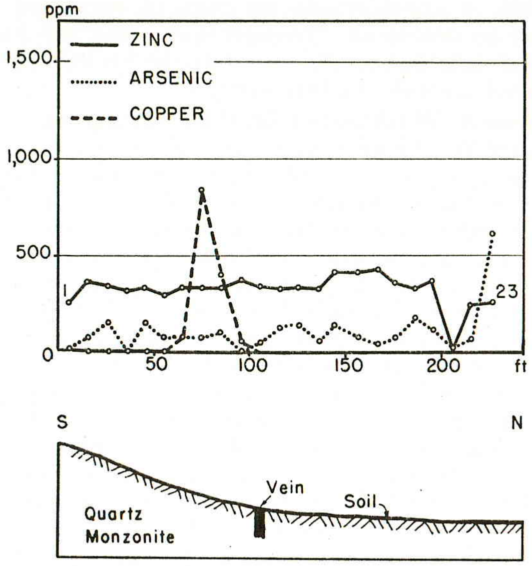


Figure 45. BLUE BIRD VEIN, WICKES

Table 43—Bluebird Mine, Wickes

Analyses of soil samples collected above the shaft across the vein which strikes N. 70° W. Traverse bearing S. 20° W. on grassy slope of 20° to 0°. Sample interval 10 ft. Soils thin, 2-3 in. and rocky.

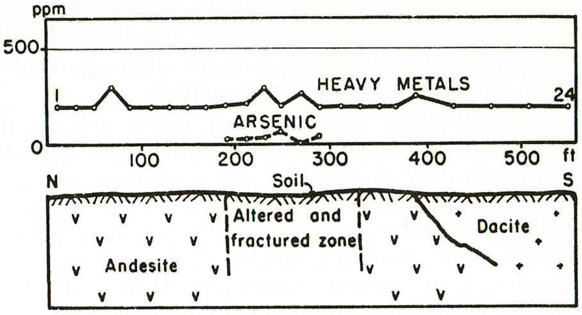
(a) Chemical analyses.

(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	100 ft. S of vein	0	262	0	15	2390	200
2	90 " " " "	23	386	0	77	3130	250
3	80 " " " "	73	361	0	146	2040	250
4	70 " " " "	0	322	0	0	1910	200
5	60 " " " "	31	337	0	146	2190	250
6	50 " " " "	27	296	0	69	2140	250
7	40 " " " "	0	341	90	61	2110	100
8	30 " " " "	0	335	830	61	1945	200
9	20 " " " "	0	333	390	100	2220	200
10	10 " " " "	0	341	55	8	1720	200
11	On strike of vein	0	382	0	46	1848	200
12	10 ft. N of vein	50	328	0	123	1860	250
13	20 " " " "	35	339	0	146	1705	250
14	30 " " " "	138	333	0	54	1420	100
15	40 " " " "	165	417	0	154	2330	200
16	50 " " " "	150	411	0	77	1735	250
17	60 " " " "	235	425	0	31	1750	300
18	70 " " " "	100	360	0	69	1918	200
19	80 " " " "	131	328	0	177	1840	300
20	90 " " " "	96	388	0	108	3290	200
21	100 " " " "	46	0	0	0	2685	200
22	110 " " " "	58	245	0	69	2565	200
23	120 " " " "	435	268	325	615	2730	200

The center of the broad quartz-pyrite structure is at Sample 11. Of interest is the distribution of the metals across the zone in which the vein is located. Lead, for example, appears to be concentrated 50 ft. north of the conspicuous vein structure; copper is definitely 30 ft. south in the opposite direction; high manganese analyses appear to flank the mineralized zone. The combined heavy metals test shows no pattern. This vein structure, like many others in the northern part of the Boulder batholith, might be systematically sampled along the strike of the vein in a narrow grid pattern, 2and very possibly covered ore shoots might be discovered.

The strong alteration zone between the Mount Washington and Bluebird mines was traversed over a manifest fracture zone, although no evidence of mineralization was found at the locality of the traverse. The wide iron-stained and bleached zone is similar to the alteration zone at the Mount Washington vein. No heavy-metal or distinct metal anomalies are found across these strong structures. Lead, zinc, copper, arsenic, manganese, and heavy-metal analyses were made on the soils from this traverse as listed in Table 44. Arsenic and manganese make a small high, which may represent the vein structure. This traverse adds evidence that vein structures with strongly altered wall rocks do not necessarily contain ore minerals.



Barren zone west of Mount Washington mine

Figure 46 WASHINGTON VEIN STRUCTURE BETWEEN MT. WASHINGTON AND BLUE BIRD MINES, WICKES

Table 44—Barren Zone on Vein between Mount Washington and Bluebird Mines, Wickes

Analyses of soil samples collected across strike of Mount Washington vein 75 ft. N. of andesiate-dacite contact north of Mount Washington shaft. Sample interval 10 and 20 ft. on bearing S. 20° W. Soils 10 in.; slope 0°.

(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	N end of traverse	51	151	0	0	1290	200
2	10 ft. S of traverse	0	174	0	0	1770	200
3	20 “ “ “ “	0	159	0	0	1340	200
4	30 “ “ “ “	0	149	0	0	1830	200
5	40 “ “ “ “	0	147	0	0	1640	300
6	50 “ “ “ “	15	149	0	0	1730	200
7	60 “ “ “ “	0	139	0	0	1832	200
8	70 “ “ “ “	10	151	0	0	1920	200
9	80 “ “ “ “	19	174	0	0	1970	200
10	90 “ “ “ “	31	194	0	23	1870	200
11	100 “ “ “ “	19	180	0	38	1590	200
12	110 “ “ “ “	8	194	0	46	1910	200
13	120 “ “ “ “	15	194	0	69	1750	300
14	130 “ “ “ “	37	149	0	0	1680	200
15	140 “ “ “ “	37	178	0	23	1460	250
16	150 “ “ “ “	54	175	0	0	1610	200
17	160 “ “ “ “	15	163	0	0	1600	200
18	170 “ “ “ “	50	143	0	0	1700	200
19	180 “ “ “ “	40	143	0	0	1385	200
20	200 “ “ “ “	60	169	0	31	1335	200
21	220 “ “ “ “	100	159	0	0	1320	250
22	240 “ “ “ “	119	157	0	100	1520	200
23	260 “ “ “ “	185	933	0	138	1760	200
24	280 “ “ “ “	104	182	0	0	1290	200

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.

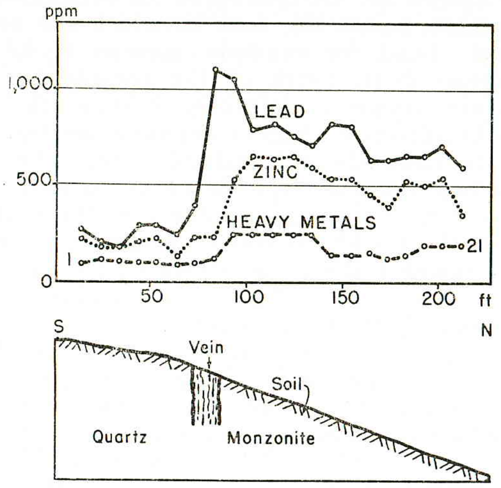


Figure 47. GREGORY VEIN, WICKES

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

East of the eastermost known mineralization on the vein, another traverse was made to determine whether it is possible to pick up the vein by geochemical methods. Figure 48 shows a distinct heavy-metal anomaly and serves to indicate the position of the vein. Table 46 lists the heavy-metal analyses.

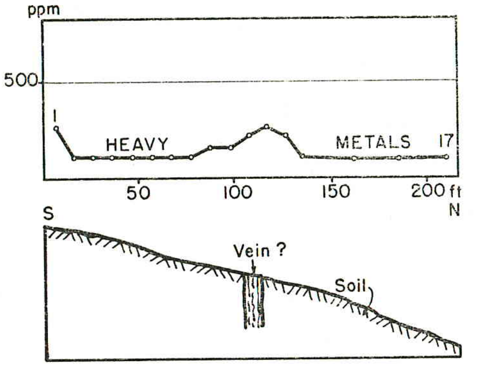


Figure 48. GREGORY VEIN IN UNEXPLORED AREA, WICKES

Table 46—Gregory Vein in Unexplored Area, Wickes

Chemical analyses of soil samples collected across presumed position of Gregory vein, about 2000 ft. east of shaft. Traverse bearing S. 10° E., sample interval 10 and 20 ft., grassy slope 15-20°, soils 3-6 in.

Sample No.	Location of Sample	Heavy Metals ppm	Remarks
1	N end of traverse	250	
2	10 ft. S of traverse	100	
3	20 " " " "	100	
4	30 " " " "	100	
5	40 " " " "	100	
6	50 " " " "	100	
7	60 " " " "	100	
8	70 " " " "	100	
9	80 " " " "	150	
10	90 " " " "	150	
11	100 " " " "	200	
12	110 " " " "	250	Vein?
13	120 " " " "	200	
14	130 " " " "	100	
15	150 " " " "	100	
16	170 " " " "	100	
17	190 " " " "	100	
18*	210 " " " "	100	
19*	230 " " " "	100	
20*	250 " " " "	100	
21*	270 " " " "	100	

*Not shown in Figure 48.

About 1¼ miles east, a northwest traverse was made across a very intensely altered andesite zone, in which aplite and hydrothermally altered granite occur. Heavy-metal analyses range from 50 ppm to 125 ppm without showing any conspicuous anomaly, which may be attributed to the Gregory vein structure.

Alta Mine.—The Alta mine is the most important and productive mine in the district. It is at present being mined by open-cut methods. The presence of many dumps and workings on the surface make it almost impossible to select an area for a geochemical traverse which would not be subject to possible contamination. The Alta vein is large, and the extent of the alteration is wide. A series of soil samples was collected south and east of the Alta mine, across the zone of alteration in the Alta structure and extending from the latites (younger than the vein) across the vein structure and into quartz monzonite. The heavy-mineral analyses range from 100 to 150 ppm, without indicating the position of the vein structure. Assays for lead and zinc might be more revealing. The background count is relatively higher than in the completely barren andesites and quartz monzonite, which are commonly from 50 to 100 ppm combined heavy metals.

North of the Mount Washington is a prominent cirque. Several small veins with wall-rock alteration and silicification were noted in the cliff walls. Samples were collected at 50-ft. intervals along a 2150-ft. traverse in the hope that heavy-metal analyses might serve to pick up the veins. All of the assays registered 50 ppm combined heavy metals, with no anomalies, and the background is normal of unmineralized areas in andesite throughout many of the district from which samples have been obtained.

WINSTON DISTRICT

The Winston mining district is about 20 miles southeast of Helena. The principal workings investigated are on Weasel Creek from 6 to 8 miles southwest of Winston. The region is mountainous with very steep slopes, which are in part forested and in part open park at elevations from 4500 to 8000 ft.

Pre-batholithic andesitic tuffs and minor andesitic flows were intruded by porphyritic quartz monzonite stocks. In the district, are several east-west veins, three of which were tested by geochemical means. The geology of the district was briefly described by Pardee and Schrader (1933: 211-226). The U. S. Geological Survey has recently mapped the area in detail, but the report is not yet available.

East Pacific Mine.—The northernmost mine in the district, the East Pacific is on an east-west quartz vein which contains silver and lead. A geochemical traverse was run in a north-south direction across the vein in an area that presum-

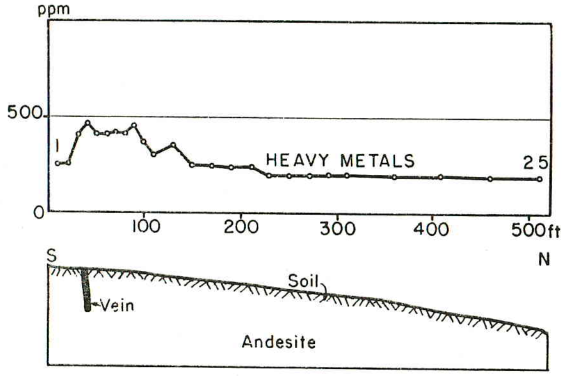


Figure 49. EAST PACIFIC VEIN, WINSTON

ably was stoped to the surface for lead and silver. The heavy-metal anomaly is conspicuous, as shown in Figure 49. Undoubtedly, lead and zinc analyses would reveal an even more conspicuous anomaly. Table 47 lists the heavy-metal analyses.

Table 47—East Pacific Mine, Winston

Chemical analyses of soil samples collected across vein, on top of hill above the adit. Numerous small shafts and caved stopes reveal the location of the vein. Traverse bearing due North, approximately at right angles to the vein structure. Slope angle 5°, soils thin, 3-4 in. with large blocky float of andesite tuff. Sample interval 10, 20 and 50 ft. as shown in Figure 49.

