STATE OF MONTANA
BUREAU OF MINES AND GEOLOGY
E. G. Koch, Director

BULLETIN 48

GEOCHEMICAL RECONNAISSANCE STREAM-SEDIMENT SAMPLING IN FLATHEAD AND LINCOLN COUNTIES, MONTANA

by

U. M. Sahinen, W. M. Johns, and D. C. Lawson
Montana Bureau of Mines and Geology

This report has been prepared by the Montana Bureau of Mines and Geology under a cooperative agreement with the Great Northern Railway Company and the Pacific Power & Light Company

MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY
Butte, Montana
October 1965

Free from

Montana Bureau of Mines and Geology

Room 203-B, Main Hall

Montana College of Mineral Science and Technology

Butte, Montana

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ABSTRACT

Samples of stream sediment were collected at half-mile intervals along all drainages in three areas in northwestern Montana--the Yaak River area in the Purcell Mountains and the Star Meadows and Hog Heaven areas in the Salish Mountains. Total project area was 818 square miles, and 1,284 samples were collected. Samples were analyzed for total heavy metals by the citrate method and for copper, lead, and zinc (individually) by the pyrosulfate-fusion method. A few selected samples were analyzed for beryllium and molybdenum. Further investigation of twenty-five specific localities by soil sampling is recommended.

INTRODUCTION

A 6-year reconnaissance mapping and mineral survey program in northwest Montana, principally in Lincoln and Flathead Counties, was completed by the Montana Bureau of Mines and Geology in 1963. This program, the Kootenai-Flathead Project, was made possible [illegible] by the Pacific Power & Light Company and the Great Northern Railway Company.

As a follow-up program, a geochemical project was started during the 1964 field season. This project involved reconnaissance stream-sediment sampling for base-metal mineralization in three areas thought to be promising on the basis of previous mapping. These areas are in the Purcell Mountains north of Troy and in the Salish Mountains northwest and southwest of Kalispell. Total geochemical-project area amounts to 818 square miles. This phase of the project was financed by an additional $12,000 provided by the co-sponsors.

The field crew, supervised by D. C. Lawson, consisted of R. F. Heaphy, J. C. Taylor, E. J. Smith, and R. J. Glovan. Field work commenced July 9 and terminated September 26, 1964. During this $10\frac{1}{2}$ weeks, 1,284 stream-sediment samples, including check samples, were obtained from the Yaak River, Star Meadows, and Hog Heaven areas. Additional soil sampling during a 5-day period in October by W. M. Johns and D. C. Lawson filled in sections of the Hog Heaven district where stream-sediment sampling coverage was not adequate.

METHOD OF SAMPLING

All stream-sediment samples were taken at half-mile intervals or at each stream intersection, whichever was reached first. The streams were sampled to within half a mile of their heads, or to where active stream sediments were no longer developed. Marshes and swamps were avoided because of abnormal concentration of base metals accumulated there.

Sampling procedure was to completely fill the sample sack with approximately three-quarters of a pound of active sediment, consisting of black loam intermixed with organic material, obtained from several spots in the stream bed. Samples were then dried in aluminum pans, stirred with wooden stirrers, at 450° to 500° F, to burn off all organic material, which interferes with the dithizone color reaction. When each sample was completely dried and all chunks broken, the material was screened through a nylon cloth and the -80 mesh fraction placed in sample bags marked by stream name and sample number corresponding to a number on the work map.

Soil-sample traverses were made where stream sediments had not been sufficiently developed or were absent. Individual soil samples were spaced one-tenth mile apart and were taken from the mineralized "C" zone, or mixtures of "A" and "C" zones, of the soil, dried and screened in the procedure described above, and analyzed by both citrate and fusion methods in the laboratory.

Lawson analyzed all stream-sediment samples for total heavy metals in the field. All analyses of soil samples and lead, zinc, and copper fusions of stream-sediment samples were done in the laboratory by Lawson, assisted by F. P. Jones. X-ray analyses were made and evaluated by J. M. Chelini.

