DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES
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PAMPHLET

MINERAL RESOURCE POTENTIAL OF THE FOSSIL RIDGE WILDERNESS STUDY AREA, GUNNISON COUNTY, 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," and "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 Fossil Ridge Wilderness Study Area, Gunnison National Forest, Gunnison County, Colorado. The area was established as a wilderness study area by Public Law 96-560, 1980.

MINERAL RESOURCE POTENTIAL SUMMARY STATEMENT

Parts of the Fossil Ridge Wilderness Study Area have a high resource potential for gold and silver in small deposits, uranium in medium-size deposits, and high-calcium limestone in large deposits. Parts have a moderate to high potential for uranium, thorium, and light rare-earth elements in small- to medium-size deposits, a moderate potential for copper, lead, and zinc in small deposits, a low potential for molybdenum in small deposits, and an unknown potential for molybdenum in deposits of unknown size. Parts of the area have a low potential for cobalt, chromium, tungsten, beryllium, boron, and tin in small deposits. And, depending on the extraction of precious metals, parts of the area could have a low potential for arsenic in small deposits. Tungsten, rare-earth elements, and tin could not be considered resources except for coexisting base metals, thorium, and uranium.

Areas that immediately adjoin the Fossil Ridge Wilderness Study Area have a high potential for molybdenum in large deposits, lead in medium-size deposits, and zinc in small- to medium-size deposits. Depending on the extraction of base metals, parts of the adjoining areas could have a low resource potential for bismuth and cadmium as byproducts in medium-size deposits.

INTRODUCTION

The Fossil Ridge Wilderness Study Area occupies 85.5 mi^2 within the Gunnison National Forest of central Colorado (fig. 1). Access to the area is by paved roads along the Taylor River and Quartz Creek, and by graveled roads along Willow Creek and Gold Creek. The Gold Brick and Quartz Creek mining districts border the area on the southeast, and the Tincup district adjoins the area on the east (Kluender and McColly, 1983). The Cross Mountain mining district is within the north-central part of the area. Elevations range from 9,200 ft along the Taylor River and Gold Creek to more than 13,200 ft on Fairview Peak and Henry Mountain. The mountainous terrain is characterized by steep-sided glacial valleys and cirques in the central and eastern parts of the area, but it is more subdued in the western part. Thick conifer forests at the lower elevations change to alpine tundra and meadows above 11,400 ft.

An area much larger than the Fossil Ridge Wilderness Study Area, the Crystal Creek Study Area, was inventoried during the Roadless Area Review and Evaluation (RARE II) from 1977 to 1980. The Crystal Creek Study Area was rejected for wilderness designation partly because of its mineral resource potential. The Colorado Wilderness Act of 1980 reduced the size of the Crystal Creek Study Area and renamed a part of it the Fossil Ridge Wilderness Study Area.

Acknowledgments

Many companies and persons supplied unpublished maps and data during the study of the Fossil Ridge

