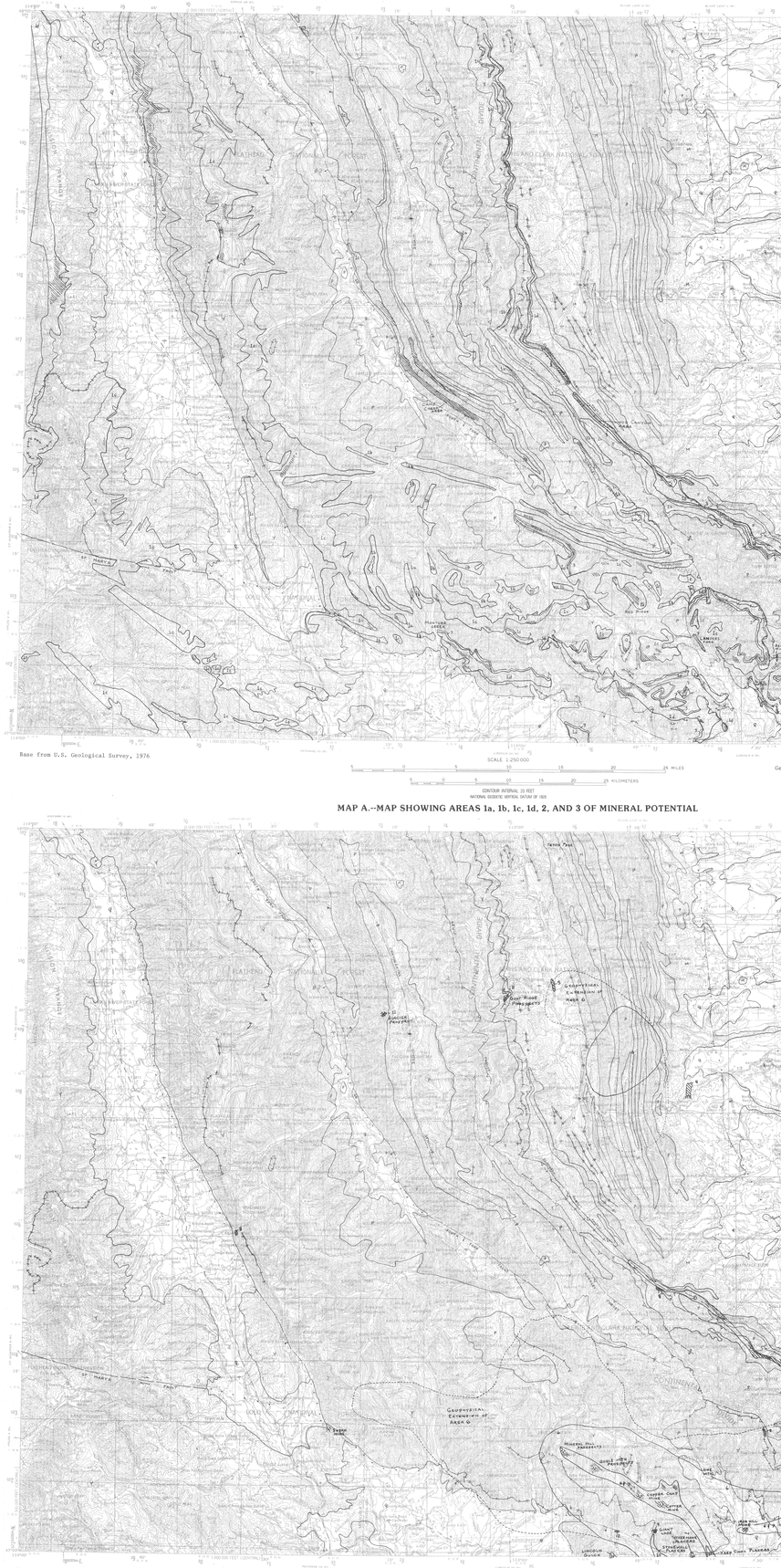
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES
MAP MF-858-A
FOLIO, CHOTEAU 1° X 2° QUAD., MONT.
MINERAL RESOURCE POTENTIAL




MAP A.--MAP SHOWING AREAS 1a, 1b, 1c, 1d, 2, AND 3 OF MINERAL POTENTIAL




MAP B.--MAP SHOWING AREAS 4-12 OF MINERAL POTENTIAL

# MINERAL RESOURCES OF THE CHOTEAU 1° X 2° QUADRANGLE, MONTANA

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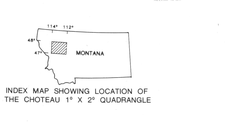


INDEX MAP SHOWING LOCATION OF THE CHOTEAU 1° X 2° QUADRANGLE

The Choteau 1°x2° quadrangle contains a variety of mineral resources (table 1), but mineral production was modest from the area. Production of silver, lead, zinc, silver, and gold were produced from high-grade zones in vein deposits. Minor amounts of silver and copper have been recovered from a stratabound deposit at the base of the Belt Supergroup (T. 15 N., R. 6 W.), where production has been small-scale and intermittent. Metals ore produced in the quadrangle was from mines, now inactive, in the Heddleston District (map B, T. 15 N., R. 6 W.) and as of 1958, totaled approximately $25 million according to Miller and others (1973). Mines with a history of production are listed in table 2 along with the value or amount of their recorded production. These data are from the U.S. Geological Survey's Mineral Resource Information Bank (MRIB) supplemented by data from the U.S. Bureau of Mines Mineral Industry Location System (MILS). The amount of recorded production for the entire Choteau quadrangle is significantly lower than the estimate by Miller and others (1973) for the Heddleston District alone. Miller's estimate may include production not available in public records. Small quantities of nonmetallic materials, principally sand, gravel, and riprap were quarried at several localities for use as road-building material and for earthwork.

