UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Geology and Geochemistry of Some Hydrothermally Altered Rocks, Pioneer Mountains, Beaverhead County, Montana

By

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Abstract

Hydrothermally altered rocks that contain sparse molybdenite have been found in three separate bodies in the Pioneer batholith, central Pioneer Mountains, Montana. Small quartz porphyry bodies are associated with the altered rocks. South of Jacobson Meadows a fracture stockwork more than a km across consists of quartz-pyrite veins and a potassic alteration-mineral assemblage. Two bodies of greisen-like rock north of Elkhorn Springs are 1.3 and 3 km long and 0.3 and 0.5 km wide, respectively. Though deeply weathered they seem to consist of vuggy aggregates of muscovite, quartz, pyrite, and locally K-feldspar. Muscovite from two samples gives K-Ar ages of 66.0±2 and 69.4±1.6 m.y. The three bodies merit further study in the search for molybdenum deposits.

Introduction

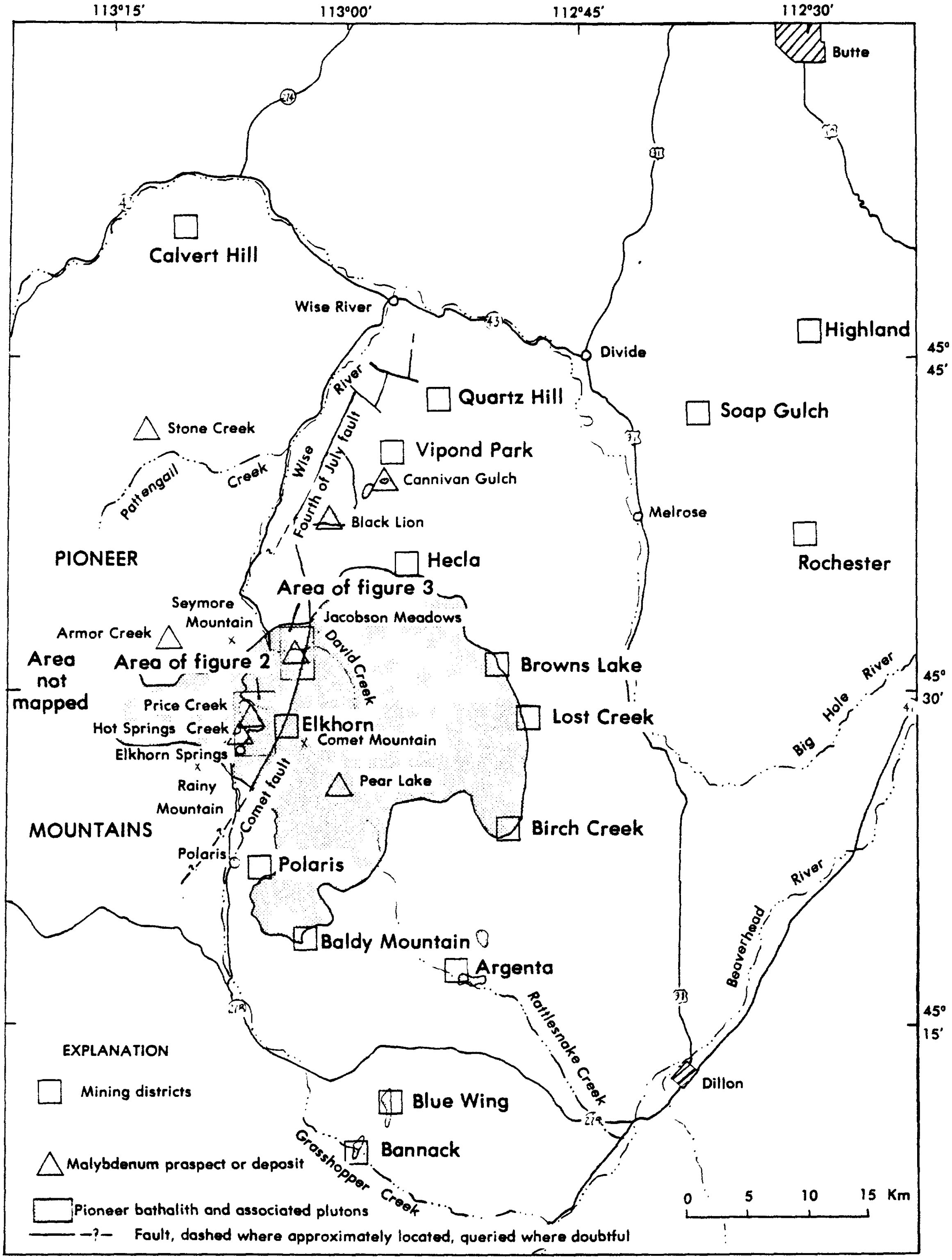
Three large bodies of hydrothermally altered rocks have been found in the Pioneer batholith during geologic and geochemical studies in the Pioneer Mountains, Beaverhead County, southwest Montana. The altered rocks are likely targets for mineral exploration as they are similar in mineralogy, rock associations, and geochemistry to nearby prospects currently being explored or developed for molybdenum deposits. One of the bodies of altered rock is a fracture stockwork consisting of intersecting quartz-pyrite veins typical of molybdenum deposits. The other two bodies differ from typical molybdenum deposits in that the alteration was pervasive and produced a greisen-like rock; these two bodies also seem to lack close-spaced fracturing or any evident local structural control. Molybdenite has been found in small amounts in all three zones. Principal hydrothermal minerals in all zones are quartz, pyrite, muscovite, K-feldspar, and rutile. In addition, hydrothermal biotite and magnetite are common in the body that consists of intersecting veins. All three bodies are associated with small intrusions of quartz porphyry.

Scattered prospect workings in the altered rocks appear to date back at least several decades--most of them probably to the late 19th and early 20th centuries when mining activity was at a peak in the nearby Elkhorn mining district. These bodies of altered rock probably were not recognized at that time as parts of one or more large hydrothermal systems of the type that formed large copper and molybdenum deposits nearby such as at Butte and Cannivan Gulch. The purpose of this report is to call attention to these potential exploration targets and to present the available preliminary data based on several days field work. Some additional work in under way, and other studies are planned to refine further the distribution, age, and character of rock bodies, alteration-mineral assemblages, and geochemical anomalies. This work is a product of a mineral resource evaluation of the Dillon 1°x2° quadrangle under the Conterminous United States Mineral Assessment Program (CUSMAP) of the U.S. Geological Survey.

The altered rocks are about 75 km southwest of Butte, Montana, near the center of the Pioneer Mountains (fig. 1). All three bodies are 2 km or less from the maintained gravel road that trends about north through the middle of the Pioneers, following the north-flowing Wise River and the south-flowing Grasshopper Creek and connecting State Highways 43 on the north and 278 on the south.

For convenience, the three bodies of altered rock are referred to as the Jacobson Meadows, the Price Creek, and the Hot Springs Creek zones. The Jacobson Meadows zone lies about 4 km north of the Elkhorn mining district and east of the confluence of Jacobson Creek and Elkhorn Creek. The Price Creek and Hot Springs Creek zones lie about 2 km west of the Elkhorn district and are crossed by the Grasshopper Creek-Wise River road north of Elkhorn Springs.

We acknowledge the very capable assistance of Terry Grotbo and Jan van der Voort, who collected soil samples and assisted in the mapping.



Base from U.S. Geological Survey,
Dillon 1°x 2° quadrangle, 1955-62.

Geology compiled by R. C. Pearson from mapping by R. C. Pearson, 1978-1979; L. W. Snee, 1979, E-an Zen, 1960-1979; D. R. Zimbleman, 1978-1979, and modified from Calbeck (1975), Lowell (1965), Myers (1952), and Snee (1978).

Figure 1.--Index map of Pioneer Mountains and vicinity, southwestern Montana

Geology and Mineral Deposits in the Pioneer Mountains

The Pioneer Mountains are a subcircular range about 60 km across that consists mainly of strongly folded and faulted sedimentary rocks ranging in age from Precambrian to Cretaceous (Myers, 1952; Lowell, 1965; Fraser and Waldrop, 1972). The sedimentary rocks presumably overlie Archean or Proterozoic gneissic granitic rocks that crop out locally in the northeast part of the Pioneers as fault blocks (E-an Zen, oral commun., 1978). The Pioneer batholith and other plutons of latest Cretaceous and early Tertiary age intrude the older rocks (Zen and others, 1975). Tectonically, the range is on line with the Idaho-Wyoming thrust belt, and several thrusts are known within the range as well as east and west of it (Myers, 1952; Ruppel, 1978).

The Precambrian sedimentary rocks are dominantly quartzitic and have a general resemblance to the Belt Supergroup to the north and northwest. Phanerozoic sedimentary rocks of Cambrian through Mississippian age are dominantly carbonatic, and those of Pennsylvanian through Cretaceous age are mainly detrital.