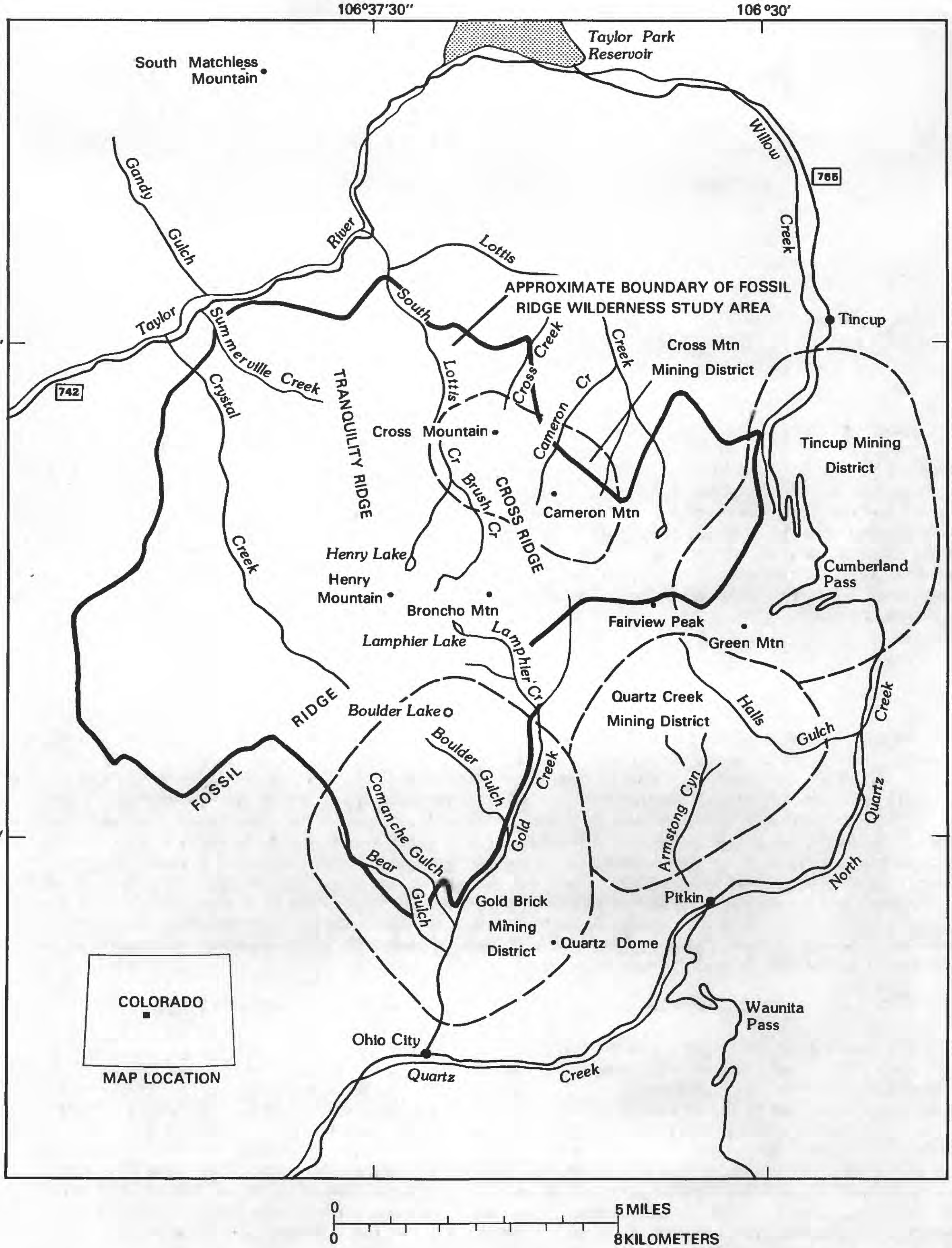


Figure 1.--Location map of the Fossil Ridge Wilderness Study Area, Gunnison County, Colorado.

Wilderness Study Area, including John Thomas of AMAX Exploration, Gene Rosenlund of American Minerals Exploration and Development, Bob Perry of Canyon Resources, George Apostalos of Colorado Minerals Corp., Dave Ellis of Conoco Minerals, A. J. Pansze of Cruson and Pansze Associates, H. G. Brown, III, of Exxon USA, and Neil Brown of Rocky Mountain Energy. Access to the Gold Links mine was provided by John Tippit and Maury Biggs, and to the Raymond and Carter mines by Dave Lobb. Much of the mining history of the area was gleaned through conversations with Eudora Moore, Mrs. Chenoweth, and Earl McLain.

GEOLOGY

The wilderness study area is underlain chiefly by granitic and metamorphic rocks of Early to Middle Proterozoic age, which are partly mantled by a thin cover of Paleozoic sedimentary strata (fig. 2). Both the Proterozoic and Paleozoic rocks are cut by many small Tertiary intrusive bodies. Pleistocene glacial deposits locally obscure much of the bedrock. Faults of probable Laramide to middle Tertiary age cut all but the youngest rock units and locally have vertical offsets of 2,300–2,950 ft.

Rock units

The oldest rock unit in the study area is a bimodal sequence of metamorphosed basalt flows, agglomerates, and tuffs, and metamorphosed rhyolite and dacite flows(?), tuffs, and intrusive bodies. This bimodal metavolcanic sequence is shown as one map unit in figure 2 (unit Xv). The metavolcanic sequence is intruded by numerous stocks, dikes, and subvolcanic sills of diorite or metagabbro (unit Xd, fig. 2) that range from foliated to nonfoliated. Metavolcanic rocks are exposed between Gold Creek and the Boulder fault, from Fairview Peak to south of Comanche Creek. The metavolcanic sequence is probably temporally equivalent to 1,740- to 1,760-m.y.-old rocks south and southwest of Gunnison (Sheridan and others, 1981; Boardman and Bickford, 1982). The metavolcanic sequence is overlain, probably conformably, by a predominantly metasedimentary sequence consisting of mica schist, quartzite, metagraywacke, and metaconglomerate (unit Xms, fig. 2). The petrology of both the metavolcanic and metasedimentary units has been described in part by Crawford and Worcester (1916), and in detail by Usdansky (1981). The metasedimentary rocks flank the metavolcanic unit to the northwest along Fossil Ridge.

