UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

MOLYBDENUM AND TUNGSTEN MINERALIZATION ASSOCIATED WITH TWO STOCKS IN THE HARVEY CREEK AREA, NORTHEASTERN WASHINGTON

By

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INTRODUCTION

During recent geologic mapping for the U. S. Geological Survey, significant amounts of molybdenum mineralization and geochemical indications of tungsten mineralization were discovered in and around two small granodiorite stocks in the Harvey Creek and Noisy Creek drainages, Pend Oreille County, Washington (figs. 1 and 2). In addition, another pluton of the same rock type about 14 km to the east, is inferred to be the source of anomalous amounts of molybdenum in a single stream-sediment sample (fig. 2). All mineralization was discovered late in the 1981 field season, and data are limited; this preliminary report was prepared to make information on the occurrences immediately available.

All the mineralization appears to be associated with muscovite-biotite granodiorite of Cretaceous age that crops out in at least five non-contiguous plutons ranging from about 0.2 km^2 to about 35 km^2 in area (fig. 2). Molybdenum mineralization occurs primarily in a small stock, here referred to as the Harvey Creek body (see figs. 2, 3, and 4), cut by numerous quartz veins that range from less than 1 mm to several centimeters in width. The pluton inferred to be responsible for the single anomalous molybdenum value in a stream-sediment sample is here called the Boulder Mountain body; its areal extent has been mapped, but to date (February 1982), it has not been further.

Tungsten mineralization is indicated only by chemical anomalies in stream-sediment samples and apparently is associated with a pluton having a composition similar to the Boulder Mountain and Harvey Creek bodies. This pluton is about 3 km northwest of the Harvey Creek body and is here called the Hall Mountain body. It intrudes carbonate rocks of the Proterozoic Y Wallace Formation for a strike length of at least 1.2 km. A thin veneer of glacial material and slope wash covers the contact, which presumably is the site of the tungsten mineralization. Gold and silver anomalies have been detected in stream-sediment samples from drainages east and northeast of the Hall Mountain body and may be related to that pluton. These samples were all collected outside the area shown in figure 3 and are not described here. Each of the three bodies mentioned above and two others shown in figure 2 are separate plutons of a single plutonic type hereafter referred to as the granodiorite of Hall Mountain. Because most mineralization is associated with the Hall Mountain and Harvey Creek bodies, discussion in this report is focused on those two plutons.

GEOLOGIC SETTING OF PLUTONS

The Hall Mountain and Harvey Creek bodies intrude a structurally complex assemblage of rocks ranging in age from Proterozoic Y to Early Cambrian. Most or all of the multiple deformation structures in these host rocks predate the emplacement of the plutons. However, a variable and (or) foliation in both plutons may be primary, possibly reflecting movement of magma during emplacement. On the other hand, the plutons may have been emplaced during the latest stages of deformation that affected the host rocks.

The oldest rocks intruded are part of the Proterozoic Y Wallace Formation of the Belt Supergroup. The formation consists of dolomite, dolomitic limestone, phyllite or argillite, siltite, and quartzite. These lithologies are shown as separate map units in figures 3 and 4 but do not necessarily correspond to informal subdivisions used by Harrison and Jobin (1963) in the Clark Fork area, by Miller (1974) and Miller and Clark (1975) in the Newport and Chewelah-Loon Lake areas, or by Hobbs and others (1965) in the Coeur d' Alene district. Dynamic and thermal metamorphism complicated by probable sedimentary facies changes between these other areas and the Harvey Creek-Hall Mountain area make unit-by-unit correlations currently impossible.

Phyllite or argillite layers are abundant in both the carbonate and quartzite units. Sedimentary structures and bedding features characteristic of the Wallace Formation are preserved locally despite intense development of slip cleavage in most of the rocks.

The Wallace Formation is unconformably overlain by conglomerate or conglomeratic phyllite of the Shedroof Conglomerate, which forms the base of the Proterozoic Z Windermere Supergroup. This relationship is well exposed in the northern part of sec. 24, T. 38 N., R. 44 E. (fig. 3), where at least 600 m of boulder and cobble conglomerate rests on well-bedded carbonate rocks of the Wallace Formation. The conglomerate grades upward through conglomeratic phyllite into arenaceous phyllite that contains a few thin conglomeratic beds. About 600 m above the base of the phyllite is a 60-m-thick zone of gray, locally arenaceous limestone which, in turn, is overlain by more phyllite.

On the mountain north of the Harvey Creek stock, the Shedroof Conglomerate is much finer grained and has smaller, more widely spaced clasts than elsewhere in the region. The conglomeratic parts are separated by zones of interbedded dark pyrite-bearing phyllite and tan arkosic quartzite. Even though the conglomeratic parts of the unit are similar to the Shedroof at other places, the overall aspect of the formation is different enough to suggest that it could be another Windermere unit, possibly the Monk Formation.

Almost all of the rocks shown as Leola Volcanics in figures 3 and 4 are intrusive sills related to the thick extrusive accumulations that make up this formation at other places in the region. The Leola Volcanics overlies the Shedroof Conglomerate but, except for the intrusive sills, occurs only in sec. 22, T. 38 N., R. 44 E. in the area shown in figure 3.

The Monk Formation unconformably overlies the Leola Volcanics, but the base is not exposed. Within the area, the Monk Formation is made up of interbedded argillite and dolomitic limestone. None of the conglomerate zones, which make up about 10 percent of the formation where it is best exposed about 20 km to the north, are exposed in the Harvey Creek drainage. Some of the rocks mapped as Monk Formation could actually be Wallace Formation; positive identification is not possible because of poor exposure and the effects of dynamic and thermal metamorphism. Questionable assignments of rocks to the Monk Formation have been made on the basis of gross lithologic similarities and on stratigraphic position relative to the grit and quartzite of the overlying Three Sisters Formation.

The Monk Formation grades unquestionably into the overlying Three Sisters Formation where contact relations are exposed about 25 km to the north. The latter formation is made up of quartzite, grit, conglomerate, and, in the lower third, abundant phyllite interlayered with beds of grit 1-10-m thick. The conglomerate and grit of the Three Sisters contrasts with conglomerate of the Shedroof and Monk in that it is a much more mature sedimentary rock that consists mainly of quartz grains and contains relatively little feldspar and argillaceous material. The Three Sisters Formation forms the top of the Windermere Supergroup in the area.

The Gypsy Quartzite overlies the Windermere Supergroup with angular unconformity, but the contact is not exposed in the area shown in figure 3. The Gypsy consists chiefly of medium- to fine-grained, well-bedded vitreous quartzite. Argillite zones from less than 1 m to more than 30 m thick are progressively more abundant upward in the formation. The upper 200 m of the formation is about half argillite (or phyllite) and half quartzite.

The Maitlen Phyllite gradationally overlies the Gypsy Quartzite, except about 60 m of tan and gray limestone separates the two formations and forms the base of the Maitlen. The limestone, however, is seen only in areas where exposure is nearly 100 percent complete. The lower one-fourth to one-third of the formation is made up of greenish-gray argillite interlayered with quartzite beds that progressively thin upwards in the unit. The middle part is almost completely phyllite, and the upper one half to one third is phyllitic limestone.

Quaternary glacial and alluvial material mantles slopes and underlies all modern stream channels. Much of the area shown as bedrock contains thin discontinuous patches of glacial debris.

Numerous faults and folds are shown in figure 3, but the predominant mesoscopic structures are a pervasive slip cleavage and numerous small scale folds. Bedding attitudes, representative of those in a moderate-sized area, are measurable at very few places in the dominently argillitic or phyllitic units. Small-scale folds and slip cleavage completely destroy bedding at most places. The cleavage, which in many places is demonstrably axial plane to the small-scale folds, is in some places shown as a foliation on figure 3 because intensity of development has imparted a phyllitic or schistose character to the rock.