The Pioneer batholith is one of several plutons east of the Idaho batholith within the Cordilleran fold and thrust belt. The main part of the Pioneer batholith crops out in the eastern part of the Pioneer Mountains as a body 20x30 km trending north (fig. 1). On the west side, the main part of the batholith narrows to an apophysis 5 km wide that extends west at least 15 km into the western part of the Pioneer Mountains. The altered rocks discussed in this report are located where the batholith narrows. The Pioneer batholith has been shown by Zen and others (1975) and Snee (1978) to be a calc-alkalic pluton the same age as (about 68-75 m.y.), and chemically similar to the Boulder batholith. Rocks of the Pioneer batholith are dominantly biotite-hornblende granodiorite and biotite granite. Minor leucocratic rocks include small bodies of pegmatite, alaskite (some of which is aplitic and some is very unevenly grained), and hypabyssal quartz-feldspar porphyry with aphanitic to fine-grained groundmass. All of these rocks seem to be related to the batholith and were considered as such by Snee (1978). The quartz porphyry has the texture of a hypabyssal rock, which contrasts markedly with the granitoid rock it cuts, and in some localities it seems to be the focus of extensive hydrothermal alteration and mineralization that affected the surrounding granitic rocks, as well as the porphyry itself. Quartz porphyry bodies are present in all three altered zones discussed in this report, and similar rocks are known elsewhere in the Pioneer Mountains. K-Ar ages of 66.0 and 69.4 m.y. on muscovite from altered rocks suggests that the quartz porphyry represents a late-stage event of the Pioneer batholith at this locality. The K-Ar ages are discussed in the section, "Altered rocks at Hot Springs Creek and Price Creek."

High-angle faults younger than the plutons are widespread in the Pioneers but seem to have little continuity except for the Comet fault in the Elkhorn district and the Fourth of July fault (Calbeck, 1975) in the Wise River valley. These two faults probably connect and form a major north-south structure that crosses the entire range (fig. 1). The Comet fault may have helped to localize the veins of the Elkhorn mining district, and may also have had a fundamental control on the hydrothermal alteration and mineralization at Jacobson Meadows. Movement on the Comet-Fourth of July fault probably took place at several times during the Tertiary and perhaps very late in the Tertiary to account for the fact that the eastern Pioneers are several hundred meters higher than the western Pioneers.

Glacial deposits, particularly moraines of the Wise River glacier, cover some of the altered rocks of the Price Creek and Jacobson Meadows zones.

Numerous small- to medium-sized mining districts in the Pioneer Mountains (fig. 1) are in close proximity to both the Pioneer batholith and to satellitic plutons that are similar in age or are a few million years younger than the batholith. Previous studies of the several districts include Winchell (1914), Shenon (1931), Karlstrom (1948), Pattee (1960), and Geach (1972). The Quartz Hill, Hecla, Polaris, and Argenta districts produced ore valued mainly for silver from veins and replacement deposits in Paleozoic sedimentary rocks. The Bannack district--known mainly for gold placers on Grasshopper Creek--also produced substantial gold, silver, copper, and lead from replacement deposits in carbonate rocks. Tungsten-bearing tactite has been mined from the Amsden Formation of Mississippian(?) and Pennsylvanian age in the Browns Lake, Lost Creek, Birch Creek, Baldy Mountain, and Calvert Hill districts. The Elkhorn district has produced mainly silver, copper, and lead from quartz veins in the Pioneer batholith.

Although the mineral production in the past has been valued mainly for gold, silver, lead, copper, zinc, and tungsten, and exploration continues actively for gold and silver, the current exploration is mainly for molybdenum. The Cannivan Gulch deposit (Schmidt and Worthington, 1977; Schmidt and others, 1979) is being drilled out, and the Stone Creek and Armor Creek prospects were being explored by drilling in August 1979. In addition, other molybdenum prospects (fig. 1) have been claimed and investigated in the last few years. The altered and geochemically anomalous rocks described in this report represent still other prospects and more probably remain to be found. The large number of molybdenum deposits, prospects, and occurrences now known suggests that the Pioneer Mountains may become a very significant molybdenum-producing area.

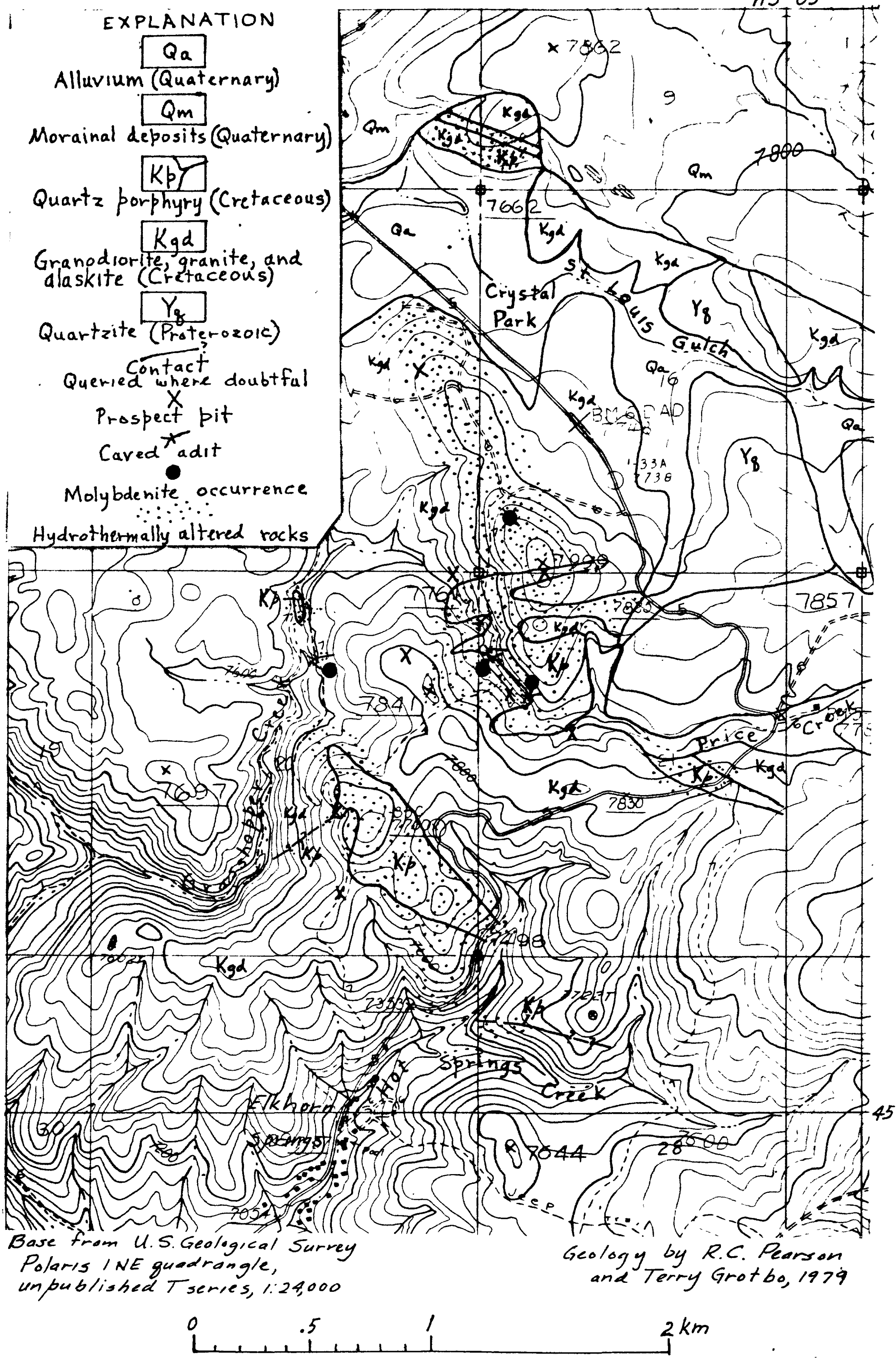
Altered Rocks at Hot Springs Creek and Price Creek

Two subparallel bodies of strongly altered rocks lie north of Elkhorn Springs in the headwaters of Grasshopper Creek (fig. 2). One body extends from south of Price Creek northward for perhaps 3 km and is referred to as the Price Creek zone. A smaller body, en echelon southwest of the Price Creek zone, is referred to as the Hot Springs Creek zone.

The bodies of altered rock occupy a broad area of low relief and generally poor bedrock exposure between the high, rugged, glaciated mountains to the east and the lower, rounded, timbered mountains to the west. Comet Mountain rises steeply to a height of 3,113 m about 3 km to the east (fig. 1). The altered rocks crop out mainly along timber-covered ridges that rise about 50-100 m above broad meadows such as Harrison Park and Crystal Park. Thick residual soil covers much of the altered rocks. To the north, bedrock is completely covered by the 4-km-wide lateral moraine of the Wise River.

The Price Creek zone is best exposed on the low ridge between lower Price Creek and St. Louis Gulch (fig. 2). North of St. Louis Gulch strongly altered rocks crop out on the south side of an unglaciated hill between the alluviated valley of St. Louis Gulch and the moraine; these altered rocks may be part of the Price Creek zone. South of Price Creek in an area of poor exposure, the effects of alteration seem to gradually diminish to a point along the road 200 m south of Price Creek where a porphyry dike about 100 m wide and adjacent granodiorite are weakly altered and mineralized. From this dike northward to the exposed limits of alteration north of St. Louis Gulch, the zone is about 0.5 km wide and 3 km long and is slightly arcuate and concave to the east.

