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UNITED STATES GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES
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PAMPHLET

MINERAL RESOURCE POTENTIAL OF THE VASQUEZ PEAK WILDERNESS STUDY AREA, AND THE ST. LOUIS PEAK AND WILLIAMS FORK ROADLESS AREAS, CLEAR CREEK, GRAND, AND SUMMIT COUNTIES, COLORADO

By

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STUDIES RELATED TO WILDERNESS

Under the provisions of the Wilderness Act (Public Law 88-577, September 3, 1964) and related acts, the U.S. Geological Survey and the U.S. Bureau of Mines have been conducting mineral surveys of wilderness and primitive areas. Areas officially designated as "wilderness," "wild," or "canoe" when the act was passed were incorporated into the National Wilderness Preservation System, and some of them are presently being studied. The act provided that areas under consideration for wilderness designation should be studied for suitability for incorporation into the Wilderness System. The mineral surveys constitute one aspect of the suitability studies. The act directs that the results of such surveys are to be made available to the public and be submitted to the President and the Congress. This report discusses the results of a mineral survey of the Vasquez Peak Wilderness Study Area (A2361), and the Williams Fork (02114) and St. Louis Peak (E2361) Roadless Areas in the Arapaho National Forest, Clear Creek, Grand, and Summit Counties, Colorado. The Vasquez Peak Wilderness Study Area was established as a wilderness study area by Public Law 96-560, 1980. The Williams Fork and St. Louis Peak Roadless Areas were classified as further planning areas during the Second Roadless Area Review and Evaluation (RARE II) by the U.S. Forest Service, January 1979.

MINERAL RESOURCE POTENTIAL SUMMARY STATEMENT

The northern parts of the St. Louis Peak and Williams Fork Roadless Areas and the southern part of the Williams Fork Roadless Area have a low to moderate potential for the occurrence of silver, lead, zinc, and copper resources in massive sulfide deposits and for the occurrence of tungsten resources in skarns in calcic metamorphic rocks. The eastern part of the Vasquez Peak Wilderness Study Area has a low potential for vein-type uranium resources in highly sheared rocks of the Berthoud Pass fault zone. Along the Middle Fork Williams Fork River and along the western edge of the Williams Fork Study Area there is a low to moderate potential for lead in veins. The northeastern corner of the Vasquez Peak Wilderness Study Area has a low potential for feldspar and muscovite resources in pegmatites in Proterozoic rocks. A large area of the southeastern part of the three study areas has a moderate to high potential for either individual high-grade silver resources or larger, lower grade, silver-rich resources. Moderate potential for stockwork molybdenum resources exists beneath the silver-rich veins.

INTRODUCTION

This report summarizes the results of field studies conducted jointly by the U.S. Geological Survey and the U.S. Bureau of Mines, from 1979 through 1982 on three areas in Arapaho National Forest. The three study areas, the St. Louis Peak Roadless Area (E2361, acreage: 12,800), the Vasquez Peak Wilderness Study Area (A2361, acreage: 12,800) and the Williams Fork Roadless Area (02114, acreage: 74,820), are located in Clear Creek, Grand, and Summit Counties, Colo., north of Interstate Highway 70 and west of U.S. Highway 40, on the west side of the Front Range (fig. 1). All three study areas have a combined area of approximately 135 mi^2. The U.S. Geological Survey made geological, geophysical, and geochemical investigations and the U.S. Bureau of Mines studied the mines and prospects in the study areas to define the extent of known mineralization and to determine the potential for mineral resources.

The boundaries of the areas are irregular and are generally defined by highways, gravel roads, unimproved dirt roads, a powerline, and the Continental Divide (fig. 1). The Henderson mine, south of the Vasquez Peak Wilderness Study Area, and the Henderson Mill to the northwest of the Williams Fork Roadless Area, are connected by a railroad tunnel under parts of the Williams Fork and St. Louis Peak Roadless Areas. The surficial expressions of this tunnel are an exhaust vent, located on the Williams Fork River at about 9,820-ft altitude, and an approximately 30-ft-wide blazed survey line cutting parts of the St. Louis Peak Roadless Area. An overhead high-tension powerline connects the two

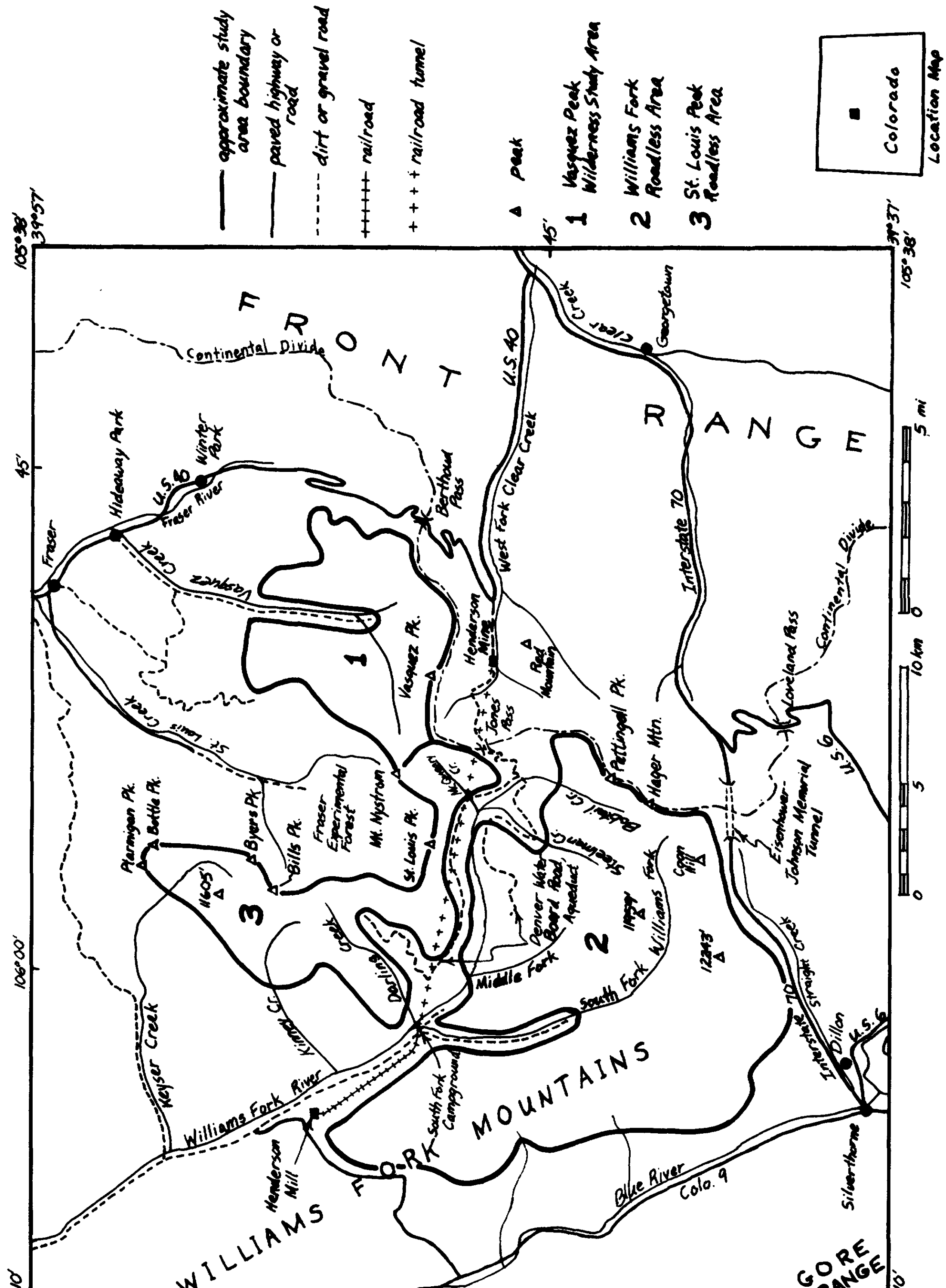


Figure 1.--Location of the Vasquez Peak Wilderness Study Area, and the Williams Fork and St. Louis Peak Roadless Areas, Colo.