Maps A and B show areas of mineral potential classified by deposit type (table 3). The potential hydrocarbon resources are discussed by Nudge and others (1980). The mineral resources maps reflect the compilation and interpretation of results from published reports, as cited in the following text discussion, and from geological, geochemical, and geophysical studies now in progress on the Choteau 1°x2° quadrangle. Potential areas of production for some nonmetallic mineral commodities, such as limestone, are discussed in the following text but are not shown specifically on a map. A map showing the distribution of adequately illustrated on the geologic map (Mudge and others, 1979a).

The spacing of mapping traverses and the investigative detail var from area to area within the quadrangle. Areas known or suspected to be mineralized, such as the western mountain part of the quadrangle, were studied in detail. The geology of areas in the northeastern part has been compiled and published at scales of 1:24,000 (Schmidt, 1972) and 1:48,000 (Whipple, 1979).

In the 1960's, the Anaconda Company discovered and evaluated porphyry copper-molybdenum deposits in the Heddleston District (Miller and others, 1973). These deposits are the most known in the Choteau quadrangle. In the late 1960's and early 1970's, mineral resource studies of wilderness and proposed wilderness areas by the U.S. Geological Survey (Harrison and others, 1974; Mudge and others, 1974; Earhart and others, 1977; and Earhart, 1978) resulted in the discovery of widespread copper-silver occurrences in Belt Supergroup sedimentary rocks (Belt Supergroup). The known occurrences are not presently economic, but some may be of economic importance in the future.

The areas of mineral potential outlined on maps A and B reflect areas that are favorable for surface or near-surface mineral deposits, except for areas numbered 4, which have a potential for concealed porphyry deposits. Crosshatching is used to show where economic minerals were observed or geochemically detected in highly anomalous amounts.

Other mineral deposits probably occur at depth. Most notably, stratabound copper-silver occurrences may be locally present at depth throughout much of the Precambrian terrane. Lack of subsurface data, however, precludes an attempt to define areas of such potential.

## METALLIC MINERAL DEPOSITS

### Stratabound Deposits

Deposits of metallic minerals that are contained in certain strata are widespread in the Choteau quadrangle. They consist of 1 principal types: (1) copper-silver deposits in Proterozoic (Belt) arenites and argillites, (2) lead-zinc and locally copper-silver deposits in carbonate rocks units of the Helena formation, and (3) titaniferous magnetite deposits in sandstones of Cretaceous age. Type 1 deposits include green-bed deposits in several formations and deposits in gray quartzite of the Spokane formation.

### Green-bed Deposits (map A, areas 1a, 1b, 1c, and 1d)

Anomalous amounts of copper occur in green beds in all formations of the Belt in the Choteau quadrangle except the Garnet Range Formation and the Ronner Quartzite (Harrison, 1972; Mudge and others, 1979a). The formations or parts of formations most favorable for green-bed deposits are outlined on map A and are crosshatched where rocks with copper sulfide minerals or their oxidized products were observed and sampled (Grimes and Leitz, 1980a). Other widespread occurrences that are not favorable for mining, but particularly those in the Helena and Shepard formations, appear to be insignificant and are not shown.

All green-bed deposits are contained in greenish-to olive-gray strata included in an alternating sequence of green (reduced) beds and red (oxidized) beds. The copper and silver minerals occur locally in quartzite, silt\ite, and argillite, and typically all three rock types are mineralized in any specific locality. Green-bed deposits differ from the deposits in light-gray quartzite, in the Spokane Formation, in that the latter does not occur in a green-bed sequence. Green-bed deposits are grossly concordant to the enclosing strata; internal discordant features, such as the concentration of copper minerals along penecontemporaneous and post-depositional crosscutting fractures are common.

The character of green-bed deposits varies somewhat with rock type. Quartzite lenses in the green-bed occurrences generally contain the highest concentrations of copper and silver minerals which are disseminated in the matrix of the rock, replace mineral grains, and are commonly concentrated along sedimentary structures such as forset laminae. Occurrences in siltite are similar, but with greater concentration of the copper and silver minerals in the coarser laminae at the base of graded beds. The copper and silver minerals in argillite are in discordant structures, such as shrinkage cracks, or along thin, coarser-grained laminae.