From the samples collected within or near mineralized areas and intrusive and extrusive igneous rocks in the Hog Heaven area, 97 were selected for Lawson to analyze for beryllium and molybdenum. None of the samples analyzed contained beryllium, but about a third contained molybdenum in amounts ranging from 5 to 20 ppm. All analytical techniques are included in the Appendix.

LOCATION

Project areas are in the Purcell and Salish Mountains of northwest Montana. The Kootenai River valley lies between the Purcell Mountains to the west and Salish Mountains to the east.

Fifteen days were spent in the Yaak River area, including the Sylvanite mining district, in the Purcell Mountains north of Troy, where 15 streams and their tributaries were sampled. Sampling was confined within an area bounded on the north by the Hellroaring Creek-Spread Creek divide, on the east and southeast by Yaak River, on the southwest by Pine Creek, and on the west by the Idaho boundary. A total of 214 stream-sediment samples were obtained within 100 square miles, at stream intersections or at half-mile intervals.

Star Meadows, in the Salish Mountains, is approximately 35 miles northwest of Kalispell. The sampled area is bounded on the north by the Good Creek-Martin Creek divide, on the east by the Stillwater River valley, on the south by U. S. Highway 2, and on the west from Marion to Elk Mountain by the Flathead Forest boundary. Approximately 42 days were spent sampling streams within this 451 square miles from which 580 stream-sediment samples were obtained.

The third area, totaling 267 square miles, includes the Hog Heaven mining district, about 25 miles southwest of Kalispell, and Hubbart Reservoir to the west. The area extends northward to U. S. Highway 2, eastward to Lake Mary Ronan, southward to the Flathead-Sanders County line, and westward to the divide between Little Bitterroot and Thompson Rivers. In 17 days 358 stream-sediment samples were collected within the described area.

TOPOGRAPHY

The Yaak River area in the Purcell Range of Lincoln County is mountainous and heavily forested, maximum relief amounting to 4,000 feet. Mount Baldy (6,536 feet) and Newton Mountain (6,534 feet) are near the north and south ends of the area, respectively. Consequent streams drain eastward to the Yaak River, whose junction with the Kootenai River is at an altitude of 1,832 feet.

Topography in the central Salish Range surrounding Star Meadows is mountainous, although somewhat more subdued than the Yaak River country, and the mountains are timbered. Maximum relief is about 2,500 feet; average relief amounts to 2,000 feet. Elk Mountain, at the head of Good Creek, attains an altitude of 6,581 feet, and most valleys are at 4,000 feet or higher. Drainage is eastward to the Stillwater River.

In the Hog Heaven district, occupying the northern part of the Horse Plains quadrangle, terrain rises from low and rolling mature hills in the eastern sector to a 7,000-foot ridge along the west boundary. Valleys within are at altitudes of about 3,300 feet. Drainage is to Little Bitterroot River flowing south, and by north-flowing Mount Creek to Ashley Creek and Flathead River.

GENERAL GEOLOGY

YAAK RIVER AREA

Belt rocks (Precambrian) of the Ravalli Group and the pre-Ravalli Prichard Formation underlie the sampled area (Johns, 1959, 1961). Prichard rocks here range from white medium-grained quartzite through dark- and medium-gray phyllite to laminated dark- and medium-gray and tan argillite, commonly sericitic and ferruginous. A rusty brown weathering is characteristic for upper beds, the result of weathering of biotite, pyrite, and pyrrhotite randomly distributed throughout the rock. Thickness of the pre-Ravalli rocks is believed to exceed 12,000 feet in this region. The base is not exposed.

Conformably overlying the Prichard is the Ravalli Group (undifferentiated), which is even-grained hard white to light-gray thin- to thick-bedded quartzite. The Ravalli Group, about 7,000 feet thick in this region, contains sparse to moderate amounts of magnetite octahedra and exhibits sedimentary features such as ripple marks, mud cracks, and cross bedding.

Metadiorite sills a few feet to several hundred feet thick occur in the sample area. Glacial drift from the Cordilleran ice sheet is present in the Yaak River valley and locally near Buckhorn Mountain ridge.

The northwest-trending Sylvanite anticline is a broad, symmetrical fold paralleling the regional strike of Belt rocks. In the Purcell Mountains it is the major fold, and the trace of its axial plane cuts the Sylvanite mining district. Northwest and northeast faults displace folds and sills.