Henderson facilities. Both the tunnel line and powerline are generally confined to the corridor separating the Williams Fork Roadless Area to the south and the St. Louis Peak Roadless Area and Vasquez Peak Wilderness Study Area to the north. The city of Denver has water rights to the Williams Fork drainage system and diverts water along aqueducts from McQueary Creek and Steelman Creek to the Jones Pass Tunnel. These aqueducts are outside the study area boundaries, but the locked maintenance road for the Steelman Creek diversion continues west of Steelman Creek at approximately the 10,600-ft level for 3.8 mi within the Williams Fork Roadless Area. An unimproved dirt road branches off the west side of the Jones Pass road and heads southward to a patented mining claim about 1 mi inside the Williams Fork Roadless Area. The Fraser Experimental Forest at the head of St. Louis Creek separates the St. Louis Peak Roadless Area and the Vasquez Peak Wilderness Study Area.

Major access into the areas is from the South Fork Campground on the west, Interstate 70 on the south, Jones Pass to the east, and roads up St. Louis and Vasquez Creeks on the north.

The local topography is dominated by the Williams Fork Mountains and the main crest of the Front Range. The Williams Fork Mountains rise to an elevation of 12,480 ft in the south-central part of the Williams Fork Roadless Area. The Front Range rises to 13,552 ft on Pettingel Peak along the eastern edge of the Williams Fork Roadless Area. The lowest elevation is 8,950 ft on North Acorn Creek on the western edge of the Williams Fork Roadless Area. Major drainages within the three study areas are the northwest-trending Blue and Williams Fork Rivers, the north-northeast-trending St. Louis and Vasquez Creeks, the east-trending West Fork Clear Creek, and the west-southwest-trending Straight Creek. Most of the relief is in the main valley walls. The upland, generally above timberline, has a subdued topography, but rugged alpine topography is present along the Continental Divide in the vicinity of Pettingel Peak and at the north end of the St. Louis Peak Roadless Area, in the vicinity of Byers Peak.

GEOLOGY

The three areas of study are generally underlain by Proterozoic metamorphic and igneous rocks (fig. 2). Mesozoic sedimentary rocks underlay a narrow strip along the west side of the Williams Fork Mountains. Early and middle Tertiary dikes cut the Proterozoic rocks in the central and eastern parts of the study areas. A complex mesh of faults, ranging in age from Proterozoic to Cenozoic, segments the rock units. Cover on bedrock is extensive and ranges from a periglacially deformed, deep regolith on the gentler slopes flanking ridgetops, through a variety of glacial deposits on valley walls and floors, to broad alluvial plains on the lower valley bottoms.

The crystalline rocks form the westernmost part of the Front Range Highland. In this area, they have been uplifted and thrust westward over the eastern edge of the generally synclinal basin of Mesozoic sedimentary rocks that underlay the Blue River valley to the west. The eastern part of the area has been included in the Front Range mineral belt since the discovery of the Henderson ore body, although the Dailey (Atlantic) mining district was originally considered to be outside of the mineral belt (Lovering and Goddard, 1950, p. 280-282). A detailed description of the geology is given in Eppinger and others (in press).

Proterozoic rocks

The metamorphic rocks can be subdivided into two distinctive groups where detailed geologic mapping exists. The northern group, generally within the northern part of the St. Louis Peak Roadless Area and the northwest corner of the Vasquez Peak Wilderness Study Area, is characterized by bands of hornblende and biotite gneiss interlayered with, and locally grading into, a variety of calc-silicate gneisses. As a group, these rocks are notably more calcic than the other metamorphic rocks. A similar group of calcic gneisses has been mapped in the southern part of the Williams Fork Roadless Area.

The metamorphic rocks south of Darling Creek in the St. Louis Peak Roadless Area, in the central part of the Williams Fork Roadless Area, and in the western part of the Vasquez Peak Wilderness Study Area are characterized by medium- to coarse-grained, sillimanite-rich, biotite-muscovite gneisses interlayered with fine- to medium-grained, quartz-rich, biotite gneisses. The sillimanite-rich gneisses are characterized by the segregation of quartz and sillimanite into distinctive "eyes." The quartz-rich, biotite gneisses are generally not as well foliated as the biotite gneisses of the calcic group of rocks and are distinctly more siliceous, grading locally into nearly pure quartzites.

The distinction between these two groups of metamorphic rocks can be made in the Vasquez Peak Wilderness Study Area, the St. Louis Peak Roadless Area, and the north-central part of the Williams Fork Roadless Area, where geologic mapping at 1:24,000 scale is available. The reconnaissance mapping in the eastern, southern, and western parts of the Williams Fork Roadless Area is not sufficiently detailed to make this distinction.

Two major Proterozoic igneous events are recognized in the study areas. The oldest of these is represented by generally conformable, usually well-foliated, relatively small bodies of rock that range in composition from quartz diorite to biotite-quartz monzonite. They correlate with the Boulder Creek Granite, which yields radiometric ages of about 1.7 b.y. in other parts of the Front Range.

A batholith crops out in the Vasquez Peak Wilderness Study Area, the southern part of the St. Louis Peak Roadless Area, and the central and eastern parts of the Williams Fork Roadless Area. The batholith ranges in composition from a biotite-rich quartz monzonite, where severely contaminated by assimilation of the metamorphic rocks, through the more normal felsic quartz monzonite, to true granite, muscovite alaskite, and pegmatite. Pegmatites are most abundant near the inferred top of the mass in the northern part of the Vasquez Peak Wilderness Study Area. The rocks of the batholith are compositionally, texturally, and structurally correlative with the Silver Plume Granite, which yields radiometric ages of about 1.4 b.y. elsewhere in the Front Range.