The Hot Springs Creek zone is poorly exposed along the road from 0.7 to 1.2 km north of Elkhorn Springs. Altered quartz porphyry and adjacent granodiorite are also exposed about 0.9 km northeast of Elkhorn Springs (fig. 2)



Base from U.S. Geological Survey Polaris 1 NE quadrangle, unpublished T series, 1:24,000

Geology by R.C. Pearson and Terry Grotbo, 1979

Figure 2. Geologic map of the Price Creek-Hot Springs Creek area, Beaverhead County, Montana

along a road newly constructed in 1979. From this point the Hot Springs Creek zone extends north-northwest about 1.3 km, and seems to be continuous nearly to Grasshopper Creek. Over that distance it averages about 0.3 km wide. Farther north two small bodies of altered and mineralized rocks are exposed adjacent to Grasshopper Creek.

The Hot Springs Creek and Price Creek zones have formed in part in biotite-hornblende granodiorite typical of the Pioneer batholith and in part in quartz porphyry. Small alaskite dikes, which are common throughout the batholith, seem to be more abundant than normal in the vicinity of the altered zones. West of the mouth of Price Creek the batholithic rocks are more heterogeneous and more leucocratic than normal.

The country rock of the batholith in the vicinity of the altered rocks is Precambrian quartzite which forms Rainy Mountain to the south and Seymore Mountain to the north (fig. 1). An inclusion or roof remnant of the quartzite, 0.6x1.4 km in size, lies in the batholith east of the altered areas (fig. 2); it is strongly recrystallized to a coarse granoblastic aggregate of quartz and also contains metamorphic biotite, muscovite, and feldspar.

The quartz porphyry is confined to the altered zones and hence its original nature is largely obscured. However, in the less altered areas it is evident that the original rock consisted of phenocrysts of quartz, plagioclase, K-feldspar, and biotite in an aphanitic, leucocratic groundmass. Where alteration is least, as in the dike 900 m northeast of Elkhorn Springs, partially altered biotite remains in the rock. Quartz and plagioclase are the most abundant phenocrysts; they range from less than 0.1 mm to about 5 mm in diameter and comprise about 15 percent each of the rock. Most plagioclase crystals are euhedral; some quartz phenocrysts are euhedral, but many are rounded and partially embayed by resorption. K-feldspar is in euhedral crystals 1-4 mm long (other dikes contain K-feldspar phenocrysts 10-40 mm long). Biotite is in crystals 0.1-0.5 mm long partly altered to muscovite and rutile. K-feldspar and biotite each constitute about 4 percent of the rock. The groundmass is a very fine-grained aggregate of quartz and alkali feldspar partly altered to muscovite. Cubes of pyrite, partly altered to limonite, are sparsely disseminated through the rock and occupy veinlets along which the rock commonly breaks. The freshest available porphyry has a pale gray to chalky white appearance, and except in the most severely altered dikes where the texture is totally destroyed, the feldspar phenocrysts tend to weather out leaving small rectangular pits in the surface.

Alteration minerals in both zones are principally muscovite, quartz, K-feldspar, and pyrite in varying amounts. Many of the rocks have the appearance of greisen although no topaz, fluorite, tourmaline, or other minerals characteristic of greisen have yet been found. The central part of the Price Creek zone seems to be the most intensely and most completely altered. From the 7,999-foot hill (fig. 2) northward the rock, which was largely granodiorite, was completely converted to rather coarsely crystalline muscovite and quartz to judge from the resistant fragments in the thick residual soil. A few remnant masses of unaltered granodiorite several meters across are scattered through the otherwise altered rocks.

The contact between the zones of altered rock and the surrounding fresh rock is generally not exposed but seems to be fairly abrupt. Fresh granodiorite occurs several meters from intensely altered rocks. However, most unaltered rock in the area is weathered to grus and to rounded case-hardened boulder-like masses in which weak alteration may be difficult to recognize.

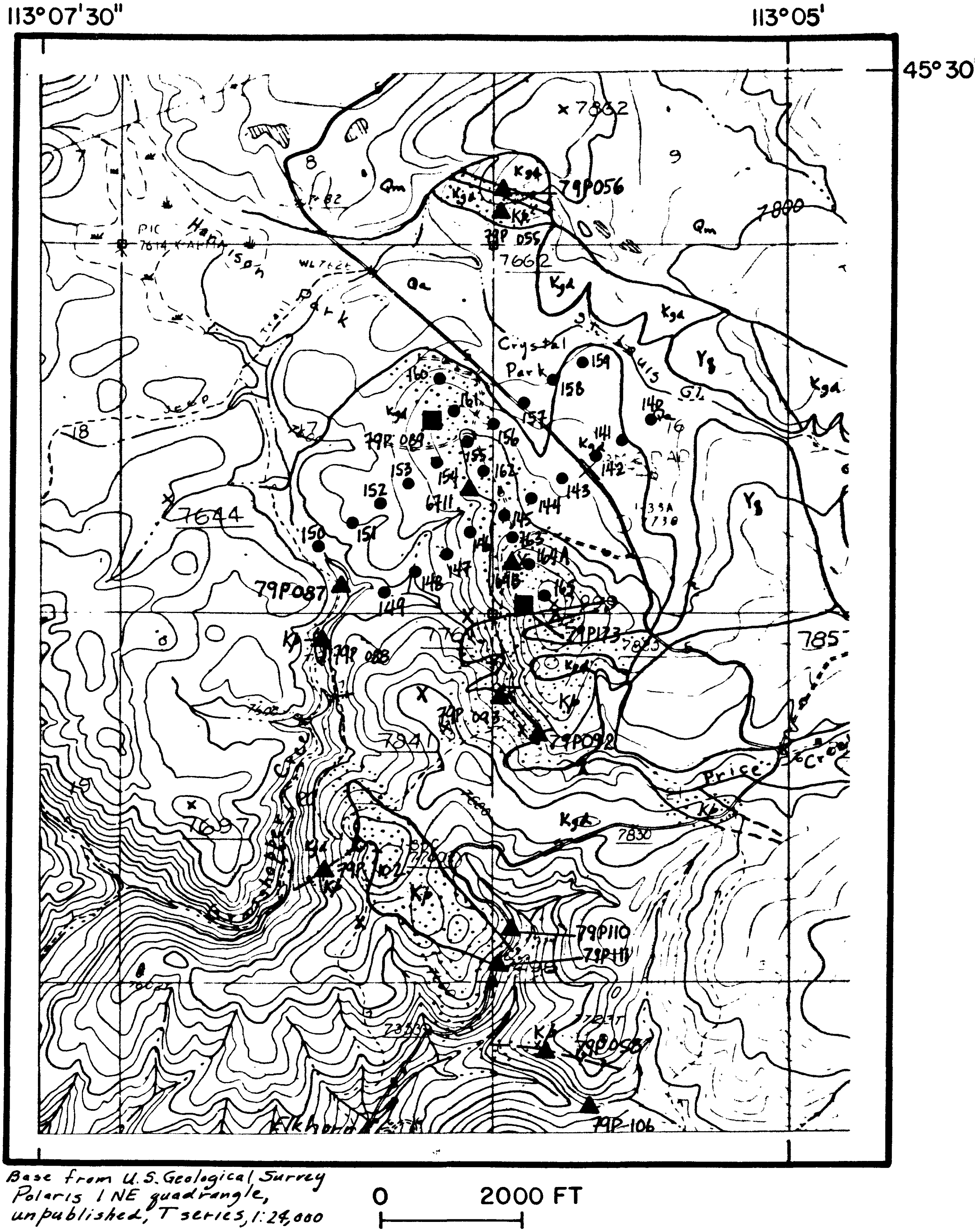
Much of the flat part of the ridge at an altitude of about 7,800 feet has been searched for quartz crystals by mineral collectors for many years. Many shallow pits dug in this endeavor reveal a deeply leached and oxidized soil 1-2 m deep or more, in which the most resistant fragments consist of intergrown coarsely crystalline muscovite and quartz in porous vuggy aggregates. Masses of limonite, which locally contain residual cores of pyrite, and liver-brown jasperoid fill or partially fill the vugs and angular spaces among the intergrown muscovite and quartz crystals. Minor rutile is intergrown with muscovite. Chalcedony lines or fills vugs, fractures, and angular interstices in aggregates of muscovite.

Muscovite is in irregular plates, sheaves, and rosettes that range from 1 to 5 mm in diameter. Most muscovite is stained light yellowish brown or medium brown by iron oxides though some is white to pale green. Quartz is in crystals that range from clear and colorless through various shades of white, yellow, pink, and smoky. The crystals are typically 1-10 mm across and a few millimeters to a few centimeters long. They form singly terminated crystals lining vugs and veins, doubly terminated crystals found in the soil, and anhedral aggregates. Most quartz is in irregular bunches with or without vugs, but some is in irregular veins or disseminated in muscovite. K-feldspar is abundant locally intergrown with quartz and muscovite in a porous medium-grained rock. K-feldspar forms euhedral to anhedral crystals that locally are enclosed in quartz and thus appear to be paragenetically early.