All the major faults appear to predate the granodiorite of Hall Mountain. The major north-trending fault in sections 25 and 36, T. 38 N., R 44 E., is apparently the same structure as the fault bounding the west side of the Shedroof Conglomerate at the north end of the Hall Mountain pluton in sec. 10, T. 38 N., R. 44 E. Most of the faults that strike parallel to bedding or foliation are reverse faults, relatively up on the northwest side. The fault on the east side of the Maitlen Phyllite in sec. 10, T. 38 N., R. 44 E., and the fault near the center of sec. 24, T. 38 N., R. 44 E. are both normal faults and show major separations across their traces.

GRANODIORITE OF HALL MOUNTAIN AND ASSOCIATED MINERALIZATION

General features

The granodiorite of Hall Mountain is a medium- to fine-grained muscovite-biotite granodiorite. The modal composition ranges from tonalite to calcic monzogranite, but at least 90 percent of the rocks sampled thus far are granodiorite (see fig. 5). The average color index is 9, and the ratio of biotite to primary muscovite is 10:1. (The name muscovite is used herein as a descriptive term only; we do not know that these white micas are chemically and structurally true muscovites. They may have a significant celadonite component.) The apparently primary muscovite postdates crystallization of biotite and probably is late stage. Biotite in most of the rock is brown or olive green, but in mineralized rock containing abundant quartz veinlets biotite is reddish brown. Muscovite is spacially associated with biotite in the rock and rarely occurs as solitary crystals that are not in contact with biotite. Plagioclase ranges from about an_{25} to an_{35} but averages closer to the calcic end of that range. Potassium feldspar is microcline; crystals characteristically have numerous relatively large plagioclase, and less commonly biotite, crystals included in them. The many included minerals impart a poikilitic look to the microcline on a stained slab. Quartz occurs as irregularly shaped crystals that average about 4 mm in size and commonly are aggregates of smaller broken and rehealed fragments. Accessory minerals include epidote, clinozoisite, allanite, zircon, apatite, rutile, and minor opaque mineral(s).

Texturally, the larger plutons are hypidiomorphic-granular in the interior parts but lineate and (or) foliate in the outer parts. The directional fabric becomes progressively more intense towards the outer margins. Systematic measurements of the fabric have not been made, but presumably it is primary, having formed during emplacement of the bodies.

Most of the plutons, particularly the smaller bodies, have noticeably chilled margins of finer grained rock, suggesting emplacement into a relatively cool host rock. This relatively low temperature environment also is reflected in the presence of narrow contact-metamorphic aureoles in which megascopic recrystallization rarely extends more than 10-20 m from the plutons. Locally, however, particularly in the carbonate-mineral-bearing host rocks, contact metamorphism extends farther, but contacts or rocks within a 100 m of contacts are seen rarely because of generally incomplete exposure. A common assemblage developed within 20 m of the plutons in pelitic rocks includes tourmaline-andalusite-plagioclase(?)-phlogopitic biotite-sericite-quartz; in impure carbonate rocks, the assemblage is quartz-sericite-tremolite-clinozoisite-calcite or tourmaline-sericite-tremolite-phlogopitic biotite-quartz-calcite. More than 100 m from any of the plutons, contact-metamorphic effects are not separable from regional metamorphic effects.

Plutons of Hall Mountain-type granodiorite all appear to be shallower level equivalents of a much larger muscovite-biotite intrusion, the granodiorite of Reeder Creek. This latter pluton underlies about 140 km^2 and centers on Priest Lake about 20 km southeast of the Boulder Mountain body. The granodiorite of Reeder Creek is petrographically, mineralogically, and modally the same as the Hall Mountain type (see fig. 5) but is coarser grained and shows none of the shallower level characteristics of the latter rocks.

Only the Hall Mountain and Harvey Creek bodies have been examined to date in any detail, and even those two have not been studied systematically. The borders of the other three larger plutons are mapped, but the interior parts of the bodies need additional study.

Hall Mountain body

The Hall Mountain body is about 5 km long and averages about 0.8 km in width. It intrudes both Belt and Windermere Supergroup rocks. The northern part is relatively unaltered and forms good outcrops, but much of the southern and southwestern parts are highly altered sericitized rock that crops out little or not at all. Sparse outcrops separated by wide intervals of dense second-growth forest are found where the south-southwest-trending ridge of granodiorite intersects the section line between sections 15 and 22, T. 38 N., R. 44 W. The rock in this area is very leucocratic contains noticable amounts of disseminated pyrite, contains a few thin quartz veins, and is thoroughly stained by iron oxides. Most of the biotite appears to have been replaced by secondary white mica and much of the remaining biotite is reddish brown.

Of three panned stream-sediment samples taken from streams draining this pluton, two (samples 4 and 5, Table 2 and fig. 3) contain anomalous tungsten concentrations and one (no. 5) has 10 ppm molybdenum. Both these streams drain the altered southern part of the pluton and a part of the body that intrudes carbonate rock of the Wallace Formation for a strike length of about 1.2 km. In addition, stream-sediment samples 1, 2, 3, and 9, from drainages where the granodiorite is not known to occur, yielded anomalous tungsten values. Extensive areas in all these drainages are underlain by carbonate rock, however, and the Hall Mountain body is not far away. Presumably, either the granodiorite is present but concealed in these drainages, or mineralization related to the granodiorite extends into the drainages. Almost all the reported anomalous tungsten concentrations are accompanied by anomalous amounts of bismuth.

A fairly wide area of carbonate rocks in the southern part of sec. 27, T. 38 N., R. 44 E., presumably part of the Monk Formation, is highly recrystallized and contains abundant tremolite, phlogopitic biotite, and sericite. These rocks are at least 3 km from the nearest recognized outcrops of granitic rock and are 10 times fruther from the Hall Mountain body than the outer extent of the contact-metamorphic aureole typically associated with it. This area of recrystallized rocks may indicate that the west side of the Hall Mountain body dips shallowly westward or that another pluton shallowly underlies this area, probably not more than 100 or 200 m below the surface.

No tungsten mineralization was seen in outcrop or in the few hand specimens collected, but work in this specific area was done before analytical results from stream-sediment sampling had been received, and no particular reason to search for tungsten minerals existed at the time sampling was done.

Harvey Creek body

The Harvey Creek body is a small east-trending dike-form stock about 900 m long and averaging about 200 m in width (fig. 4). Both ends of the stock are concealed by Quaternary deposits, and the actual east-west extent of the stock is not known. Exposures at the east end are extremely poor, and the stock may actually terminate before reaching the Quaternary deposits as mapped. The body occurs almost entirely within the drainage of the South Fork of Granite Creek, except for a small part along the north edge that is in the Harvey Creek drainage. Stream-sediment samples 1 and 3 (fig. 3), both down-drainage from the small part of the stock that extends into Harvey Creek drainage, show no geochemical expression of the molybenite mineralization associated with this body. Muscovite from an unaltered appearing sample collected at locality 7 (fig. 4) yielded a potassium-argon age of 96.4 m.y. The dated rock contained fresh biotite and showed no apparent indications of alteration in hand specimen or thin section. The muscovite age is in accordance with ages other plutons in the region, all of which have potassium-argon ages of about 95 m.y. to 100 m.y. (Miller and Engels, 1975).