STAR MEADOWS AREA

The Star Meadows area is underlain by lower and middle Belt rocks; in ascending order they are the pre-Ravalli Prichard Formation, Ravalli (undifferentiated), and Piegan (Johns, 1962). The Piegan Group here is represented by the lower unit (P_1) and middle unit (P_2, Ross's Siyeh Formation). The upper unit (P_3) is missing west of Kalispell and Lake Mary Ronan.

Prichard rocks, consisting of a homogenous sequence of laminated dark-gray, medium-gray, and light-gray sericitic argillite, are exposed along a northwest-trending thrust fault that brings several hundred feet of upper beds of this formation to the surface. Two exposures in the sample area are east of Sheppard Peak and Tepee Hill.

The Ravalli Group, ranging in thickness from 7,000 to 10,000 feet and covering a fairly extensive area, is thin- and medium-bedded white, light-gray, and purple-toned quartzite, argillaceous quartzite, and argillite, containing magnetite, biotite, and sericite. These beds form cliffs and resistant ridges.

Lower and middle Piegan strata occupy the central and eastern part of the Star Meadows area, where the lower (P_1) unit is a laminated or medium-bedded gray-green calcareous argillite and noncalcareous argillite conformably overlain by the middle (P_2) unit of dark-gray, purple-gray, and light-gray molar-tooth limestone and interbedded calcareous argillite. Combined thickness of the two units of the Piegan Group is about 6,000 feet.

Sparse metadiorite dikes trend east and sills trend northwest, respectively almost perpendicular and almost parallel to the regional strike of the Belt rocks. Valleys are floored with Quaternary glaciofluvial and fluvial gravel. Recent alluvium borders streams.

Symmetrical and asymmetrical broad and tight folds plunge northwest and southeast. Northwest normal faults, high-angle thrusts, and east-striking transverse faults displace folds.

HOG HEAVEN AREA

Sedimentary rocks of the Ravalli Group (undifferentiated) are the surface rocks in this sample area south of U. S. Highway 2 to the Flathead-Sanders County line, excepting several square miles of basal Piegan strata (P_1) north of Haskill Mountain (sec. 3, T. 26 N., R. 23 W.) (Johns and others, 1963). The Ravalli is reported as about 10,000 feet thick in the area to the south. Only the lower several hundred feet of the Piegan (P_1) unit crops out north of Haskill Mountain.

The Ravalli Group here is greenish-gray and gray argillite that grades upward into light-gray, purple-banded quartzite, followed by purple-toned argillite.

The basal Piegan (P_1) unit is commonly mud-cracked, laminated or medium-bedded pale-green, gray-green, yellow-green, and medium-gray argillite and calcareous argillite. Locally, gray finely crystalline limestone and thin beds of gray to white calcareous-cemented quartzite occur within the unit.

Cenozoic igneous rocks occurring as volcanic flows and intrusive plugs have an areal extent of about 25 square miles. Flow rocks include andesite, latite, and andesite tuff. Intrusive bodies are composed of andesite, latite, quartz latite, and basalt. The Flathead and West Flathead ore bodies are associated with flow rocks and intrusive rocks.

Discontinuous gentle folds plunge south, the major structure being a broad, poorly defined anticline.

Three categories of faults cut the area. They are north-trending normal and reverse faults, east-trending transverse faults and a group of smaller faults related to volcanic rocks.

ANOMALOUS STREAM-SEDIMENT SAMPLING RESULTS*

The Kootenai-Flathead project is being conducted in stages; the initial geologic mapping program determined the more favorable broadly metalliferous areas, and subsequent stream-sediment sampling may indicate possible new mining districts in sampled areas. Stream sediments were sampled to point out areas of above-normal concentrations of base-metal ions where detailed work through soil sampling may be warranted. The purpose of this report is to present data on the stream-sediment survey and determine whether additional detailed geochemical work (soil sampling) is advisable.

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*Tabulated results of sampling are on open file at the offices of the Montana Bureau of Mines and Geology, Butte, where they can be consulted by interested parties. Results are shown symbolically on Plates 1, 2, and 3.