The primary copper minerals, in order of overall abundance, are bornite, chalcocite, and chalcopyrite. In some occurrences, chalcocite is more abundant than bornite; chalcopyrite is most abundant in only a few occurrences in the McNamara Formation. The copper sulfide minerals in outcrops are partially altered to covellite, malachite, and rarely to azurite. The silver mineral(s) has not been identified, but silver apparently occurs as a sulfide and in some cases as native silver in close association with the copper minerals. In addition to silver, green-bed deposits commonly contain anomalous amounts of lead and molybdenum (Earhart, 1978, p. 94). Anomalous amounts of mercury were detected in some samples that contained about 10 ppm (parts per million) or more silver.

Green-bed deposits in the McNamara Formation (areas 1a) are commonly in glauconitic beds. The glauconite and associated copper minerals are most abundant near the top of the lower half of the formation. The sulfide minerals include chalcopyrite, bornite, chalcocite, and locally pyrite. The highest concentrations of copper and silver, such as 1.5 percent and 10 ppm respectively, were found in glauconitic quartzites. Most mineralized zones of outcrops are less than 0.5 m thick and can rarely be traced for more than 2 or 3 m laterally. Green-bed deposits in the McNamara have a low potential for submarginal resources because they are small and discontinuous.

Green-bed deposits in the Mount Shields Formation (areas 1b) occur in the upper and upper-middle parts of the formation, in the central and southern parts of the quadrangle. The copper mineral is dominantly bornite, and the highest grade and most continuous mineralized zones are in quartzite lenses in argillite and siltite. A copper occurrence in the upper part of the Mount Shields at Red Ridge (map A, T. 17 N., R. 9 W.) was traced along the strike for 90 m and is an average of 0.9 m thick (Mudge and others, 1974). If the second lateral dimension is also 90 m, this deposit would contain about 20,000 t of submarginal material that averages about 0.15 percent copper and .07 oz silver per ton (1.98 g/t). Two less continuous deposits, that have somewhat lower grades of copper and silver, occur in a stratigraphic interval about 30 m thick in the upper-middle part of the formation.

Green-bed deposits in the Snowslip Formation (areas 1c) are widespread throughout the formation in the central, southern, and western parts of the quadrangle. The primary copper minerals are bornite, chalcocite, and rarely chalcopyrite. The Snowslip contains more green beds and more green-bed deposits over a greater area than do the Mount Shields and McNamara formations. However, green-bed sequences in the Snowslip are typically lenticular, and mineralized zones commonly are difficult to trace laterally for more than a few meters. In some places, such as near Camp Creek (map A, T. 20 N., R. 12 W.), numerous green beds are mineralized, and the copper and silver content of selected samples are as much as 1.5 percent and 50 ppm respectively (Earhart, 1978). The Snowslip in this area may contain several submarginal deposits comparable in size and somewhat higher in grade than the deposit in the Mount Shields Formation at Red Ridge. Numerous green-bed deposits in the Snowslip contain anomalous amounts of lead and molybdenum than do deposits in the older Proterozoic formations (Earhart, 1978, p. 94).

### Green-bed Deposits in the Spokane and Sequence Formations (map A, areas 1a, 1b, 1c, and 1d)

Green-bed deposits in the Spokane are mostly in the upper 200 m of the formation. The lower part of the formation, near the transitional contact with the underlying Greyson Formation, contains a few, very thin, copper-bearing strata that are less mineralized than those in the upper part of the formation.

In the upper part of the Spokane, as many as 16 green-bed zones, that are each as thick as 18.5 m are interbedded with red strata. The green beds consist mostly of siltite and argillite that form graded (fining upward) sequences from 1 to 15 m thick. Locally, the siltite coarsens to fine sand. The copper and silver minerals are commonly near the middle of a green-bed sequence. Mineralized zones range in thickness and reach a maximum of about 3 m near Copper Camp mine (map B, T. 15 N., R. 9 W.) where the greatest average is 0.17 percent copper and about 0.25 oz of silver per ton (7.1 g/t). This stratigraphic interval has been explored and inferred to be mineralized where present from near Montare Creek (map A, T. 16 N., R. 12 W.) to Alice Creek (map A, T. 16 N., R. 7 W.), a distance of 95 km. The strike trace of the upper part of the Spokane in this region is about 95 km. Assuming a continuous mineralized zone with a specific gravity of 2.7 that averages 1.5 m thick and extends down dip for 100 m, this one zone in the upper part of the Spokane may contain about 15 million t of submarginal resources that averages about 0.1 percent copper and 0.25 oz of silver per ton (7.1 g/t). Eight other mineralized zones are known in the Copper Camp area, but most of these are probably not traceable over great distances. A detailed study of the siltite unit, would be required to estimate accurately the extent and grade of the mineralized zones.

The copper sulfide minerals in the Spokane green-bed deposits are, in order of abundance, chalcocite, digenite, and bornite. Malachite and azurite are disseminations in the coarser laminae; in outcrops, these minerals are partly altered to covellite, malachite, and azurite. The silver-bearing minerals have not been identified.