Four igneous bodies have discordantly intruded the layered units and diorite or metagabbro. The oldest body, a pluton composed of the granodiorite of Fairview Peak (unit Xf, fig. 2), is foliated to gneissic in all exposures and is restricted in outcrop to east of Cross Ridge and Gold Creek. This granodiorite is probably only slightly younger than the layered rocks. The granite of Roosevelt Gulch (unit Xr, fig. 2) is not in contact with any other plutonic bodies, but its faint foliation probably indicates that it is younger than the granodiorite of Fairview Peak. A nonfoliated pluton having a quartz monzonite rim and a syenite core (unit Xg, fig. 2) is also not in contact with any other plutonic units but is probably younger than the granite of Roosevelt Gulch. The lithology of this pluton is similar to the quartz monzonite of Staatz and Trites (1955) and with hornblende-biotite syenite and pyroxene monzonite of Crawford and Worcester (1916). The granite of Henry Mountain (unit Xh, fig. 2), a coarse-grained, porphyritic (microcline) biotite-muscovite granite, is normally in fault contact with the granodiorite of Fairview Peak, but the undeformed nature of the granite suggests that it is younger than the granodiorite. This granite correlates with the coarse-grained granite of Staatz and Trites (1955) and the Quartz Creek Granite of Aldrich and others (1956), south of Fossil Ridge. The granite of Henry Mountain was metamorphosed about 1,350 m.y. ago but is probably 1,650–1,700 m.y. old, as indicated by U-Th-Pb zircon and Rb-Sr data (Aldrich and others, 1956; Wetherill and Bickford, 1965). The biotite-muscovite granite of Taylor River (unit Yt, fig. 2) forms the youngest major Proterozoic plutons in the area and is at least 1,385 m.y. old (Wetherill and Bickford, 1965), but is probably not older than 1,450 m.y.

Paleozoic rocks (unit Pz, fig. 2) rest unconformably on the Proterozoic crystalline basement and consist of the Cambrian Sawatch Quartzite, Ordovician Manitou Dolomite, Ordovician Harding Sandstone, Ordovician Fremont Limestone, Devonian and Mississippian(?) Chaffee Group, Mississippian Leadville Limestone, and Pennsylvanian Belden Shale. Thicknesses of these units were measured by R. S. Zech (U.S. Geological Survey, unpub. mapping, 1982) and are as follows: The Sawatch ranges from 118 ft thick in the southern part of the Fossil Ridge area to 348 ft thick in the northern part of the area. Near the Taylor River the Sawatch includes equivalents of the Peerless Formation (Johnson, 1944). The Manitou is uniformly thick and averages 157 ft. The Harding ranges from 6 to 13 ft and thins westward. The Fremont averages 49 ft thick and varies little in thickness. The Chaffee Group, which includes the Parting Formation and the Dyer Dolomite, ranges from 262 to 295 ft and thickens southward. The Leadville is 308 ft thick on Fossil Ridge and thickens southward. At most, 66–82 ft of the Belden are preserved in the area. The Paleozoic rocks cap some of the highest ridges in the area and have locally been preserved in down-dropped blocks along normal and reverse faults.

Mesozoic strata (unit Mzu, fig. 2) are not present within the wilderness study area, but the Junction Creek Sandstone, Morrison Formation, and Dakota Sandstone rest unconformably on Paleozoic rocks 1.5 mi southwest of the study area boundary.

Pre-Oligocene(?) porphyritic (plagioclase-hornblende) andesite-latite bodies (unit Ta, fig. 2) and lower to middle Miocene(?) porphyritic (quartz-feldspar) rhyolite bodies (unit Tr, fig. 2) intrude all the older rocks. The andesite-latite forms sills, laccoliths, and small stocks, predominantly in the Paleozoic strata. The rhyolite forms dikes and small plugs in both Paleozoic and Proterozoic units. Extensive glacial and alluvial deposits that blanket the valleys of the area are not shown in figure 2.