Part of the rock making up the stock is muscovite-biotite granodiorite, similar to that in the other plutons of the granodiorite of Hall Mountain. Much of the rock in the Harvey Creek body, however, is finer grained than that in the other four plutons identified in figure 2 and is cut by numerous dikes and relatively closely spaced quartz veins (figs. 6 and 7). Almost all the Harvey Creek body shows some hydrothermal alteration, and much of it is highly altered. Many if not most of the quartz veins contain small amounts of fine-grained molybdenite. The veins range in thickness from less than 1 mm to 50 cm; more than the average number of thick veins occur in the vicinity of locality no. 1 (fig. 4). Pyrite is common to abundant near many of the quartz veins and is extremely abundant in tabular-shaped altered zones that range in width from 1 cm to 1 m and reach at least 50 m in length. These altered masses appear to be most abundant in the northern part of the body, where the bulk of the known molybdenite occurs. Two of the largest and most intensely altered areas examined are north of locality 2 and in the vicinity of locality 9 (fig. 4). Even though not visible with hand lens, small amounts of molybenite are also disseminated in the apparently unaltered granodiorite. Small amounts of molybenite were obtained in the nonmagnetic heavy fraction during preparation of the mineral separate for the potassium-argon date.

Numerous dikes having the same modal mineralogy as the granodiorite occur in and around the stock mapped in the Harvey Creek area, but they are much finer grained. Some of the dikes have quartz phenocrysts. Several of these dikes intrude both the Leola Volcanics and the basal part of the Shedroof Conglomerate on the north side of the Harvey Creek stock. Most dikes are altered, and they commonly are cut by thin quartz veins.

An unusual retrograded contact metamorphic assemblage occurs at localities numbers 5 and 8 (fig. 4) along the south side of the Harvey Creek stock, where the country rock is impure carbonate rock of the Wallace Formation. The mineral assemblage is pyrite-magnetite-brucite-antigorite(?)-calcite, and one or more fine-grained unidentified mineral(s), all in an equally fine-grained mixture of calcite or dolomite. The rock at locality 5 appears to have a few small aggregates of molybdenite crystals in it. The brucite and antigorite are probably retrograde from periclase and forsterite, respectively, and may have formed during the mineralization event that deposited the pyrite and molybdenite.

Mineralogy of veins and altered rock--In all, about 40 thin sections were studied from the biotite-muscovite granodiorite of Harvey Creek and the immediately adjacent Proterozoic host rocks. The igneous fabric and mineralogy of the granodiorite is altered throughly to composite assemblages of white mica ± carbonate ± rutile ± chlorite ± pyrite ± molybdenite ± clay (s) in the areas where the quartz-molybdenite veins are most concentrated. Specific assemblages of the veins include: 1) quartz-tourmaline-pyrite ± molybdenite (altered to ferrimolybdite) ± rutile ± white mica, 2) quartz-molybdenite-pyrite ± potassium feldspar (trace), 3) quartz-white mica ± pyrite, 4) quartz-molybdenite-white mica-carbonate-pyrite-rutile, and 5) quartz-potassium feldspar ± white mica (sparse) ± molybdenite (trace) ± carbonate ± pyrite (trace).

In the samples studied, the association of molybdenite with potassium feldspar is extremely rare, and there is an overall dearth of potassium feldspar in the veins. Molybdenite is most commonly associated with white mica; generally the two minerals are intergrown with each other. There is no preferred locus of crystallization of the molybdenite. Some occurs in small clusters randomly distributed through veins, whereas in a set of obviously early, wispy quartz-potassium feldspar veins, molybdenite is concentrated near the walls of the veins. The early veins also show increased enrichment of potassium feldspar immediately adjacent to the granodiorite. These incompletely alteration halos of potassium feldspar are in turn surrounded by white mica, and, in places, include abundant secondary carbonate minerals. Elsewhere, clusters of fine-grained molybdenite are scattered in quartz that fills miarolitic cavities in the granodiorite. Although rare, some molybdenite occurs as a secondary coating along cross-fractures that are oriented at high angles to veins.

All of the parageneses outlined above suggest prolonged deposition of molybdenite in the mineralized system. At the levels now exposed, however, the bulk of the molybdenite shows a preferred association with white mica, a relation generally interpreted to indicate deposition during the retrograde collapse of a hydrothermal system.

Fluid-inclusion studies--Fluid-inclusion relations in the veins and in the primary quartz of the altered biotite-muscovite granodiorite of Harvey Creek suggest that the fluids associated with the bulk of the mineralized system were boiling at the current levels of exposure. The fluid-inclusion signature of this system includes widespread: (a) two-phase, liquid-plus-vapor types (including both liquid-rich and vapor-rich varieties); (b) crystal-rich types including halite and(or) sylvite daughter minerals, possibly together with an unknown carbonate mineral, or anhydrite, or iron chloride; and (c) a liquid-carbon-dioxide-bearing type that at room temperature, shows wide-ranging ratios in its proportion of liquid carbon dioxide to vapor carbon dioxide. Many samples show complex mixtures of all these fluid-inclusion types, both throughout individual crystals of quartz and along the narrow traces of microscopic annealed, secondary and pseudosecondary fractures through both hydrothermal vein quartz and primary igneous quartz. The best preserved fluid inclusions are generally 15 to 20 m (1 m = 10^{-6} m) across, although many of the veins examined contain fluid inclusions that are typically less than 5 m across.

We infer from the estimated proportions of daughter minerals, liquid, and vapor in all these fluid inclusion, that only locally did the mineralized system become intermittently saturated with respect to NaCl and KCl as it evolved. Moreover, these saline fluids now trapped in both hydrothermal and primary quartz probably reflect residual, increased salinities resulting from the effervescing of very dilute, vapor-dominated portions. Our reconnaissance fluid-inclusion studies of the quartz veins is based only on thin sections, and reveals no apparent correspondence of molybdenum content with a predominant type of fluid inclusion. Some veins showing an overwhelming abundance of the highly saline crystal-rich fluid inclusions show minimal contents of molybdenum, as do some of the veins which are characterized by mostly gas-rich fluid inclusions. Nonetheless, almost all the samples examined from the system have some fluid inclusions that contain liquid carbon dioxide at room temperature, a characteristic common among fluorine-deficient porphyry molybdenum systems. On the basis of comparisons of these fluid relations with those of other known fluorine-deficient porphyry molybdenum deposits in the Cordillera of the western United States, we suggest that the high concentrations of molybdenum at the surface are likely to continue at depth.

Geochemical results--Preliminary bedrock geochemical studies substantiate the anomalous concentration of molybdenite in the Harvey Creek stock of the granodiorite of Hall Mountain. Thirty-three fist-sized rock samples were collected from an area 100m by 200m in the SW 1/4 sec. 31, T. 38 N., R. 45 E. (localities 2, 3, 4, and 6 in fig. 4). The analytical results are tabulated in table 1. Molybdenum occurs at concentrations greater than 8 ppm (parts per million) in 30 of the 33 samples; 16 of the samples analyzed contain more than 150 ppm (0.015 weight percent) molybdenum. Turekian and Wedepohl (1961) and Vinogradov (1962) gave average molybdenum contents of about 1.0 ppm for felsic granite, granodiorite, and granite. The highest concentration of molybdenum found in the samples from the Harvey Creek stock is 990 ppm (analysis no. 18). In the 16 samples containing more than 150 ppm molybdenum, the molybdenum:copper ratio is very high, about 35. Consequently, at the present erosion surface, the mineralized system does not appear to show an epigenetic introduction of copper. In addition, highly anomalous concentrations of lead (1,800 ppm) and zinc (1,200 and 1,800 ppm) were detected in two of the samples (analysis nos. 2 and 6). The lead and zinc in these samples, together with somewhat elevated concentrations of cadmium (26 and 17 ppm), probably reflect the presence of some galena and sphalerite in the rocks. Finally, the relatively low values of F, Li, Nb, Sn, and W in the analyzed samples all suggest that the mineralized rocks at Harvey Creek contain molybdenum mineralization unlike the well-known climax-type porphyry-molybdenum systems.