Geology of individual districts should be considered when evaluating stream-sediment sampling. In the Sylvanite mining district of the Yaak River area the rocks are Prichard argillite and Ravalli quartzite, both good host rocks for mineralization. The Sylvanite properties produced native gold from quartz veins containing little or no associated base metals, hence there may be but sparse lead and zinc ions available for concentration in stream sediments here.

In the Star Meadows mining district, host rock for most northeast- and east-trending veins is the lower Piegan calcareous argillite. This unit and the associated P_2 and P_3 units and Missoula Group sedimentary rocks throughout western Montana, northern Idaho, and British Columbia are recognized as poor host rock. The ore found here contains principally copper, the minerals being chalcopyrite, bornite, and chalcocite in a siderite and quartz gangue. No zinc minerals were recognized at any properties; small amounts of galena have been reported only from the Sanko mine in upper Sanko Creek.

Silver-lead mineralization in Ravalli sedimentary rocks and Tertiary igneous rocks, both favorable hosts, in the Hog Heaven mining district is of the replacement type; at the Flathead mine, a zone a few hundred feet wide is mineralized, in contrast to narrow veins 1 to 5 feet wide in the other two districts. Sphalerite and tetrahedrite are associated with these silver-lead ores. At or near igneous-sedimentary rock contacts near the surface, ore minerals at the West Flathead mine have been found in replacement veins and near horizontal solution holes or tubes as "fumarole mud".

It is believed pertinent to point out that the mines in sec. 17, T. 25 N., R. 23 W. (Flathead and West Flathead), have produced ore valued at a total of $8,000,000, which represents only ore containing more than 40 ounces of silver a ton. The anomalies indicated by the sampling (excluding contamination from a millsite and numerous mine dumps affecting Sullivan Creek samples 6, 7a, 7b, 8, 9, 10) are not impressive for a property with such a production record. Hawkes and Webb (1962, p. 275) state: "Mining and smelting activity constitutes one of the most serious sources of contamination of surface water. Extremely high metal concentration normally occurs in water draining old workings and ore piles where the primary sulfide minerals have been artifically exposed to the air and the oxidation process thereby greatly accelerated. It has been estimated that the metal content of such waters may be 10 or even 100 times higher than if the deposits had not been opened up." Although the statement applies to water sampling, stream sediments deposited by creeks would also be affected by mill tailings and mine dumps.

Within the West Flathead adit is a 60-foot winze on a massive tetrahedrite vein ranging in width from 1 to 3 feet. The top of the winze is probably within 40 feet of the surface, yet stream sediments (Sullivan Creek samples 3, 5, 6, 8, 9, 10) gave copper values of 20 to 30 ppm, which are only background values for copper distribution in the area. Sample Sullivan-7a gave a copper value of 120 ppm, probably in most part from contamination from the Flathead mine dump. Sample 7b is believed possibly to reflect copper minerals occurring in or near the West Flathead ore body. For these reasons consideration should be given all anomalous samples within the three districts, even though the strength and number of the anomalies do not compare favorably with numerical values from producing or formerly productive mining districts elsewhere.

Background values have been defined as the normal abundance of elements in barren earth material, and they may vary from area to area depending on the nature of the material sampled and the distribution of elements, whereas anomalies are defined as the deviation from normal geochemical patterns. In soil or stream sediment, background is rarely uniform, so it is more realistic to view background and subanomalous and anomalous values as ranges of values rather than fixed numerical figures.

To determine the ranges for background and anomalous values for each area described in this report, a statistical frequency distribution for total heavy metals and each individual element for stream-sediment and soil sampling was determined, and the upper $2\frac{1}{2}$ percent of the total number of samples in each case (excluding very high erratic values) were arbitrarily taken as anomalous, thus establishing a lower limit for the anomalous range. The limit between background range and subanomalous range was determined visually from statistical histograms for total heavy metals and for each element.

Anomalous areas indicated by stream sediment and soil samples in which the authors place the greatest reliability are those that show anomalies for all four determinations--total heavy metals, zinc, copper, and lead. Twenty-five areas that may warrant further investigation by standard soil-sampling procedures are listed by districts below.