Structural features

Proterozoic rocks older than the granite of Roosevelt Gulch have been metamorphosed to middle amphibolite facies (Crawford and Worcester, 1916; Usdansky, 1981) and have a regional foliation that

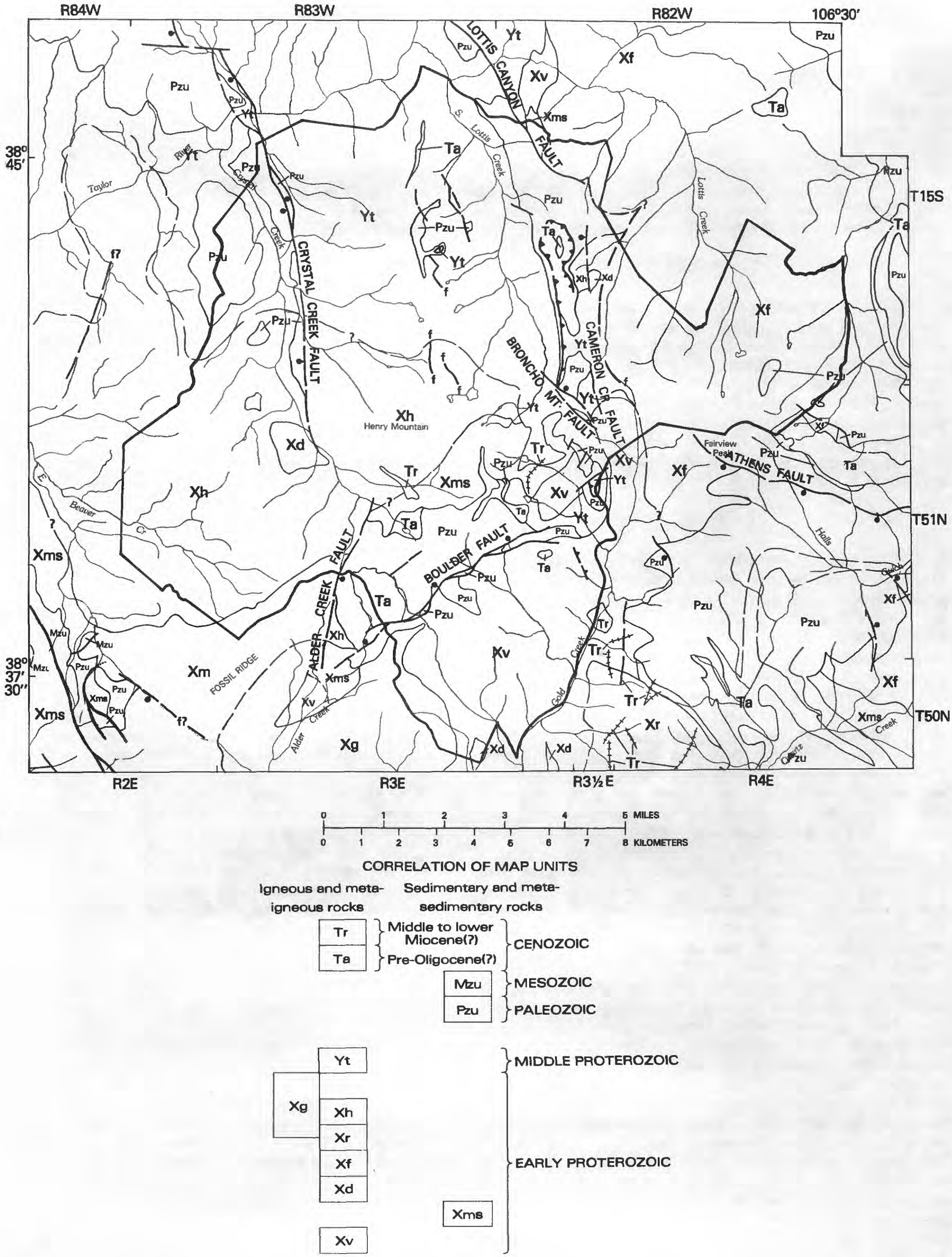


Figure 2.--Simplified geologic map of the Fossil Ridge Wilderness Study Area, Gunnison County, Colorado.