Sample No.	Location of Sample	Heavy Metals ppm
1	30 ft. S. of vein	250
2	20 " " " "	250
3	10 " " " "	400
4	Over vein	450
5	10 ft. N of vein	400
6	20 " " " "	400
7	30 " " " "	400
8	40 " " " "	400
9	50 " " " "	450
10	60 " " " "	350
11	70 " " " "	300
12	90 " " " "	350
13	100 " " " "	250
14	120 " " " "	250
15	140 " " " "	250
16	160 " " " "	250
17	180 " " " "	250
18	200 " " " "	200
19	250 " " " "	200
20	300 " " " "	200
21	350 " " " "	200
22	400 " " " "	200
23	450 " " " "	200
24	500 " " " "	200
25	550 " " " "	200

January Mine.—The January mine is just to the south of the East Pacific, and the only operating property in the district at the time of investigation. Its vein strikes easterly; the eastern part is in porphyritic quartz monzonite and the western part in altered andesitic tuffs. Three traverses were made across the vein: the first was over an air raise, from which good ore was stoped nearly to surface; the second and third traverses were made farther to the west in the andesite, where probable extensions of the structure were expected. No geochemical anomalies were recorded, a result expected, as there is definite lead and zinc mineralization in the vein near the surface. At the time the traverses were made, a thin veneer of an old glacial till was not recognized. Subsequently, bulldozer cuts made at the property revealed the presence of the glacial deposits, which are very thin for the most part. The absence of an anomaly is due to the "foreign" nature of the soils. The heavy-metal analyses for the soils were quite erratic: from 50 to 250 ppm, without any detectable pattern.

Kleinschmidt Claims.—The Kleinschmidt claims are on a quartz-monzonite stock. The principal vein is an east-west quartz fissure which contains precious and base metals. Two traverses were made across the vein, both in areas presumed to have been mined to the surface. Small, but detectable heavy-metal anomalies were recorded (as shown in Figure 50), with heavy-metal analyses for one of the traverses but not for the other. The analyses are listed in Table 48. Lead and zinc analyses probably would be more helpful in demonstrating the shape of the anomaly.

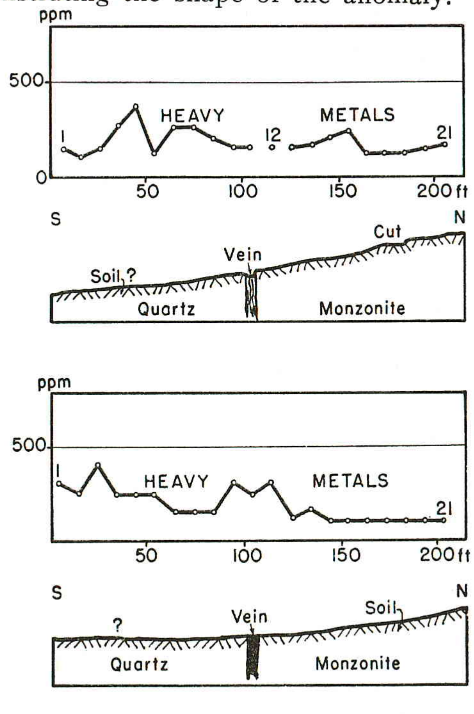


Figure 50 KLEINSCHMIDT VEIN, WINSTON

Table 48—Kleinschmidt Mine, Winston

Chemical analyses of soil samples collected across vein structure. Table 48a for traverse uphill to east of main adit of Kleinschmidt mine in area of two shafts; and Table 48b about 100 ft. east of portal of main adit. Table 48a: samples collected on traverse bearing N. 15° E. across caved adit. Slope 5-10°, soils thin, in area of lodgepole pine. Sample interval 10 ft. Table 48b: samples collected on traverse bearing N. 15° E. between two shafts, in which vein strikes N. 75° W. Slope of traverse 5°, sample interval 10 ft. Soils 10-12 in. in area of lodgepole pine cover.

Table 48a

Sample No.	Location of Sample	Heavy Metals ppm	Remarks
1	100 ft. S of vein	150	
2	90 " " " "	100	
3	80 " " "	150	
4	70 " " " "	250	
5	60 " " " "	350	
6	50 " " " "	100	
7	40 " " " "	250	
8	30 " " " "	250	
9	20 " " " "	200	
10	10 " " " "	150	
11	Over vein	150	
12	10 ft. N of vein	150	Sample missing
13	20 " " " "	150	
14	30 " " " "	200	
15	40 " " " "	250	
16	50 " " " "	100	
17	60 " " " "	100	
18	70 " " " "	100	
19	80 " " " "	150	
20	90 " " " "	150	
21	100 " " " "	100	

Table 48b

Sample No.	Location of Sample	Heavy Metals ppm	Remarks
1	100 ft. S of vein	300	
2	90 " " " "	250	
3	80 " " " "	400	Vein structure?
4	70 " " " "	250	
5	60 " " " "	250	
6	50 " " " "	250	
7	40 " " " "	150	
8	30 " " " "	150	
9	20 " " " "	150	
10	10 " " " "	300	
11	Over vein	250	
12	10 ft. N of vein	300	
13	20 " " " "	100	
14	30 " " " "	150	
15	40 " " " "	100	
16	50 " " " "	100	
17	60 " " " "	100	
18	70 " " " "	100	
19	80 " " " "	100	
20	90 " " " "	100	
21	100 " " " "	100	

ZOSELL (Emery) DISTRICT

The Zosell (Emery) district is about 7 miles east of Deer Lodge on the west side of an unnamed ridge of mountains composed of Upper Cretaceous andesites. Two types of veins occur in the district: one set consists of low-angle veins; the other is nearly vertical east-west veins. The geology is described by Robertson (1953).

Emery Mine.—The most important vein in the district, the Emery lode strikes nearly north-south and dips 30° W. The vein averages only 7 in. in width but contains valuable amounts of gold and silver, with lead and zinc. A suite of soil samples was collected across the strike of the vein near the Emery incline shaft. The soils are very thin and very rocky—characteristic of the soils in the andesite areas. Figure 51 shows the conspicuous geochemical anomaly which was recorded over the vein and for about 100 ft. east on an open hillslope.

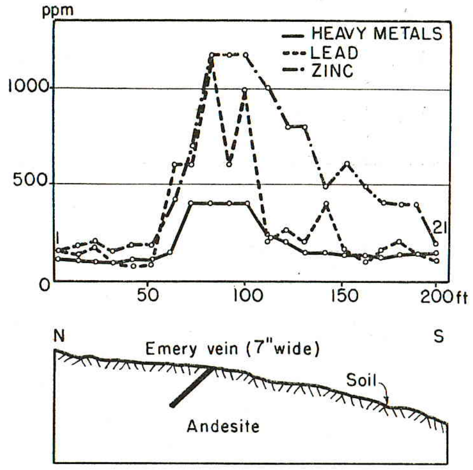


Figure 51. EMERY MINE, EMERY

Table 49 lists the analytical data for this traverse. The combined heavy-metal analyses in the uphill background are about 1/3 the combined lead plus zinc analyses; but over the vein, zinc plus lead is about six times the total heavy-metal analyses. This is further evidence of the insensitivity of the combined heavy-metals test in this region.

Arsenic shows a strong anomaly more closely identified with the actual vein than the lead and zinc, which have their maximum 20 ft. south of the vein. The gold in the Emery vein is associated with arsenopyrite. This example suggests that many arsenical gold veins may be prospected by geochemical methods employing the arsenic test.

Table 49—Emery Mine, Zosell

Chemical analyses of soil samples collected across the Emery vein just south of the incline shaft on bearing S. 60° E., approxixmately at right angles to the strike of the vein. Slope variable 5-10°. Soils thin, 3-6 in. with many blocks of dark andesite. Sample interval 10 ft.

Sample No.	Location of Sample	Lead ppm	Zinc ppm	Arsenic ppm	Heavy Metals ppm	Remarks
1	50 ft. uphill from vein	125	200	100	100	
2	40 " " " "	150	200	100	100	
3	30 " " " "	200	250	100	100	
4	20 " " " "	100	200	100	100	
5	10 " " " "	100	250	100	100	
6	Over vein	100	250	1000	125	Uphill side of caved stope
7	10 ft. below vein	600	400	800	150	
8	20 " " "	600	700		400	
9	30 " " "	1200	1200	600	400	
10	40 " " "	600	1200	800	400	
11	50 " " "	1000	1200	800	400	
12	60 " " "	200	1000	800	250	
13	70 " " "	250	800	1400	200	
14	80 " " "	200	800	300	150	
15	90 " " "	400	500	300	150	
16	100 " " "	150	600	200	150	
17	110 " " "	100	500	100	150	
18	120 " " "	150	400	200	150	
19	130 " " "	200	400	200	150	
20	140 " " "	150	400	100	150	
21	150 " " "	150	400	200	150	

Bonanza Mine.—A traverse was made north of the shaft of the Bonanza mine across the vein in an area of known mineralization whhich was exposed in a bulldozer cut. Because of the slumped condition of the cut, the precise position of the vein was not determinable at the time the sample traverse was made. The position is strongly indicated by the geochemical anomaly shown in Figure 52, which shows the strongest lead anomaly reported from veins in andesitic rocks. Table 50 lists the analytical data.

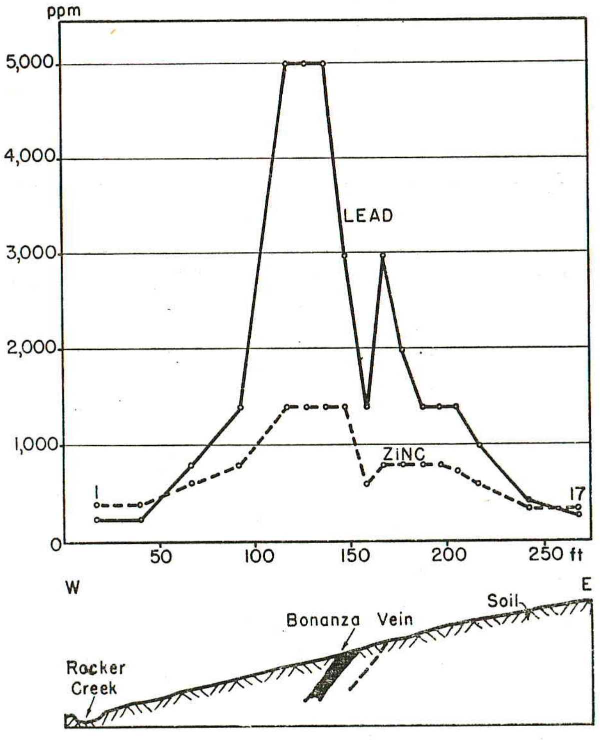


Figure 52. BONANZA VEIN, EMERY

Table 50—Bonanza Mine, Zosell

Chemical analyses of soil samples collected across Bonanza vein at bulldozer cut, 500-600 ft. northwest of Bonanza incline shaft. Traverse bearing approximately S. 30° W. about at right angles to the vein structure. Grassy slope variable, averaging 5°. Sample interval 10 and 25 ft. as shown in Figure 52.

Sample No.	Location of Sample	Lead ppm	Zinc ppm	Remarks
1	130 ft. downhill from vein	250	400	Edge of slope to Cottonwood Gulch
2	105 " " " "	250	400	
3	80 " " " "	800	600	
4	65 " " " "	1400	800	
5	30 " " " "	5000	1200	
6	20 " " " "	5000	1200	
7	10 " " " "	5000	1200	
8	Over vein?	3000	1200	
9	10 ft. uphill from vein	1200	600	
10	20 " " " "	3000	600	Subsidiary vein?
11	30 " " " "	2000	800	
12	40 " " " "	1200	800	
13	50 " " " "	1200	800	
14	60 " " " "	1200	700	
15	70 " " " "	1000	600	
16	95 " " " "	400	350	
17	120 " " " "	300	350	

CHAPTER IV

SUMMARY OF RESULTS FROM TYPES OF MINERAL DEPOSITS

Many types of mineral deposits were tested by geochemical methods: the principal types of fissure veins, replacement lodes, combined fissure and replacement deposits, breccia zones and pipes, and contact metamorphic deposits. The greatest attention was paid to fissure veins, as they are the most numerous of the types of deposits which have heretofore been developed.

The soils over fissure veins in which base metals are known to be present have given geochemical anomalies in all places. From the limited data, it appears possible that veins in sedimentary and metamorphic rocks contain sufficient concentrations of base metals to determine the position of the vein even in the so-called "barren" parts of the veins as shown by traverses at the Galt mine, Neihart district (see Figure 20).

In contrast to the through-going veins in sedimentary and metamorphic rocks, strong vein structures in the Boulder and Philipsburg batholiths reveal strong geochemical anomalies where the veins contain base-metal ore shoots; but in "barren" parts of the structures, there may be insufficient base metals in the veins to yield enough metals to show the location of the vein, even for those veins which are many feet wide and show intense wall-rock alteration. This fact is demonstrated by such multiple soil-sample traverses as were conducted on the Comet-Grey Eagle vein (Figure 8), the Washington-Bluebird vein at Wickes (Figures 44 and 45), and the Julia vein in the Elliston district. The Gregory vein at Wickes can be traced, at least in part, by geochemical analyses in what had been considered to be barren or unprospected zones.

A possible explanation of the presence of an anomaly over a "barren" part of a vein may be that in sedimentary and metamorphic rocks, the vein acts as a channel for through-going mineralizing solutions which contain the base metals. Traces of the metals are deposited in the veins and wall rocks even in the more unfavorable areas of the structure which do not develop commercial ore shoots. In the case of the veins in the granitic rocks of the batholiths, the strong veins may never have been formed by solutions which contained base metals at the time the intense wall-rock alteration adjacent to the veins were produced. The base metals in many of the veins are definitely late, appearing generally to have been confined to late fractures within, or at the sides of the major early vein structures. In many cases, wall-rock alteration appears to have been accomplished prior to the introduction of a significant amout of zinc or lead.