Three generations of folding, two generations of foliation, three generations of metamorphism, and at

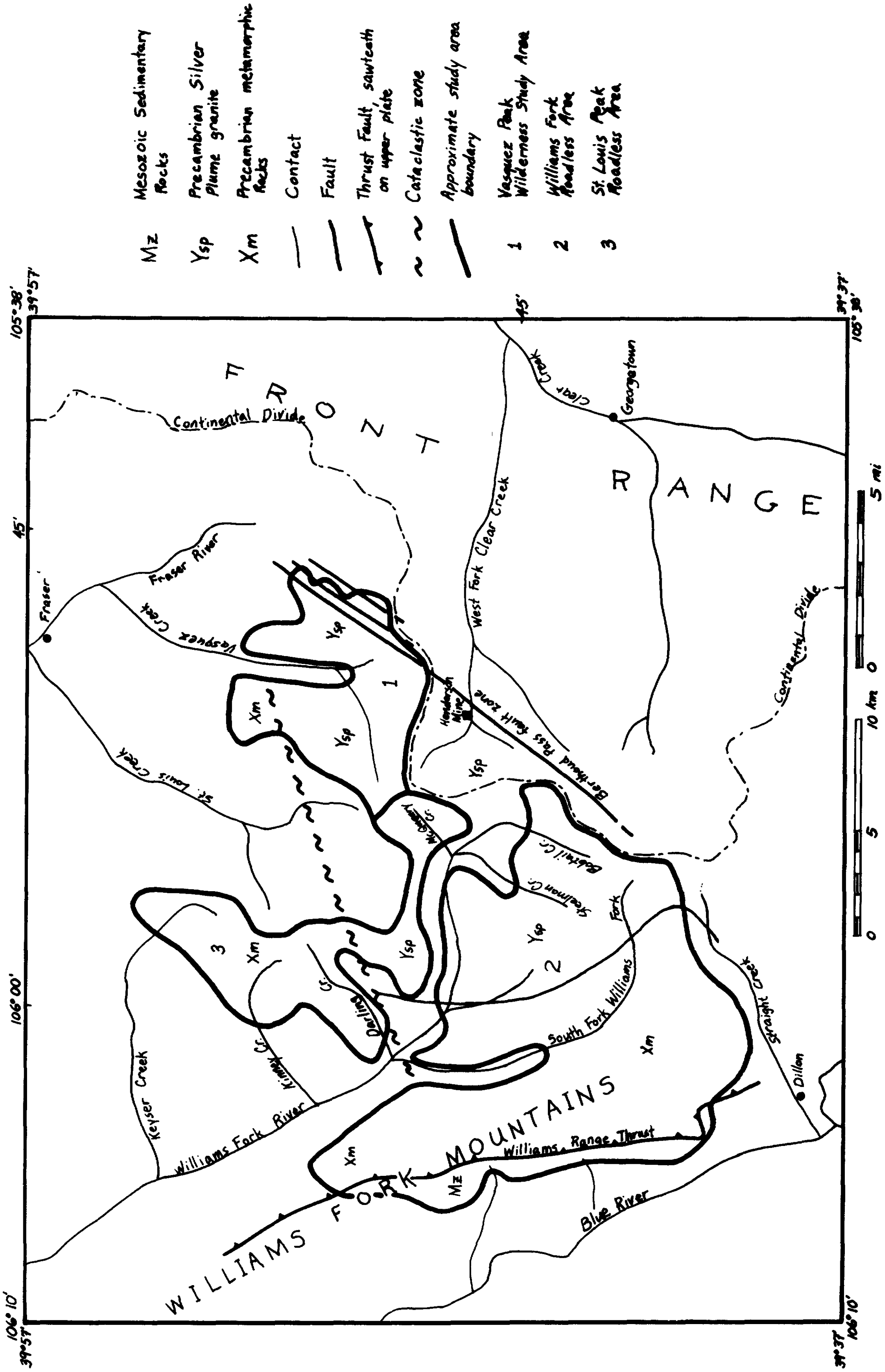


Figure 2.--Simplified geology of the three wilderness areas (from Eppinger and others, 1983).

least two generations of faulting can be inferred for the Proterozoic Eon. This complex structural system established the framework within which later events were constrained.

Paleozoic rocks

Rocks of the Paleozoic age have not been confirmed in the study areas. At a single locality on the northwest side of Steelman Creek, thin wedges of a dense bluish-gray limestone are enclosed in the gouge of a broad fault zone. These tectonically introduced exotic blocks are lithologically similar to Paleozoic limestones exposed many miles to the west and southwest of the study areas.

Mesozoic rocks

Mesozoic rocks, ranging in age from Jurassic to Late Cretaceous, are exposed along the west side of the Williams Fork Roadless Area and at the extreme north end of the St. Louis Peak Roadless Area. These rocks were not studied in detail because their distribution and nature are adequately known from the mapping by other workers (Taylor, 1975; Izett and others, 1971). Jurassic rocks rest directly on the Proterozoic rocks at the north end of the St. Louis Peak Roadless Area. To the west of the Williams Fork Study Area, on the west side of the Blue River valley, the oldest sedimentary rocks present are also of Jurassic age (Tweto and others, 1970). All older sedimentary rocks were stripped from the study areas during a major erosional cycle that preceded the Middle Jurassic.

Cenozoic rocks

All Cenozoic bedrock units are igneous. Surficial deposits of this age are abundant over much of the study areas.

The oldest Cenozoic igneous rocks are dikes and dikelike bodies of augite diorite. They occur in a narrow belt stretching in a north-northwesterly direction from the head of the South Fork Williams Fork River across the Williams Fork and St. Louis Peak Roadless Areas.

A group of quartz-rich porphyries of Oligocene age is associated with the volcanic center near the Henderson mine and is the locus for mineralization at Red Mountain (Wallace and others, 1978). Dikes of porphyritic, siliceous rhyolite related to these porphyries have been seen in the southern part of the Vasquez Peak Wilderness Study Area and in the eastern parts of the St. Louis Peak and Williams Fork Roadless Areas. The dikes are in areas of intense shearing, alteration, and many quartz veins.

The surficial deposits are predominantly of two ages and types: pre-late Pleistocene, periglacially deformed regolith, on gentle slopes flanking ridgetops, and late Pleistocene to Holocene deposits of glacial debris and alluvium. Alluvial gravel and sand, in volume, is largely confined to the lower reaches of the Williams Fork River, generally below its confluence with the South Fork Williams Fork River, outside of the study areas. The surficial deposits obscure the direct observation of the bedrock in at least 70 percent of the areas that were mapped in detail and thus hinder efforts to assess the mineral resource potential.

Phanerozoic structure

The Phanerozoic structural evolution in the vicinity of the three study areas has been dominated by brittle fracture of the preexisting rocks. The resultant maze of faults, fractures, and breccia zones provided the principal avenues for intrusion of Tertiary igneous rocks, the loci for hydrothermal alteration and mineralization, and provided the major zones of weakness along which ice and water carved the present topography.

Two regional fault systems bound the study areas. On the eastern edges of the Vasquez Peak Wilderness Study Area and Williams Fork Roadless Area, the Berthoud Pass fault zone is more than a mile wide and trends about N. 30° E. It consists of anastomosing, nearly vertical faults parallel to the principal trend and numerous minor faults of various attitudes that link the strands. The Williams Range thrust fault, a moderately steep, east-dipping, north-northwest-trending fault, forms the west boundary of the crystalline rocks on the west side of the Williams Fork Roadless Area. East of the thrust a family of near-vertical faults parallels the general trend of the fault.

North- to north-northeast-trending faults predominate in the central and western parts of the Vasquez Peak Wilderness Study Area and in the eastern part of the St. Louis Peak Roadless Area. The valley of the West Fork Clear Creek is underlain by a prominent, east-trending, gouge-filled fault that probably continues westward through the maze of faults that crosses the ridge in the vicinity of Jones Pass and continues into the head of the main Williams Fork. In some places, the east-trending faults offset the north-trending faults (Wallace and others, 1978, fig. 3); at other places the reverse is true, suggesting that the faults have been active more or less synchronously.

The Berthoud Pass fault zone and the Williams Range thrust with its associated high-angle faults converge southward, effectively pinching off the southward extension of the north- and east-trending fault sets. In the triangular area between these three major structural domains, faults and fractures are more numerous than elsewhere, trends are more erratic and often curved, and continuous structures are hard to define.