CONCLUSIONS

The combination of abundant quartz veins, widespread but locally intense alteration, and sparse but widely distributed molybdenite in the Harvey Creek body and nearby host rocks warrants detailed exploration of the stock. In addition, the fluid-inclusion studies suggest that the major part of the molybdenum system has not been removed by erosion.

Anomalous concentrations of tungsten and locally anomalous molybdenum values from panned stream-sediment samples taken in streams draining the Hall Mountain body suggest that parts of that pluton and the carbonate rocks near it are attractive shallow exploration targets.

Insufficient work has been done on the other bodies of Hall Mountain-type granodiorite to ascertain their economic potential, but the anomalous molybdenum content in the panned stream-sediment sample from the Boulder Mountain body and the abundant quartz veins in parts of that body suggest that mineralization is fairly widespread. At least two occurrences of tungsten-molybdenum mineralization (written communications, Knopf, 1943, and Reno, 1952) are associated with the granodiorite of Reeder Creek about 25 km southeast of the Hall Mountain body, but neither has been examined by the authors. The granodiorite of Reeder Creek is similar to, and possibly is genetically related to, the granodiorite of Hall Mountain. We consider that the several associations of tungsten-molybdenum occurrences with this rock type qualifies it as an exploration target.

ACKNOWLEDGMENTS

We would like to express our gratitude to David Grimes of the U.S. Geological Survey for analyzing our stream-sediment samples on extremely short notice. Dennis H. Sorg did the mineral separation for the potassium-argon date and recognized molybdenite in one of the two fractions. Rowland Tabor did the argon analysis.

REFERENCES CITED

Harrison, J. E., and Jobin, D. A., 1963, Geology of the Clark Fork quadrangle, Idaho-Montana: U. S. Geological Survey Bulletin 1141-K, 38 p.

Hobbs, S. W., Griggs, A. B., Wallace, R. E., and Campbell, A. B., 1965, Geology of the Couer d'Alene district, Shoshone County, Idaho: U. S. Geological Survey Professional Paper 478, 139 p.

Miller, F. K., 1974, Preliminary geologic map of the Newport number 1 quadrangle, Pend Oreille County, Washington and Bonner Countyies, Idaho: Washington Division of Geology and Earth Resources Map GM-10, scale 1:62,500.

Miller, F. K., and Clark, L. D., 1975, Geology of the Chewelah-Loon Lake area, Stevens and Spokane Counties, Washington: U. S. Geological Survey Professional Paper 806, 74 p.

Miller, F. K., and Engels, J. C., 1975, Distribution and trends of discordant ages of the plutonic rocks of northeastern Washington and northern Idaho: Geological Society of America Bulletin, v. 86, p. 517-528.

Scott, R. H., and Kokot, M. L., 1975, Application of inductively coupled plasmas to the analysis of geochemical samples: Analytica Chimica Acta, v. 75, p. 257-270.

Shapiro, Leonard, 1975, Rapid analysis of silicate, carbonate, and phosphate rocks

--revised edition: U. S. Geological Survey Bulletin 1401, 76 p.

Streckeisen, A. L., 1973, Plutonic rocks: Classification and nomenclature recommended by the IUGS Subcommission on the Systematics of Igneous Rocks: Geotimes, v. 18, no. 10, p. 26-30.

Turekian, K. K., and Wedepohl, K. H., 1961, Distribution of the elements in some major units of the earth's crust: Geological Society of America Bulletin, v. 72, p. 175-192.

Vinogradov, A. P., 1962, Average content of chemical elements in the principal types of igneous rocks of the earth's crust: Geochemistry, no. 7, p. 641-664.

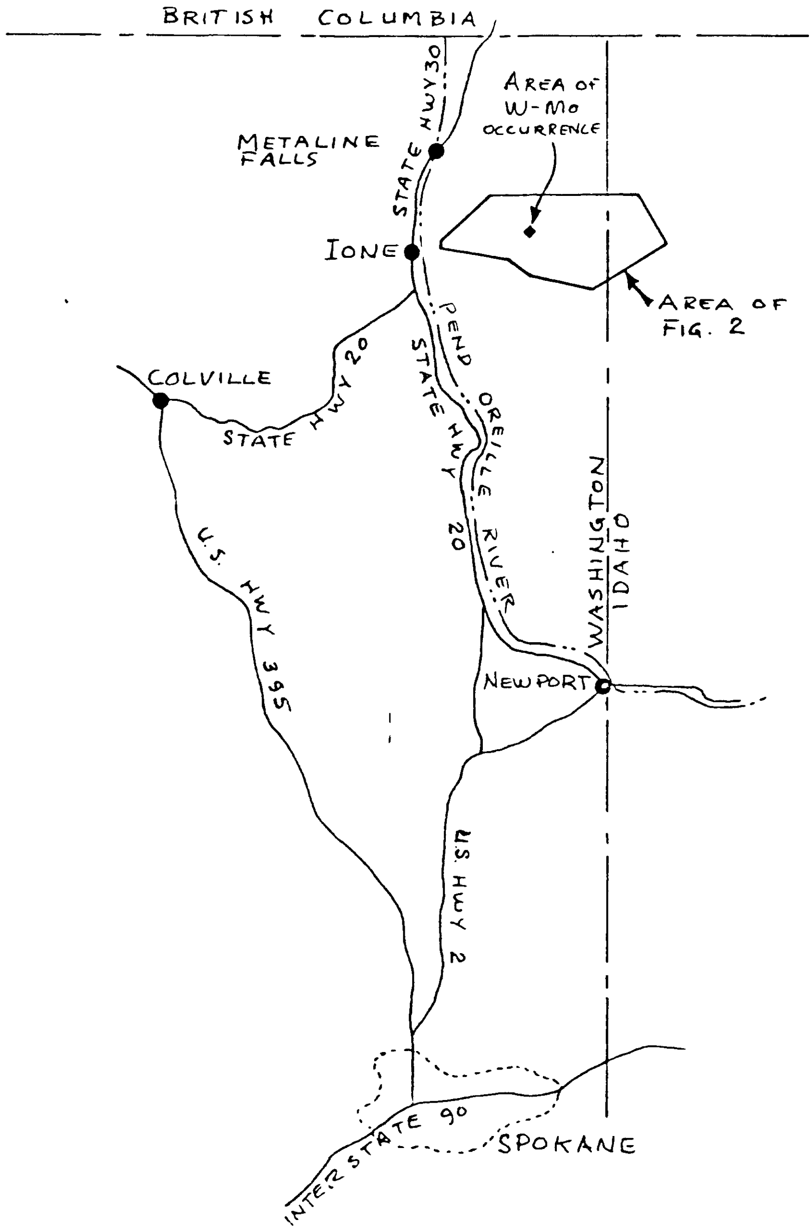
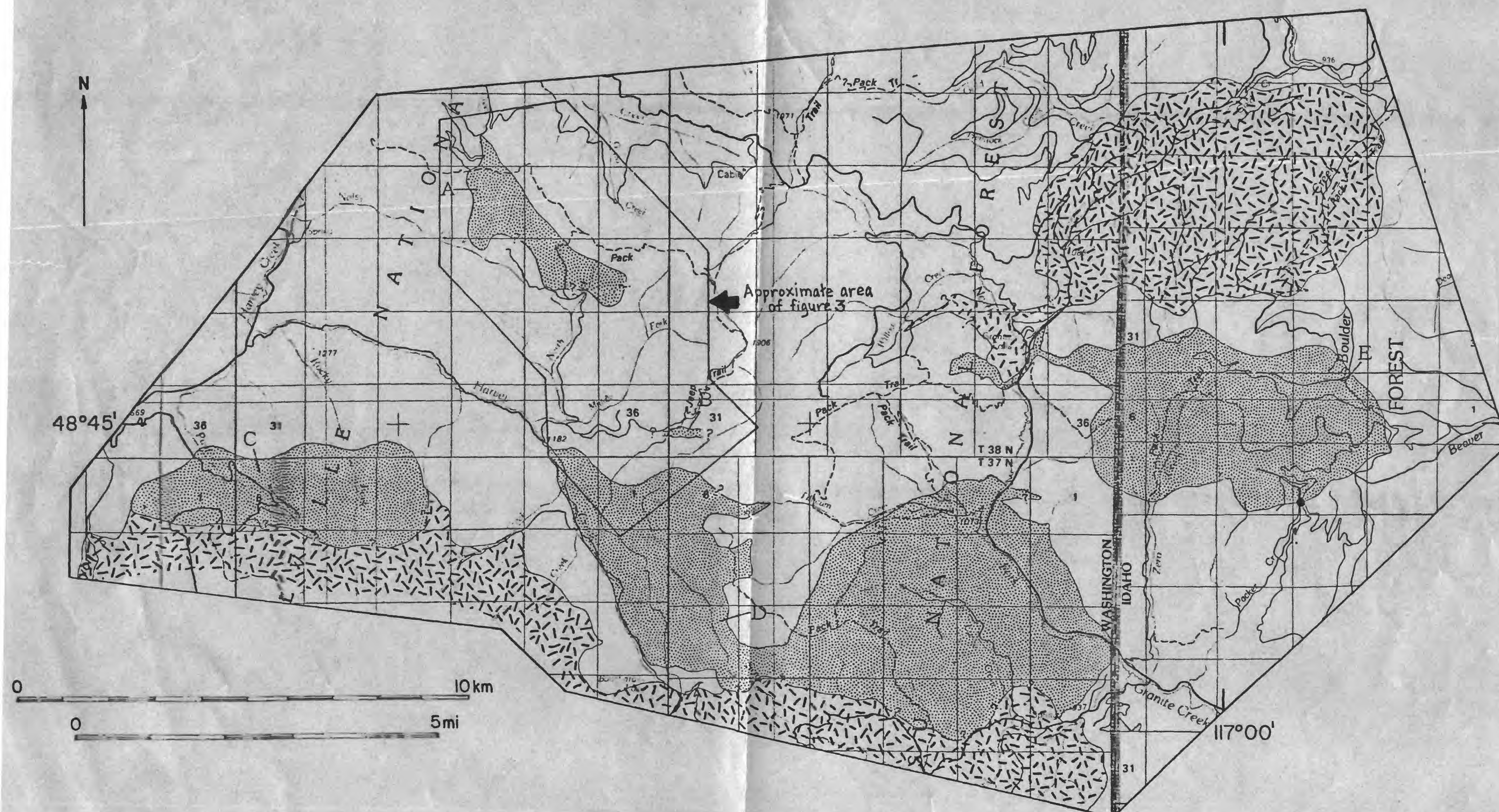