Individual heavy-metal or base-metal anomalies are recorded in granitic rocks where known ore shoots occur such as at the Mount Washington mine (Figure 44), Bullion mine (Figure 13), Gregory mine (Figure 47), Lee Mountani mine (Figure 43), Ontario mine (Figure 11), and Pearl vein (Figures 29 and 30). In most cases, the anomalies over base-metal ore shoots are not so large in granitic rocks as are those recorded in sedimentary rocks. In some places commercial ore is recorded whereas equally intense anomalies are produced on other veins where lower grade ores are indicated, as at the Pearl vein in the Philipsburg district. In all cases, the heavy-metal anomaly is lost downhill from 100 to 200 ft., even on very steep slopes with thick or thin soil cover. Thus, it is evident that the heavy-metals are found in significant quantities for geochemical testing only in areas close to the mineralization.

Gold-bearing structures in large veins which carry pyrite and quartz (with or without tourmaline), and which may likewise show intense alteration to sericite along the margin of the veins, may not have enough heavy-base metals in them to make it possible to distinguish the geological structure. This condition is demonstrated in the veins already mentioned, as well as at the Drumlummon mine (Figure 19). If, however, the gold is associated with arsenopyrite or arsenical pyrite, the arsenic geochemical test appears to offer real possibilities for exploring for gold structures. The Lee Mountain mine shows a strong lead and zinc anomaly, which is about 30 ft. from the main gold stope. (See Figure 43). Base-metal anomalies are separated from main precious-metal ore shoots, as suggested at the Bluebird mine (Figure 45). Frequently, lead, zinc, and copper anomalies are not precisely in the some position over a vein. (Note Pearl vein, Figure 30, and the Figures at the Big Blue and Duke claims, Figures 23 to 25.)

Geochemical work on fissure veins in the prebatholithic andesites was not so uniformly satisfactory as in other rock types. A strong anomaly is recorded at the Bonanza (Figure 52), and detectable anomalies in veins at the Emery (Figure 51), and East Pacific veins (Figure 49). On the other hand, vein structures on Nigger Mountain yielded negative geochemical results or showed only minor anomalies.

Fissure veins in older metamorphic rocks, such as in the Neihart district, reveal especially strong geochemical anomalies, i.e. at the Galt mine (Figure 20), where striking anomalies were recorded over known ore and over the structure in a noncommercial segment of the vein.

The most striking anomalies were recorded in the sedimentary rocks, particularly in limestones. The heavy-metal anomalies appear to be proportional to ore grades in some of the veins, a situation thought to be true at the Hand mine (Figure 4) and the Republic mine (Figure 27). The Mike Horse mine (Figure 16) yielded a surprisingly small anomaly; however, insufficient work was done in areas of argillite to make any generalization regarding its utility. In the Philipsburg district, where the Algonquin vein is represented by a rather small vein west of the Trout shaft, a conspicuous heavy-metal and manganese anomaly was recorded, as shown in Figure 28.

Breccia Fillings and Replacements. — At the Clark prospect in the Elliston district, a breccia zone, which contains sphalerite, yielded a strong geochemical anomaly. A pace-and-compass grid was laid out at the property, and the soils were sampled. The results are shown in Figure 15, which indicates a distinct northeast trend to the mineralized breccia zone.

At the Jo Dandy claim in the Radersburg district, the principal ore shoots appear to be in breccia pipes controlled by intersections of faults and favorable limestone beds. The ore shoots are strikingly brecciated, although replacement appears to play a significant role. As shown in Figure 40, a very strong lead anomaly was recorded at the Jo Dandy.

The only open-space (cave?) filling which was sampled is at the Governor Tilden claim in the Argenta district, as shown in Figure 5.

Replacement Deposits. — Disseminated copper occurs in altered monzonite at the McClaren mine in the New World (Cooke City) district, and in a syenite at the Copper King prospect, also in the New World district. A long traverse was made over and above the McClaren mine, and a very distinct copper anomaly was recorded as shown in Figure 21. At the Copper King prospect, the conditions were not favorable for geochemical prospecting; however, very strong copper anomalies were recorded, and a very high background was found throughout the length of the traverses which were made. Both of these localities are above timber line, in areas where there is virtually no soil in the ordinary sense of the term. The results seem to indicate that such deposits are distinctly susceptible to geochemical exploration, as indicated by the work of Lovering at the San Manuel property in Arizona (Lovering, 1938).

Replacement lodes are particularly abundant in the sedimentary beds. In a large number of places in the western part of Montana, lead and zinc deposits occur as replacements in limestones and dolomites. In the Philipsburg district, the Headlight bed has been an important producer, especially in those areas where east-west fissures cut the bed, where the fissures themselves are small and carry no minable ores. One geochemical traverse was made over a mined zone of the Headlight bed, and a second traverse over a barren zone on the same bed. The results of these traverses are shown in Figures 34 and 35. It is apparent that commercial mineralization is detectable by geochemical methods; but in addition, the bed can be picked by geochemical sampling in nonmineralized portions of the formation. It appears that geochemical methods may be used to locate stratigraphic horizons obscured by soil.

In the New World district, the lower Gallatin limestone is conspicuously mineralized not only at the Republic mine, but elsewhere in the district. Other limestone horizons are mineralized as well. At the Big Blue claim, a strong geochemical anomaly was recorded immediately downhill from a mined-out ore shoot. Anomalies recorded at the Big Blue and Duke claims are shown in Figures 23 to 26.

In the Elkhorn district, the Pilgrim dolomite is the important host for the replacement deposits in the Elkhorn mine. Two geochemical traverses were made across the zone as shown in Tables 8 and 9. Favorable sedimentary horizons susceptible to mineralization are also present at the Jo Dandy claim in the Radersburg district. In this case a fracture zone and breccia pipes are superimposed.

In the Philipsburg district, geochemical traverses easily detected the contact between the granodiorite of the batholith and the Jefferson formation. Figure 36 illustrates a strong anomaly at the Scratch All mine. Near the San Francisco mine, in an area where no commercial ore is known to exist in the limestone at the contact, a strong anomaly was reported as shown in Figure 39. Because of the variations in the heavy-metal content in the sedimentary and igneous rocks, it appears highly probable that the contact can be located by geochemical methods. It may be possible to distinguish contacts in other localities by these methods.

CHAPTER V

CONTAMINATION AS A SOURCE OF ERROR IN GEOCHEMICAL PROSPECTING

The possibility of contamination in any geochemical work must always be considered. Contamination may be introduced in a number of ways. In sample collecting, contamination may be introduced by a trace of foreign matter which has no bearing on a primary anomaly produced by a mineral deposit. For example, a grain of galena in a sample destroys the value of the soil sample. In sample preparation, galvanized screens and other equipment not carefully selected with contamination in mind may lead to errors not related to a primary anomaly. Contamination in analytical procedures is another source of error which must be dealt with in any study of geochemical results.

All of the above errors, resulting from contamination of an individual sample or an individual error in analysis, lead to individual "spot" anomalies which may throw off a study to some extent. However, a primary geochemical anomaly is rarely indicated by a single sample, but rather it is shown by a consistency of "high" analyses. An individual high analysis should be regarded with some distrust in most cases and discarded altogether in others.

The amount of heavy metals recorded in the soil samples is very small; likewise, the sample assayed is very small, being but 1/10 of a gram. Thus, one of the principal problems in soil sampling is to avoid all possibilities of contamination by introduction of "foreign" mineral matter such as discrete particles of ore minerals. Contamination may be introduced along roadways or by surface cuts where actual ore material has been thrown out onto the surface. In all the geochemical soil samples which have been taken, a great effort was made to select the position of the traverse at locations where contamination would not be a problem. In many places, traverses could have been made were it not for the fact that present on the surface were dumps, possibly contributing to misleading and erroneous results. At a few localities, contamination may have been encountered. At the Brooks mine, for example, a roadside sample had a very large lead content, which, when resampled, showed a much lower lead content. The sample was taken at the side of a roadway which had been used as a haulage road for ore. The 30,000-ppm assay first recorded from that individual sample, selected but 20 ft. below a vein, changed to 600 ppm on resampling. It was almost certain that a small particle of galena was responsible for this individual high analysis. In other cases where contamination was suspected, it has been recorded. On the other hand, contamination appears to be less a factor than might otherwise be considered. In most cases, the geochemical anomalies are lost in such a short distance downhill that individual "high" analyses are prominently recognized for what they are—an unusual or contaminated sample.

Individual samples may likewise be inaccurately determined chemically. However, geochemical anomalies are not shown (nor obliterated) by analyses of single samples. A large enough group of samples must be collected for any geochcemical investigation to outweigh the effect of any one sample or any one individual analytical error.

Mine Dumps.—Contamination of downhill slopes below mine dumps was though to be an important source of error. Consequently, mine dumps were consistently avoided in this study. It was thought that traverses made below dumps would be difficult, or impossible, to evaluate. However, the systematic work done in the attempt to evaluate the possible extent of contamination from dumps leads the writer to believe that such contamination is highly overrated.

The problem of possible contamination from dumps should be disregarded in many places, simply because many mine dumps contain little, if any, detectable metal. In other cases, recently accumulated mine dumps have not been affected by weathering for a sufficient amount of time to permit the metals to have been dissolved in amounts large enough to influence soil studies.

Two mine dumps were carefully selected for study, to determine the effect of possible contamination because of downhill migration of metals derived from the dump. Actually some difficulty was encountered in selecting mine dumps which would be sure to yield reasonably conclusive information.

The dumps selected are both high on a hillslope; are old dumps; and dumps on which base metals are present in some quantity. The dump at the Emery incline shaft in the Zozell (Emery) district and the Scratch All dump at Philipsburg were investigated in some detail.

The Emery dump is an old one, which has been exposed to the atmosphere for more than 50 years. The amount of mineral here was large enough to interest a secondary mining venture in the recovery of metals from the dump. Until very recently, "highgrading" of the dump has been carried out by individuals.

Figure 53 shows the approximate limits of the dump in relation to the old mill site. Table 51 gives the lead and zinc analyses for samples collected along the toe. Two samples close to the mill (where contamination might be expected to be greatest) show high analyses, indicating contamination in the surface soils. Elsewhere along the toe, the lead and zinc analyses are from 2 to about 8 times the normal background for lead, and up to 4 times background for zinc. Thus, at the very toe of the dump, the soils appear to be unusually high in heavy metals, and at places such as at the mill contamination is definite.

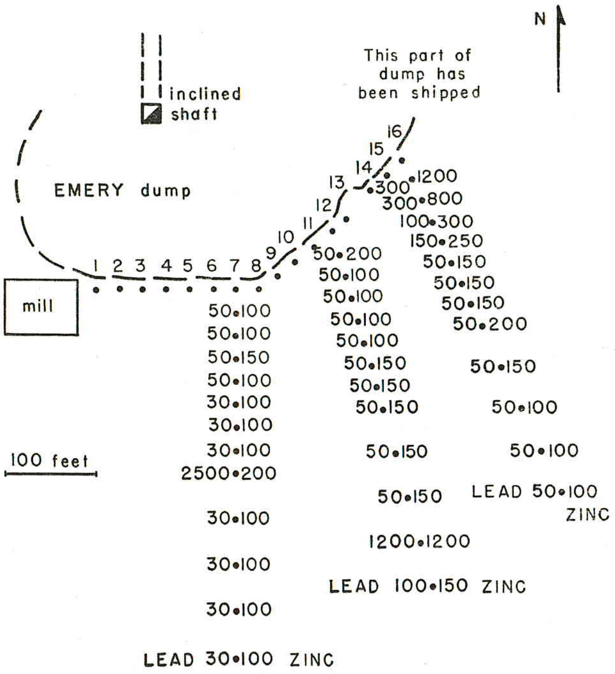


Figure 53. MINE DUMP AT EMERY INCLINE SHAFT, EMERY

Table 51—Emery Dump, Emery

Chemical analyses of soil samples taken at the toe of the Emery dump as shown in Figure 53.