Green-bed deposits in the Spokane Formation are inferred to have potential for submarginal mineral resources than those in the younger formations in the belt because more are laterally extensive, particularly in the southern part of the quadrangle. The potential for such deposits in the Spokane is further enhanced by higher concentrations than most copper-silver deposits in the other formations of the Belt.

### Deposits in Gray Quartzite (map A, area 2)

Stratabound copper-silver deposits occur in light-gray quartzite and siltite lenses in brick-red, platy siltite in the middle part of the Spokane Formation, in the southeastern part of the Choteau quadrangle. The quartzites, collectively called the quartzite of Green Mountain by Trammell (1975), are distributed through as much as 300 m of the Spokane in a tilted block of about 30 mi in the vicinity of Alice Creek (map A, T. 16 N., R. 7 W.). Although the same quartzite is commonly applied to these rocks, they are in fact very fine grained, highly feldspathic arenites and arkoses. Outcrops typically form ledges that are rarely more than 2 m thick, and range from a few tens of meters to nearly 1,000 m along the strike; two of the larger lenses appear to trend northerly. The sulfide minerals occur as disseminations and fracture fillings and are highly oxidized to malachite in outcrops. The quartzites contain an average of 0.1 percent copper and 0.1 oz silver per ton (5.7 g/t).

One high-grade, pod-shaped silver deposit at the Bear Gulch mine (map A, T. 16 N., R. 7 W.) was discovered by Bear Creek Mining Company in the early 1960's. The pod contains at least 200 t of ore that averages about 70 oz/t (1,984.5 g/t) silver; recent analyses were as high as 290 oz/t (8,221.5 g/t) silver. Copper is not noticeably enriched in the silver pod compared to quartzite outside the pod. Silver occurs as a sulfide--probably argentite, and the copper mineral is apparently chalcocite. It seems reasonable to assume that chalcocite and argentite also occur in the other gray, mineralized quartzites. In addition, Trammell (1975) identified digenite, minor bornite, and minor native silver in these deposits.

Within area 2, a minimum of 800,000 t of mineralized rock which averages 0.1 percent copper and 0.2 oz silver per ton (5.7 g/t) is estimated to crop out and continue to shallow depth. Additional deposits in the subsurface are highly probable and could include high-grade silver pods similar to that at the Bear Gulch mine.

### Deposits in Calcareous Quartzite of the Helena Formation (area 3) and Replacement Deposits (map A, area 4)

The second type of stratabound mineral occurrences in the Choteau quadrangle consists of lead-zinc and locally copper-silver, in calcareous quartzite near the base of the Helena Formation. These occurrences are widespread in the southern and southeastern parts of the quadrangle. The mineralized zones commonly are less than 0.5 m thick, planar to lenticular, and contain less than one percent combined lead-zinc. In the Wood Canyon area (map A, T. 20 N., R. 10 W.) the calcareous quartzite beyond is as much as 2.5 m thick, and at Landers Fork (map A, T. 16 N., R. 8 W.) it is structurally thickened to as much as 3.5 m. At most localities, the calcareous quartzite contains disseminated galena and sphalerite; in outcrops the sphalerite is partly altered to smithsonite. At Landers Fork, the quartzite contains chalcopyrite and an unidentified silver-bearing mineral. Selected samples from this locality contain about 0.5 percent copper and 0.2 oz silver (5.7 g/t). To the west of Landers Fork, the quartzite locally contains thin zones of low-grade copper and silver.

The occurrences at Wood Canyon are in the northern part of a lead-zinc belt described by Mudge and others (1968). Here the lead-zinc occurrences appear to be similar to that observed elsewhere in the Proterozoic calcareous quartzite; however, in the central and southern parts of the belt the lead and zinc occurrences form discordant bodies in a variety of rocks. These occurrences are discussed in the section on hydrothermal deposits, even though they form a linear extension of the stratabound deposits and are probably related to them.

### Titaniferous Magnetite Deposits (map B, area 4)

Extensive titaniferous magnetite deposits cap buttes and mesas across the northeast corner of the Choteau quadrangle. Smaller deposits lie east of the Sawtooth Mountains in the east-central and southeastern parts of the quadrangle.

These deposits are stratiform in the upper part of the Virgelle Sandstone of late Cretaceous age, thicknesses ranges from about 0.3 m to about 6 m, and averages about 1.5 m. Small stratiform deposits in the Horsethief Sandstone, also of late Cretaceous age, are not shown because they have no foreseeable resource potential.

The titaniferous, magnetite-bearing beds are beach paleoplacers containing heavy minerals that were derived in part from intermediate to mafic stills of Proterozoic Z age. The highest concentrations of iron and titanium minerals, as much as 45.5 percent iron and 7 percent titanium (Kimmler, 1946), are in regressive littoral facies at the top of the ancient beach deposits and are similar to deposits in Wyoming described by Houston and Murphy (1962). Perhaps as much as one-third of the titaniferous magnetite deposits are included in the littoral facies; the remainder commonly contains less than 15 percent iron and only small amounts of titanium.