Figure 1

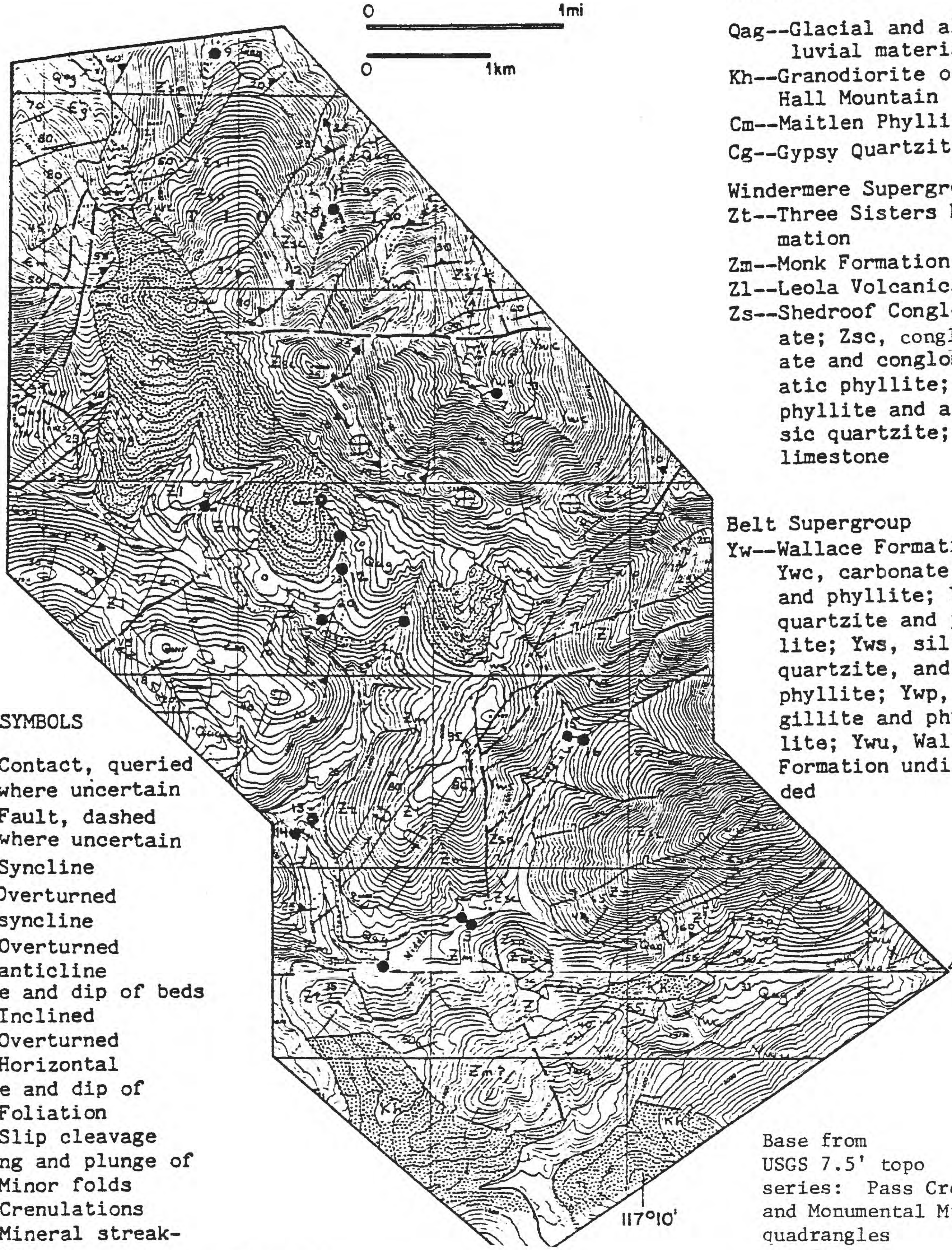
Index map showing location of W-Mo occurrence in Hall Mountain-Harvey Creek area, Washington and Idaho.



Base from U.S.G.S. 100,000 scale series: Colville and Bonners Ferry 1° X 2° quadrangles

Figure 2

Geologic sketch map showing known occurrences of granitic rock similar to granodiorite of Hall Mountain (dotted pattern). Accuracy of contacts highly variable from place to place. A, Hall Mountain body; B, Harvey Creek body; C, Paupac Creek body; D, Orwig Hump body; E, Boulder Mountain body. Other granitic rocks, all of Cretaceous age, shown by random pattern, Pre-Cretaceous metamorphic, sedimentary, and igneous rocks shown unpatterned. No Quaternary deposits shown. Solid circle indicates locality of stream sediment sample from Boulder Mountain body. Geochemical data given in table 2.