Sample No.	Location of Sample	Lead ppm	Zinc ppm	Remarks
1	20 ft. E of mill	15,000	8,000	At mill
2	25 ft. E of sample 1	1,200	600	Contaminated
3	50 " " " " "	200	100	
4	75 " " " " "	200	200	
5	100 " " " " "	100	150	
6	125 " " " " "	100	150	
7	150 " " " " "	70	100	
8	175 " " " " "	150	200	
9	25 ft. NE of sample 8	50	100	
10	50 " " " " "	250	350	
11	75 " " " " "	400	400	
12	100 " " " " "	100	400	
13	125 " " " " "	150	300	
14	175 " " " " "	250	300	
15	200 " " " " "	150	300	
16	225 " " " " "	300	300	

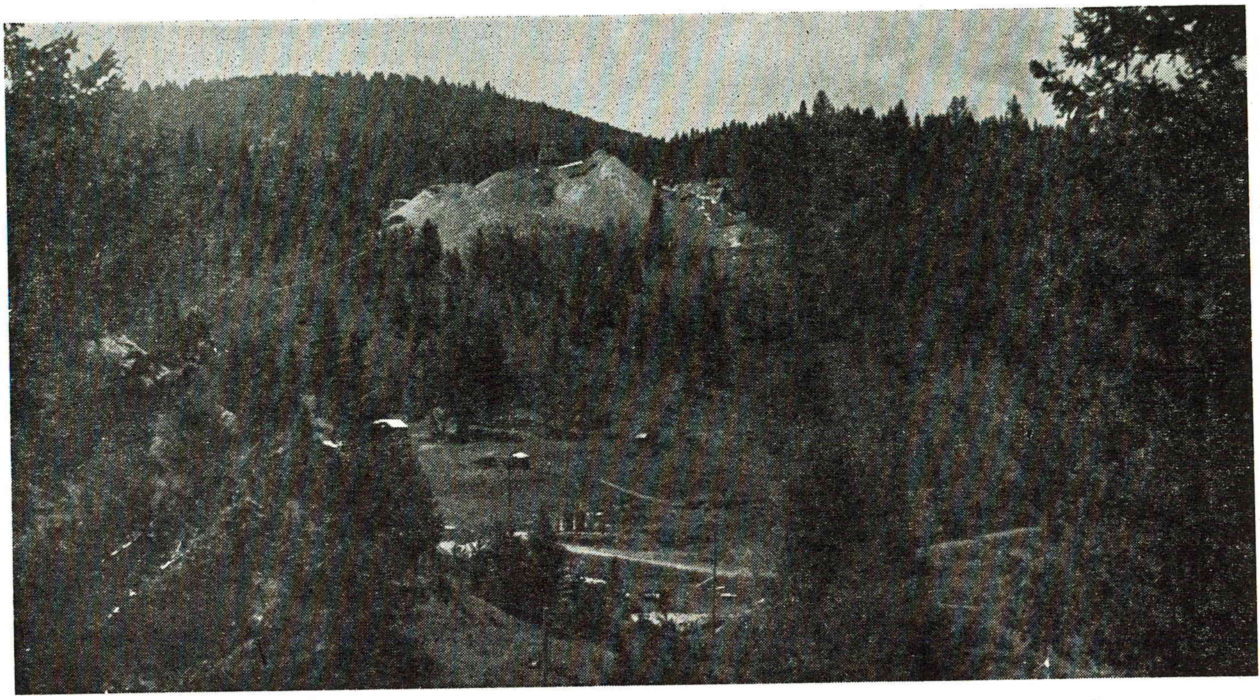


Figure 54 VIEW LOOKING SOUTH TO SCRATCH ALL MINE DUMP

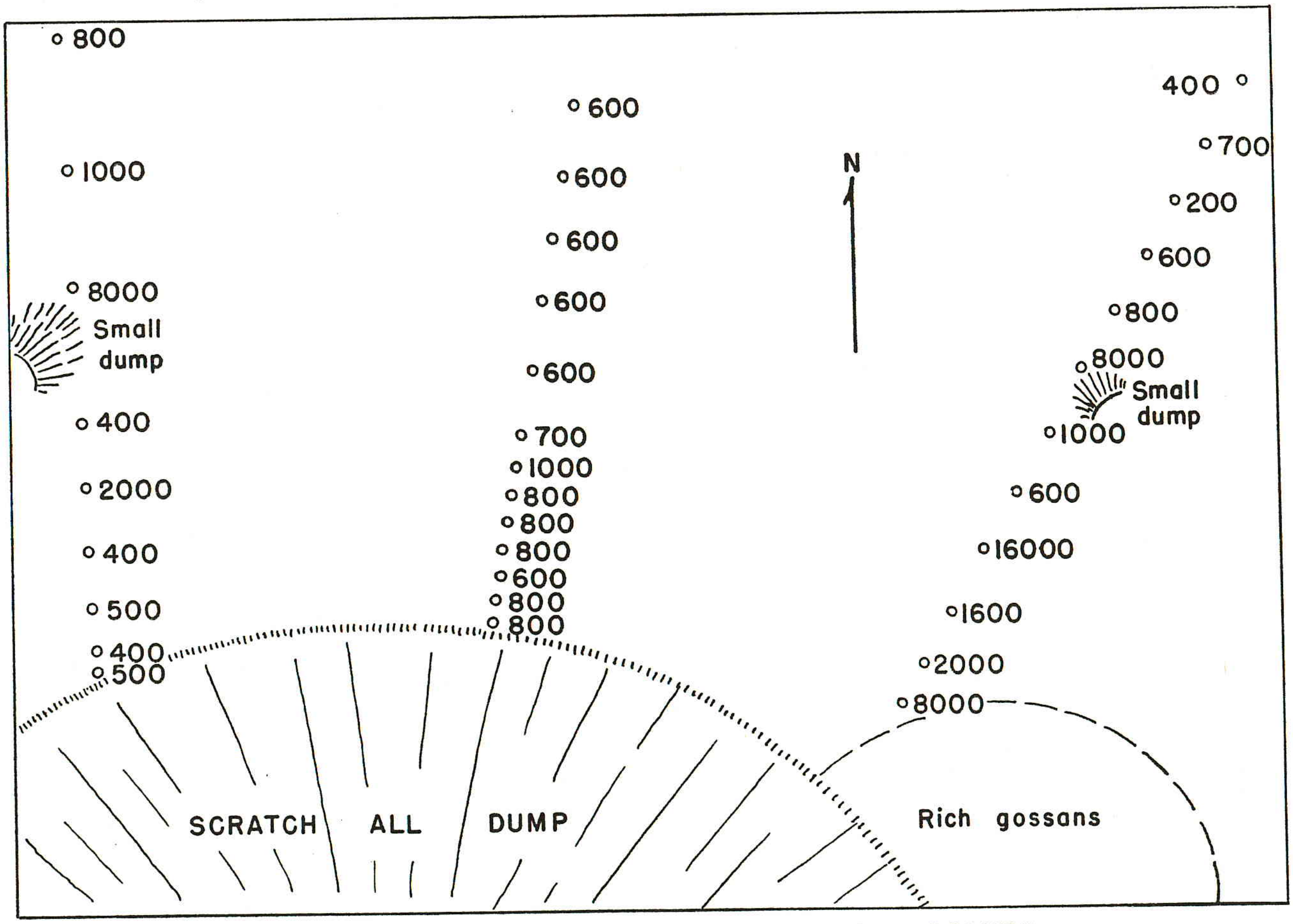


Figure 55 SCRATCH ALL MINE DUMP, PHILIPSBURG

Three lines of samples were collected downhill from the toe of the dump. The results for lead and zinc are shown in Figure 53. It is indicated that 100 ft. downhill from the toe of the dump, no anomalous metal content occurs in the soils. Contamination is indicated where a 1200-ppm lead and 1200 ppm zinc assay is recorded and a 2500-lead analysis shown.

At the Scratch All mine is a large dump with zinc and lead minerals on it. The dump is on a mountainside, as shown in Figure 54. Figure 55 shows three lines along which samples were collected from the toe of the dump downhill for about 400 ft. On all three sample lines, an abnormally high group of analyses occur in corresponding positions on each traverse and indicate a possibly covered vein structure. That such a structure may well exist is shown by the small dump from a prospect pit on the west traverse line. There is, then, some evidence that structures may be detected downhill from a mine dump, even where the general background in the region is very large, as it is in the Philipsburg district, and where dump contamination might have been suspected. The amount of contamination downhill from the dump appears to be small, and limited to perhaps 50 ft. on the average and, at most, about 200 ft. (if it be assumed that the indicated anomaly is due to contamination).

From the data accumulated at these two dumps, which have been exposed to weathering for a half a century or more, it appears that the contamination problem resulting from heavy-metal migration downhill from the dump is not a serious one. This statement does not mean that mine dumps should not be considered at all; it really means that geochemical investigations may be made in areas of mine dumps, but in all cases, the possibilities of contamination should be considered.

CHAPTER VI

HOW TO PROSPECT FOR MINERAL DEPOSITS BY SOIL ANALYSIS

This chapter is designed to help the geologist, the prospector, or anyone who may wish to search for base metals with the aid of geochemical methods. The discussion is limited to soil sampling and analysis. Analyses of plant ash and of ground water, while important methods of geochemical prospecting, are not covered.

Geochemical prospecting is inexpensive enough to make it available to the small operator as well as the large corporation. This chapter is written mainly for the small-scale prospector, but the basic principles are also applicable to large-scale explorations.

Geochemical prospecting is not a substitute for the older geological methods of searching for ore: it merely supplements them. Geochemical and geological methods should be used together. For example, the spacing pattern of soil samples depends in part on the probable size and shape of the sought-for ore shoot or other mineralized zone. The prospector uses geological methods to estimate the size and shape of such mineralized areas. No prospector should try geochemical methods without carefully studying the geology of the district.

Where Should Geochemical Prospecting be Used?.—Soil sampling methods are most suitable in areas of residual soils, that is, soils which grade downward into the bedrock from which the soil was derived by weathering. Such soil has not moved for from its source except by downhill creep. Valley alluvium, lake beds, and glacial till are leading types of transported materials, and are unsuited to geochemical prospecting except under special conditions which are not covered here.

Within an area of residual soils, still further narrowing of the area to be prospected is necessary. In most places the prospector uses a plan similar to that of successful elephant hunters: if you are hunting for elephants, go where elephants are found. For the small operator in particular, prospecting in and around known mineralized areas or mining districts is advised. In some old mining districts, an ore-bearing horizon may be known to outcrop for thousands of feet, but test pits may be too far apart to have uncovered every potential ore-shoot. Other mineralized structures may disappear under soil cover, or may be offset by faults, and these parts may have escaped exploration. In many places, ore bodies, either in the hanging wall or footwall of veins have been missed because the walls were not tested. In all such places, geochemical tests provide a good way of searching for undiscovered mineralized areas. Many worthwhile ore bodies have been found around the edges of old mining districts and in the unexplored gaps within such districts.

It should not be assumed from the foregoing paragraph that soil analysis is useless in virgin territory. Actually, soil analysis is a valuable prospecting method wherever (a) bedrock is covered by surface materials derived from the bedrock, and (b) there are reasons to suspect the existence of mineralization near the surface. Favorable indications are easiest to find in the unexplored gaps and around the margins of established mining districts, but fortunately they may also be found elsewhere, thereby offering the hope of creating a new mining district. If the prospector is fortunate enough to find favorable indications, he should be prepared to make geochemical tests regardless of whether the area is in an old mining district or not.

Identifying a Favorable Indication.—In selecting a site for a geochemical prospecting program, the problem is to locate mineralized zones in the bedrock. Where the bedrock is fully exposed, the prospector follows the well-known procedure of sampling and assaying the rock. But where the bedrock is partially or wholly covered by soil, special techniques are needed.

In these soil-bearing areas, a known mineralized vein may be traced by surface outcrops for some distance, then may disappear beneath the soil. The hidden extension of the vein is a favorable location for soil analysis. Soil sampling in such a location may give information similar to trenching, but at much less cost.

In attempting to locate a vein offset by faulting, geochemical methods may be employed by collecting samples along a line at right angles to the trend of the vein at some point presumed to be on the other side of the fault. The location of the traverse line and the length of the line along which samples should be collected is simplified if the geometry of the fault can be determined. It should be cautioned that the end of an ore shoot against a fracture does not necessarily mean that there is a continuation of the shoot across a fault. Veins do end, and often they end at some natural fracture, in which case no extension is to be expected.

A vein may be completely soil-covered, but a few pieces of mineralized "float" may betray its existence. The "float" might be directly over the vein or might have crept downhill, but in either case it offers a favorable indication for soil testing

These examples show that a favorable location for geochemical prospecting must have some geologic basis. It also has special characteristics of its own. These are: (a) It is near a mineralized area identified by other methods, but it is covered with soil. (b) It extends beyond the visible zone of mineralization, and thus enlarges the prospecting area.

The Sampling Pattern.—Having found a favorable indication that is believed to warrant a series of soil tests, the next step is to lay out on the ground a pattern or grid of points from which samples will be taken. The principles are (a) to cover the whole area indicated as favorable, and (b) within this area to space the points close enough together so that an anomaly caused by a valuable ore shoot or enriched zone will show up in at least one sample, preferable in more than one.

(a) The extent of the favorable area is a matter of geologic judgment. For example, if a partially concealed vein is being followed, the known length of other nearby veins may suggest the probable length of the vein being studied. If a whole complex of veins is known to be present, the favorable area may extend along the veins in one direction to a deep valley fill, in the other direction to an area where soil is not present and outcrops may be studied and sampled directly. The prospector should limit the area to reduce the time and money required for sampling and analysis; but at the same time he should cover all the ground that can be defined as geologically favorable.

(b) The proper spacing of sample points within the favorable area depends on the probable size of any anomaly that may be present. For example, if an ore shoot is expected to measure at least 100 feet along the strike, then sampling at intervals of not over 50 feet along the vein should be taken. In addition to samples along the presumed line of the vein, samples should be taken both uphill and downhill from this initial line. Because soil creeps downhill, the sampling grid should extend farther uphill than downhill from the line of favorable indications or inferred position of the vein.