From the 7,999-foot hill south, quartz porphyry is the main altered rock in the Price Creek zone. The effects of alteration become progressively less severe southward in that the original texture of the rocks is commonly evident. The alteration mineralogy is apparently the same though generally finer grained

The Hot Springs Creek zone is similar to but even less well exposed than the Price Creek zone. It contains abundant quartz porphyry and the same types and patterns of alteration. Fine- to coarse-grained muscovite is common (locally the rock resembles greisen); limonite staining is also common; veinlets of limonite, quartz, and muscovite are sparse; and K-feldspar rock is present along the road a kilometer north of Elkhorn Springs. In addition, propylitic assemblage is evident in rocks along Grasshopper Creek 200-300 m south of the mouth of Price Creek. At that locality the rock is granite cut by a quartz porphyry that differs from most of the quartz porphyry in the altered zones because it contains abundant fresh biotite--much of it in the groundmass. Plagioclase phenocrysts and the groundmass are altered to sericite, chlorite, epidote, and pyrite. Veinlets contain quartz, pyrite, epidote, and K-feldspar. Some biotite may be an alteration mineral.

Sulfide minerals (pyrite, molybdenite, and arsenopyrite) were found in the altered rocks only on the dumps of prospect pits, in a few outcrops along Grasshopper Creek, and in trace amounts as unweathered cores in massive limonite. Their former presence elsewhere in the altered rocks is indicated by widespread and locally abundant limonite. Pyrite is the most common sulfide observed, but molybdenite is present in small amounts at most places where pyrite was found. Arsenopyrite and pyrite occur in vein quartz in altered granodiorite on a dump of an adit along Price Creek (sample 79P092, fig. 3); molybdenite and rutile are disseminated in adjacent wall rock that is almost completely altered to muscovite. A trace of molybdenite was found disseminated in quartz porphyry along Price Creek about 200 m northwest of this adit (sample 79P093, fig. 3). The most abundant sulfides were found on the dump of a prospect pit about 230 m north-northwest of the 7,999-foot hill that is south of Crystal Park. On this dump brassy pyrite and molybdenite are intergrown with massive muscovite and minor quartz.



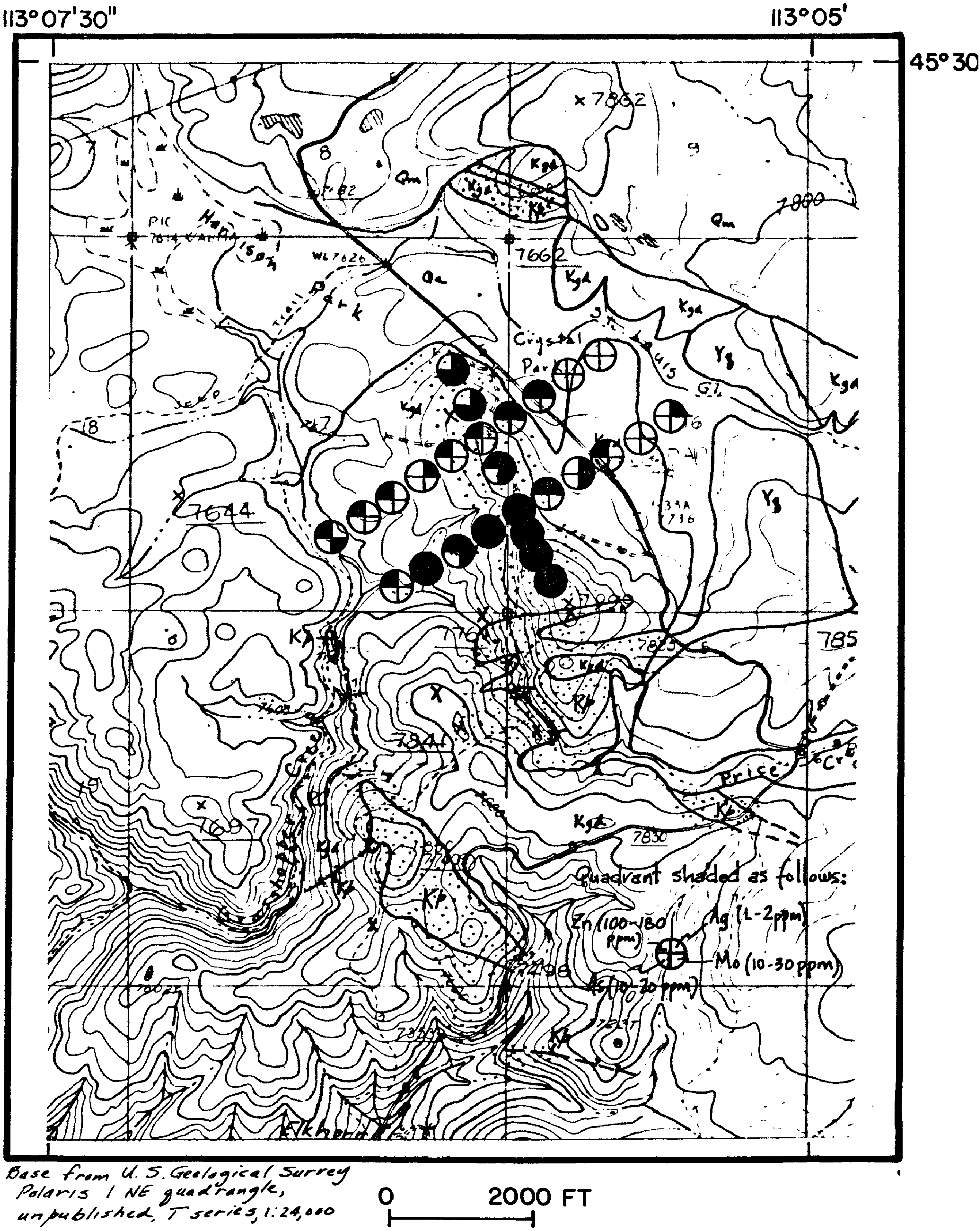
Base from U.S. Geological Survey Polaris 1 NE quadrangle, unpublished, T series, 1:24,000

Figure 3. Geochemical sample localities, Price Creek and Hot Springs Creek altered zones. ●, soil samples; ▲, rock samples; ■, K-Ar age samples For explanation of geology, see figure 2.

Geochemical data for the Price Creek and Hot Springs Creek zones were obtained from samples of soil and rocks. Twenty-six B-horizon soil samples were collected from the Price Creek zone along three traverses (fig. 3). Two parallel traverses 350 m apart were oriented northeast across the zone and the third was oriented northwest within and parallel to the zone. The samples were collected about 150 m apart. The rock samples were collected to represent various types of mineralized rocks obtained from dumps, outcrops, and float at widely scattered localities in the Price Creek and Hot Springs zones. Spectrographic, atomic absorption, and colorimetric analyses of the soil samples are shown in table 1. Similar data on rock samples are shown in table 2.

Many soil samples contain amounts of silver, molybdenum, arsenic, and zinc that are considered anomalous, as shown on figure 4. Silver was detected (as much as 2 ppm) in more than half the samples, molybdenum ranged from 10 to 30 ppm in about half the samples, arsenic ranged from 10 to 20 ppm in 8 of the 26 samples, and zinc ranged from 100 to 180 ppm (by atomic absorption) in most of the samples. Figure 4 illustrates graphically that the soil samples from the altered zone are, in general, more metal-rich that those from either side and that the samples from the southern part of the surveyed area contain the highest amounts of these metals.

Molybdenum is the only element consistently present in all of the rock samples. Silver is present in two-thirds of the rock samples, zinc and tungsten are anomalous in one-half, and tin and arsenic are found in one-third (table 2).



Base from U.S. Geological Survey
Polaris 1 NE quadrangle,
unpublished, T series, 1:24,000

Figure 4. Diagram showing anomalous valued of silver, molybdenum, arsenic, and zinc in soil samples, Price Creek altered zone. Sample numbers on figure 3; analytical data in table 1; explanation of geology on figure 2.

K-Ar ages of 66.0±2.2 and 69.4±1.6 m.y.[1] have been determined on muscovite from altered rock of the Price Creek zone (R. F. Marvin, written commun., 1980). The sample localities are shown on figure 3. The samples consisted of porous greisen-like rock probably derived from granodiorite and composed mainly of muscovite and quartz. Sample 79P173 was collected from probable outcrops; sample 79P089 was collected from the dump of a prospect pit. The age of 66.0±2.2 m.y. is indistinguishable with assigned error, from K-Ar ages of 66.2±2.4 m.y. and 67.0±2.1 m.y. on hydrothermal muscovite associated with quartz porphyry intrusives and molybdenite near Pear Lake (fig. 1; Willis, 1978). These ages appear to be slightly older than a K-Ar age of 62.5±2.3 m.y. on muscovite from the Cannivan Gulch molybdenum deposit (fig. 1; Schmidt and others, 1979); however, assigned errors overlap by about 50 percent.

Although greisen is common in small amounts in molybdenum deposits, no deposits are known in rocks like those at Price Creek and Hot Springs Creek. If molybdenum deposits exist in these rocks they would represent a new deposit type. Rutile and muscovite may be byproducts of mining such deposits.