DESCRIPTION OF MAP UNITS

Tr	RHYOLITE (MIDDLE TO LOWER MIOCENE?)--Dikes and small plugs of porphyritic (quartz-feldspar) rhyolite
Ta	ANDESITE (PRE-OLIGOCENE?)--Sills, laccoliths, and stocks of porphyritic (plagioclase-hornblende) andesite-latite and porphyritic dacite
Mzu	UNDIFFERENTIATED SEDIMENTARY ROCK UNITS (MESOZOIC)--Dakota Sandstone, Morrison Formation, and Junction Creek Sandstone
Pzu	UNDIFFERENTIATED UNITS (PALEOZOIC)--Belden Formation, Leadville Limestone, Chaffee Group, Fremont Limestone, Harding Sandstone, Manitou Dolomite, and Sawatch Quartzite
Yt	GRANITE OF THE TAYLOR RIVER (PROTEROZOIC Y)--Small and large plutons of muscovite granite
Xg	UNNAMED GRANITE-SYENITE-MONZONITE (PROTEROZOIC X)--Zoned pluton of quartz monzonite-syenite that may possibly be in part Proterozoic Y in age
Xh	GRANITE OF HENRY MOUNTAIN (PROTEROZOIC X)--Large pluton of coarse-grained, porphyritic (microcline) biotite-muscovite granite
Xr	GRANITE OF ROOSEVELT GULCH (PROTEROZOIC X)--Large pluton of biotite granite
Xf	GRANODIORITE OF FAIRVIEW PEAK (PROTEROZOIC X)--Large pluton of well-foliated biotite granodiorite
Xd	UNNAMED DIORITE (PROTEROZOIC X)--Stocks and subvolcanic sills of diorite, quartz diorite, and metagabbro
Xms	UNNAMED METASEDIMENTARY UNITS (PROTEROZOIC X)--Muscovite-biotite-andalusite-cordierite schist, metaquartzite, metagraywacke, and minor metaconglomerate
Xv	UNNAMED METAVOLCANIC UNITS (PROTEROZOIC X)--Bimodal sequence of amphibolite, metabasalt, meta-andesite, layered calc-silicate gneiss, and meta-agglomerate, and metarhyolite and metadacite tuffs and intrusive bodies

trends northeast in the southwestern and south-central part of the area and north in the northeastern part of the area. The structure within the metasedimentary and metavolcanic terrane is complex and poorly understood. Faults of probable Pennsylvanian to Cretaceous age juxtapose Mesozoic, Paleozoic, and Proterozoic units in the far southwest corner of the area of figure 2 and record activity related to the uplift of the Uncompahgre highlands (Mallory, 1972).

The Crystal Creek and Lottis Canyon faults trend north to northwest and are normal or reverse faults along which various Proterozoic units have been placed against the Paleozoic section. Displacement on the Crystal Creek fault between Tranquility Ridge (an informal name used in this report for the ridge between Crystal Creek and South Lottis Creek) and Crystal Creek is 3,030 ft, but the displacement decreases to the north. The displacement on the Lottis Canyon fault is unknown but is probably hundreds to possibly thousands of feet. The latest displacement on the faults occurred after the emplacement of andesite-latite sills, as the faults truncate the projection of the sills in the Paleozoic section.

Other north-trending normal or reverse faults are the Alder Creek fault on the west side of Fossil Ridge and shear zones in the high cirques west of South Lottis Creek. The Alder Creek fault trends north-northeast and displaces the Paleozoic section at least 394 ft. The shear zones west of South Lottis Creek also displace the Paleozoic rocks in that area, but the amount of displacement is uncertain.

The Athens and Broncho Mountain faults are reverse and (or) thrust faults that trend northwest, along which Proterozoic units were placed against the Paleozoic section. Displacement on the Athens fault apparently decreases from east to west. The fault cannot be traced with certainty west of Fairview Peak. The Broncho Mountain fault displaces the Sawatch Quartzite 1,310 ft, and the sense of displacement is opposite to that of the Athens fault.

The Cameron Creek fault trends north; it is poorly exposed and juxtaposes Paleozoic and Proterozoic units. The Lottis Canyon fault may be the northwest continuation of the Cameron Creek fault (R. S. Zech, unpub. mapping, 1983), but poor exposures in the area of Cross Creek do not permit confirmation of this hypothesis. Lateral displacement may have been greater than vertical displacement on the Cameron Creek fault.

The Boulder fault is an arcuate, northeast-trending reverse fault along which Proterozoic rocks were placed against folded Paleozoic strata and pre-Oligocene(?) andesite-latite bodies. Between Boulder and Comanche Gulches the fault has 785 ft of offset, and the Sawatch Quartzite was placed against the Belden Shale.