The deposits in the northeastern part of the quadrangle are potentially minable because they are extensive and are covered with negligible amounts of overburden. One deposit in the area, the Choteau deposit (map B), was explored by the U.S. Bureau of Mines who drilled 76 core holes to depths ranging from 1.6 m to 7 m (Kimmler, 1946). Thirty-three of these holes recovered titaniferous, magnetite-bearing rock that averaged greater than 30 percent iron. The total reserves of the Choteau deposit, as determined by Burlington Northern Inc., is 10,290,000 t of which 3,215,000 t contains greater than 30 percent magnetite. If the thickness and occurrence of the Choteau deposit is representative of that in the area outlined on the northeast part of map B, the total reserves in this area may be about 90,000,000 t of which 30,000,000 t may contain more than 30 percent iron.

Wimmler (1946) reports that the ilmenite and magnetite in these deposits occur as small individual grains and as closely intergrown grains. Metallurgical testing by the U.S. Bureau of Mines, in 1946, did not result in a method that satisfactorily separates the magnetite from the ilmenite.

### Hydrothermal Deposits

Metallic mineral deposits related to hydrothermal activity are mostly associated with Tertiary intrusive rocks in the southeastern part of the quadrangle. A few minor occurrences are associated with Proterozoic diorite sills in the central, northern, and western parts. In the southeastern part, some of the stratabound deposits previously described may be locally modified and enhanced by hydrothermal activity associated with the Tertiary intrusives.

The hydrothermal deposits include: (1) fracture-filling and replacement deposits of lead and zinc, (2) deposits of copper and molybdenum associated with porphyritic intrusive rocks, (3) vein deposits of base and precious metals, and (4) gold-bearing veins.

### Fracture Filling and Replacement Lead-Zinc Deposits (map B, areas 5)

Lead-zinc minerals in the southern part of a mineralized belt described by Mudge and others (1968) occur as fracture fillings, disseminations, and pod-like replacement deposits in a variety of rocks, mostly of Cambrian and Devonian ages. The occurrences show a clear spatial relationship to the Eldorado thrust fault (Mudge and others, 1968; Leinz and Grimes, 1980). Although the occurrences in area 5 are markedly different than the stratabound occurrences in area 3 at Wood Canyon (map A, T. 20 N., R. 10 W.), the presence of both types in the same linear belt suggests that they are related. Area 5 may represent a part of the lead-zinc belt that was remobilized during thrust faulting. The potential for submarginal deposits of lead and zinc is highest in the southern part of the belt.

### Porphyry Copper-Molybdenum Deposits (map B, areas 6)

The known porphyry-type deposits of copper and molybdenum in the Choteau quadrangle are in the Heddleston District (T. 15 N., R. 6 W.). These deposits have been explored and described by the Anaconda Company (Miller and others, 1973); the following descriptions are summarized from their report. Tonnage and grade estimates of the deposits have not been published, but "the Heddleston District contains several significant copper-molybdenum zones economically exploitable by open-pit methods."

The Heddleston deposits are associated with multiple igneous intrusions. The main unit is a quartz monzonite porphyry. The intrusive complex also includes quartz porphyry as well as late quartz monzonite porphyry dikes and breccia pipes. An age of 44.5 m.y. (Bl.2 m.y.), by K/Ar methods, was obtained on sericite from an altered part of the quartz monzonite by American Metals Climax Corporation (Miller and others, 1973). A base- and precious-metal vein system extends for more than the porphyry system has been the source of past lead-zinc-copper-silver-gold production. The vein system trends northwesterly within and peripheral to the intrusive complex.

Principal ore minerals in the porphyry are chalcopyrite and molybdenite which occur as disseminations and in veinlets in the early to late phases of the intrusive complex. Secondary copper minerals, chalcocite and covellite, are most abundant in steeply dipping zones that follow pre-mineral structures.

Altered rocks are most evident in the earlier-formed phase of the quartz monzonite and are predominantly sericitic and pyritic, grading outward to propylitic. The intrusive complex was replaced in beds of the Spokane Formation and a diorite sill. The Spokane strata are bleached and limonitic in a broad halo around the intrusive contact and the sill is chloritized and epidotized.

Area 6, which extends northwesterly from the Heddleston District about 45 km, has a high potential for concealed porphyry deposits of copper and molybdenum. Geologic evidence for this is that at Heddleston, crops out along a part of Alice Creek (T. 15 N., R. 7 W.) and that mine is economic but too small to show on the geologic map at the Cotter Mine (T. 15 N., R. 7 W.), which suggest a northwesterly alinement of the quartz monzonite intrusives. Quartz carbonate veins, exposed intensively from the Cotter Mine to the Mineral Hill prospects (T. 16 N., R. 10 W.), contain base and precious metals, and trend northwesterly parallel to the trend of veins at the Heddleston deposit and to the alinement of quartz monzonite intrusives. Geologic evidence suggesting a possible buried porphyry system is supported by geochemical studies (Grimes and Leitz, 1980a,b; Leinz and Grimes, 1980c). Mercury, which is commonly concentrated in outer halos of copper-molybdenum porphyry deposits (J. H. McCarthy, oral commun., 1979), occurs in highly anomalous amounts along the northwesterly trend of the vein system that extends to the Mineral Hill prospects. The rocks immediately adjacent to the Heddleston deposits contain low amounts of mercury (mostly below 0.4 ppm). Approximately 4,000 m from the deposits, mercury values in rock samples are 1.5 ppm and increase to 4 ppm about 8,000 m from the deposits. Mercury values in area 6 are as much as 10 ppm and could reflect halos over buried porphyry deposits. The distribution of hydrothermally derived mercury is probably dependent on a number of factors including the size, temperature, and chemistry of the hydrothermal system as well as the composition, porosity, and competency of the country rocks. Thus, the depth to possible buried porphyry deposits in area 6 cannot be estimated on the basis of mercury distribution.