Exploration for Hidden Tops of Ore Shoots Along Unexposed Parts of Veins.—To the writer, the exploration for the tops of ore shoots along unexplored parts of large veins appears to offer one of the most potentially fruitful applications of soil sampling. In many mining areas, and particularly in the smaller districts, exploration has not been systematic or complete. In too many places the development has proceeded as follows. A prospector finds a promising showing and proceeds to develop it and mine it out. During the actual mining operation, he pays little attention to setting aside time and money for the search for a new deposit to be operated when the current ore shoot is depleted. Thus, when an ore shoot is worked out, he makes a belated and often futile search for another ore shoot on the same structure. Finding none, he moves on to "greener" pastures in search of another discovery. At a later date, another prospector, finding that an earlier discovery had been made, scratches around, attempts to trace out the vein, digs in different spots, and perhaps finds another shoot and proceeds to mine it out in much the same fashion, so that when this body is worked out, no new deposit has been developed. In this way, by history repeating itself, many of the larger structures in many districts have been partly uncovered. It should be possible in many places to trace out structures on the surface with a considerable degree of accuracy, and systematically to collect soil samples along the structures, particularly in those parts of the structures which are not exposed and which are covered by grass or forest lands.

The presence of a group of pits in a row, however, should not be considered sufficient grounds for collecting a group of soil samples. Ideally, the structure should be carefully mapped on the surface, and insofar as possible, all underground operations mapped and the geology carefully plotted. Particular attention should be paid to mineralogy and structure. The type of minerals should control the specific geochemical tests to be applied. Attention to the structural details may well determine the success or failure of the project. After the structure has been carefully traced on the surface, samples should, of course, be collected from the downhill side of the vein, but as close to the position of the vein as is possible. As already noted, samples should be reasonably closely spaced. Valuable ore shoots could be missed at 100-ft. intervals. Sampling in 50-ft. intervals, or even closer, is desirable.

When the trace of a vein is projected under soil cover for a distance of a quarter of a mile, its position may easily be missed by a hundred feet or more, especially if the vein is not steeply dipping and crops out on an irregular hillslope. In such places, it may be desirable first to determine the position of the structure by collecting a group of samples in a line at right angles to the structure, extending from 100-200 ft. on either side of the point where the vein is thought to occur. A series of such traverses should help to establish the position of the structure (and, incidentally, may assist in picking up side structures, which are so common, and which are frequently missed in small mining operations). The limitations of this method for veins in granite are indicated in the last part of Chapter III.

Prospecting for Hidden Deposits. — In many regions it was found that the vein which contained no commercial mineralization at the sampling site could be detected by geochemical methods. In other places the position of the vein could not be detected. In general, it was found that veins in sedimentary and metamorphic rocks are more easily detected than are those veins in the granite rocks of the batholiths.

If the only indication of a possible mineral deposit is a piece of mineralized "float" on the hillside, it may reasonably be concluded that the float migrated more or less directly downhill from the deposit. Thus a systematic series of samples collected directly uphill from the site of the float sample should serve to indicate the possible position of the ore or the vein. Soil samples should be collected at intervals not greater than 25-ft. and sampling should be done in exactly the same manner as in geochemical sampling over a known vein. After the samples are analyzed, the position of the highest metal analysis should be on, or slightly downhill from, the mineralized structure. A prospect pit should be dug in an attempt to find the vein and get the strike and dip of the structure in order to be able to trace it on the surface by geochemical or other methods. Once the vein has been actually exposed, then proceed as if prospecting a known vein.

How to Prospect for Covered Breccia Pipes or Replacement Lodes.—If indications seem to favor the occurrence of metals in an area, although the geological structure is not known, a grid pattern of sample collection is recommended, as suggested in Figure 56. Usually such favorable indication is a sample of ore in a float boulder found on a hillside. A sample of limestone containing oxidized lead and zinc minerals, for example, may indicate a replacement body. A large boulder of breccia ore may suggest the presence of a breccia vein or pipe.

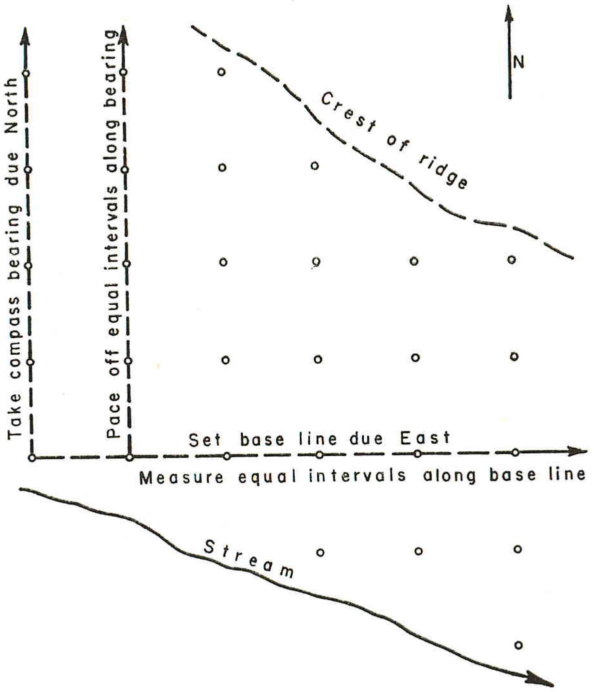


Figure 56. IDEALIZED GRID LAYOUT FOR GEOCHEMICAL SOIL SAMPLING

The first thing, of course, should be to carefully walk over the ground to determine whether any outcrops can be found. If no outcrops occur in the area, and if the region is soil covered, a grid of soil samples may be laid out.

Start from some easily identified spot such as a shaft, a cabin, a road intersection, or a trail marker. Lay out two sets of lines at right angles. One set of lines may be more or less parallel to the drainage and the other set at right angles to the drainage, or, as shown in Figure 56, the traverse lines may be laid out according to compass bearings. It may be advisable to blaze trees or to mark the lines with stakes. Collect samples at from 50- to 100-ft. intervals (100-ft. intervals if a relatively large area is involved and if the target or mineral deposit is thought to be rather large). For complete sampling of a 20-acre claim, about 100 samples are necessary at 100-ft. intervals. Collect and label all samples as described in the next section. Be sure to draw a sketch map showing the location of all samples by number and indicating the position of roads and cabins. Record the assays for each sample. If a group of high samples are clustered on the grid, then it may be desirable to resample, using more closely spaced intervals. Figures 15 and 23-26 show two grid sampling plans which were laid out in the Elliston and New Word districts.

Sampling Procedure. — When the area to be sampled and the spacing between samples have been decided on, a simple sampling procedure is followed. The important points are (a) to know where each sample was taken, and (b) to collect clean, uncontaminated samples. The steps are as follows:

1. Starting from an easily located spot, lay out the sampling pattern on the ground. Note the compass direction of each line of samples, and mark the ends of each line by stakes or tree blazes. Locate each sample point on the line by tape measurements, or at least by careful pacing. Using an engineer's notebook containing cross-ruled pages, draw a sketch map to scale, showing each location from which a sample is to be taken. Satisfactory scales are 1 in.=100 ft. or 50 ft.

2. At each sample location, dig a hole 10 to 12 in. deep (where possible).

3. Collect a soil sample of about 2 to 4 oz. (enough to make a small pile in the palm of the hand) from the bottom of the hole. Use the hand or a steel spoon. Do not use brass, german silver, or any implement containing the metals for which tests are to be made. Avoid stones, roots, leaves, pine needles, or other debris. Avoid kicking any surface material into the hole before the sample is removed. Place sample in a small heavy manila envelope; close the flap securely. Number the envelope plainly, preferable on front and back, and enter the same number at the proper location on the sketch map in your notebook. The envelope and map may also be dated to insure correct identification. To avoid premature disclosure of information, do not write anything on the envelope that reveals the location where the sample was taken.

4. File the envelopes systematically in a box of proper size. Deliver to your geochemical analyst.

5. When you receive the analyst's report, enter the results in small numerals on your sketch map, or on an office map made from the sktech map.

6. If important anomalies are found, plot the assay values on a profile chart. To make this chart, use cross-ruled paper. Taking a line of samples at a time, and using the same scale as the map, draw a horizontal line to represent the line of samples. On this line locate the position of each sample to correct scale. Then plot the assay value of each sample to a suitable vertical scale, making a mark directly above the sample location. The height of the mark will be small for low assays, large for high assays. Then connect the assay values with a curve. This will clearly show the extent and tenor of any area where an anomaly exists. This is the information you sought. From it you will decide whether to abandon the area, or to make further explorations by drilling or by development openings.

Analysis of Samples.—Geochemical methods of analysis of soil samples are so new that there are few laboratories for this work at the present time. Inquiries directed to Montana Bureau of Mines and Geology, Butte, Montana, or to the Geochemical Branch of the U. S. Geological Survey, Denver, Colorado, will obtain up-to-date information on laboratories.

For the prospector who would prefer to analyze his own samples, Chapter VII has been prepared. In it, rapid field methods are described in detail in order to enable the prospector to follow the step-by-step directions with some assurance that if the steps are followed **precisely,** satisfactory results may be expected. It should be remembered, however, that the analyses are for part-per-million and not for several per cent, consequently much greater care against contamination must be taken than in ordinary chemical analyses.

CHAPTER VII

CHEMICAL METHODS USEFUL IN PROSPECTING

by

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INTRODUCTION

Several simple field methods of trace analysis which are now being used in geochemical prospecting are described in this chapter. They include two methods of analysis for heavy metals as a group and separate methods of analysis for copper, lead, zinc, and manganese. These methods are described in detail giving a step-by-step procedure in much the same manner as a recipe is given in a cook book. It is the hope of the authors that anyone interested in using these methods will find it comparatively easy to follow successfully the directions given in this chapter.

In the development of these field methods for geochemical prospecting, special attention was paid to speed and economy; the overall consideration was simplicity, both of techniques and equipment. Speed is necessary to follow up any likely prospects while in the field. Economy and simplicity are essential to any prospecting program because hundreds of samples may have to be analyzed and the cost of the program will be affected accordingly.

A sensitive reagent that reacts with a metal, or group of metals, to give colored compounds is used in each of the methods to measure the amount of metal in a soil or rock sample. One such reagent is dithizone which gives colored compounds with many metals. It is a violet-black fluffy material which may be dissolved in carbon tetrachloride, chloroform, or xylene to give a deep-green solution. When the sample solution is shaken with a solution of dithizone, the dithizone solution will change color if certain metals are present, this change in color is proportional to the amount of the metal present. This reagent can be used to detect very small amounts of such metals as copper, lead, and zinc.

Dithizone solutions change color in the presence of extraordinarily small amounts of metals, thus ordinary tap water usually contains enough zinc to change the color of the dithizone solution from green to red. Consequently, extreme care must be exercised to avoid using materials that contain traces of the metals sought in the analysis, and the water used in performing the analyses described in this chapter must be free of traces of metals. Natural water from streams and lakes is found to be sufficiently free of metal in many instances, whereas water supplied through metal pipes is usually contaminated. Such water should be purified prior to use and this is easily accomplished by using one of the many demineralizers available from laboratory supply firms. A method for testing water will be given in the notes. In this chapter all references to water will mean water which is metal-free. The chemicals which are used are also often contaminated, and instructions for purifying the chemicals are given in the notes as required.

A list of essential equipment and chemicals is given with each method and these materials can usually be purchased from local laboratory supply firms. The dry chemicals may be previously weighed and packaged in small cartons or vials for field work, and arrangements can usually be made with a laboratory to weigh and pack these chemicals when necessary, thus eliminating the need for taking a balance into the field. It is also convenient to prepare and purify solutions before going into the field.

The description of each of the methods will include a list of reagents and equipment and directions for running the test, along with explanatory notes. A glossary of technical terms, or words with a particular meaning, is given at the end of the chapter, followed by a list of publications which have been used in preparing this chapter.

Publication authorized by the Director, U. S. Geological Survey

RAPID METHOD OF MEASURING COPPER, LEAD, AND ZINC AS A GROUP IN SOILS, ROCKS, AND SEDIMENTS

Heavy Metals Test

This is a method that is both simple and fast. The materials necessary may be carried easily in the large pockets of a hunting packet. The samples are treated with a solvent which only partially dissolves the metals present, but this is often adequate to detect the increasing metal content surrounding ore.

The chemicals required to determine heavy metals on about 100 samples are listed below. The desired stock is given in units listed by supply firms and consequently some chemicals are in excess. The solutions prepared from these chemicals are listed under "Reagents and Equipment."

Ammonium citrate	Reagent grade	¼ lb.
Hydroxylamine hydrochloride	" "	¼ lb.
Dithizone (Diphenylthiocarbazone)	" "	1 gram
Ammonium hydroxide, concentrated	" "	1 bottle (5 lbs.)
Carbon tetrachloride	" "	1 bottle (5 lbs.)
Chloroform	" "	1 bottle (5 lbs.)