Alteration and mineralization

Boxworks lined by iron oxides, pseudomorphs of iron oxides after massive pyrite, and blocks of gossan in float and till are remnants of small pods of massive sulfides that occur in the calcic metamorphic rocks. These massive sulfides appear to be an inherent part of the metamorphic rock sequences. Altered rock other than that from supergene processes was not noted in the vicinity of the calcic sequence, suggesting that the original deposits were either attended by slight alteration or that the original alteration halos were obliterated by metamorphism. Massive sulfide deposits could be expected in the calcic metamorphic rocks north of the main Proterozoic shear zone in the St. Louis Peak Roadless Area and in the southern part of the Williams Fork Roadless Area.

Veins and altered and mineralized rock are common in a large area including the eastern parts of the Williams Fork Roadless Area, the southeast corner of the St. Louis Peak Roadless Area, and the southern and southeastern parts of the Vasquez Peak Wilderness Study Area. Veins follow all of the structural trends. Most are quartz veins, though carbonate veins occur along the west side of the map area, and drusy quartz-feldspar veins are common near and west of the mouth of McQueary Creek. Most of the quartz is crystalline but in several areas the veins have a dense, cryptocrystalline appearance. These latter veins are most numerous in areas of pervasive silicification and where rhyolite dikes or float have been found.

Hydrothermally altered rock is not limited to vein walls and includes larger masses of rock which have been pervasively altered. The pervasively altered rock does not uniformly blanket the area but occurs in discrete patches. The most common alteration minerals are chlorite, clays, sericite, and quartz. Alteration zoning is common but is neither ubiquitous nor uniform; zonation is usually inward from chlorite to sericite or sericite and quartz. In some areas, alteration to clays or quartz appears to be independent of other alteration types. Colorless to purple fluorite is a common mineral in the altered rocks, particularly in chlorite-rich rocks (Eppinger and Theobald, in press).

Pyrite or iron-oxide pseudomorphs of pyrite are the most common metallic minerals of the area. These minerals are seen in most of the extensively altered rocks and in many of the veins. Galena, sphalerite, chalcopyrite, arsenopyrite, and secondary minerals of copper are present locally.

The altered and mineralized rock seen along the West Fork Clear Creek are most likely related to an Oligocene center of hydrothermal activity near the Henderson mine. The altered and mineralized rock west of the Continental Divide are more likely related to other, similar centers of hydrothermal activity.

GEOCHEMISTRY

Heavy-mineral concentrates from stream sediments provided the major sample media for the preliminary geochemical survey. Soils, heavy-mineral concentrates from soils, and selected rock samples augmented the preliminary survey. Details on sample preparation and analysis, along with the presentation of data and sample sites, are found in Barton and Turner (in press) and in Eppinger and others (1983). All samples were analyzed for 31 elements by the semiquantitative emission spectrographic method of Grimes and Marranzino (1968).

The nonmagnetic fraction of the heavy-mineral concentrate from stream sediments was selected as the sample medium for the preliminary geochemical survey. Concentrates were collected from 164 sites, giving a sample density of approximately one sample per square mile. In addition to several small anomalous areas, the preliminary survey revealed two large anomalous areas: (1) the northern part of the St. Louis Peak Roadless Area, which is anomalous for tungsten, boron, lead, zinc, and thorium, and (2) an area including the eastern part of the Williams Fork Roadless Area, the southeastern lobe of the St. Louis Peak Roadless Area, and the southern and eastern parts of the Vasquez Peak Wilderness Study Area. Scattered samples from the second area contained anomalous silver, boron, barium, bismuth, cadmium, copper, molybdenum, lead, tin, tungsten, zinc, and thorium values. Anomalous values for lead, zinc, and silver occurred in heavy mineral concentrate samples from streams draining the slopes along the Continental Divide from Interstate Highway 70 north to Mount Nystrom. Small areas having anomalous lead values occurred in the Middle Fork Williams Fork, South Fork Williams Fork, and Straight Creek drainages, and in drainages in Summit County along the western boundary of the Williams Fork Roadless Area. Anomalous barium was found in two areas: one associated with the Mesozoic Pierre Shale on the west edge of the Williams Fork Roadless Area, and another in drainages east of Pettingel Peak.

Ridgetop soils and heavy-mineral concentrates from the soils were selected as the sample media for more detailed work (Barton and Turner, in press). Sample spacing along ridgetops varied from 500 to 1,000 ft. Anomalous values for lead and thorium occurred on the Continental Divide from Interstate Highway 70 to Jones Pass. A sample from a site south of Pettingel Peak was anomalous for gold and silver, and one northeast of Pettingel Peak was rich in silver. Molybdenum anomalies occurred on the Continental Divide near the head of Butler Gulch. Two samples, anomalous in tungsten, are from a peak 1.6 mi northeast of Pettingel Peak. Six samples anomalous in tungsten, two samples anomalous in bismuth, and a sample anomalous in gold are from a ridge west of Coon Hill in the southern part of the Williams Fork Roadless Area. A single sample anomalous in zinc is from the ridge between Bobtail and Steelman Creeks.

Rock and soil samples were taken at 257 sites during the course of geologic mapping (Eppinger and others, 1983). These are biased samples from fault zones, alteration zones, and prospects that provide an indication of the type and local intensity of mineralization. The soil samples were generally taken within or across fault zones and in many cases are simply fault gouge.

The two large anomalous areas revealed in the preliminary geochemical survey were again identified in the analyses of rock and soil samples. The anomalous area in the St. Louis Peak Roadless Area is centered near Horseshoe Lake and is 4 mi in diameter. The area is characterized by anomalous values of lead, copper, molybdenum, zinc, silver, and beryllium. The second anomalous area is centered near the junctions of Bobtail, Steelman, and McQueary Creeks and is about 3 mi in diameter. Anomalous values occur for lead, copper, molybdenum, zinc, silver, arsenic, and antimony. A third area where the rocks are weakly anomalous for lead, copper, molybdenum, zinc, silver, and arsenic, is near the head of the South Fork Williams Fork River.

Ore-related minerals

Scheelite and locally powellite were observed in heavy-mineral concentrates from stream sediments that were collected from drainages in the calcic metamorphic terranes and that were anomalous in tungsten. No scheelite was observed in outcrops. Gahnite, a zinc-aluminum spinel, was occasionally observed in samples from the St. Louis Peak Roadless Area. Samples rich in thorium and lanthanum contained monazite. Pyrite was ubiquitous in samples from the southern and eastern portions of the Williams Fork Roadless Area and from the southern portion of the Vasquez Creek Wilderness Study Area; it was also common in the northern part of the St. Louis Peak Roadless Area. Galena, fluorite, molybdenite, sphalerite, chalcopyrite, and secondary copper minerals were occasionally observed in the heavy-mineral concentrates from stream-sediments.

Pyrite, or iron-oxide pseudomorphs after pyrite, was often observed at the rock sample sites, galena and (or) sphalerite were also generally present at those sites having highly anomalous values of lead, zinc, and silver. Arsenopyrite was observed in an outcrop at one rock sample site anomalous in arsenic. Chalcopyrite and (or) secondary copper minerals were rarely observed in outcrops. Fluorite, most often purple, but also green or colorless, was commonly seen in the southeastern part of the areas of study. The highest concentration of fluorite is on the north end of the ridge just west of Steelman Creek, where purple fluorite occurs on fracture surfaces, in vein fillings, and is disseminated in the rock adjacent to fractures and veins (Eppinger and Theobald, in press).