Mineral zoning in the vicinity of the Heddleston, in some respects, is similar to the typical copper-molybdenum porphyry model (Lowell and Guilbert, 1970). Galena and sphalerite veins with minor silver and gold occur mostly beyond the outer shell of disseminated chalcopyrite mineralization. There is, however, no clear-cut chalcopyrite-pyrite zonal pattern typical of most porphyry deposits. On a regional scale, mineral zoning patterns which may be associated with buried porphyry deposits are observed due to the effects of other types of mineral deposits, mainly Proterozoic stratabound deposits of copper and silver. The vein system that extends to the Mineral Hill prospects is within a part of the Proterozoic section which, adjacent to the veins and elsewhere in the southeastern part of the quadrangle, contains stratabound deposits of green-bed copper and of lead and zinc in calcareous quartzite. This overlap between the vein system and stratabound occurrences which may have contributed copper, lead, zinc, and silver to selected veins, complicates a prediction of depth or location of possible buried copper-molybdenum porphyry deposits based on mineral zoning associated with a porphyry system.

Aeromagnetic data (Kleinkopf, 1980) suggest that the Heddleston deposits are on the fringe of a large concealed batholithic body to the northeast. Area 6, to the northwest of the Heddleston deposit, is along a steep northeasterly trending magnetic gradient on the fringe of a magnetic high to the north, somewhat analogous to the magnetic expression in the vicinity of the Heddleston. Along this same trend, the gravity data (Wilson, 1980) indicate a northeasterly trend of gravity highs and lows; the lows could be associated with hydrothermally altered intrusive rocks at depth. On the basis of the geophysical data, the area of potential for concealed porphyry-type deposits (area included by the dashed line) is extended beyond the area outlined on the basis of favorable geology and geochemistry.

Area 6, northeast of the center of the quadrangle, could contain a buried molybdenum-bearing porphyry deposit, although no intrusives, veins, or hydrothermal alteration features are exposed. Selected samples of ferruginous Jurassic and Cretaceous sedimentary rocks in this area contain anomalous amounts of molybdenum and zinc which are highly mobile elements in the geologic environment (D. J. Grimes, oral commun., 1980). The geochemical anomaly is superimposed on a broad and a negative magnetic anomaly (M. D. Kleinkopf, oral commun., 1980), and on a negative gravity anomaly (Wilson, 1980).

### Vein Deposits (map B, areas 7 and 8)

Vein deposits associated with Tertiary intrusives (map B, area 7) are mostly restricted to the southeastern part of the quadrangle. They are, at least in part, spatially associated with porphyry-type systems. Most of the past production of base metals and silver was from these deposits. Lead, zinc, copper, silver, and gold were mined from veins at the Mike Horse and at other mines near the Heddleston porphyry deposits (Pardee and Schrader, 1933; Miller and others, 1973). Small amounts of copper and precious metals were produced from the Cotter and Copper Camp mines northwest of the Heddleston District in the upper reaches of Copper Creek, and from the Rosetta Mine and other nearby small workings to the east about 7.2 km west of Wolf Creek (Pardee and Schrader, 1933; Schmidt, 1978). The principal economic minerals in veins at the Mike Horse and at nearby mines in the Heddleston District, are galena and sphalerite; some of the veins contain significant amounts of chalcopyrite and bornite. Several deposits, particularly those in the Heddleston District and at Copper Camp, contain small but significant amounts of tetrahedrite, which may be the principal silver-bearing mineral in the vein system. The gangue minerals in the veins include quartz, calcite, and locally barite.

Mineralized veins associated with Proterozoic Z sills (map A, areas 8) occur in the central, western, and southern parts of the quadrangle. Most of the veins are predominantly calcite and occur near the hanging wall of the sill and in adjacent country rock. The principal sulfide mineral in the veins is chalcopyrite; galena, sphalerite, and an unidentified silver mineral occur in subordinate amounts. Typical veins are more than 2 m thick and are discontinuous. Veins are exposed in an adit and in pits at Goat Ridge (map B, T. 23 N., R. 11 W.), in smaller prospects at several localities to the south, and at one locality in the western part of the quadrangle, but none have known production.