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[1] Constants: $K^{40}\lambda_{\varepsilon} = 0.581 \times 10^{-10}$/yr $\lambda_{\beta} = 4.962 \times 10^{-10}$/yr

Atomic abundance: $K^{40} = 1.167 \times 10^{-4}$

Potassium determinations made with an Instrumentation Laboratories flame photometer with a Li internal standard

Lab. No.	Field No.	K_2O %	*Ar^{40} (10^{-10} moles/gram)	%*Ar^{40}	*Ar^{40}/K^{40}	Age m.y. ±2σ
D2862M	79P089	10.33 avg.	10.52	90	0.00411	69.4±1.6
D2864M	79P173	9.87 avg	9.550	91	0.00391	66.0±2.2

*Radiogenic argon

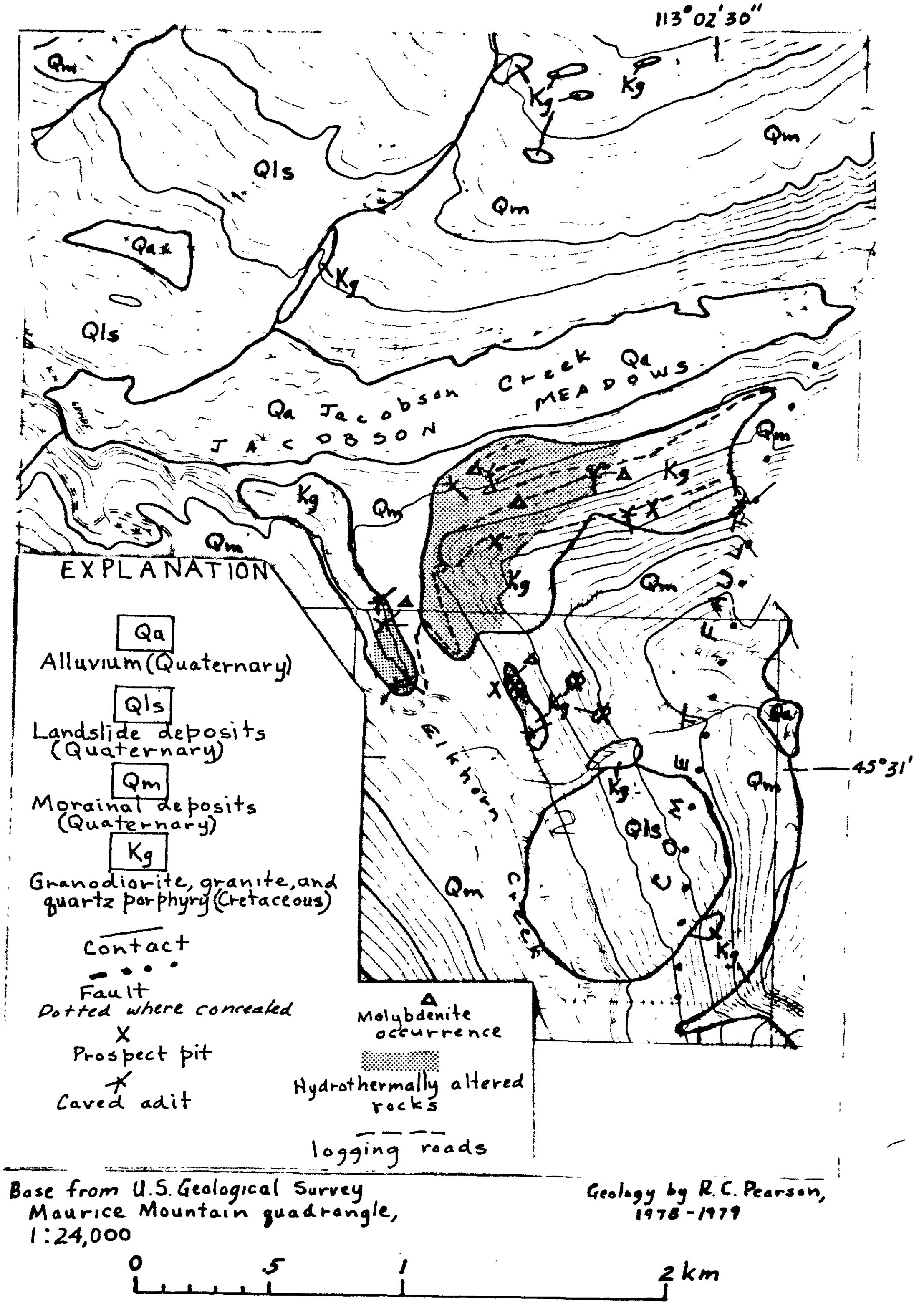
Analysts: R. F. Marvin, H. H. Mehnert, J. J. Kenney, V. M. Merritt

Altered Rocks at Jacobson Meadows

The Jacobson Meadows altered zone is exposed in a triangular area about 1.5 km on a side south of Jacobson Meadows and east of lower Elkhorn Creek (figs. 1 and 5). Until 1978 the bedrock in the area was very poorly exposed owing to forest, soil, and moraine cover. In 1978 several logging roads were constructed primarily on the steep slope south of Jacobson Meadows to provide access to timber on several patented mining claims, which cover parts of the altered zone. These roads exposed altered rocks that were totally obscured before. Also, several prospect workings became visible that previously were effectively hidden in the trees.

The Jacobson Meadows zone is in the Pioneer batholith on the west side of the main mass near where it begins to narrow into the apophysis that extends through the Price Creek and Hot Springs Creek zones into the west Pioneer Mountains. The country rock is dominantly biotite granite or granodiorite, but quartz porphyry is common, especially in the western part of the zone. The contacts of the individual porphyry bodies have not been delimited. The Comet fault is inferred to cross the ridge between Jacobson and Elkhorn Creek at an altitude of about 2,480 m and to occupy the steep gully that trends north from the ridge (fig. 5).

Three tributary glaciers--those of Elkhorn, David, and Jacobson Creeks--merged in the vicinity of Jacobson Meadows and formed the Wise River glacier. Much of the area in and around the altered zone is mantled by till and other surficial deposits. Jacobson Meadows is underlain by thick alluvium deposited behind a post-glacial landslide dam to the west. Southwestward to the Price Creek altered zone, bedrock is completely covered by morainal deposits.



Base from U.S. Geological Survey Maurice Mountain quadrangle, 1:24,000

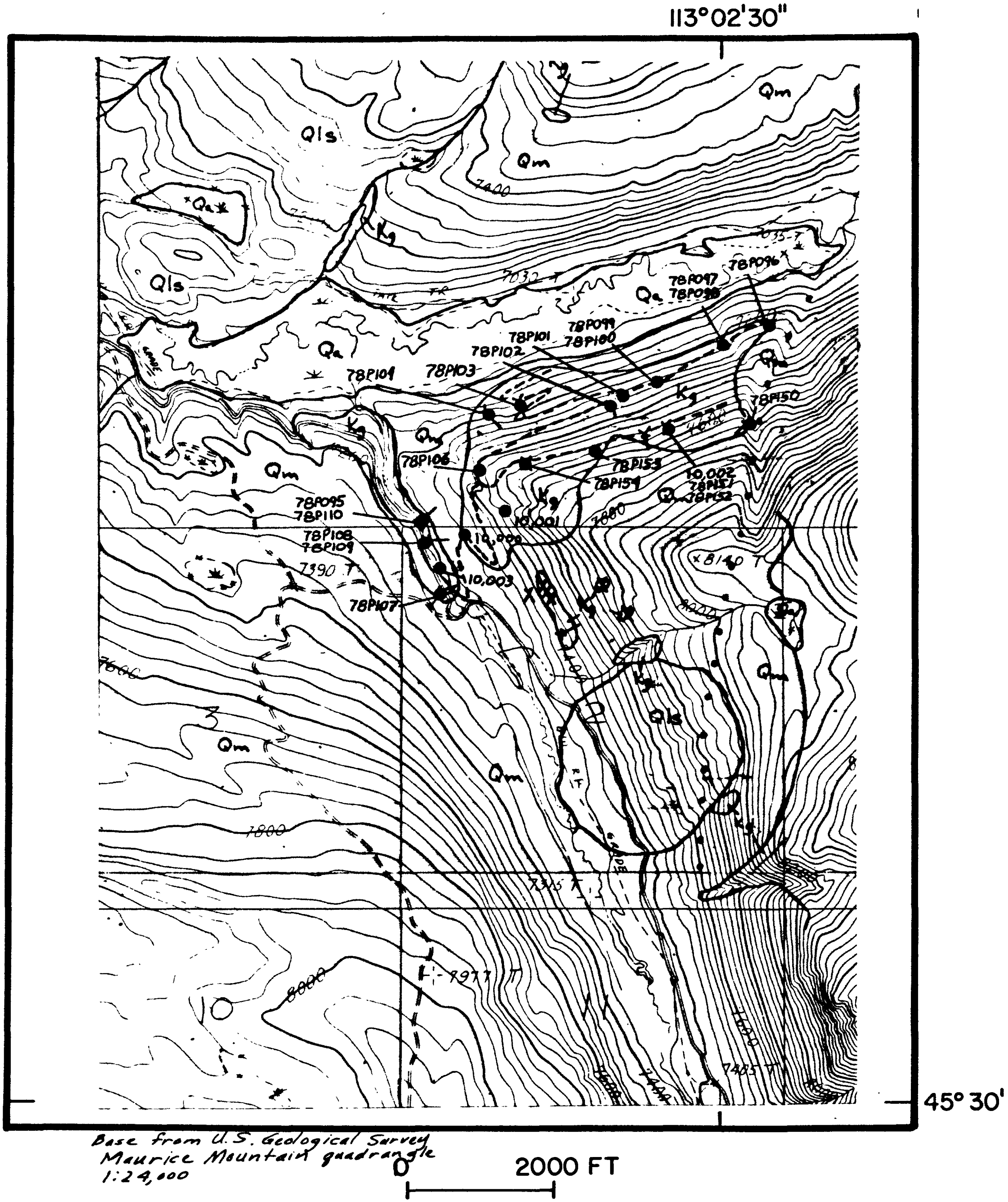
Geology by R. C. Pearson, 1978-1979

Figure 5. Geologic map of the Jacobson Meadows area, Beaverhead County, Montana.