YAAK RIVER DISTRICT

Crawford Creek samples 1 to 4 were taken about 1 to $1\frac{1}{2}$ miles west of Yaak River in the Sylvanite district. Zinc and lead anomalies are present here in stream sediments. Additional soil sampling may be warranted in the $N\frac{1}{2}$ sec. 16 and 17, T. 34 N., R. 33 W., to determine whether the lead-zinc is associated with the northwest-trending Morning Glory-Keystone-Goldflint vein or another unknown vein in this vicinity.

On upper True Newton Creek in sec. 25, T. 34 N., R. 34 W., of the Yaak River district, samples 6, 7, 8, and 10 gave anomalous values for zinc, and samples 9 and 10 gave anomalous copper values. The sample area is underlain by the Prichard Formation of the Belt Series. A northeast-striking metadiorite dike in the NE$\frac{1}{4}$ sec. 26 may be the source of the metals.

Samples 11 and 12 collected about midway up Red Top Creek, in sec. 11, T. 34 N., R. 34 W., gave anomalous values for total heavy metals and lead, and samples 19 and 20 gave above-background values for total heavy metals, zinc, and lead. Country rock is Prichard argillite and phyllite. A metadiorite sill trends northwestward through the area. Again a metadiorite intrusive body may have caused the anomaly.

Toward the head of the South Fork of Meadow Creek, samples 5, 6, and 7 gave anomalous results for zinc, sample 6 for heavy metals, and sample 7 for lead. The country rock is Prichard argillite intruded by a metadiorite sill. The sill may have some bearing on the anomalies.

At the very head of the North Fork of Meadow Creek, on the southeast flank of Keno Mountain, several anomalous values were obtained for heavy metals, zinc, and copper. Metadiorite sills cut Prichard argillite and quartzite on the northeast and southwest flanks of the mountain, and two thin quartz veins, less than a foot thick, were observed to the west of the anomalous area. The anomalies seem to represent other mineralization, however, and may bear further investigation. The anomalies may be due to a concealed southeastward extension of the Buckhorn vein, which is exposed in the SW$\frac{1}{4}$ sec. 20, T. 36 N., R. 34 W., and which has yielded some ore on the Idaho side of the state boundary.

STAR MEADOWS DISTRICT

On Sullivan Creek in sec. 19, T. 30 N., R. 24 W., adjacent to the Foolsberg and West Virginia mines, is an area where additional soil sampling seems warranted. Anomalous values for heavy metals, zinc, copper, and lead were obtained.

From sec. 1 through 6, T. 30 N., R. 25 W., anomalies were obtained on an east-west lineament where crossed by Swanson, Swaney, Listle, and Dunsire Creeks. On the geologic map (Johns, 1962) this lineament appears as a large east-west fault zone. Additional soil sampling here is indicated.

In sec. 5, 6, 7, 8, and 18, T. 31 N., R. 24 W., along Trixie Creek and next drainage east (First East, Trixie Creek), several samples show above-average values for lead. These samples are within or adjacent to tight folds and a northwest fault in the Piegan Group P_1 (argillite) and P_2 (limestone) units. A small quartz-diorite stock or boss occurs in the extreme northern part of sec. 19, T. 31 N., R. 24 W., which suggests a source of metalliferous solutions. Systematic soil sampling seems to be warranted.

On Brown Creek in sec. 3 and 4, T. 29 N., R. 23 W., is an anomalous buildup (samples 2 to 6) in copper to 70 ppm. Additional sampling here may be warranted. The country rock is Piegan limestone cut by a northeast fault near the head of the creek.

The Blacktail vein near the head of Sanko Creek may extend west into the N$\frac{1}{2}$ sec. 30, T. 31 N., R. 24 W. Additional soil sampling in the N$\frac{1}{2}$ sec. 30 is recommended, even though stream-sediment anomalies were not found on Sanko Creek.