Reagents and Equipment	Notes
1. **Dithizone solution.** Dissolve 0.015 gram of dithizone (diphenylthiocarbazone) in 500 milliliters (ml) of xylene.	1. Store the dithizone solution in a dark bottle away from heat. Strong light or heat will cause the dithizone solution to deteriorate (oxidize). As oxidation progresses the color of the dithizone solution changes from the original dark green (unoxidized) to light green and finally to yellowish brown. A Pyrex bottle wrapped with dark paper may be used to store the dithizone solution. The dithizone solution will remain good for several weeks if kept cool and away from light; otherwise prepare fresh daily. To test for oxidation transfer 5 ml of the dithizone solution to a glass-stoppered graduate containing 10 ml of water. Add 5 drops of 1 N ammonium hydroxide, cap tube and shake vigorously for 15 seconds. The xylene phase should be colorless; if it is yellow, the dithizone is oxidized and cannot be used for the test.
2. **Stock dithizone solution.** Dissolve 0.05 g of dithizone in 500 ml of carbon tetrachloride. Shake well and allow to stand overnight before using.	2. The stock dithizone solution is used to purify chemical solutions and is the same as the stock dithizone solution used for the more accurate heavy metals test.
3. **Solvent solution.** Dissolve 25 g of ammonium citrate and 4 g of hydroxylamine hydrochloride in 400 ml of water. Add concentrated ammonium hydroxide in about 5-ml portions, shake the solution after each addition and transfer a drop of the solution to a piece of Hydrion paper. Continue the addition of ammonium hydroxide as directed above until a drop of the solvent solution turns the Hydrion paper blue (pH 8.5). Add water until the total volume is 500 ml. Purify the solvent solution by shaking with small portions (50 ml) of stock dithizone solution until the dithizone remains green. Drain the spent dithizone after each shaking and shake the solution with 50-ml portions of chloroform until colorless. Remove the chloroform dissolved in the solvent solution by shaking with two 50-ml portions of carbon tetrachloride.	3. The solvent solution dissolves extractable metals in the sample. The pH is a measure of the alkalinity or acidity of a solution. Hydrion paper is a pH paper which changes color with a change in pH and is used to test th esolution. Hydrion paper gives a blue color when the solution is at pH 8.5. The shaking is conveniently done in a large Pyrex separatory funnel. The funnel has a stopcock, or valve, at the bottom to drain the heavier liquids. The dithizone in carbon tetrachloride will separate at the bottom. If the solution contains much metal it may be necessary to shake several times with dithizone before the dithizone remains green. When all the dithizone is removed from the solution by repeated shaking with chloroform, the chloroform layer will be colorless.

Reagents and Equipment	Notes
4. **Two 500-ml polyethylene wash bottles.** The dithizone solution and the solvent solution are carried in these bottles.	
5. **One graduated cylinder, 25-ml glass-stoppered.**	
6. **A small scoop** which will hold about 0.1 g of sample.	6. A scoop may be made by drilling a hole about ⅛ inch deep and ¼ inch in diameter in a piece of plexiglass or hard wood. The scoop is about 2 inches long, ½ inch wide and ⅜ in thick.

Procedure	Notes
1. Place a 0.1 scoopful of soil sample into the glass-stoppered graduate.	1. The sample should be uniformly packed in the scoop. Best results usually are obtained with finely ground rock or the fine fraction of soils.
2. Add 5 ml of solvent solution to the graduate.	2. The 5 milliliters is measured by reading the scale on the side of the graduate. The solvent solution dissolves extractable metals in the sample.
3. Add 1 ml of dithizone solution to the graduate.	
4. Cap and shake the graduate vigorously for 5 seconds.	4. The dissolved metal is extracted into the xylene-dithizone solution with shaking.
5. Allow the layers to separate and note the color in the xylene-dithizone layer.	5. The xylene-dithizone solution is lighter than water and will float on top.
6. If the color is purple or red, add 1 ml more of dithizone solution and shake 5 seconds.	
7. Repeat the addition of dithizone in 2-ml portions with shaking, until the dithizone solution is blue in color.	
8. Record the volume of dithizone solution used to obtain the blue color.	8. The volume of dithizone solution used is a measure of extractable heavy metals. For example: If 2 ml of dithizone solution are used to obtain the blue color in sample no. 1 and 10 ml are used for sample no. 2, sample no. 2 contains five times as much extractable metal as sample no. 1.

MORE ACCURATE HEAVY METALS TEST FOR SOILS AND ROCKS

This is a second method of measuring copper, lead, and zinc, as a group. Although not as rapid as the previous test, one may run as many as 100 samples per day. The advantage of this test is that more metal is extracted, and results indicate more nearly the true metal content of the sample. This is achieved by boiling the sample in acid.

The chemicals required to determine heavy metals on about 250 samples are listed below. The desired stock is given in units listed by supply firms and consequently some chemicals are in excess of the amounts needed. The solutions prepared from these chemicals are listed under "Reagents and Equipment."

Sodium acetate, anhydrous	Reagent	grade	1 lb.
Ammonium fluoride	"	"	1 lb.
Dithizone (Diphenylthiocarbazone)	"	"	1 gram
Nitric acid, concentrated	"	"	1 bottle (7 lbs.)
Carbon tetrachloride	"	"	1 bottle (5 lbs.)

Reagents and Equipment	Notes
1. **Stock dithizone solution (0.01 percent).** Dissolve 0.1 g dithizone in 1000 ml of carbon tetrachloride.	1. The stock solution should be stored in a dark bottle away from heat. If stored in a refrigerator, the stock solution will be good for several weeks; otherwise prepare fresh solution daily.

Reagents and Equipment	Notes
2. **Dithizone test solution (0.001 percent).** Add 100 ml of stock dithizone solution to 900 ml of carbon tetrachloride.	2. The test dithizone solution will be good for several days if kept cool and away from light; otherwise prepare fresh daily.
3. **Sodium acetate solution.** Dissolve 250 g of anhydrous sodium acetate in about 600 ml of water. Clean the solution by shaking with the stock dithizone solution. Remove the dithizone, dissolve in the water phase by shaking with carbon tetrachloride. Dilute to 100 m with water.	3. Heavy metals are removed from the sodium acetate solution by the method used to purify the solvent solution in the previous test. See note 3 on page 80.
4. **Ammonium fluoride solution.** Dissolve 100 g of ammonium fluoride in 500 ml of water. Clean as above. Dilute to 1000 ml with water.	
5. **Buffer solution.** Add 200 ml of the sodium acetate solution and 100 ml of the ammonium fluoride solution to 700 ml of water. Mix well.	5. This solution is prepared as needed. The purpose of the buffer solution is to complex certain metals and maintain the proper pH.
6. **1+7 Nitric acid.** Add 140 ml of concentrated nitric acid to 860 ml of water.	
7. **50 Pyrex test tubes, 12×110 mm.** These should be drawn to a point and marked at 4 ml.	7. The bottom of the test tubes should be heated until soft and gently pushed out with a pointed carbon rod. The pointed tube eliminates bumping of the sample during digestion. Bumping, or spitting, of the sample solution is caused by uneven heat distribution in the sample solution. When cool, the tubes are marked by adding 4 ml of water and scratching the side of the tube with a file at the 4 ml level.
8. **Digestion tube rack to hold 25 test tubes.**	8. The rack may be made by drilling a series of holes in a piece of wood about 8 inches square and ¾ inch thick, and fitting it with legs. The holes should be ½ inch in diameter on 1 inch centers. This rack is also used to hold the test tubes. See Figure 57.
9. **10 screw-cap culture tubes,** 25×200 mm, marked at 35 ml.	9. Cardboard or plastic gaskets should be cut to fit inside the caps. Cork or rubber gaskets are unsatisfactory because they often contain zinc. The tubes are marked by adding 35 ml of water and scratching the tube with a file at the 35 ml level.
10. **Culture tube rack.**	10. A rack may be made by drilling holes about 1 inch in diameter in the side of a piece of 2×6 wood.
11. **A small electric hot plate,** with about 6-inch-square heating surface.	11. A metal plate may be placed over a gasoline stove for use in the field.
12. **Two 0.1-ml serological pipettes,** graduated in 1/100 ml.	
13. **One 5-ml automatic pipette.**	13. The automatic pipette is used to transfer the dithizone solution.
14. **A sample scoop** to contain 1/3 g of soil.	14. A scoop may be made in the same way as described before. Drill a hole about ¼ inch deep and ¼ inch in diameter in a piece of plexiglass.
15. **A demineralizer cartridge.** Demineralizers may be obtained in various sizes; a large one (a cylinder about 18 inches long and 3 inches in diameter) will produce about 100 gallons of metal-free water. A small one (about 10 inches long and 1 inch in diameter) may be attached directly to a tap and will produce about 10 gallons of metal-free water.	15. Natural water from a lake or stream may be used if sufficiently metal-free. To test, add 10 ml of water to a culture tube containing 5 ml of dithizone test solution and shake tube vigorously for ½ minute. If the dithizone solution remains green, the water may be used.

Montana Bureau of Mines and Geology

Butte, Montana

ERRATUM

Bulletin 7, "Geochemical Prospecting by Soil Analysis in Montana."

Page 82, No. 3. Sodium acetate solution.

Line 5, Reads: Dilute to 100 m with water.

Should read: Dilute to 1000 ml with water.

Reagents and Equipment

16. **1-liter Pyrex or polyethylene bottle** for storing metal-free water.
17. **4 dozen cork stoppers, no. 2, regular.**

Notes

Procedure

1. Place a scoopful of soil sample in a pointed test tube.
2. Add 1+7 nitric acid to the 4 ml mark and tap gently to wet sample.
3. Place test tubes in the digesting rack over a hot plate and boil gently for 1 hour.
4. Remove the tubes from the hot plate, cool and add water to the 4 ml mark.
5. When cool, insert a clean cork in each tube and shake to mix well. Allow the sample solution to settle for a few minutes.
6. Using the 0.1 ml pipette, transfer a 0.1 aliquot of the sample solution to a screw-cap culture tube.
7. Add 35 ml of buffer solution to the tube.
8. Using an automatic pipette, add 5 ml of dithizone test solution to the tube; cap the tube and shake vigorously for ½ minute.
9. Note the color of the dithizone solution layer on the bottom, and read the parts per million of metal in the sample, indicated in the table following.
10. If the color of the dithizone solution is red, a smaller aliquot of the sample solution should be taken. If the color of the dithizone solution is unchanged, a 0.2-ml aliquot may be taken.

Notes

1. A uniform packing of the fine soil particles in the scoop will usually give the best results.

4. A small amount of water is lost in boiling. It is necessary to maintain the same volume.

6. Measured portions of the sample solution are called aliquots.

8. Carbon tetrachloride is **toxic** and should be transferred with an automatic pipette. It is important to add the same amount of dithizone solution to each sample for accurate color comparisons. The color obtained when the sample solution is shaken with dithizone solution is a mixture of the colored dithizone solution which has reacted with metal and green dithizone solution which has not reacted. This is known as a mixed-color method. The metal content of a soil solution is proportional to the change in color of the dithizone solution.

10. An aliquot larger than 0.2 ml will change the pH of the buffer solution and should not be used.

Table for estimating heavy metals content in parts per million of sample

Aliquot	Green	Blue Green	Blue	Purple	Red Purple	Purple Red	Red
0.2 ml	0	50	100	150	200	250	300 or more
0.1 ml	0	100	200	300	400	500	600 or more
0.05 ml	0	200	400	600	800	1000	1200 or more
0.01 ml	0	1000	2000	3000	4000	5000	6000 or more

The content of the heavy metals in the sample, extracted by the acid digestion, is given in parts of metal per million parts of sample taken. The table is used by reading the aliquot taken in the column on the left, then reading across the table to the column headed by the color obtained with that aliquot; parts per million is shown by the number at the junction of the two columns. For example: If a 0.05-ml aliquot is used and the color of the dithizone solution is purple, the sample contains 600 parts per million of heavy metals extracted in the procedure. If the color of the dithizone solution is red, a smaller aliquot of the sample solution should be taken, in order that a color be obtained measurable as parts per million of metal in the above chart. An aliquot greater than 0.2 should not be used.

INDIVIDUAL MEASUREMENT OF COPPER, LEAD, AND ZINC

The methods given for measuring heavy metals are excellent for general prospecting of a large area. They offer a rapid, inexpensive means of attaining information on heavy metals, but do not tell how much of each metal is present. As one metal may obscure the others in a heavy metals test, individual measurement of each metal gives more specific information.

For these methods the samples are digested in an acid solution. The solution is then brought to a definite volume and aliquots of the solution are taken for each of the tests. (Aliquots are measured portions of the sample solution.) The colors developed in the procedure for the sample aliquots are compared with a standard series of colors obtained from known amounts of each metal which are prepared prior to running a group of samples. By carefully comparing sample colors with standards, the metal content of the sample is determined.

The chemicals required to determine copper, lead, and zinc on about 250 samples are listed below. The solutions prepared from these chemicals are listed under "Reagents and Equipment." The desired stock is given in units listed by supply firms and consequently some chemicals are in excess of the amount needed.

Potassium cyanide	Reagent grade	¼ lb.
Ammonium citrate	" "	½ lb.
Hydroxylamine hydrochloride	" "	¼ lb.
Sodium thiosulphate	" "	½ lb.
Sodium acetate	" "	1 lb.
Dithizone (Diphenylthiocarbazone)	" "	1 gram
Thymol blue, sodium salt	" "	1 gram
Copper sulfate (Monohydrate)	" "	¼ lb.
Zinc, metal	" "	¼ lb.
Lead Nitrate (anhydrous)	" "	¼ lb.
Hydrion paper, pH paper 1-11		1 package
Ammonium hydroxide, concentrated	Reagent grade	1 bottle (5 lb.)
Nitric acid, concentrated	" "	1 bottle (7 lb.)
Acetic acid, glacial	" "	1 bottle (1 lb.)
Carbon tetrachloride	" "	2 bottles (5 lb. ea.)
Chloroform	" "	1 bottle (5 lb.)
Hydrochloric acid, concentrated	" "	1 bottle (1 lb.)

Reagents and Equipment

1. **Potassium cyanide solution (0.2 percent).** Dissolve 2 g of potassium cyanide in 100 ml of water.