The altered rocks in the Jacobson Meadows zone differ in several respects from those in the Price Creek and Hot Springs Creek zones. The most obvious difference is the absence at Jacobson Meadows of the griesen-like alteration, in which the texture of the original rock has been destroyed. Instead, the principal effects of alteration and mineralization are (1) intersecting veinlets mainly of quartz and pyrite and (2) disseminated pyrite in fresh-appearing rocks. Other minerals common in the veins are magnetite, muscovite, biotite, chlorite, K-feldspar, and rutile in various proportions and associations. Molybdenite has been found in quartz-pyrite veins at five localities (fig. 5). Envelopes of alteration minerals are present along some veins and absent along others.

Stream-sediment samples collected in connection with a mineral assessment of the eastern part of the Pioneer Mountains bear on the interpretation of the Jacobson Meadows zone. The analytical data resulting from that study are listed in Berger and others (1979). Molybdenum and uranium determined in a few water samples from the area are given in Broxton (1979). Altered and mineralized rock samples were collected from prospect pits, roadcuts, and outcrops. Sample localities are shown on figure 6 and the data listed in Table 3.

Figures 7-9 show the outlines of areas that might have provided sediment to the sites where anomalous stream-sediment samples were collected. Arsenic, lead, and zinc form a halo around the exposed altered zone, while copper tends to form a blanket over the whole extent of the hydrothermal system. Molybdenum and uranium determined in water samples (Broxton, 1979) are less dispersed than the above elements, thereby more closely delineating the focus of the mineralization. All of these data suggest that the Elkhorn mines may be a peripheral part of the Jacobson Meadows porphyry system. If so, the total geochemical influence of the hydrothermal activity was a minimum of 80 square kilometers.



Base from U.S. Geological Survey
Maurice Mountain quadrangle
1:24,000

Figure 6. Sample localities of analyzed rocks, Jacobson Meadows altered zone. Explanation of geology on figure 5; analytical data in table 3.

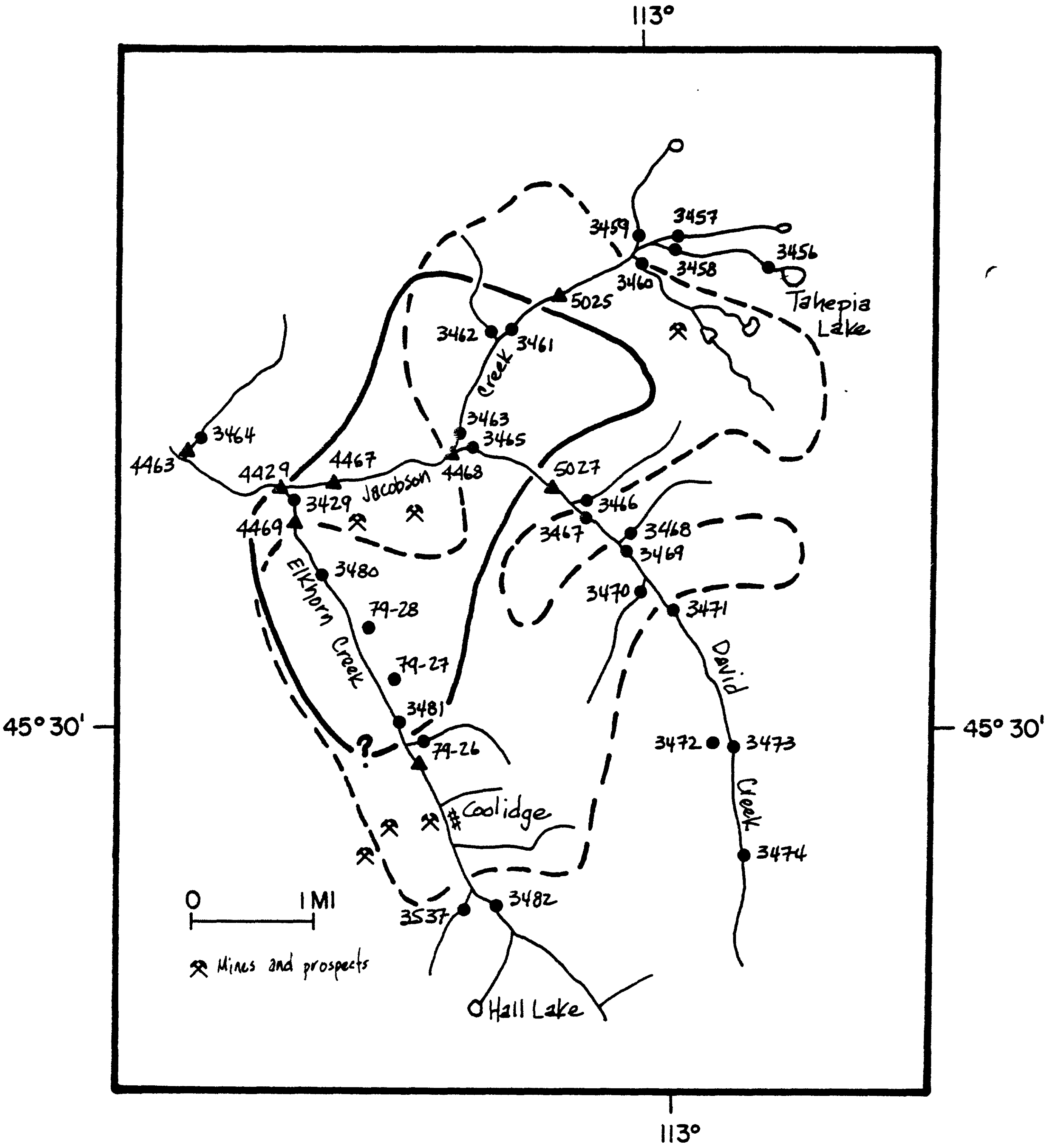


Figure 7. Distribution of >25 ppb molybdenum in stream water (solid line) (Broxton, 1979) and >50 ppm copper in -200-mesh stream sediments (dashed line) (Berger and others, 1979) in the Jacobson Meadows area. ●, stream-sediment sample locality; ▲, water-sample locality.