Anomalous values for zinc were obtained in upper Sheppard Creek, Star Meadows district, from samples 22, 24, and 25, sec. 18, T. 30 N., R. 25 W., samples 19, 20, and 21, sec. 13, samples 6 and 7, sec. 23, sample 15, sec. 24, and samples 8, 9, and 13 in sec. 26, T. 30 N., R. 26 W. Total heavy metals anomalies were recorded in sec. 18, T. 30 N., R. 25 W., and in sec. 23, 24, and 26, T. 30 N., R. 26 W. The area is underlain by Prichard argillite, Ravalli quartzite, and the lower P_1 unit of the Piegan Group. Two large northwest-striking faults near Sylvia Lake bisect the sampled area, and may have been avenues of metallization that resulted in the anomalies.

Sample 7 on Swanson Creek near the center of the N$\frac{1}{2}$ sec. 36, T. 31 N., R. 25 W., gave anomalous values for copper, zinc, and lead. Sample sites are underlain by the Piegan argillite. Samples 2, 3, and 4 on Star Creek and sample 1 on Sinclair, both east of Swanson Creek, gave anomalous values for copper and zinc. This area needs further investigation.

An interesting group of anomalies, principally lead, were recorded for Bowen Creek, Plume Creek, Robertson Creek, and upper Good Creek in the eastern part of T. 31 N., R. 26 W., and the western part of T. 31 N., R. 25 W. The country rock here is Piegan limestone and argillite and Ravalli quartzite. The cause of these anomalies is not apparent, and the area should be investigated further by systematic soil sampling.

On lower Alder Creek in sec. 2, 3, 4, and 11, T. 31 N., R. 25 W., weakly anomalous values for copper and lead were recorded. The lower and middle units of the Piegan Group (argillite and limestone) underlies the area.

Anomalous values for lead and zinc were recorded for sample 16 on Herrig Creek, in sec. 26, T. 28 N., R. 25 W. Some copper and zinc anomalies were noted in the north along the creek and a south-flowing tributary. The sample site is near or on an east-striking fault. Country rock is the Prichard Formation.

Samples 4, 5, and 6 on Miller Creek, in sec. 21, T. 32 N., R. 24 W., gave anomalous values for lead. Values for zinc, copper, and total heavy metals were not above background range. The area is underlain by the Piegan Group limestone.

HOG HEAVEN DISTRICT

Total heavy metals, zinc, copper, and lead anomalies were determined along Sullivan Creek in sec. 17, 20, 28, and 29, T. 25 N., R. 23 W. Metals were derived from the Flathead and West Flathead ore bodies, apparently accompanied by considerable contamination from mine dumps and a mill-site on Sullivan Creek in the center of the W$\frac{1}{2}$ sec. 20.

In Upper Little Meadow Creek, close-spaced samples in sec. 5, 6, 7, and 8, T. 25 N., R. 23 W., show anomalies for heavy metals, zinc, copper, and lead, which might be related to buried(?) igneous rocks, an extension of the stock exposed at the Flathead and West Flathead mines. Additional sampling is indicated.

Samples collected on the upper two-thirds of Section 16 Creek, sec. 16, 22, and 34, T. 25 N., R. 23 W., were anomalous. The contact of the stock with Ravalli sedimentary rock trends northwest through this section, a possible exploration target here. The Birdseye mine is near the center of the W$\frac{1}{2}$ sec. 16, a state-owned section.

On a tributary of Section 16 Creek, samples 19, 20, 21, 22, and 23 show a buildup of copper values from the mouth to the head of the tributary. These sample sites are in sec. 13, 23, and 26, T. 25 N., R. 23 W. The area is underlain by the Ravalli Formation of the Belt Series, and may bear further investigation.

Samples 10, 11, and 12 on a tributary of Lower Little Meadow Creek, sec. 26, and 27, T. 25 N., R. 24 W., gave anomalous values for zinc, and sample 10 also gave an anomalous value for lead. Country rock is Ravalli quartzite and argillite.

At the head of Mount Creek in sec. 10 and 11, T. 25 N., R. 23 W., samples 2 and 3 gave anomalous values for copper. Country rock in the area is the Ravalli Formation.

OTHER ANOMALOUS AREAS

After stream-sediment sampling in the Hog Heaven district was complete, it was noted that there were several large areas where, because of the lack of stream sediments, no sampling had been done. These areas were then crossed by soil-sampling traverses, significant results of which are given below.