2. **Lead complexing solution.** Dissolves 50 g of ammonium citrate, 10 g of potassium cyanide, and 8 g of hydroxylamine hydrochloride in 800 ml of water. Add concentrated ammonium hydroxide until the solution has a pH of 8.5. Dilute to 1000 ml with water. Purify the solution by shaking with stock dithizone solution until the dithizone solution remains green. Extract the complexing solution with 50-ml portions of chloroform until the chloroform remains colorless. Remove the chloroform dissolved in the complexing solution by shaking with two 50-ml portions of carbon tetrachloride.
3. **Zinc buffer solution.**
   A. Dissolve 125 g of sodium thiosulfate in 500 ml of water. Purify by shaking with stock dithizone solution, then remove dissolved dithizone from the buffer with carbon tetrachloride.
   B. Dissolve 306 g of sodium acetate in 500 ml of water containing 60 ml of glacial acetic acid. Purify as above. Mix A and B together and dilute to 2000 ml with water.

Notes

1. **CAUTION!** Potassium cyanide is very **poisonous.** Never measure a cyanide solution with a pipette operated by mouth, and never add acid to cyanide or to a cyanide solution.
2. Hydrion pH test paper is used to show when the solution has a pH of 8.5. The same procedure is used for cleaning the lead complexing solution as was used for cleaning the solvent solution in the heavy metals test. At the pH of 8.5, more dithizone is dissolved in the aqueous phase than at a lower pH. The dithizone is more soluble in chloroform than in carbon tetrachloride; hence, chloroform is used here.

Reagents and Equipment	Notes
4. **Copper buffer solution.** Dissolve 100 g of ammonium citrate in 1000 ml of water.	4. If a good grade of ammonium citrate is used it is not necessary to purify the solution. Shake 1 ml of the copper buffer solution with 2.5 ml of dithizone solution. If the dithizone solution remains green, it will not be necessary to purify the buffer solution. If necessary the solution may be purified by the same procedure as the one used to purify the zinc buffer solution.
5. **Stock dithizone solution (0.01 percent).** Dissolve 0.1 g of dithizone in 1000 ml of carbon tetrachloride. Shake well and let stand overnight .	5. This stock solution is diluted as needed and will last for several weeks if stored in a cool dark place. Continued shaking is necessary to dissolve the dithizone in carbon tetrachloride.
6. **Dithizone test solution (0.001 percent).** Dilute 100 ml of 0.01 per cent dithizone solution to 1000 ml with carbon tetrachloride.	6. The 0.001 percent dithizone solution is used in the analysis of copper, lead, and zinc. Dithizone solutions are easily oxidized in strong light or heat. Oxidized dithizone solutions are light green to yellow in color and cannot be used. It is difficult to see the color change when the solution is slightly oxidized. To test for slight oxidation, transfer 5 ml of the dithizone solution to a screw-cap culture tube containing 10 ml of water. Add 5 drops of 1 N ammonium hydroxide, cap tube and shake vigorously for 15 seconds. The carbon tetrachloride phase should be colorless. If it is yellow, the dithizone is oxidized. It should be discarded and a fresh solution prepared.
7. **1+3 nitric acid.** Add 200 ml of concentrated nitric acid to 600 ml of water. Mix well.	7. The 1+3 nitric acid solution is used to digest the samples.
8. **Ammonium hydroxide.** 1 normal (1 N). Dilute 67 ml of concentrated ammonium hydroxide to 1000 ml with water.	
9. **Thymol blue indicator.** Dissolve 0.4 g of the sodium salt of thymol blue in 100 ml of water.	
10. **Hydrochloric acid.** 1 normal (1 N). Dilute 83 ml of concentrated hydrochloric acid to 1000 ml with water.	
11. **Standard copper solution, 0.01 percent,** (100 micrograms per ml). Dissolve 0.1964 g of copper sulfate in water; add 50 ml of 1 N hydrochloric acid and dilute to 500 ml with water.	11. The standard solutions should be stored in Pyrex. The stock solutions (0.01 percent) may be kept for many months. The dilute solutions (0.001 percent) may be kept for several weeks.
12. **Standard copper solution, 0.001 percent** (10 micrograms per ml). Transfer 10 ml of the above to a 100-ml volumetric flask. Add 10 ml of 1 N hydrochloric acid and dilute to 100-ml volume with water.	
13. **Standard zinc solution, 0.01 percent** (100 micrograms per ml). Dissolve 0.1 g reagent grade zinc in 10 ml of 1 N hydrochloric acid and dilute to 1 liter with water.	
14. **Standard zinc solution, 0.001 percent** (10 micrograms per ml). Transfer 10 ml of above solution to a 100-ml volumetric flask and dilute to 100-ml with water.	

Reagents and Equipment	Notes
15. **Standard lead solution, 0.01 percent** (100 micrograms per ml). Dissolve 0.016 g of dry reagent grade lead nitrate in 25 ml of water containing 1 ml of concentrated nitric acid, and dilute to 100-ml volume with water.	
16. **Standard lead solution, 0.001 percent** (10 micrograms per ml). Add 10 ml of above solution to about 25 ml of water containing 1 ml of concentrated nitric acid and dilute to 100-ml volume with water.	
17. **Hot plate.** Same as for heavy metals test.	
18. **Digestion rack.** A rack similar to the one used for the heavy metals test, but with holes 11/16 inch in diameter, to accommodate 16× 150 mm culture tubes. See Figure 57.	
19. **50 Pyrex culture tubes,** 16×1500 mm, marked at 10 ml.	
20. **Culture tube rack,** ,to accommodate 16×150 mm tubes.	
21. **10 screw-cap culture tubes,** 20×200 mm.	
22. **Sieve,** with 80-mesh stainless-steel wire or bolting cloth.	22. A satisfactory sieve may be made by removing the center piece from the cover of a 1-pint round ice cream container. Replace the center piece with 80-mesh silk bolting cloth and press the band of the cover back in place. Then remove the bottom of the container.
23. **Separatory funnel.** One, Squibb type, 125-ml size.	23. Add 10 ml of water to the separatory funnel and mark with a file at the 10-ml level.
24. **6 Graduated cylinders,** 25-ml, glass-stoppered.	
25. **A 2-ml and a 5-ml automatic pipette** to dispense the dithizone test solution.	25. Carbon tetrachloride is **toxic**; do not use a pipette operated by mouth to dispense carbon tetrachloride dithizone solutions.
26. **Sample scoop.** To hold 0.1 g of 80-mesh sample. The 0.1 g scoop made for the heavy metals test may be used.	26. More precise analysis can be made by weighing the sample on a balance.
27. **3 Serological pipettes:** 1.0-, 5.0-, 10.0-ml sizes graduated in 1/10 ml.	
28. **3 Volumetric pipettes:** 1.0-, 2.0-, and3.0-ml sizes.	
29. **Anti-bump sticks.** Cut 4 mm outside diameter Pyrex tubing into 7-inch length. Heat each tube 1 inch from the bottom until soft, then pinch together with a pair of tongs to make an airtight seal.	
30. **Dropping bottles:** Four 125-ml size.	30. The dropping bottles are used to dispense thymol blue, 1 N hydrochloric acid, concentrated, and 1 N ammonium hydroxide.
31. **Reagent bottles:** One 2000-ml, eight 1000-ml and two 500-ml Pyrex bottles.	31. All reagents should be stored in Pyrex bottles, as soft glass bottles often cause contamination with traces of metals in the glass.
32. **Wash bottle.** 500-ml, polyethylene.	32. This is convenient for washing pipettes and adding water to test tubes.
33. **6 Volumetric flasks,** Pyrex, capacity 100 ml.	
34. **4 dozen cork stoppers,** No. 4, regular.	

PREPARATION OF SAMPLE SOLUTION

Procedure	Notes
1. Sieve the dry sample and collect several grams of the minus 80-mesh fraction. Mix thoroughly, then take 0.1 g of the sample with the measuring scoop and dump it into a 16 × 150 mm culture tube.	
2. Add 3 ml of 1 + 3 nitric acid and shake to wet the sample.	
3. Place the culture tube in the rack over the hot plate and boil the contents gently for 1 hour.	3. An anti-bump tube placed in the culture tube will prevent bumping of the tube during digestion. See Figure 57. The bumping is caused by superheating at the bottom of the tube. If half of the solution boils away, add 1 ml of water and continue digestion.
4. Remove the culture tubes from the hot plate and bring the volume to 10-ml mark with water.	
5. When cool, insert a clean cork in each tube and shake to mix well. Let the tube stand in the rack for about half an hour or until the solution clears. This is the sample solution which which aliquots are taken to run copper, lead, and zinc.	

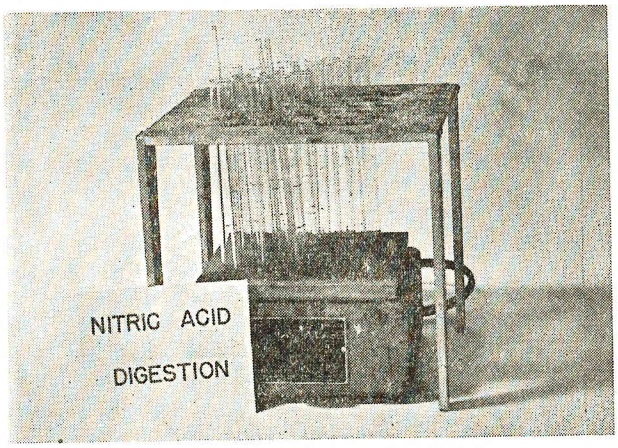

Figure 57—Digestion Rack

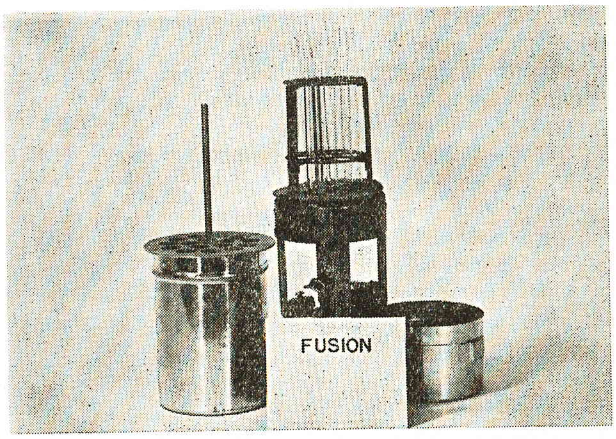

Figure 58—Fusion Apparatus

DETERMINATION OF ZINC

Procedure	Notes
1. Transfer a 1-ml aliquot of the sample solution into a screw-cap culture tube.	1. See Step 5 of "Preparation of Sample Solution."
2. Add 8 ml of zinc buffer solution to the tube.	2. The sodium thiosulfate in the zinc buffer complexes or "blocks-out" the copper and lead, leaving only zinc to react with the dithizone solution. The sodium acetate in the buffer solution maintains a constant pH.
3. Add 5 ml of dithizone test solution to the tube with an automatic pipette. Screw on the cap and shake the tube vigorously for half a minute.	
4. Match the color of the dithizone solution with the color of the nearest zinc standard (described below). If the color is green, take a 2-ml aliquot and repeat test. If red, take a smaller aliquot and repeat.	

Procedure	Notes
5. Record the volume of the aliquot and the micrograms of zinc in the standard it matches.	
6, Calculate the parts per million of zinc in the sample.	6. See sample calculation given on page 90.

ZINC STANDARDS

Procedure	Notes
1. Using a 1-ml graduated pipette transfer 0.1, 0.2, 0.3, and 0.4 ml of standard zinc solution (10 micrograms/ml) to 4 screw-cap culture tubes; add a fifth culture tube for a blank. These correspond to 0, 1, 2, 3, and 4 micrograms of zinc, respectively. Mark the tubes for identification.	
2. Add 8 ml of zinc buffer and 5 ml of dithizone test solution to each of the five culture tubes. Shake tubes vigorously for half a minute.	2. The standards are always prepared in the same manner as the samples. The dithizone test solution in the tube which contains no zinc should remain green; the 1 microgram standard is blue green; the 2 is blue purple; the 3 is purple; and the 4 is red purple. The standards would be prepared fresh daily.

DETERMINATION OF COPPER

Procedure	Notes
1. Transfer 2 ml of the sample solution into a screw-cap culture tube.	1. The sample solution is that prepared in Step 5 of "Preparation of Sample solution."
2. Add 1 ml of copper buffer solution.	2. The buffer solution helps to maintain the pH and also complexes iron which might otherwise interfere.
3. Add 2 drops of thymol blue indicator and 1 N ammonium hydroxide until the solution is yellow. Then add 1 N hydrochloric acid dropwise until the solution is a faint orange color (pH about 2.5).	3. Thymol blue is red in color below pH 1.2 and yellow above 2.8. The faint orange color is seen when the pH is slightly below 2.8. Titration with ammonium hydroxide until the solution is yellow, then back titration with acid to a faint orange color is the most reliable method of obtaining the faint orange color.
4. Add 2.5 ml of dithizone test solution to each tube.	4. At this pH the lead and zinc will not react with dithizone.
5. Screw on cap and shake tues vigorously for 2 minutes.	
6. Match the color of the dithizone solution with the color of the nearest copper standard.	
7. Record the volume of the aliquot and the micrograms of copper in the standard it matches.	
8. Calculate the parts per million of copper in the sample.	8. The copper content is calculated in the same way as the zinc. See sample calculation on page 90.