GEOPHYSICAL SURVEYS

Data from reconnaissance gravity and aeromagnetic surveys were analyzed to assist in the delineation of concealed geologic features of the study areas (Moss, in press). In this geologic setting, the gravity data are believed to be indicative of possible mineral environments.

An earlier geophysical investigation of the Front Range mineral belt (Brinkworth, 1973) provides a valuable reference, discussing both regional and local gravity features associated with mineral occurrences. Figure 3 illustrates the primary regional association, where each of three known major stockwork molybdenum deposits lies on a single large gravity low at a point where the gravity gradient steepens outward. These deposits are associated individually with rhyolitic, subvolcanic Oligocene stocks, and with cogenetic base- and precious-metal deposits (Mutschler and others, 1978).

The regional gravity low is believed to originate from two crustal sources, one deep and broad, the other shallow and confined to axial portions of the gravity low (Brinkworth, 1973; Case, 1966). The nature of the deep source is conjectural, possibly being a thickened section of the crust or an occurrence of less dense crustal rocks. The shallow source is postulated to be a silicic batholith, which is less dense than surrounding Precambrian metamorphic rocks. The age of the batholith is most likely Tertiary, or possibly Precambrian if related to the Silver Plume granite. If of Tertiary age, the batholith may have constituted a magma reservoir for the Oligocene stocks.

Laboratory measurements of rock densities (Brinkworth, 1973) show that rocks of the Oligocene stocks are among the least dense in the region. Consequently, local gravity lows might be expected where these stocks occur, and indeed, detailed fieldwork by Brinkworth (1973) confirms this relationship. However, because the stocks generally have small horizontal dimensions, precise gravity data from a network of more closely spaced stations would be required in order to detect the stocks with a high degree of certainty. For example, an isolated gravity low is not indicated in the generalized gravity data of figure 3 at any of the known deposits. Similarly, an isolated low is not indicated at the Henderson deposit on the more detailed gravity map prepared for the study areas (Moss, in press), although the deposit is on a prominent narrow eastern extension of the main low. Station density is greater on the latter map, but it is still only approximately one station per square mile. Thus, other small stocks may remain undetected, or only weakly reflected, by the sparse data. Empirically, from their position on the margin of the regional gravity low, several local gravity lows on the map by Moss (in press) may reflect Oligocene intrusions and thus potential centers of hydrothermal deposits.

MINES AND PROSPECTS

To provide an indication of mining interest in the study areas, the U.S. Bureau of Mines searched mining claim records at the Summit, Grand, and Clear Creek County Courthouses, as well as from the U.S. Bureau of Land Management State Office. Mines, prospects, and mineralized areas were examined, mapped, and sampled (Bielski and others, 1983). A total of 305 samples were taken from mineral occurrences or from the dumps of inaccessible prospects and mines. Samples were analyzed for 42 elements, including gold, silver, copper, lead, molybdenum, uranium, and zinc. Complete sample analyses from this investigation are available for public inspection at the U.S. Bureau of Mines, Intermountain Field Operations Center, Denver Federal Center, Denver, Colo. 80225.

Current mining and exploration

No mining is being conducted within the study areas. At Red Mountain, about 2 mi south of the Vasquez Peak Wilderness Study Area and about 2 mi east of the Williams Fork Roadless Area, the Urad and Henderson deposits (fig. 4) are recognized as one of the largest known accumulations of molybdenum ore in the world (Wallace and others, 1978). Until closed in 1974, the Urad mine produced 14 million tons of ore averaging 0.35 percent MoS_2. The Henderson mine began production in 1976 and has a rated output of 30,000 tons of molybdenum ore per day. Ore is hauled by rail through a tunnel more or less beneath the corridor between the Williams Fork and St. Louis Peak Roadless Areas to the mill just northwest of the Williams Fork Roadless Area.

Mineral exploration was conducted or is planned in three areas in or adjacent to the study areas. Amoco Metals Company conducted a uranium exploration program on claims along the northeast boundary of the Vasquez Peak Wilderness Study Area in August 1982, and AMAX, Inc., continued exploration on claims near the Puzzler mine on the southern boundary of the Vasquez Peak Wilderness Study Area. The La Plata mine, in the eastern part of the Williams Fork Roadless Area, was leased in 1982, but scheduled silver exploration was aborted because Jones Pass remained snowbound through most of the summer.

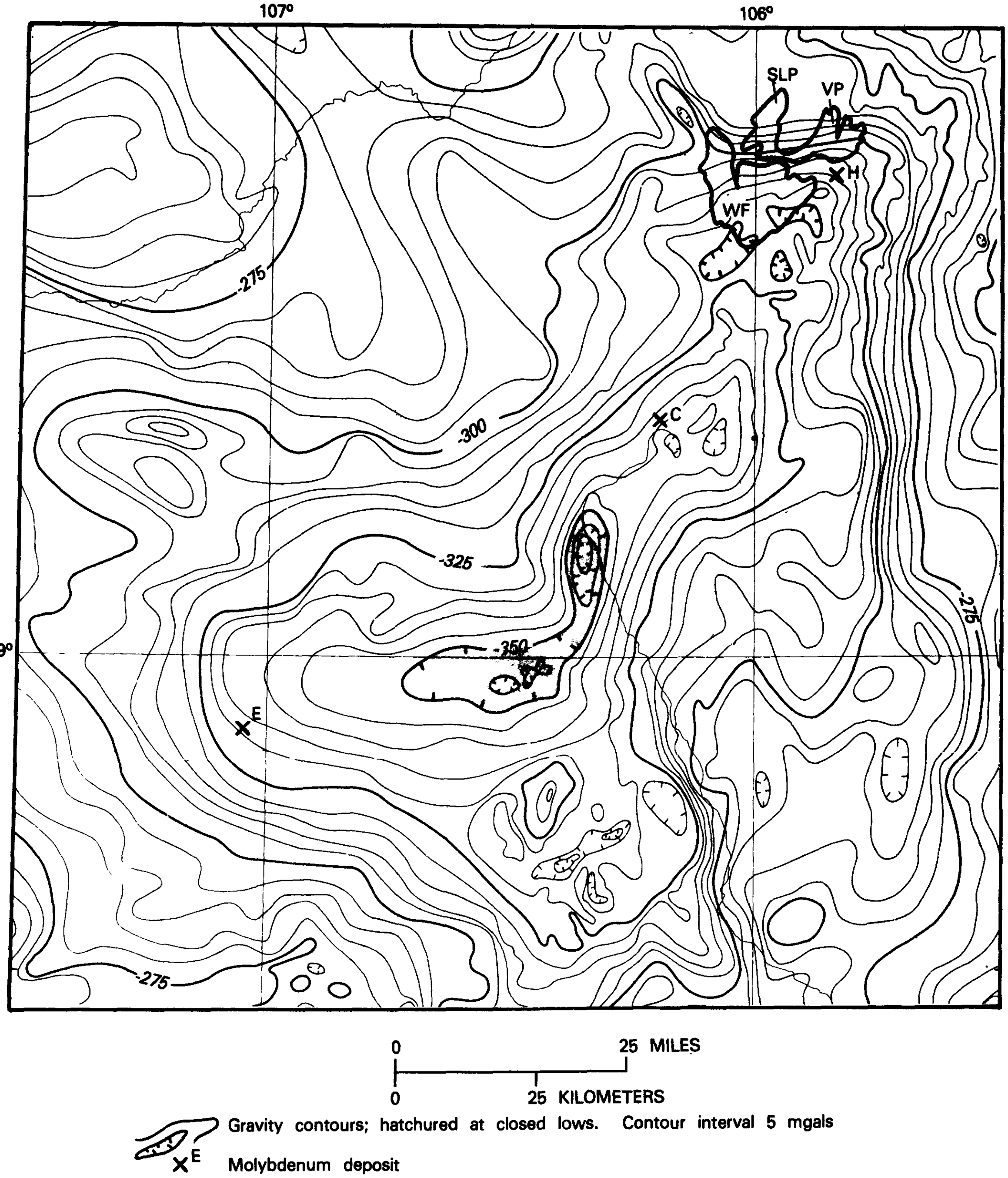


Figure 3.--Bouguer gravity map of west-central Colorado and locations of the wilderness and roadless areas and major molybdenum deposits. Study areas: SLP=St. Louis Peak; WF=Williams Fork; VP=Vasquez Peak. Molybdenum deposits: H=Henderson; C=Climax; E=Mt. Emmons. Gravity map from Behrendt and Bajwa (1974).