On traverse 1, soil samples 1-2 through 1-6 in the SW$\frac{1}{4}$ sec. 20, T. 25 N., R. 23 W., and on a second traverse soil samples 2-2 through 2-5 in the E$\frac{1}{2}$ sec. 19, T. 25 N., R. 23 W., gave anomalous heavy metals, lead, and zinc values. Anomalies here may be related to either one of two igneous-sedimentary rock contacts or the northwest-trending fault on which the Martin and Battle Butte mines are located.

On soil traverse 4, west of Brooks Creek in the NE$\frac{1}{4}$ sec. 9, and NW$\frac{1}{4}$ sec. 10, T. 25 N., R. 24 W., samples 4-2 to 4-6 showed anomalies for total heavy metals and zinc, which may be related to a small Tertiary stock cropping out on the west side of Brooks Creek. The sample locations are in intrusive latite and the Ravalli Formation.

Between Tamarack and Briggs Creeks on soil traverse 6, sec. 35 and 36, T. 26 N., R. 25 W., and sec. 2, T. 25 N., R. 25 W., sample site 6-1 to 6-3, 6-5, 6-16, 6-17, and 6-21 to 6-24 showed above-background values for zinc. The country rock is the Ravalli Formation. Basalt dikes crop out northeast of Briggs Creek, and the anomalies may be related to base metals associated with similar but covered intrusive bodies.

On traverse 7, soil samples 7-26 and 7-27 were taken on the west shore of Hubbart Reservoir across a protruding tongue of igneous rocks in the NE$\frac{1}{4}$ sec. 7, T. 25 N., R. 24 W. Analyses for these samples were high, relative to background values for the area.

Also on traverse 7, soil samples 7-52 and 7-54 in the N$\frac{1}{2}$ sec. 17, T. 25 N., R. 24 W., and samples 7-32 and 7-36 in the E$\frac{1}{2}$ sec. 13, T. 25 N., R. 25 W., may warrant further investigation. Sampling was done within an igneous stock and above roads used for logging operations. Possible contamination of the samples at these locations should be kept in mind.

X-RAY ANALYSES

Thirty-nine samples selected from stream sediment and soil samples containing above-average base-metal content from the Sylvanite, Hog Heaven, and Star Meadows mining districts were analyzed qualitatively on the Norelco x-ray fluorescence spectrograph to determine whether any elements were present in addition to those determined by geochemical analysis.

Preparation of samples entailed pulverizing and screening to -200 mesh. Each sample was irradiated with tungsten radiation, at a voltage potential of 35 kilovolts and a filament current at 25 milliamperes. A scanning speed of one degree 2 θ per minute and scale of 418 (scale factor, 4; multiplier, 1; time constant, 8) were used.

Spectrographs of the samples corroborated the existence of the elements zinc, lead, and copper determined geochemically, and revealed, in addition to these, the presence of iron, manganese, rubidium, strontium, zirconium, and nickel. Nickel and zinc were found to be present in trace amounts in several samples from each district, and the presence of nickel should probably be investigated further. Manganese, rubidium, strontium, and zircon were common to all samples. Zircon, strontium, and rubidium are common constituents of sedimentary and igneous rocks and their presence in all spectrographs is not significant.

CONCLUSIONS AND RECOMMENDATIONS

The twenty-five sites described under "Anomalous stream-sediment sampling results" are recommended for possible further investigation by means of a soil-sampling program. Many of the anomalous areas described separately are actually interrelated segments of a much larger anomalous area. For instance, in the Hog Heaven district, stream-sediment anomalies described under Upper Little Meadow Creek, upper Mount Creek, Sullivan Creek, Section 16 Creek, and soil-sampling traverses 1 and 2 are undoubtedly closely interrelated parts of a regional anomalous area outlined in Plates 2 and 3. A similar grouping is suggested for the Sheppard Creek area in the Star Meadows district. A regional anomalous area for lead is suggested on upper Good Creek and its tributaries.

Some above-average metal values for the described samples are believed to be related to possible areas of weak to moderate fissure or replacement-type mineralization, which only additional work can prove or disprove.