### Gold Lode Deposits (map B, area 9)

The only known gold lode deposit in the Choteau quadrangle is the Glant Lode (T. 15 N., R. 9 W.) in the extreme southern part. The gold is associated with quartz stringers in epidotized, chloritized, sheared diorite of Proterozoic age. Samples of the veinlets and adjacent diorite contain as much as 0.5 oz/t gold (14.17 g/t) and small amounts of copper, but the occurrence is small (Earhart and others, 1977). A similar gold lode deposit in Lincoln Gulch a short distance south of the Choteau quadrangle was described by Pardee and Schrader (1933, p. 116). As previously mentioned, gold has been recovered from base metal veins in and near the Heddleston District. Gold contents as much as 0.44 oz/t (12.47 g/t) were found in a base metal quartz-carbonate vein at the Cotter Mine (Earhart and others, 1977).

### Gold Placer Deposits (map B, areas 10)

Placer deposits of gold have been prospected in drainages near the Gold Lode occurrences described above. The richest and most productive placer was in Lincoln Gulch (T. 14 N., R. 10 W.), south of the Choteau quadrangle (Pardee and Schrader, 1933). Only the headwaters of Lincoln Gulch are in the Choteau quadrangle, and the small amount of gravels in this part of the drainage precludes the discovery of significant amounts of gold. Placer deposits in Livermore and Keep Cool Creeks (T. 14 N., R. 9 W.) are small and irregular, and have accounted for very small past production (Pardee and Schrader, 1933, p. 119). Gold production from placer workings on Stonewall Creek (T. 14 N., R. 9 W.) is unknown but was probably small; samples of the workings did not contain detectable amounts (Earhart and others, 1977).

## NONMETALLIC MINERALS

The Choteau quadrangle contains a variety of nonmetallic mineral resources, but only areas with potential for vein deposits of barite and for lithium-bearing oil shale are shown on map B. The distribution of the other nonmetallic minerals is adequately illustrated by using appropriate parts of the following sections in conjunction with the geologic map of the Choteau quadrangle (Mudge and others, 1979a) to identify favorable areas for deposits of sand and gravel, high-purity limestone and dolomite, construction stone, bentonite, and coal.

### Vein Deposits of Barite (map B, area 11)

Vein deposits of barite occur in the McNamara Formation at the Glacier prospect (T. 23 N., R. 13 W.), in the northern part of the quadrangle. The veins, as much as 3 m thick, consist of nearly pure barite and are exposed in trenches and pits over a slope distance of about 100 m (Earhart, 1978). Marks (1978) estimated reserves of 80,000 t that average 92 percent $BaSO_4$.

### Oil Shale Deposits (map B, area 12)

Shales of Oligocene age in the southeastern part of the quadrangle (T. 15 N., R. 9 W.) contain as much as 93 l/t of oil. The oil-bearing beds also contain as much as 1,500 ppm lithium (Bremner-Tourtelot and others, 1978). Drilling by the U.S. Geological Survey indicated that the sequence of rocks that contain the oil is about 1,300 m long by 300 m wide, and significant amounts of hydrocarbons are restricted to narrow stratigraphic zones. Bremner-Tourtelot and others (1978) concluded that the lithium-bearing rocks were a submarginal resource in 1978.

### Sand and Gravel Deposits

Sand and gravel deposits are widespread on the flood plains and alluvial terraces of the major streams and rivers in the Choteau quadrangle. Other possible sources of sand and gravel are in glacial outwash deposits. A large deposit of preglacial gravel occurs at Lone Mountain (map B, T. 16 N., R. 8 W.) in the southeastern part of the quadrangle. The deposit is as much as 780 m thick but would be difficult to process because it is well cemented in places.

### Limestone and Dolomite Deposits

High-purity limestone and dolomite occur in Paleozoic carbonate rocks in the Choteau quadrangle. The largest deposits are in the Sawtooth Range from the central to the northern part of the quadrangle. A few analyses of high-purity limestone from the middle member of the Allan Mountain Limestone of Mississippian age suggest that it may average about 96 percent $CaCO_3$. Resources of high-purity dolomite, in the Devils Glen Dolomite of Cambrian age (Earhart, 1978), were estimated at a few localities and may average about 45 percent $MgCO_3$.

### Construction Stone

Several formations in the Choteau quadrangle contain rocks suitable for dimension stone and crushed stone. Several of the Proterozoic formations, notably the Ronner Quartzite and the Mount Shields Formation, contain large deposits of quartzite suitable for dimension stone. Other formations with deposits included the Flathead Sandstone of Cambrian age and the Kootenai Formation of Cretaceous age. Cambrian and Mississippian carbonate rocks would also be suitable dimension stone. The Cambrian Devils Glen Dolomite, which is uniformly near-white and thick bedded, is high-quality dimension stone. Schmidt (1978) noted that lattice from Neogenic volcanic rocks in the southeast corner of the map area would be usable for dimension stone. He also noted that some thinly laminated argillite and siltite in the Proterozoic Greyson Formation in that area bear a resemblance to slate, and have been used as roofing shale and Flagstone. Nearly all of the rocks of Proterozoic through Neogenic age would be suitable for crushed stone.