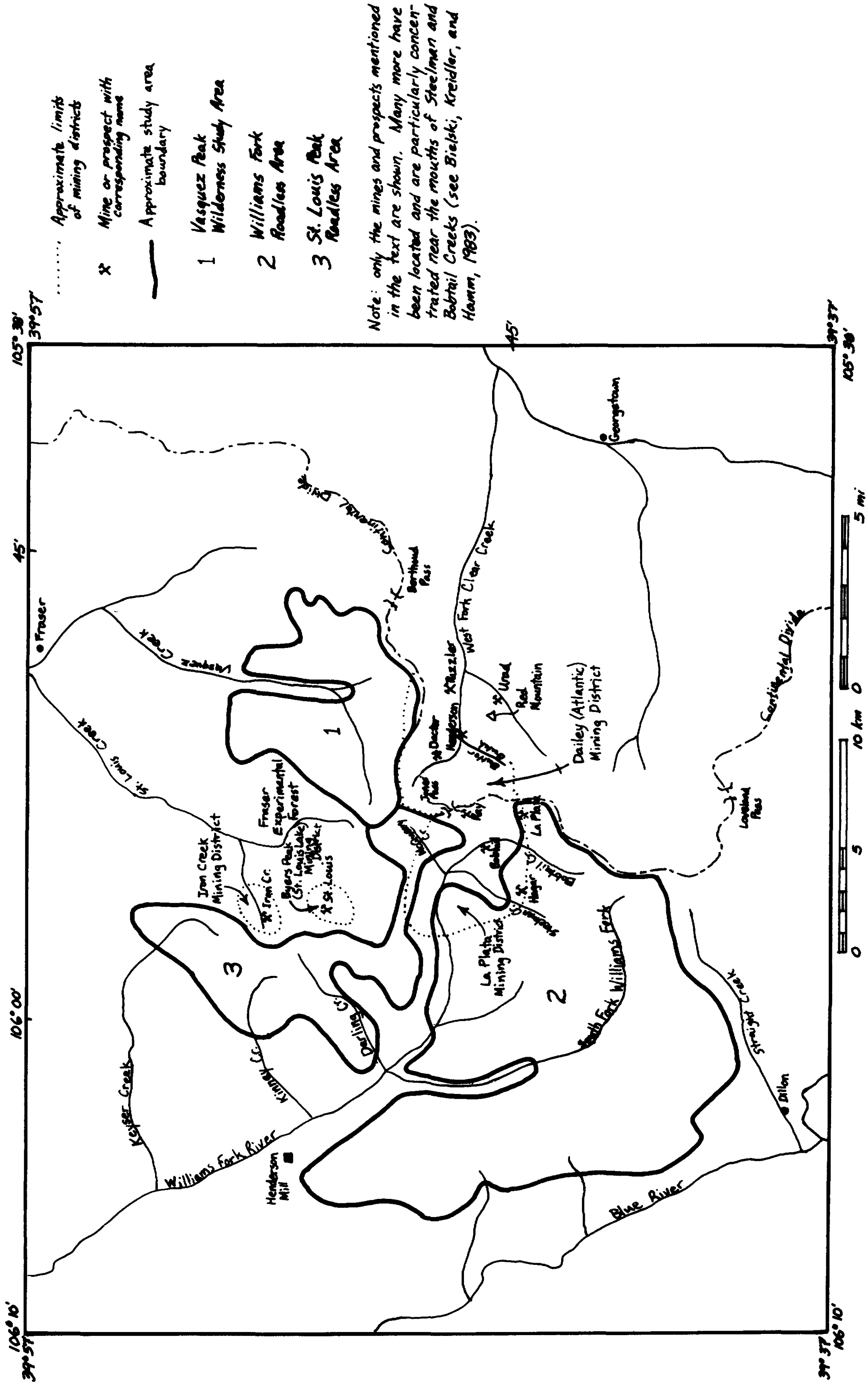


Figure 4.—Mining districts in the vicinity of the study areas.

Mining districts and mineralized areas

Silver-rich, lead-zinc veins have been prospected and mined in the Jones Pass area since 1866. Unpublished U.S. Bureau of Mines records indicate that, for the years 1914-43, intermittent production from mines just west of Jones Pass totaled (gross metal content): 6,074 oz silver, 1 oz gold, 6,609 lb lead, and 658 lb zinc. For many of the developed deposits in the area, production was not recorded; thus, the actual amount of ore produced probably was greater than that indicated by the above figures.

Two organized mining districts are in or near the study areas, the La Plata and the Dailey (Atlantic), which are separated by the Continental Divide. Two unorganized districts, the Byers Peak (St. Louis Lake) and the Iron Creek, are located east of the St. Louis Peak Roadless Area (fig. 4).

La Plata mining district

The northeastern part of the Williams Fork Roadless Area and the southeastern corner of the St. Louis Peak Roadless Area are in the La Plata mining district. Evidence of past mining activity within the district extends westward from the Continental Divide and Jones Pass, along Bobtail and Steelman Creeks, to the confluence of Bobtail, Steelman, and McQueary Creeks (Bielski and others, 1983). Records at the Grand and Summit County Courthouses indicate more than 300 mining claims have been located in the district since 1866. Eighteen of these claims, as well as 12 patented lode claims and 2 patented placer claims, have been recorded at the Bureau of Land Management State Office.

The environment and mode of occurrence of the epithermal quartz veins, containing lead, zinc, and silver minerals, are all similar. Workings range in size from small prospect pits, which are a few feet in depth and expose minor mineral occurrences, to mines extending more than 2,000 ft along major vein systems. Veins are as wide as 5.0 ft, are poorly exposed, and cannot be traced any great distance because most of the surface area is covered by surficial deposits and vegetation. The limited exposures make it difficult to estimate the overall size and grade of individual mineral occurrences and provide for the possibility that similar occurrences may remain undetected.

Galena, sphalerite, and minor, very fine grained chalcopyrite are common in the veins. Tetrahedrite, argentite, and cerussite were seen at the La Plata mine. Analyses of samples from the veins yielded values as high as 29.0 oz of silver per ton, 1.82 percent lead, and 4.1 percent zinc. High concentrations of arsenic, gold, barium, cadmium, cobalt, copper, lanthanum, lithium, manganese, molybdenum, nickel, and vanadium were reported in the assay data for some samples (Bielski and others, 1983).