EXPLANATION

Qag--Glacial and alluvial material
Kh--Granodiorite of Hall Mountain
Cm--Maitlen Phyllite
Cg--Gypsy Quartzite

Windermere Supergroup
Zt--Three Sisters Formation
Zm--Monk Formation
Zl--Leola Volcanics
Zs--Shedroof Conglomerate; Zsc, conglomerate and conglomeratic phyllite; Zsp, phyllite and arkosic quartzite; Zsl, limestone

Belt Supergroup
Yw--Wallace Formation; Ywc, carbonate rock and phyllite; Ywq, quartzite and phyllite; Yws, siltite, quartzite, and phyllite; Ywp, argillite and phyllite; Ywu, Wallace Formation undivided

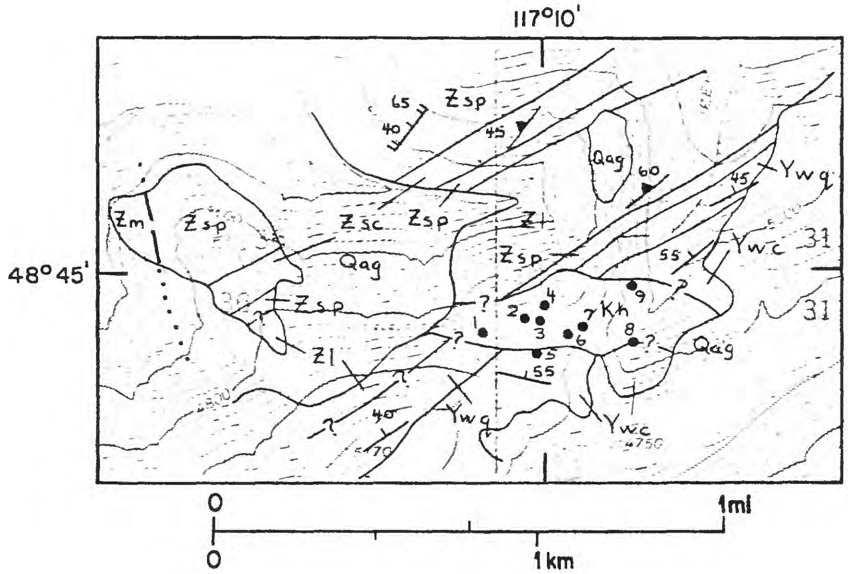
SYMBOLS

—?— Contact, queried where uncertain
——-- Fault, dashed where uncertain
Syncline
Overturned syncline
Overturned anticline
Strike and dip of beds
70 Inclined
70 Overturned
Horizontal
Strike and dip of
70 Foliation
70 Slip cleavage
Bearing and plunge of
70 Minor folds
70 Crenulations
70 Mineral streaking

Symbols may be used in combination.

Base from USGS 7.5' topo series: Pass Creek and Monumental Mtn quadrangles

Figure 3
Geologic map showing setting of Hall Mountain and Harvey Creek bodies of granodiorite of Hall Mountain. Solid circles show where panned stream sediment was sampled. Geochemical data given in table 2.



Base from USGS 7.5' topo
series: Pass Creek and Monu-
mental Mtn quadrangles

Figure 4
Geologic map showing sample localities in and around Harvey Creek body of granodiorite of Hall Mountain. Geochemical data given in table 1. Symbols and map units same as those in figure 3 except solid circles here show localities where rock samples were collected.

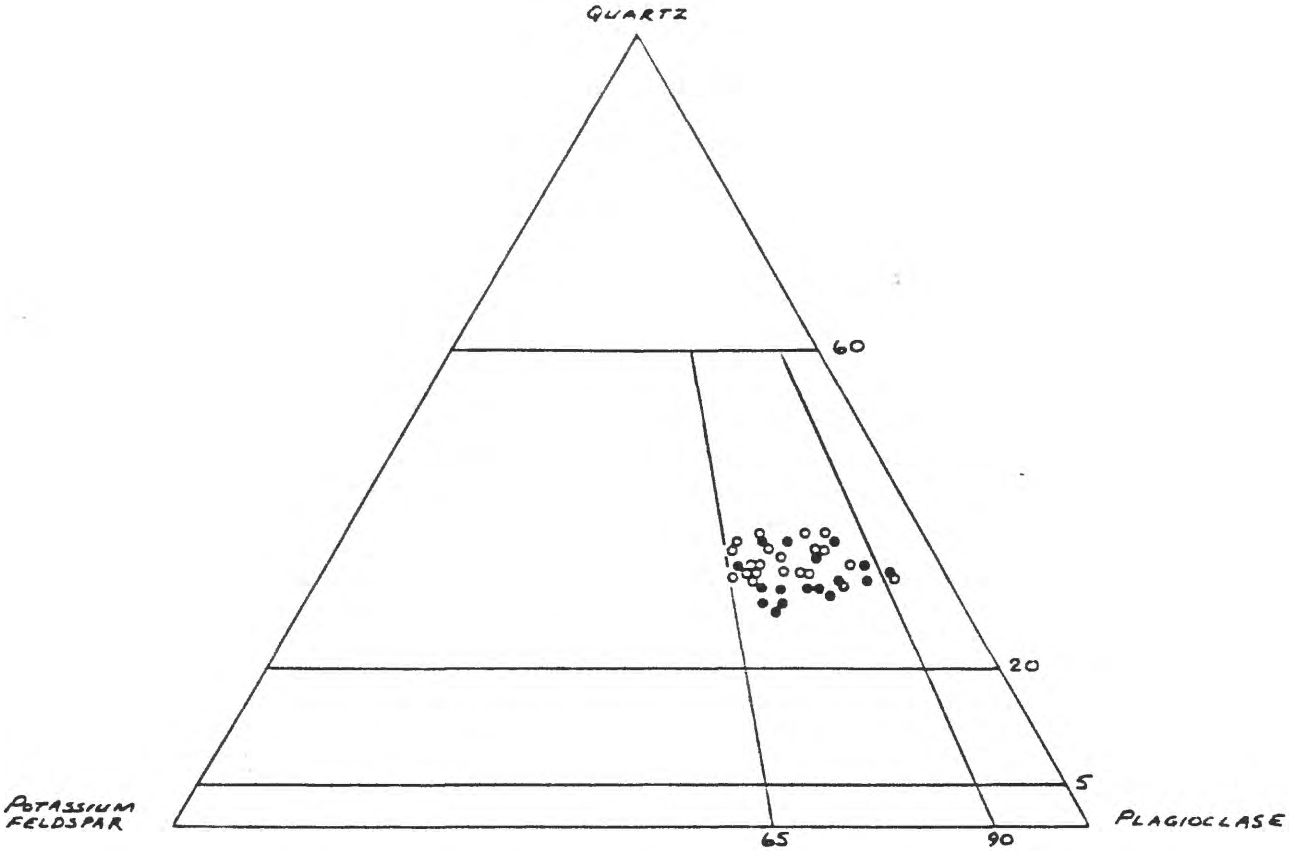


Figure 5. Ternary diagram showing modal composition of granodiorite of Hall Mountain (closed circles) and granodiorite of Reeder Creek (open circles). Classification from Streckeisen (1973).