A low-angle thrust fault on Cross Ridge (an informal name used in this report) locally placed the granite of Taylor River (unit Yt) and its cover of Paleozoic strata over the section of Cambrian through Devonian rocks. This thrust fault is truncated by the Broncho Mountain fault to the south, but extensions of the thrust to the south are indicated by a klippe of the granite of Taylor River on Sawatch Quartzite between Lamphier Creek and Gold Creek, and by a low-angle fault east of Sheep Mountain (fig. 2). The thrust fault on Cross Ridge was apparently folded into a monoclinal flexure by movement on the Lottis Creek fault. A similar(?) low-angle fault on Tranquility Ridge is indicated by a klippe of the granite of Taylor River on the Sawatch (fig. 2). The direction of transport on these thrust faults was apparently from the north or northwest, as the granite of Taylor River in the upper plate is not found east of the Cameron Creek fault. If transport were from the east, the granodiorite of Fairview Peak (unit Xf) must be allochthonous on the granite of Taylor River. The age of displacement on the thrust fault may range from Pennsylvanian to Tertiary.

GEOCHEMISTRY

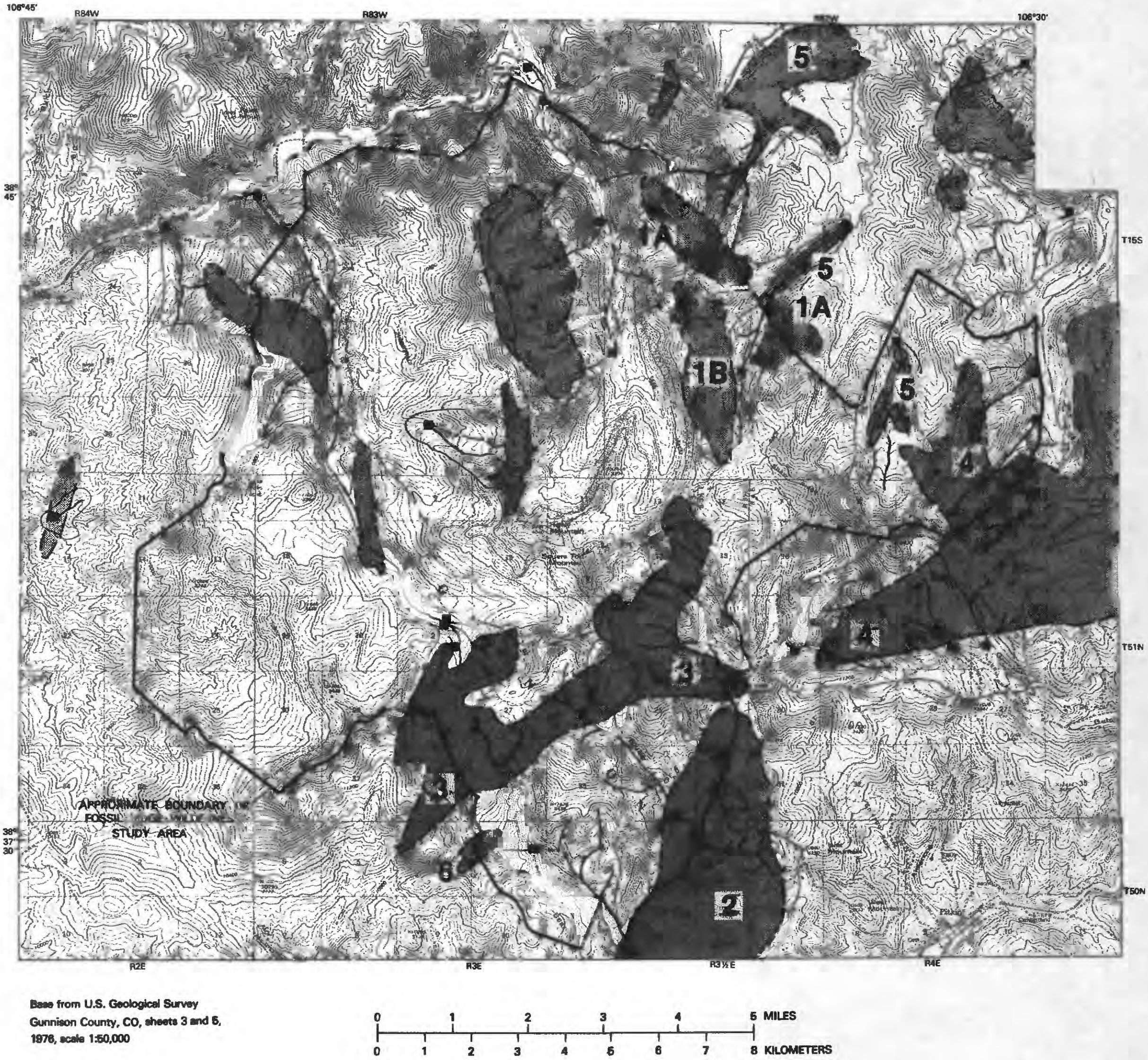
Geochemical data from uranium resource studies (Broxton and others, 1979; Maasen, 1981) and from the present wilderness assessment (Adrian and others, 1984) have been utilized in this report and are discussed extensively in the section on "Mineral resource assessment." Localities of samples that are considered anomalous from these studies are shown in figures 3-8. Table 1 lists concentrations of selected elements that are considered slightly to highly anomalous in samples from the wilderness study area. Also, Goodknight and Ludlam (1981) and Bolivar and others (1981) characterized the uranium occurrences and gave background geochemical values for selected elements within and surrounding the Fossil Ridge area.