Gangue minerals are mostly quartz and pyrite, but fluorite and marcasite were noted at the Hagar mine. The country rock, Silver Plume granite and inclusions of older metamorphic rocks, is fractured and hydrothermally altered along the margins of faults and veins. The faults served as conduits for mineralizing fluids, and the brecciated character of the ore minerals indicates that movement on the faults also occurred after the emplacement of vein material. The intensity of mineralization is extremely variable along the course of the veins, and metal concentrations are localized in discontinuous zones. High-grade zones occur at vein intersections and near the surface, where weathering processes have caused secondary enrichment.

The Dailey (Atlantic) mining district

The Dailey (Atlantic) mining district extends eastward from the Continental Divide and Jones Pass well beyond the vicinity of the study areas along the West Fork Clear Creek and Butler Gulch (Bielski and others, 1983). The northeasternmost part of the Williams Fork Roadless Areas and the southern part of the Vasquez Peak Wilderness Study Area are in this district. Of the hundreds of claims that have been located in the district, approximately 200 claims are on file at the Bureau of Land Management State Office, and five have been patented.

The mineralized rocks in this district consist of vein quartz with lead, zinc, and silver minerals and are, in many respects, similar to those of the La Plata district. Numerous prospects and mines encircle the head of the West Fork Clear Creek, but most of the underground workings are now inaccessible. The Doctor mine reportedly has more than 1,000 ft of workings (Lovering and Goddard, 1950, p. 281-282). Veins exposed in accessible workings are as much as 3 ft in width. As much as 3 oz of silver per ton were found in samples of vein material from the Puzzler mine collected for this investigation. Lovering and Goddard (1950, p. 282) report assays as high as 15 percent zinc and 10 oz of silver per ton for the Doctor mine. Pyrite is the principal metallic mineral together with sphalerite, galena, and locally chalcopyrite or molybdenite.

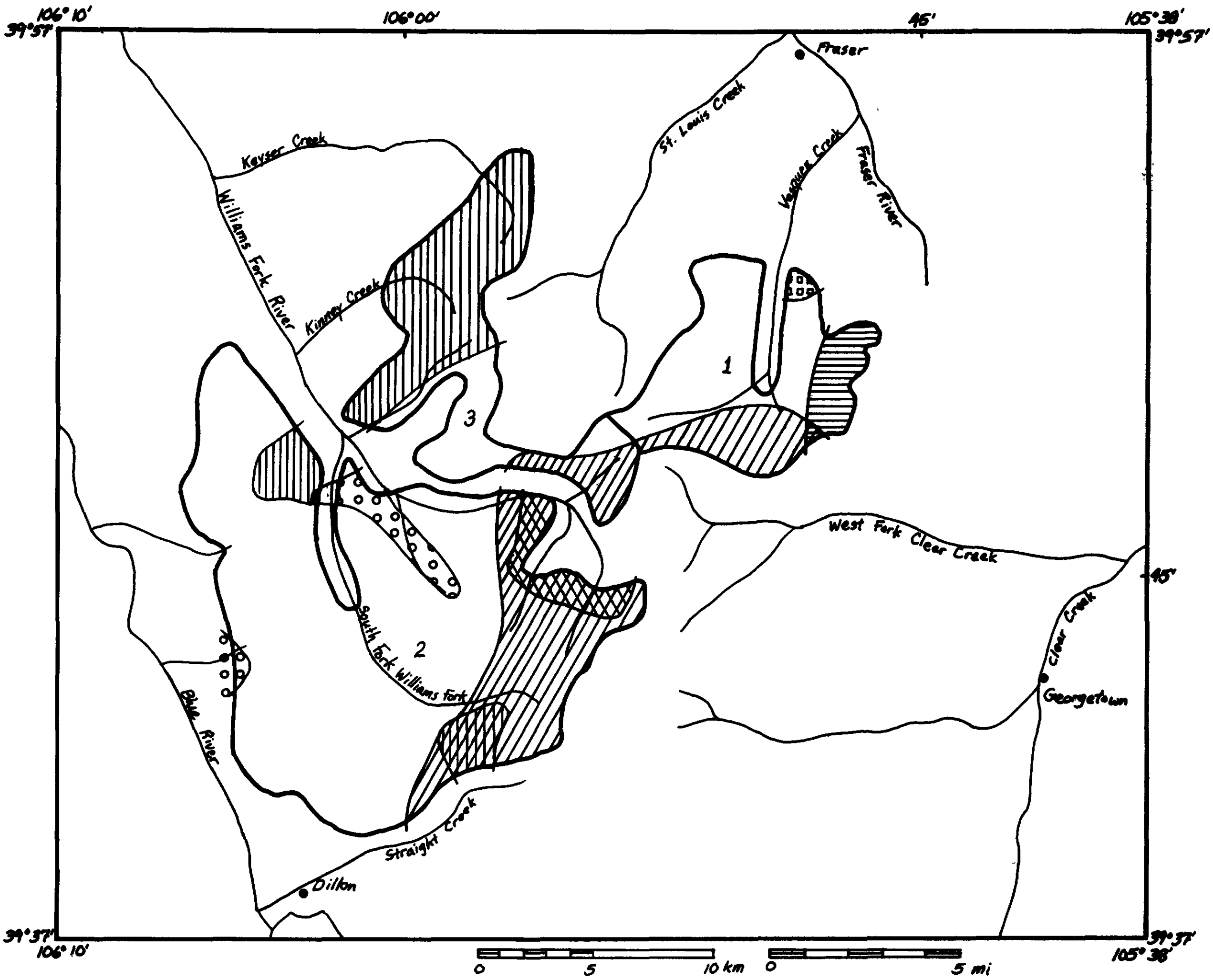
The country rock of the veins is Silver Plume Granite and included gneisses. The country rock is highly faulted, which provided numerous conduits for mineralizing solutions. The rocks near and between veins are pervasively altered; argillic, sericitic, and silicic alteration types have been recognized.

Much of the mineralized rock in the district probably reflects outer zones surrounding the molybdenum deposits at Red Mountain (Art Bookstrom, Amax, Inc., oral commun., 1982).

Byers Peak (St. Louis Lake) and Iron Creek mining districts

Just east of the St. Louis Peak Roadless Area are the unorganized Byers Peak (St. Louis Lake) and Iron Creek mining districts. Approximately 25 claims have been located in these districts since 1908; those that could be plotted are shown in Bielski and others (1983). The mining districts are within the Fraser Experimental Forest, which was withdrawn from mineral entry in 1955.

Two short adits, one at the St. Louis mine and the other at the Iron Creek mine, as well as numerous prospect pits, comprise the total activity in these two districts. At the St. Louis mine, pyrite, galena, sphalerite, and possibly magnetite are in a gangue of quartz, diopside, and calcite. A 3-ft chip sample across the face of the adit assayed 1.8 oz of silver per ton, 6.3 percent zinc, and 3.5 percent lead (Bielski and others, 1983). The host rock is a Proterozoic quartz-



EXPLANATION

High potential for silver-rich lead-zinc veins

Moderate potential for silver-rich lead-zinc veins and for concealed molybdenum-rich stockwork

Low to moderate potential for silver, lead, zinc, and copper in massive sulfides or for tungsten in skarns in calcic metamorphic rocks

Low to moderate potential for lead in veins

Low potential for uranium in veins

Low potential for muscovite and feldspar in pegmatites

Approximate study area boundary

1 Vasquez Peak Wilderness Study Area
2 Williams Fork Roadless Area
3 St. Louis Peak Roadless Area

Figure 5.--Mineral resource potential of the three study areas.

diopside marble. At the Iron Creek mine, disseminated pyrite occurs in quartz-potassium-feldspar pegmatite veinlets in hornblende gneiss. A 3-ft sample across the back at the portal assayed 0.5 oz of silver per ton.