Figure 6

Figure 7

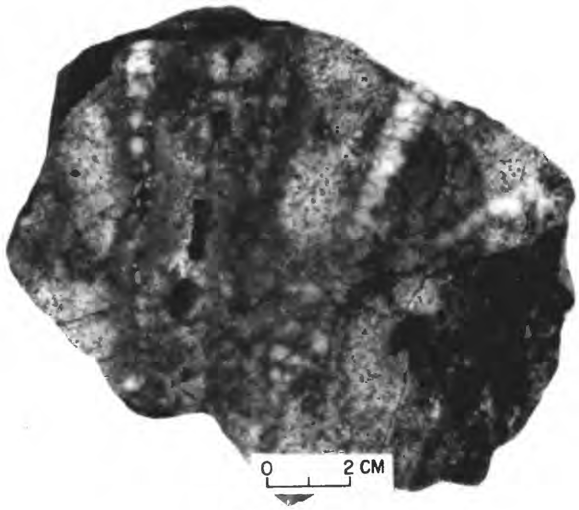


Figure 8

Table 1.--Analytical data from the two-mica granodiorite of Harvey Creek

	1	2	3	4	5	6	7
Map locality (fig. 4)	4	4	4	4	4	4	4
Optical-emission spectrometric analyses (weight percent)							
Ti	0.09	0.22	0.22	0.13	0.13	0.24	0.07
Ba	.062	.17	.12	.072	.11	.19	.056
Be	.0004	.0004	.0005	.0005	.0005	.0003	.0003
Cd	<.0004	.0026	<.0004	<.0004	<.0004	.0017	<.0004
Ce	.006	.009	.009	.003	.007	.009	.004
Co	<.0004	<.0004	<.0004	<.0004	<.0004	<.0004	<.0004
Cr	<.0004	<.0004	.0005	<.0004	<.0004	<.0004	<.0004
Cu	<.0004	.0061	.004	.0048	.0068	.0096	<.0004
Ga	.004	.003	.003	.002	.002	.003	<.002
La	.0039	.0047	.0051	.002	.0045	.0051	.0024
Li	<.0008	.0029	.0041	.0017	.0027	.28	.0012
Mn	.0029	.058	.018	.029	.019	.03	.0021
Mo	.067	.0026	.0008	.0016	.053	.0023	.04
Nb	<.001	<.001	.001	<.001	<.001	<.001	<.001
Ni	<.0008	<.0008	<.0008	<.0008	<.0008	<.0008	<.0008
Pb	.024	.011	.006	.002	.003	.18	.009
Sc	.0015	<.0008	.0009	.0009	<.0008	.0008	<.0008
Sn	<.001	.002	<.001	<.001	<.001	.003	.001
Sr	.017	.047	.074	.024	.055	.037	.013
Th	<.0008	.0011	.0019	.0012	.0009	.0017	<.0008
U	<.008	<.008	<.008	<.008	<.008	<.008	<.008
V	.0053	.0026	.0035	.0046	.0022	.0028	.0022
Y	<.0008	.0013	.0017	.0009	.0012	.001	<.0008
Zn	.0015	.12	.0012	.0039	.0016	.18	.0015
Pr	<.002	.002	<.002	<.002	<.002	<.002	<.002
Nd	.004	.004	.005	.003	.004	.005	.003
Sm	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Eu	<.0008	<.0008	<.0008	<.0008	<.0008	<.0008	<.0008
Gd	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Tb	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Dy	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Ho	<.0008	<.0008	<.0008	<.0008	<.0008	<.0008	<.0008
Er	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Yb	<.0004	<.0004	<.0004	<.0004	<.0004	<.0004	<.0004
Chemical analyses (weight percent)							
F	0.04	0.05	0.05	0.05	0.04	0.06	0.03
W	.00017	.00043	.0001	.00042	.00031	.00045	.00022

Table 1.--Analytical data from the two-mica granodiorite of Harvey Creek (Continued)

	8	9	10	11	12	13	14
Map locality (fig. 4)	4	4	4	4	3	3	3
Optical emission-spectrometric analyses (weight percent)							
Ti	0.18	0.19	0.2	0.23	0.13	.016	.016
Ba	.11	.13	.13	.13	.11	.17	.14
Be	.0006	.0005	.0017	.0004	.0003	.0005	.0004
Cd	<.0004	<.0004	<.0004	<.0004	<.0004	<.0004	<.0004
Ce	.004	.005	.008	.009	.006	.008	.01
Co	<.0004	<.0004	<.0004	<.0004	<.0004	<.0004	<.0004
Cr	<.0004	.0004	<.0004	.0005	<.0004	.0004	<.0004
Cu	.0087	.0076	.002	.0028	.006	.0064	.0018
Ga	.003	.003	.002	.002	.003	.003	.003
La	.003	.0032	.0047	.0051	.0038	.0046	.0054
Li	.0026	.0026	.004	.003	.0029	.0051	.0033
Mn	.0083	.012	.021	.022	.03	.0064	.033
Mo	.0046	.001	<.0008	.0049	.046	.019	.0056
Nb	<.001	.001	<.001	.001	<.001	<.001	<.001
Ni	<.0008	<.0008	<.0008	<.0008	<.0008	<.0008	<.0008
Pb	.003	.005	.003	.005	.002	.002	.004
Sc	<.0008	<.0008	<.00089	<.0008	<.0008	<.0008	<.0008
Sn	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Sr	.035	.043	.071	.065	.015	.0043	.054
Th	<.0008	.0017	.0014	.0017	.0014	.002	.0018
U	<.008	<.008	<.008	<.008	<.008	<.008	<.008
V	.0027	.0028	.0028	.0028	.0023	.003	.003
Y	.0008	.0011	.0013	.0016	.0012	.0008	.0016
Zn	.0015	.019	.0027	.0028	.0024	.0009	.003
Pr	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Nd	.003	.002	.004	.006	.003	.004	.005
Sm	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Eu	<.0008	<.0008	<.0008	<.0008	<.0008	<.0008	<.0008
Gd	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Tb	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Dy	<.0001	<.0001	<.0001	<.0001	<.0001	<.001	<.001
Ho	<.0008	<.0008	<.0008	<.0008	<.0008	<.0008	<.0008
Er	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Yb	<.0004	<.0004	<.0004	<.0004	<.0004	<.0004	<.0004
Chemical analyses (weight percent)							
F	0.04	0.04	0.05	0.04	0.06	0.08	0.05
W	.0005	.00035	.00015	.0001	.0007	.0015	.0031

Table 1.--Analytical data from the two-mica granodiorite of Harvey Creek (Continued)

	15	16	17	18	19	20	21
Map locality (fig. 4)	3	3	3	3	3	2	2
Optical-emission-spectrometric analyses (weight percent)							
Ti	0.14	0.18	0.18	0.16	0.14	0.21	0.24
Ba	.11	.13	.12	.13	.13	.16	.14
Be	.0003	.0005	.0003	.0005	.0004	.0003	.0005
Cd	<.0004	<.0004	<.0004	<.0004	<.0004	<.0004	<.0004
Ce	.006	.009	.008	.007	.013	.008	.01
Co	<.0004	<.0004	<.0004	<.0004	<.0004	<.0004	<.0004
Cr	.0006	.0005	<.0004	.0004	<.0004	.0007	<.0004
Cu	.0045	.0017	.009	.003	.0039	.0077	.0083
Ga	.002	.004	.003	.003	.003	.003	.004
La	.0033	.0045	.0045	.004	.0073	.0044	.0061
Li	.0026	.0031	.0029	.0028	.0023	.0037	.0065
Mn	.032	.021	.0052	.029	.023	.0082	.013
Mo	.048	.027	.022	.099	.032	.053	.016
Nb	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Ni	<.0008	<.0008	<.0008	<.0008	<.0008	<.0008	<.0008
Pb	.003	.004	.005	.004	.003	.005	.005
Sc	<.0008	<.0008	<.0008	<.0008	<.0008	<.0008	<.0008
Sn	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Sr	.022	.057	.058	.048	.05	.065	.069
Th	.0013	.0024	.0015	.0019	.002	.0015	.0026
U	<.008	<.008	<.008	<.008	<.008	<.008	<.008
V	.0026	.0033	.0029	.0025	.0024	.0035	.004
Y	.0011	.0015	.0013	.0016	.0016	.0013	.0018
Zn	.0047	.0011	.0012	.0013	.0012	.0013	.0021
Pr	<.002	<.002	.002	<.002	.002	.002	<.002
Nd	.003	.006	.005	.004	.007	.004	.007
Sm	<.001	.001	<.001	<.001	.001	<.001	<.001
Eu	<.0008	<.0008	<.0008	<.0008	<.0008	<.0008	<.0008
Gd	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Tb	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Dy	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Ho	<.0008	<.0008	<.0008	<.0008	<.0008	<.0008	<.0008
Er	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Yb	<.0004	<.0004	<.0004	<.0004	<.0004	<.0004	<.0004
Chemical analyses (weight percent)							
F	0.05	0.05	0.05	0.05	0.04	0.04	0.04
W	.00046	.00026	.00014	.0003	.0002	.00016	.00013