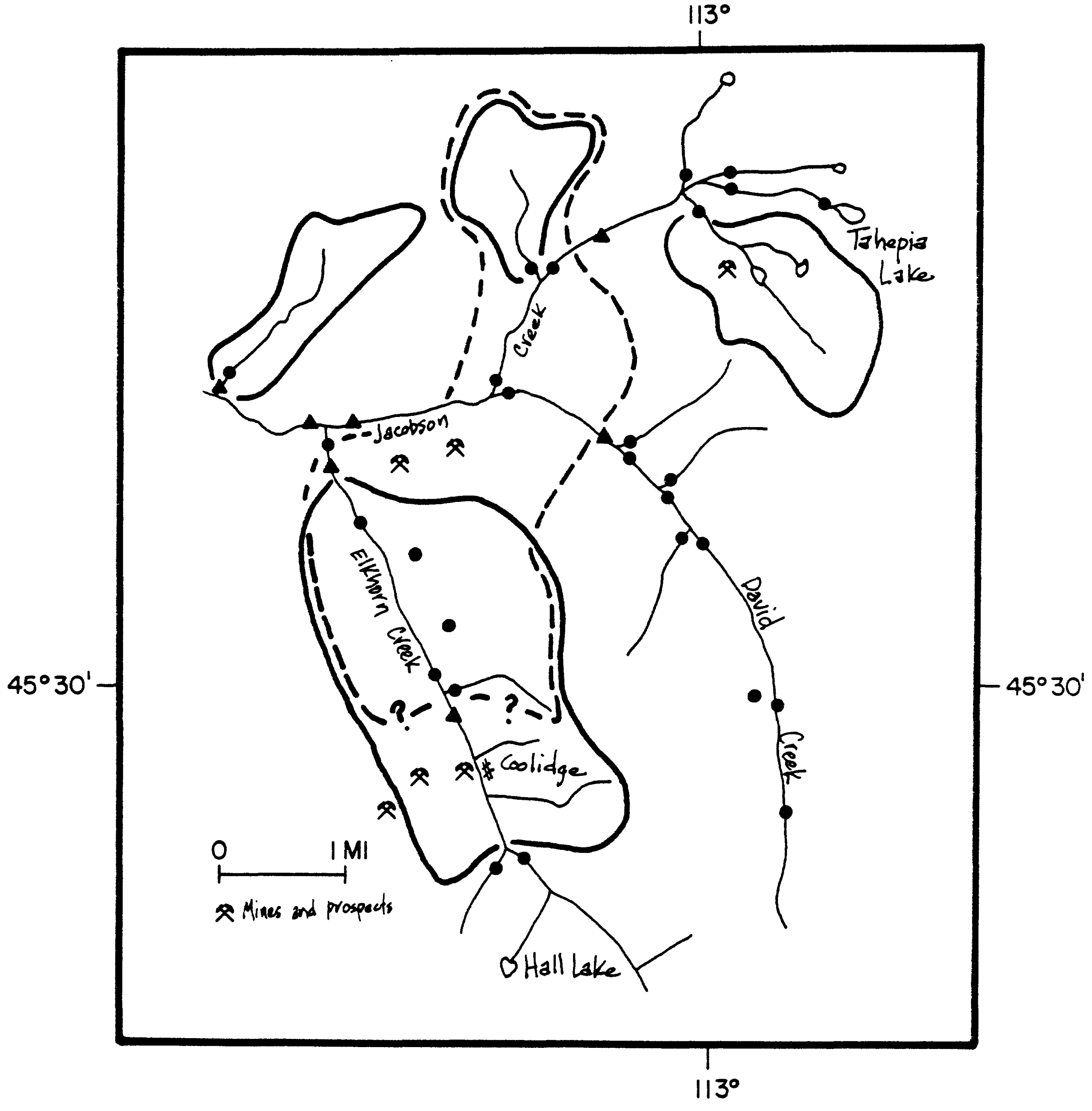


Figure 8. Distribution of >1 ppb uranium in water (dashed line) (Broxton, 1979) and >10 ppm arsenic in -200-mesh stream sediment (solid line) OBerger and others, 1979) in the Jacobson Meadows zone. ●, stream-sediment sample locality; ▲, water-sample locality. Sample numbers given on figure 7.

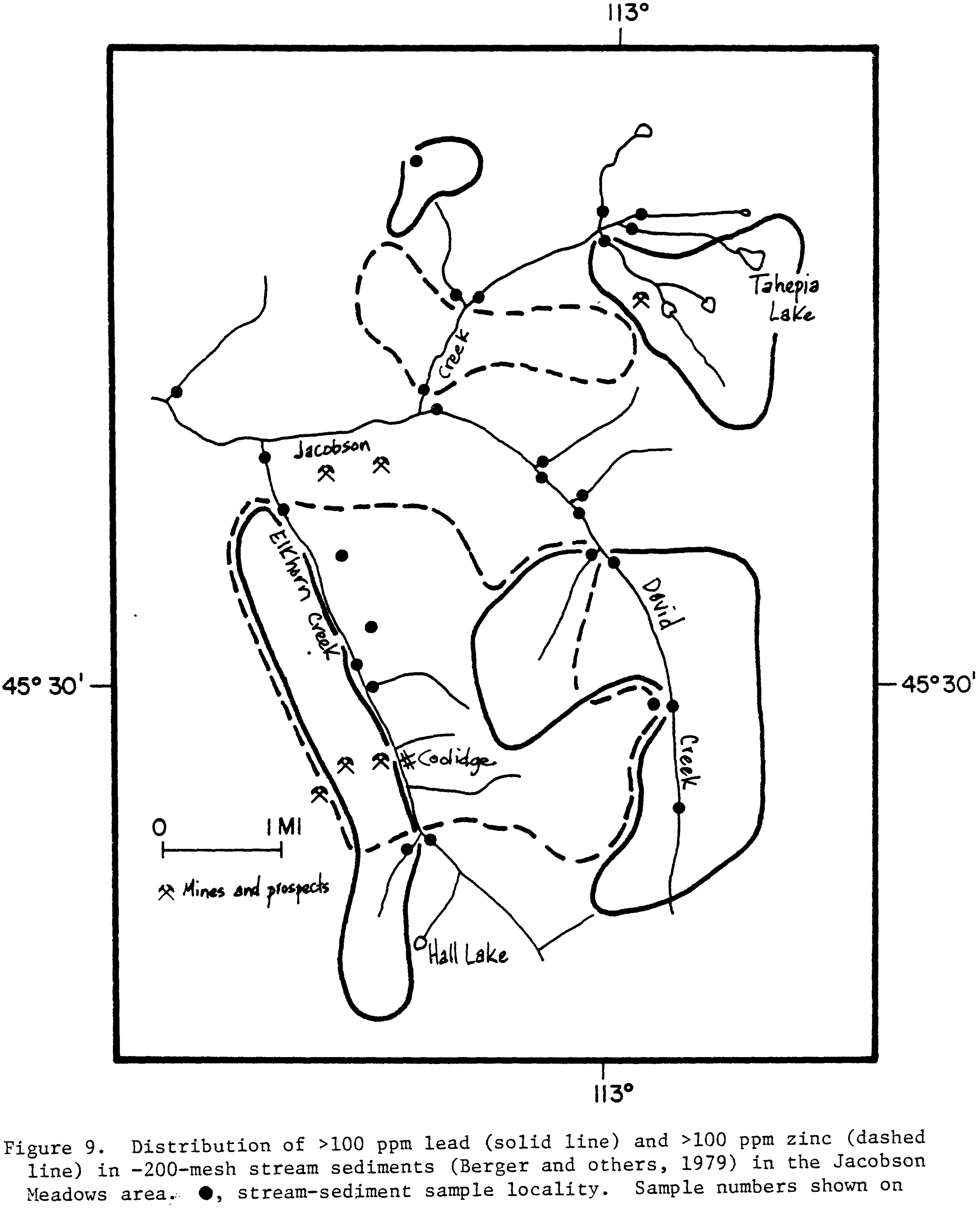


Figure 9. Distribution of >100 ppm lead (solid line) and >100 ppm zinc (dashed line) in -200-mesh stream sediments (Berger and others, 1979) in the Jacobson Meadows area. ●, stream-sediment sample locality. Sample numbers shown on figure 7.

Rock samples collected from several mines and prospects in the altered area and from the various mines in the region contain anomalous concentrations of certain trace elements. The complex-sulfide veins in the Elkhorn mines south of the altered area contain the trace-element suite Ag-As-Bi-Cd-Cu-Mo-Pb-Sb-Sn-W-Zn, and the suite Ag-As-Ba-Cd-Cu-Mo-Pb-Sb-Zn occurs near Schulz Lakes.

Molybdenum is the only element consistently present in rock samples from the main part of the altered area. Silver and zinc are frequently in association with the molybdenum while copper and lead are associated less frequently. Tin and tungsten occur only rarely.

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Tables 1-3.--The results of the chemical analyses are given in tables 1-3. All analyses were conducted in laboratories of the U.S. Geological Survey. The semiquantitative spectrographic analyses were done by David F. Siems using a six-step technique (Grimes and Marranzino, 1968). The wet-chemical analyses were done by Eric P. Welsch. Atomic absorption spectrometric techniques were used to analyze for zinc (Ward and others, 1969) and antimony (Welsch and Chao, 1975), and a colorimetric technique was used to analyze for arsenic (Almond, 1953).

The following abbreviations are used in the tables of data:

N	Not detected at the limit of detection
L	Detected, but below limit of reproducible determination for standards used
H	Interference prevented determination of value
G	Greater than value shown

Table 1.--*Semiquantitative spectrographic and chemical analyses of selected elements from B-horizon soil samples, Price Creek altered zone*

/Numbers in brackets are the lower limit of determination. In parts per million (ppm) except where noted./

Element	Sample No.	140	141	142	143	144	145	146	147	148	149	150	151	152
Fe(%)	[.05]	2	2	3	5	5	5	5	5	5	5	5	7	5
Mg(%)	[.02]	0.2	0.7	0.7	0.7	0.7	0.5	0.7	0.7	0.7	1	0.7	1	0.7
Ca(%)	[.05]	.5	.5	.7	.7	1	.5	1	1	.7	1.5	1	1.5	1
Ti(%)	[.002]	.2	.2	.3	.3	.3	.3	.3	.3	.3	.2	.2	.3	.2
Mn	[10]	150	500	1000	700	1000	700	700	1000	700	1500	1000	1000	1000
Ag	[.5]	L	N	N	L	.7	1.5	L	.5	L	N	N	N	N
As+	[10]	L	L	L	L	L	10	10	L	10	L	L	L	L
B	[10]	10	15	30	15	20	30	20	20	20	15	30	15	20
Ba	[20]	300	500	700	700	700	700	700	700	700	700	700	700	700
Be	[1]	1	1	2	1.5	2	1.5	1.5	1.5	2	2	1.5	2	2
Cu	[5]	20	15	20	30	70	70	70	50	100	20	30	15	15
La	[20]	30	30	30	20	30	20	30	30	50	50	50	50	30
Mo	[5]	N	N	5	30	5	10	10	10	15	5	15	N	L
Pb	[10]	10	15	30	20	20	50	30	30	30	20	50	30	20
Sb+	[1]	N	L	L	L	L	L	N	L	N	L	2	2	1
Sr	[100]	100	150	200	200	300	150	300	300	300	300	300	500	300
V	[10]	50	50	70	100	100	70	100	100	70	100	70	100	70
Zn+	[10]	50	50	130	80	170	160	110	140	170	150	180	100	110