APPENDIX--ANALYTICAL PROCEDURES

CITRATE METHOD FOR TOTAL HEAVY METALS

A 0.1-g scoop of the -80 mesh fraction is transferred to a 25-mm glass-stopper graduated cylinder, 5 ml of the ammonium citrate solution at a pH of 8.5 is added and shaken for 10 seconds. Then 2 ml of 0.001 percent dithizone solution in toluene is added, and the sample shaken vigorously for 5 seconds.

Then dithizone is added in increments of 1 ml with continued shaking until a blue-gray color is obtained. As an index of heavy-metal content, the volume of dithizone solution used is recorded in ml. Samples showing much metal content flash red immediately when shaken, and 3 or 4 ml of dithizone solution can be added at a time until the solution turns purple, after which time the dithizone is added in increments of 1 ml until the blue-gray color appears, indicating reaction of all metal ions present. The number of ml of dithizone used can be converted to ppm of zinc, as 1 ml of .001 percent dithizone is equal to approximately 0.25 ppm of zinc standard.

PYROSULFATE-FUSION METHOD FOR COPPER, LEAD, AND ZINC

This technique gives near-total solution of the copper, lead, and zinc in most soils and rocks. Dithizone is used for determining zinc by the mixed-color method. It is also used in the presence of cyanide to determine lead by means of the monocolor method. The copper, however, is determined by using 2, 2'-biquinoline to form a monocolored copper complex.

The procedure for the fusion method is as follows: Measure 0.1 g of the sample into a 15 x 150-mm culture tube. Scoop 0.5 g of potassium pyrosulfate flux into the tube and shake the tube to mix the sample and flux. Fuse the mixture for about 2 minutes after the flux melts. Remove the tube from the flame and rotate the tube so that the melt cools in an easily digestible thin film on the sides of the tube. When the tube is cool, add 3 ml of (1:1) hydrochloric acid to the tube, and place in a hot-water bath until the melt has disintegrated. Remove the tube from the water bath and dilute the sample to 10 ml with metal-free water and shake vigorously to mix the solution. Suitable aliquots are taken from this solution for the copper, lead, and zinc determinations*, and compared colorimetrically with standards from which ion concentration is determined.

A total of 1,152 stream-sediment samples and 132 check samples were obtained from the three areas. In the Hog Heaven and Star Meadows areas 261 soil samples from nine soil traverses were obtained. Total samples amounted to 1,545 for the areas investigated. From total samples taken in the field, 1,416 heavy-metal analyses and 4,248 fusion determinations were made. For heavy-metal analyses any samples whose numerical value amounted to 12 ml .001 percent dithizone or more were rerun. Fusion determinations for all zinc and lead analyses exceeding 70 ppm and copper analyses exceeding 50 ppm were rerun. All samples showing only traces but which were bracketed by samples showing numerical values were reanalyzed, and spot checks were made on any series of low samples.

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*The procedures used for the ammonium citrate and pyrosulfate fusions were obtained from the field-methods text for the summer geochemical prospecting course taught by Prof. Harold Bloom at Colorado School of Mines.

A close check of chemical consumption for the project was kept both in the field and the laboratory. The reagent consumption for the heavy-metals ammonium citrate determinations based on 1, 545 samples was \$45. 30, or 3¢ per determination.

The reagent consumption for the potassium-pyrosulfate fusions based on 1, 416 samples and 4, 248 determinations amounted to \$126. 61, or 9¢ per sample and 3¢ per determination.

Costs for the project were:

Total cost per sq. mi.	\$ 14. 66
Total cost per sample determination	2. 11
Total chemical cost	172. 11
Chemical cost per sample.	. 12
Cost of 2, 030 sample sacks used.	69. 82

Beryllium was determined by a method described by E. C. Hunt and others (1960). Standard beryllium solutions, Dow Separan 2610, Nervanaid F, and Berrillon II solution were used.

Molybdenum was determined by a method described by F. N. Ward (1951). This method is based on the reaction between molybdenum and thiocyanate in the presence of stannous chloride. Isopropyl either is used to extract the molybdenum thiocyanate complex formed, and standard molybdenum solutions are used as references to estimate molybdenum content.

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