Other prospects in the area are similarly situated in calcic units of the metamorphic sequence or in shear zones cutting these rocks. Unlike the crosscutting, hydrothermal veins of the La Plata and Dailey districts, the mineralization in this area is related to the Proterozoic lithology and the superimposed metamorphic events.

Uranium mineralization

The Silver Plume Granite is abnormally radioactive due primarily to thorium and subordinate uranium contained in monazite. An outcrop sample of Silver Plume Granite from the eastern part of the Vasquez Peak Wilderness Study Area contained 0.005 percent U_3O_8, a concentration approximately 10 times higher than the average granite (Levinson, 1980, p. 44). Amoco Metals Company, Denver, Colo., holds a block of claims astride the eastern boundary of the Vasquez Peak Wilderness Study Area (Bielski and others, 1983). The claims are underlain by extensively faulted and sheared Silver Plume Granite and are being explored for vein-type uranium deposits.

Uranium also occurs at the Ray claims, 0.5 mi southwest of Jones Pass and 0.25 mi outside of the Williams Fork Roadless Area. A fault, trending N. 80° E. and dipping 50° NW., roughly parallels the study area boundary and is exposed in a prospect pit. The fault cuts altered Silver Plume Granite and contains the uranium minerals autunite and uranophane (U.S. Atomic Energy Commission, 1966). Two samples taken across the fault assayed 0.04 and 0.007 percent U_3O_8.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

Low, moderate and high potential rankings were used in assessing the mineral resource potential for the three study areas (fig. 5). These relative potential values were arrived at by the superpositioning of the following data upon the geologic base: (1) geochemical anomalies, (2) gravity lows, (3) past and present mining activity, (4) alteration in bedrock, (5) fluorite distribution, and (6) ore-related mineralogy. Overlapping of some or all of these criteria upon a favorable geologic environment determined the ranking of the potential. Deposits of different types have different criteria as outlined below.

Silver-rich, lead-zinc deposits are found at the heads of both the West Fork Clear Creek and the Williams Fork River. These deposits are immediately south of the Vasquez Peak Wilderness Study Area and along the east side of the St. Louis Peak and Williams Fork Roadless Areas. A gravity low, indicating a possible intrusive source rock at depth, is spatially related to the areas of alteration and the ore-related minerals and geochemical anomalies of lead and silver. Together these features define a moderate to high potential for resources of lead and silver in veins similar to those that have been prospected (fig. 5). Areas of moderate to high potential for lead and silver resources in veins occur along the southern edge of the Vasquez Peak Wilderness Study Area, throughout much of the McQueary Creek basin, and extend westward to St. Louis Peak, and southward throughout the basins of Steelman Creek, Bobtail Creek, and the head of the South Fork Williams Fork River to the south boundary of the Williams Fork Roadless Area.

The evidence described above also allows speculation of moderate potential for large volumes of rock that may contain veins and veinlets enriched in silver, lead, and zinc of sufficient frequency to allow inclusion of the entire mass in a deposit whether or not individual veins constitute a resource. Potential for this type of occurrence exists throughout the area of the silver-rich lead-zinc veins but is most likely in the vicinity of the junctions of Bobtail, Steelman, and McQueary Creeks, including the north end of the ridge between Bobtail and Steelman Creeks. Similar, though less well defined, areas can be postulated for the Continental Divide east of McQueary Creek, and for the head of the South Fork Williams Fork River.

The large molybdenum ore deposits at Red Mountain, less than 2 mi east of the Williams Fork Roadless Area and south of the Vasquez Peak Wilderness Study Area, are surrounded by vein deposits similar to those described above. The deposits east of the Continental Divide in the headwaters of the West Fork Clear Creek are most likely the distal parts of the ore-depositing system at Red Mountain. Gravity lows, sporadic rhyolite porphyry dikes, large scattered areas of altered rock, abundant fluorite, and sporadic presence of molybdenum or molybdenite occur in the eastern part of the Williams Fork Roadless Area, the southern part of the Vasquez Peak Wilderness Study Area, and the southeastern part of the St. Louis Peak Roadless Area. These are features that would be expected above molybdenum deposits like those at Red Mountain. Present evidence is not sufficient to target specific localities within the general mineralized area, although the areas identified as having potential for silver-rich, lead-zinc veins are probably the most likely candidates for molybdenum deposits at depth. Thus, a moderate potential for stockwork-molybdenum resources in rhyolite exists at depth in this area.

An isolated gravity low centered about 1 mi northeast of Vasquez Peak is in an area of altered rock, fluorite occurrences, and weak geochemical anomalies. It is apparently isolated from the gravity trough that extends eastward to Red Mountain. A moderate potential for the occurrence of molybdenum resources similar to that in the upper Williams Fork River drainage basin exists in this area.

A low to moderate resource potential for deposits of tungsten and massive sulfides is associated with the calcic metamorphic rocks in the northern part of the St. Louis Peak Roadless Area and in the northwestern and southern parts of the Williams Fork Roadless Area. Heavy-mineral concentrates from stream sediments containing scheelite and powellite, some with very high geochemical values for tungsten, were taken from localities scattered throughout the area of calcic metamorphic rocks; however, neither mineral has been identified in bedrock. The headwater areas of Keyser Creek were considered the most promising for tungsten resources, but a detailed geochemical survey using ridgetop soils failed to detect a strong tungsten anomaly. A disseminated source for tungsten in the metamorphic rocks seems likely. Pods and small masses of gossan derived from massive pyrite bodies are common in the calcic metamorphic rocks, and some of the gossan retain geochemically anomalous amounts of lead, silver, copper, and zinc. The zinc-aluminum spinel, gahnite, is present in some heavy-mineral concentrates. Traverses along the ridgetops near the headwaters of Keyser Creek again failed to locate any areas with strong mineralization signatures. All of the occurrences of massive sulfides seen are too small to be important resources, but the presence of a larger concealed deposit cannot be ruled out (Tweto, 1960).

The Silver Plume Granite is abnormally rich in thorium and uranium. Uranium minerals are found in the vicinity of the molybdenum deposits at Red Mountain and in a prospect near the east side of the Williams Fork Roadless Area. The presence of uranium in the intensely sheared rocks along the Berthoud Pass fault zone allow the postulation of a low potential for vein-type uranium resources along the zone.

Geochemically anomalous values for lead on the southwest side of the Williams Fork Roadless Area and along the Middle Fork Williams Fork River are related to young faults. Prospecting within and adjacent to the study areas has failed to identify any occurrence that justified more than a surface pit. The potential for vein-type lead resources in these areas is low to moderate.

Evidence for placer prospecting is present along the Williams Fork River. Inasmuch as gold was detected in only two heavy-mineral concentrates, one from the divide south of the South Fork Williams Fork River and one from the Continental Divide near the head of Bobtail Creek, it is unlikely that significant concentrations of gold exist in the glacial and alluvial deposits of the valleys.

Only those feldspar-muscovite pegmatites that are found over the inferred top of the Silver Plume Granite batholith are large enough to have resource potential. The southwesternmost part of the complex occupies a small area in the northern part of the Vasquez Peak Wilderness Study Area and has a low resource potential. However, the land in this area has been developed for a high-yield, conflicting use, and the area is remote from markets for these commodities.

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