Table 1.--Analytical data from the two-mica granodiorite of Harvey Creek (Continued)

	22	23	24	25	26	27	28
Map locality (fig. 4)	2	2	6	6	6	6	6
Optical emission-spectrometric analyses (weight percent)							
Ti	0.11	0.2	0.16	0.17	0.15	0.16	0.14
Ba	.1	.13	.14	.13	.089	.14	.12
Be	.0004	.0004	.0004	.0004	.0004	.0004	.0004
Cd	<.0004	<.0004	<.0004	<.0004	<.0004	<.0004	<.0004
Ce	.006	.011	.009	.01	.005	.008	.01
Co	<.0004	<.0004	<.0004	<.0004	<.0004	<.0004	<.0004
Cr	<.0004	<.0004	<.0007	<.0006	<.0004	<.0004	<.0004
Cu	.0094	.0004	<.0007	.0005	.0009	.0048	<.0004
Ga	.003	.002	.003	.003	<.002	.003	.003
La	.0033	.0056	.0051	.0055	.0032	.0057	.0053
Li	.003	.0044	.0055	.0064	.0023	.0037	.0031
Mn	.0067	.011	.016	.0034	.012	.026	.014
Mo	.011	.0008	.026	.0023	.049	.0009	.003
Nb	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Ni	<.0008	<.0008	<.0008	<.0008	<.0008	<.0008	<.0008
Pb	.001	.002	.005	.009	.003	.004	.003
Sc	<.008	<.0008	<.0008	<.0008	<.0008	<.0008	<.0008
Sn	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Sr	.0062	.022	.057	.034	.041	.05	.061
Th	.0015	.0023	.0012	.0011	.0008	.0011	.0024
U	<.008	<.008	<.008	<.008	<.008	<.008	<.008
V	.0023	.0031	.0026	.0032	.0013	.0028	.003
Y	<.0008	<.0008	.0013	.0009	.0011	.0011	.0015
Zn	.0012	.0031	.0014	.0059	.015	.0011	.0043
Pr	<.002	<.002	<.002	<.002	<.002	<.002	.002
Nd	.004	.006	.006	.003	.003	.004	.006
Sm	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Eu	<.0008	<.0008	<.0008	<.0008	<.0008	<.0008	<.0008
Gd	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Tb	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Dy	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Ho	<.0008	<.0008	<.0008	<.0008	<.0008	<.0008	<.0008
Er	<.001	<.001	<.001	<.001	<.001	<.001	<.001
Yb	<.0004	<.0004	<.0004	<.0004	<.0004	<.0004	<.0004
Chemical analyses (weight percent)							
F	0.07	0.06	0.05	0.07	0.03	0.05	0.05
W	.0013	.00076	.00023	.00064	.0001	.00024	.0002

Table 1.--Analytical data from the two-mica granodiorite of Harvey Creek (Continued)

	29	30	31	32	33
Map Locality (fig. 4)	6	6	6	6	6
Optical-emission-spectrometric analyses (weight percent)					
Ti	0.21	0.13	0.07	0.22	0.06
Ba	.15	.0064	.021	.13	.0056
Be	.0005	.0002	.0002	.0006	.0002
Cd	.0004	.0004	.0004	.0004	.0004
Ce	.009	.001	.001	.007	.001
Co	.0004	.0004	.0004	.0004	.0004
Cr	.0007	.0004	.0005	.0004	.0004
Cu	.0004	.0007	.0022	.0042	.0007
Ga	.003	.004	.002	.003	.002
La	.0051	.0008	.0008	.0038	.0008
Li	.0039	.0097	.0011	.0041	.001
Mn	.017	.013	.0079	.035	.0037
Mo	.029	.017	.0027	.0016	.0009
Nb	.001	.001	.001	.001	.001
Ni	.0008	.0008	.0008	.0008	.0008
Pb	.0003	.002	.001	.002	.001
Sc	.0008	.0023	.0011	.0008	.0009
Sn	.001	.001	.001	.001	.0001
Sr	.065	.069	.0062	.001	.001
Th	.0015	.0008	.0009	.0016	.0008
U	<.008	<.008	<.008	<.008	<.008
V	.003	.013	.0049	.004	.0036
Y	.0013	<.0008	<.0008	.0013	<.0008
Zn	.0061	.0022	.001	.0013	.0013
Pr	<.002	<.002	<.002	<.002	<.002
Nd	.006	.001	<.001	.003	<.001
Sm	<.001	<.001	<.001	<.001	<.001
Eu	<.0008	<.0008	<.0008	<.0008	<.0008
Gd	<.002	<.002	<.002	<.002	<.002
Tb	<.01	<.01	<.01	<.01	<.01
Dy	<.001	<.001	<.001	<.001	<.001
Ho	<.0008	<.0008	<.0008	<.0008	<.0008
Er	<.001	<.001	<.001	<.001	<.001
Yb	<.0004	<.0004	<.0004	<.0004	<.0004
Chemical analyses (weight percent)					
F	0.06	0.07	0.04	0.06	--
W	.00082	.00012	.0002	.00054	--

Table 2. Analysis data from stream-sediment samples (panned concentrates)

All are semi-quantitative spectorgraphic analyses except as noted.
All data in parts per million.
Semiquantitative analyses by D. E. Detra, E. L. Mosier, and J. A. Domenico. Colorimetric analyses by J. D. Sharkey. Atomic-absorption analyses by W. W. Vaughn

Limits of detection (ppm)		(1)	(10)	(100)	(20)	(500)
Sample No. (see fig. 3)	Au 1/	Ag	Mo	W	Bi	As
1	N(.05)	--	--	500	50	--
2	N(.10)	--	--	200	30	--
3	N(.05)	--	--	100	50	--
4	N(.05)	--	--	700	200	--
5	N(.05)	--	10	500	2000	--
6	N(.05)	--	--	--	200	--
7	N(.25)	5	--	--	70	120 2/
8	N(.05)	3	--	--	300	20 2/
9	N(.35)	1.5	--	500	500	60 2/
10		-- 3/	15	300	1500	--
11		-- 3/	10	200	1500	--
12		50	50	200	500	--
13		--	20	500	200	--
14		--	--	--	200	--
15		--	30	1000	1500	--
16		--	--	100	--	--
Boulder Mtn body (see fig. 2)	--	1	10	--	2000	--

1/ Colorimetric analyses; limit of detection 10 ppm on these three samples.

2/ Atomic absorption analyses; limit of detection for each sample shown in parentheses.

3/ Un-panned samples from these two localities showed 0.5 ppm Ag.