COPPER STANDARDS

Procedure	Notes
1. Transfer 0.1, 0.2, 0.3, and 0.4 ml of copper standard (10 micrograms/ml) to 4 screw-cap culture tubes; add a fifth culture tube for a blank. These correspond to 0, 1, 2, 3, and 4 micrograms of copper, respectively. Mark the tubes for identification.	

Procedure	Notes
2. Add 1 ml copper buffer solution to each tube.	
3. Add 2 drops of thymol blue and titrate to a faint orange color.	3. See Step 3 of "Determination of Copper."
4. Add 2.5 ml dithizone test solution, screw cap on tube and shake the tube vigorously for 2 minutes.	4. The 1-microgram is blue green; and 2 is deep blue; the 3 is red purple; the 4 is red. They should be protected from strong light and should be prepared fresh daily. If exposed to light the standards may begin to fade in color due to oxidation of the dithizone. This fading may be retarded by adding a few crystals of hydroxylamine hydrochloride between Steps 2 and 3 in the procedure.

DETERMINATION OF LEAD

Procedure	Notes
1. Transfer a 2-ml aliquot of the sample solution to a 125-ml separatory funnel.	1. The sample solution is that prepared in Step 5 of "Preparation of Sample solution."
2. Fill the separatory funnel to the 10-ml mark with lead complexing solution.	2. The ammonium citrate complexes iron and aluminum, the potassium cyanide complexes copper and zinc, and the hydroxylamine hydrochloride prevents oxidation of the dithizone. **CAUTION!** Potassium cyanide is very **poisonous.** Never measure a cyanide solution with a pipette operated by mouth, and never add acid to cyanide or to a cyanide solution.
3. Add 2 drops of thymol blue indicator. Then add concentrated ammonium hydroxide dropwise, shaking after each addition, until the solution is blue green in color (pH about 8.5).	3. Thymol blue is yellow in color below pH 8, green to blue between 8 and 9.6, and blue above pH 9.6. Although lead is extracted into the dithizone solution in the pH range 8 to 10, more consistent results will be obtained by titrating to the same blue green color each time. When the thymol blue indicator is added to the separatory funnel, the solution will be yellow. As concentrated ammonium hydroxide is added, the pH is raised until the solution is blue green in color (pH aobut 8.5).
4. Add 5 ml of dithizone test solution. Insert glass stopper and shake gently for 20 seconds. Allow layers to separate.	
5. Drain the dithizone solution layer into a 25-ml glass-stoppered graduated cylinder containing 10 ml of potassium cyanide solution.	5. The potassium cyanide solution has a high pH. At this pH the dithizone which has not reacted with lead is extracted into the cyanide solution, leaving the pink lead dithizonate in the carbon tetrachloride phase. **CAUTION!** Potassium cyanide is very **poisonous.** Never measure a cyanide solution with a pipette operated by mouth, and never add acid to cyanide or to a cyanide solution.
6. Insert a glass stopper and shake the cylinder gently for 10 seconds.	
7. Allow the layers to separate and match the color of the pink carbon tetrachloride solution with the color of the nearest lead standard.	
8. Record the volume of the aliquot and the micrograms of lead in the standard it matches.	
9. Calculate the parts per million lead in the sample.	9. The lead content is calculated in the same way as copper and zinc. See sample calculation on page 90.

LEAD STANDARDS

Procedure	Notes
1. Transfer 0.1 ml standard lead solution (10 micrograms/ml) into the separatory funnel.	1. A series of standards containing 0, 1, 2, and 3 micrograms of lead are prepared and range in color from colorless, to light pink, to deep pink. The standards and samples are run individually. Wash the funnel with water between each determination. The standards should be protected from strong light and prepared fresh every four hours. Certain fluorescent lights may cause the standards to fade rapidly. The comparisons can be made in daylight, but not in direct sunlight.
2. Fill the separatory funnel to the 10-ml mark with lead complexing solution.	
3. Add 2 drops thymol blue indicator and bring pH to about 8.5.	3. See Step 5 in "Determination of Lead."
4. Add 5 ml dithizone test solution. Shake and allow phases to separate and drain bottom layer into graduated cylinders containing 10 ml of cyanide solution. Insert stopper and shake the cylinder for 10 seconds.	
5. Repeat the above four steps, using 0.2, and 0.3 ml of standard lead solution containing 10 micrograms/ml; a fourth cylinder is used for a blank. The standards contain 0, 1, 2, and 3 micrograms of lead, respectively. Mark the graduated cylinders for identification.	

SAMPLE CALCULATION

The color obtained by shaking the sample solution is compared to the color of the nearest standard. If it nearly matches the 2-microgram standard, then the aliquot taken contains about 2 micrograms of the metal being measured. The metal content is calculated in micrograms per gram of sample (parts per million). The following formula may be used to calculate the parts per million only when 0.1 gram of sample is used and the volume of the sample solution (Step 5, "Preparation of Sample solution") is 10 ml.

$$\frac{100 \times \text{micrograms found}}{\text{milliliters aliquot}} = \text{parts per million in sample}$$

Example: A 1-milliliter aliquot is used and is found to contain 2 micrograms of metal.

$$\frac{100 \times 2}{1} = 200 \text{ parts per million}$$

$$\text{parts per million} \times 0.0001 = \text{percent}$$

$$200 \text{ parts per million} = 0.02 \text{ per cent}$$

DETERMINATION OF MANGANESE

In this test the sample is fused with a flux (potassium pyrosulfate) instead of boiled in acid. The fused sample is taken into solution with acid. The manganese in the sample solution is converted into potassium permanganate which has a characteristic purple color. The intensity of the purple color is proportional to the amount of manganese in the sample.

The chemicals required to determine manganese on about 1000 samples are listed below. The desired stock is given in units listed by supply firms and some chemicals are in excess of the amount needed. The solutions prepared from these chemicals are listed under "Reagents and Equipment."

Potassium pyrosulfate, fused powder	Reagent grade	1 lb.
Potassium periodate	" "	¼ lbs.
Nitric acid, concentrated	" "	1 bottle (7 lbs.)
Phosphoric acid, ortho	" "	1 bottle (1 lb.)
Sulfuric acid, concentrated	" "	1 bottle (1 lb.)

Procedure	Notes
10. To the culture tube containing the aliquot add 2 ml of 1 + 3 nitric acid. Shake.	
11. Then add 0.2 ml of sulfuric acid and 0.5 ml of phosphoric acid, shaking the culture tube after each addition.	11. Phosphoric acid forms a colorless complex with iron, thus eliminating iron interference.
12. Add about 0.2 g of potassium periodate and place tube in a hot water bath for 15 minutes. Shake the culture tube intermittently during the 15 minutes.	
13. Remove the culture tube from the hot water bath and dilute to 10-ml volume with water. Shake and let settle half an hour before comparing with standards.	
14. Match the color obtained with the color of the nearest manganese standard. Record the volume of the aliquot and the micrograms of manganese in the standard it matches.	14. A closer comparison can be made by looking through the tube from top to bottom.
15. Calculate the parts per million or percent of manganese in the sample.	15. Parts per million manganese can be calculated in the same way as copper, lead, and zinc, and may be converted to percent manganese. See page 90 for sample calculation.

MANGANESE STANDARDS

Procedure	Notes
1. Transfer 0.5, 1, 1.5, and 2.5 ml of standard manganese solution containing 20 micrograms per ml to four 16 × 150 mm culture tubes; add a fifth tube for a blank. Transfer 0.5, 1, 1.5, and 2 ml of standard manganese solution containing 200 micrograms per ml to 4 more culture tubes. Mark the tubes for identification.	1. The standards will contain 0, 10, 20, 30, 50, 100, 200, 300, and 400 micrograms of manganese, and will range in color from a faint purple to a deep purple. The standards will last several weeks if corked and kept in a dark place when not in use.
2. To the culture tubes containing the manganese standard, add 2 ml of 1 + 3 nitric acid. Shake.	
3. Then add 0.2 ml of sulfuric acid and 0.5 ml phosphoric acid, shaking the culture tubes after each addition.	
4. Add about 0.2 g potassium periodate to each tube and place tubes in a hot water bath for 15 minutes. Shake the tubes intermittently during the 15 minutes.	
5. Remove the culture tubes from the hot water bath and dilute to 10 ml with water. Shake and let settle.	

Reagents and Equipment

1. **Sample scoop.** To contain 0.1 g of sample.
2. **Flux scoop.** To contain 0.5 g of potassium pyrosulfate.
3. **Gasoline stove.**
4. **Metal rack.** To hold 6 or 7 culture tubes on the stove.
5. **50 Pyrex culture tubes.** 16 × 150 mm, marked at 10 ml.
6. **Culture tube rack.** To hold 16 × 150 mm tubes.
7. **1 + 3 nitric acid.** Add 200 ml of concentrated nitric acid to 600 ml of water and mix well.
8. **Test tube holder.** 6-inch.
9. **1 1-ml pipette,** graduated in 0.1 ml.
10. **1 5-ml pipette,** graduated in 0.1 ml.
11. **1-ml and 2-ml volumetric pipettes.**
12. **4 dozen cork stoppers,** no. 4, regular.
13. **Standard manganese solution.** Dissolve 0.1 g of pure manganese metal in 10 ml of 1 + 3 nitric acid. After the manganese metal is completely dissolved, dilute the solution to 500 ml with water and mix well. This solution contains 200 micrograms of manganese per ml.
14. **Standard manganese solution.** (20 micrograms per ml.) Dilute 10 ml of the above standard manganese solution to 100 ml with water and mix well.

Notes

1. The scoop made for the heavy metals test may be used.
2. The flux scoop is made in the same manner as the others, but make the hole 3/8 inch in diameter and ¼ inch deep.
3. A small gasoline camp stove similar to a Coleman GI stove is quite satisfactory.
4. This rack may also be used to hold the tubes in place in the water bath. See Figure 58.

Procedure

1. Add a scoopful (0.1 g) of finely ground sample to a dry 16 × 150 mm culture tube.
2. Add one large scoopful (0.5 g) of potassium pyrosulfate fused powder to the tube.
3. Alternately tap and rotate the tube to mix sample and flux well.
4. Place the tubes in the metal fusion rack over a hot flame and heat about 3 minutes after the flux is molten. Rotate the tube to get all of the sample into the melted flux.
5. Remove the tube from the flame with a test tube holder and rotate the tube so that the melt will cool in a thin film on the side of the tube.
6. When the tube is cool, add 3 ml of 1 + 3 nitric acid.
7. Place the tube in a hot water bath until the melt disintegrates into a fine powder. It may be necessary to remove the tube from the water bath and shake it to bring the melt on the sides of the tube into solution.
8. Remove the culture tube from the water bath and dilute to the 10-ml mark with water. When cool insert a clean cork into each culture tube and shake to mix well. Place in a culture tube rack and allow to settle half an hour.
9. Transfer a 2-ml aliquot of the sample solution to a 16 × 150 mm culture tube.

Notes

4. If the flux does not melt on heating, add one extra scoopful (0.5 g) of potassium pyrosulfate.

7. The top of the can which contains the stove may be used for a water bath.

GLOSSARY

Aliquot—A measured portion of an aqueous solution. The volume of sample solution used in a determination.

Buffer solution—A solution containing chemicals which resist a change in pH.

Complex—A compound or compound ion that behaves differently than the ions from which it is formed. Also used to mean forming a compound, or blocking out a metal.

Digestion—Boiling a sample in a liquid to bring it into solution.

Gram—A unit of weight in the metric system. Abbreviation is g. One gram equals 0.0022 pound. 453.6 grams equal 1 pound.

Heavy metals—Copper, lead, and zinc as a group.

Indicator—A chemical which changes color with a change in pH. Example: Thymol blue.

Liter—A unit of volume in the metric system. One liter equals 2.11 pints.

Meter—A unit of length in the metric system. Abbreviation is m. One meter equals 39.37 inches.

Microgram—One millionth of a gram. Symbol often used is the Greek letter gamma. One gram equals 0.035 ounces.

Milliliter—One thousanth of a liter. Abbreviation is ml.

Millimeter—One thousandth of a meter. Abbreviation is mm.

Normal—A normal solution contains the molecular weight in grams of the dissolved substance divided by the hydrogen equivalent (cation valence) of the dissolved substance per liter of solution.

Example:

H_2SO_4 Mol. Wt. = 98 Hydrogen equivalent = 2

$\frac{98}{2} = 49$ g of H_2SO_4 required per liter for a I N solution

Na_2SO_4 Mol. Wt. = 142 Hydrogen equivalent = 2 as Na is equivalent to H

$\frac{142}{2} = 71$ g of Na_2SO_4 required per liter for a 1 N solution

Parts per million—Number of parts of the metal in a million parts of the sample. Abbreviation is ppm. One microgram is one millionth of a gram; therefore, micrograms per gram = ppm. Parts per million × 0.0001 per cent.

pH—A measure of the alkalinity or acidity of a solution. In a strict sense, a measure of the hydrogen ion concentration.

pH paper—A paper which gives a characteristic color for each pH value.

Reagent—A chemical compound of known composition used for a specific purpose in the analysis. Also used to indicate grade of purity.

Sample solution—A solution containing a known amount of sample in a definite volume.

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