Element	Sample No.	153	154	155	156	157	158	159	160	161	162	163	164A	165
Fe(%)	[.05]	3	5	5	5	3	3	5	5	5	5	7	5	5
Mg(%)	[.02]	0.7	0.5	0.5	0.7	0.5	0.7	0.5	0.7	0.7	0.7	1	0.7	0.7
Ca(%)	[.05]	.7	.7	.7	.7	.7	1	.7	.7	.7	1.5	1	.5	.7
Ti(%)	[.002]	.3	.3	.3	.3	.2	.2	.2	.2	.3	.3	.3	.3	.3
Mn	[10]	500	1000	700	700	500	700	1000	700	500	1000	700	1000	700
Ag	[.5]	.5	N	N	L	L	N	N	2	2	.5	.7	1	1
As+	[10]	L	L	L	L	L	L	L	20	10	L	10	10	10
B	[10]	30	30	20	30	30	20	20	50	30	30	15	30	20
Ba	[20]	700	700	700	700	500	700	700	1000	700	700	1000	700	1000
Be	[1]	2	2	2	2	2	2	2	2	1.5	2	2	1.5	2
Cu	[5]	50	70	70	50	70	10	20	20	20	50	300	50	50
La	[20]	50	30	30	30	30	30	30	30	20	30	50	20	20
Mo	[5]	7	5	5	7	5	N	N	30	20	15	10	50	20
Pb	[10]	30	30	20	20	30	20	30	100	30	70	20	20	20
Sb+	[1]	2	1	1	L	1	1	1	2	1	1	1	L	1
Sr	[100]	300	300	300	200	200	300	300	300	200	300	300	200	200
V	[10]	70	70	70	70	70	70	70	70	70	70	100	70	70
Zn+	[10]	80	140	180	120	100	55	80	90	70	150	110	110	160

+ Wet-chemical determination.

Table 2.--*Semiquantitative spectrographic analyses of rock samples from the Price Creek and Hot Springs Creek zones*

/Numbers in brackets are the lower limit of determination. All values in parts per million (ppm) except where noted/

Element	Sample No.	79P055	79P056	79P058	79P087	79P088	79P092	79P093	79P102	79P106	79P110	79P111	Altered rock 6711	Vein 164B
Fe(%)	[.05]	3	2	0.7	5	5	1.5	0.7	3	3	0.7	1	15	20
Mg(%)	[.02]	0.3	0.3	.15	0.5	0.7	.15	.1	0.2	0.3	.2	1	0.3	0.05
Ca(%)	[.05]	N	.1	.3	1	1	N	.15	.15	.15	L	L	.05	.05
Ti(%)	[.002]	.2	.15	.2	.3	.3	.1	.15	.3	.2	.15	0.1	.07	.03
Mn	[10]	150	150	500	300	500	70	20	30	150	L	15	300	70
Ag	[.5]	1.5	.5	.5	N	N	10	N	L	10	N	.7	3	10
B	[10]	L	15	10	20	N	15	20	L	20	15	L	20	N
Ba	[20]	700	1000	1500	500	500	200	200	300	300	700	1000	700	700
Be	[1]	1.5	3	2	2	2	2	2	1.5	5	1	1	2	N
Cu	[5]	30	50	20	15	70	20	15	7	200	20	15	100	300
La	[20]	20	50	50	L	50	L	30	50	20	50	20	L	N
Mo	[5]	100	7	7	7	10	50	5	10	7	50	10	30	700
Pb	[10]	50	50	30	50	15	10	10	N	500	30	50	300	20
Sr	[100]	100	300	500	300	200	L	200	N	L	200	150	100	L
V	[10]	30	20	20	100	150	50	50	200	70	70	20	50	150
Zn	[200]	N	200	N	N	N	N	200	N	200	N	N	N	N
Sn	[10]	L	N	N	N	N	N	N	20	L	N	N	150	N
W	[50]	N	L	N	L	N	N	N	100	L	L	N	N	L

Table 3.--*Semiquantitative spectrographic and wet-chemical analyses for selected elements in rock samples from the Jacobson Meadows zone*

/Numbers in brackets are lower limit of determination.
All values in parts per million (ppm) except where noted./

Element	Sample No.	Altered granite 10,000	Altered granite 10,001	Altered granite 10,002	Altered granite 10,003	78P096	78P097	78P098	78P099	78P100
Fe(%)	[.05]	1.5	1.5	5	7	5	5	5	7	10
Mg(%)	[.02]	.3	.3	0.5	0.7	0.5	0.5	1	1	0.7
Ca(%)	[.05]	.5	.5	L	L	.3	.3	0.3	0.5	1.5
Ti(%)	[.002]	.15	.10	.15	.15	.3	.2	.3	.2	.3
Mn	[10]	30	50	50	300	150	200	700	300	500
Ag	[.5]	N	N	L	7	2	N	N	3	.7
As+	[10]	10	10	L	10	20	10	20	20	10
B	[10]	20	20	20	15	30	15	L	200	15
Ba	[20]	1000	1000	500	500	700	700	1000	1500	1000
Be	[1]	2	2	2	3	2	2	2	3	2
Cu	[5]	10	7	10	15	50	70	20	300	70
La	[20]	30	50	20	L	20	30	100	20	70
Mo	[5]	500	20	30	10	100	N	N	10	N
Pb	[10]	20	20	30	150	30	20	50	100	30
Sb+	[1]	1	L	1	L	3	N	N	2	L
Sr	[100]	300	300	L	L	100	100	500	150	300
V	[10]	30	30	70	100	100	100	100	150	150
Zn+	[10]	40	10	15	60	40	35	45	35	50
Sn	[10]	L	N	10	N	N	N	N	20	N
W	[50]	N	N	L	N	N	N	N	N	N

+Wet-chemical analyses.

Table 3.--*Semiquantitative spectrographic and wet-chemical analyses for selected elements in rock samples from the Jacobson Meadows zone*--Continued

/Numbers in brackets are lower limit of determination. All values in parts per million (ppm) except where noted./

Element \ Sample No.		78P101	78P102	78P103	78P104	78P106	78P107	78P108	78P109	78P110
Fe(%)	[.05]	7	20	2	2	3	3	3	1.5	1.5
Mg(%)	[.02]	0.7	0.05	0.5	0.5	0.7	0.5	0.5	0.15	.15
Ca(%)	[.05]	2	L	2	1.5	1.5	.2	.05	L	1.5
Ti(%)	[.002]	.3	.05	.2	.2	.2	.2	.2	.07	.15
Mn	[10]	500	15	70	50	300	150	200	200	200
Ag	[.5]	N	10	N	N	N	2	10	20	N
As+	[10]	10	10	10	10	10	20	10	10	20
B	[10]	10	L	L	10	L	30	30	10	10
Ba	[20]	1000	50	1500	1500	1500	1000	700	50	1000
Be	[1]	L	3	L	2	5	2	5	1.5	1.
Cu	[5]	150	15	70	100	30	100	150	100	30
La	[20]	100	L	50	70	20	50	50	20	50
Mo	[5]	N	500	5	7	7	5	200	G2000	7
Pb	[10]	30	500	10	15	20	2000	2000	2000	100
Sb+	[1]	L	N	N	N	N	5	30	2	L
Sr	[100]	500	N	700	700	700	100	100	L	700
V	[10]	150	30	50	50	50	70	70	30	30
Zn+	[10]	30	70	10	10	15	800	1300	1300	50
Sn	[10]	N	N	N	N	N	N	N	50	N
W	[50]	N	N	N	N	N	N	N	N	N

+Wet-chemical analyses.

Table 3.--*Semiquantitative spectrographic and wet-chemical analyses for selected elements in rock samples from the Jacobson Meadows zone*--Continued

[Numbers in brackets are lower limit of determination. All values in parts per million (ppm) except where noted.]

Element	Sample No.	78P095	78P150	78P151	78P152	78P153	78P154
Fe(%)	[.05]	2	20	7	3	5	5
Mg(%)	[.02]	0.2	0.5	1	1	0.7	0.5
Ca(%)	[.05]	.7	.7	1.5	1.5	1	.7
Ti(%)	[.002]	.2	.2	.3	.2	.3	.2
Mn	[10]	300	1000	500	300	300	150
Ag	[.5]	N	1.5	.5	.7	N	.5
As+	[10]	10	20	10	20	10	10
B	[10]	10	50	20	15	20	100
Ba	[20]	1000	700	1000	1000	700	1000
Be	[1]	3	2	2	2	3	3
Cu	[5]	30	150	30	50	100	50
La	[20]	30	20	30	30	70	50
Mo	[5]	20	15	10	N	50	30
Pb	[10]	30	70	100	50	50	50
Sb+	[1]	N	4	1	L	L	2
Sr	[100]	500	200	500	500	300	500
V	[10]	30	100	100	100	100	50
Zn+	[10]	15	130	50	30	20	10
Sn	[10]	N	N	N	N	N	N
W	[50]	N	N	N	N	N	N

+Wet-chemical analysis.