### Bentonite Deposits

Bentonite occurs in several of the Cretaceous formations (Mudge, 1972), but most of the deposits are too thin to be minable. Mudge (1972) has noted that more than 100 bentonite beds, each less than 0,5 m thick, occur in the Kevin Shale Member of the Marias River Shale. The thickest bentonite bed, 2.1 m, is in the Cone Member of Marias River Shale along the South Fork of the Sun River (Mudge, 1972). Schmidt (1978) reports bentonite beds as thick as 1 m in the Cone Member of the Marias River Shale and in the Two Medicine Formation in the southeastern part of the quadrangle.

### Coal

Lignite and subbituminous coal, in beds less than 0.5 m thick, occur in Cretaceous and Tertiary rocks at several localities in the Choteau quadrangle.

Low-rank coal beds in the Lower Cretaceous Vaughn Member of the Blackleaf Formation near Teton Pass (T. 26 N., R. 10 W.) range in thickness from 0.15 m to 1.2 m. One or more low-rank coal beds are widespread in the lower part of the Upper Cretaceous Two Medicine Formation. In the southeastern part of the quadrangle these beds range in thickness from 0.5 m to 2 m and have been mined on a small scale for local usage (Schmidt, 1978). Schmidt notes that good quality coal was mined from a bed 1.2 m to 1.5 m at two localities in sec. 21, T. 17 N., R. 4 W. Low-rank coal was also mined for local usage from a bed about 0.7 m thick along the Sun River in sec. 27, T. 22 N., R. 8 W. In the eastern part of the quadrangle, a 0.5 m thick bed of low-rank coal occurs locally in the lower part of the Upper Cretaceous Bx. Mary River Formation.

Thin beds of low-rank coal are observed in Tertiary sedimentary rocks at two localities: (1) near the southern boundary of the quadrangle in T. 14 N., R. 11 W. and (2) along the South fork of the Flathead River in the northwestern part of the quadrangle (Mudge and Earhart, 1978). The beds are 2.5 cm to 0.5 m thick, and the coal is of low quality.

Coal deposits in the Choteau quadrangle have a very low resource potential except for local domestic usage.

## REFERENCES

Bremner-Tourtelot, K. F., Meier, A. L., and Tourtelot, H. A., 1978, Oil shale data from the Lincoln, Pondera, and Teton counties, Montana: U.S. Geological Survey Open-File Report 78-430, 29 p.

Conner, J. J., 1980, Geochemistry of copper-silver occurrences in the Belt Supergroup, northwest Montana: Montana Bureau of Mines and Geology Abs. [abs.]: Geological Society of America Abstracts with Programs.

Earhart, R. L., 1978, A geological and geochemical investigation of the Heddleston district of the Rob Marshall Wilderness and adjacent areas, Lewis and Clark, Teton, Pondera, Flathead, Lake, Missoula, and Powell counties, Montana: U.S. Geological Survey Open-File Report 78-1, 107 p.

Earhart, R. L., Grimes, D. J., Mudge, M. R., and Marks, L. Y., 1977, Mineral resources of the proposed additions to the Scapegoat Wilderness, Powell and Lewis and Clark counties, Montana, with a section on Geochemical surveys by Geochemical Survey Units: U.S. Geological Survey Bulletin 1438, 82 p.

Grimes, D. J., and Leinz, R. W., 1980a, Geochemical and generalized geologic maps showing the distribution and abundance of copper in the Choteau 1° x 2° quadrangle, Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-858B, scale 1:250,000.

_____1980b, Geochemical and generalized geologic maps showing the distribution and abundance of silver in the Choteau 1° x 2° quadrangle, Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-858C, scale 1:250,000.

Grimes, D. J., and Leitz, R. W., 1980a, Geochemical and generalized geologic maps showing the distribution and abundance of lead in the Choteau 1° x 2° quadrangle, Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-858D, scale 1:250,000.

_____1980b, Geochemical and generalized geologic maps showing the distribution and abundance of zinc in the Choteau 1° x 2° quadrangle, Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-858E, scale 1:250,000.

Harrison, J. E., 1972, Precambrian Belt basin of northwestern United States: Its geometry, sedimentation, and copper occurrences: Geological Society of America Bulletin, v. 83, p. 1215-1240.

Harrison, J. E., Reynolds, M. W., Kleinkopf, M. D., and Pattee, E. C., 1969, Mineral resources of the Scapegoat-Bob Marshall Wilderness, Powell, Lewis and Clark, Teton, Pondera, and Missoula counties, Montana: U.S. Geological Survey Bulletin 1272-A, 33 p.

Houston, R. S., and Murphy, J. A., 1962, Titaniferous black sandstone deposits of Wyoming: Wyoming Geological Survey Bulletin 48, 139 p.

Kleinkopf, M. D., 1980, Aeromagnetic and generalized geologic maps of the Choteau 1° x 2° quadrangle, Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-858F, scale 1:250,000.

Leinz, R. W., and Grimes, D. J., 1980a, Geochemical and generalized geologic maps showing the distribution and abundance of lead in the Choteau 1° x 2° quadrangle, Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-858D, scale 1:250,000.

_____1980b, Geochemical and generalized geologic maps showing the distribution and abundance of zinc in the Choteau 1° x 2° quadrangle, Montana: U.S. Geological