GEOPHYSICS

An airborne magnetic survey of the Fossil Ridge area (U.S. Geological Survey, 1982) showed that some of the Proterozoic plutonic bodies have distinctive magnetic signatures. The granite of Taylor River has the lowest magnetic background, and averages -990 gammas. The granodiorite of Fairview Peak is slightly more magnetic, and averages -870 gammas. The granite of Henry Mountain cannot be distinguished from the metavolcanic terrane, as both average -760 gammas. The diorite-metagabbro bodies (unit Xd), especially in the upper reaches of Crystal Creek, have a much higher magnetic signature of -280 gammas. The highest magnetic reading in the area was slightly above +300 gammas, in the center of sec. 2, T. 50 N., R. 2 E. (fig. 2). This extremely high magnetic reading cannot be explained by the surface geology and may indicate a buried mafic or ultramafic stock. However, similar magnetic surveys by AMAX Exploration (John Thomas, oral commun., 1983) showed that the anomaly in section 2 has a much lower amplitude, and hence a buried pluton is not needed to explain the anomaly.

MINING DISTRICTS AND MINERAL OCCURRENCES

Parts of the Cross Mountain, Gold Brick, and Tincup organized mining districts are within the Fossil Ridge Wilderness Study Area, and the Quartz Creek district adjoins the south boundary (Kluender and McColly, 1983). Two mines having past production in the Cross Mountain district, the Gold Bug and Wahl Lode, are inside the wilderness study area boundary, and a third, unnamed, mine that is currently (1983) being worked is less than 0.3 mi north of the boundary (fig. 3). Three mines in the Gold Brick district, the



Base from U.S. Geological Survey
Gunnison County, CO, sheets 3 and 5,
1976, scale 1:50,000

Map area	Resource potential	Commod-ity	Size and type of deposit
1A-------	High---------	Au, Ag	Small; vein.
1B-------	--do---------	Au, Ag	Small; replacement and (or) vein.
2*-------	--do---------	Au, Ag	Medium; vein and (or) shear zone.
2**------	Moderate-----	Au, Ag	Small; vein.
3--------	Low----------	Au, Ag	Small; vein and (or) fracture.
4**------	Low-moderate	Au, Ag	Small; vein.
4*-------	High---------	Au, Ag	Medium; replacement.
	--do---------	Au, Ag	Small(?); vein.
5--------	Moderate-----	Au----	Small-medium; placer.
6--------	--do---------	Au----	Small; vein.

*Area outside Fossil Ridge Wilderness Study Area.
**Area inside Fossil Ridge Wilderness Study Area.

Figure 3.--Map showing mineral resource potential for gold, silver, arsenic, and antimony, Fossil Ridge Wilderness Study Area, Colorado.

EXPLANATION

• STREAM-SEDIMENT SAMPLE LOCALITY

Analyses reported by Maasen (1981) and Broxton and others (1979). Solid circle indicates anomalous values in sample.

▲ Analyses reported by Rocky Mountain Energy (unpub. data, 1982)

■ STREAM-SEDIMENT OR PANNED-CONCENTRATE SAMPLE LOCALITY--Analyses reported by Adrian and others (1984). Solid square indicates anomalous values in sample

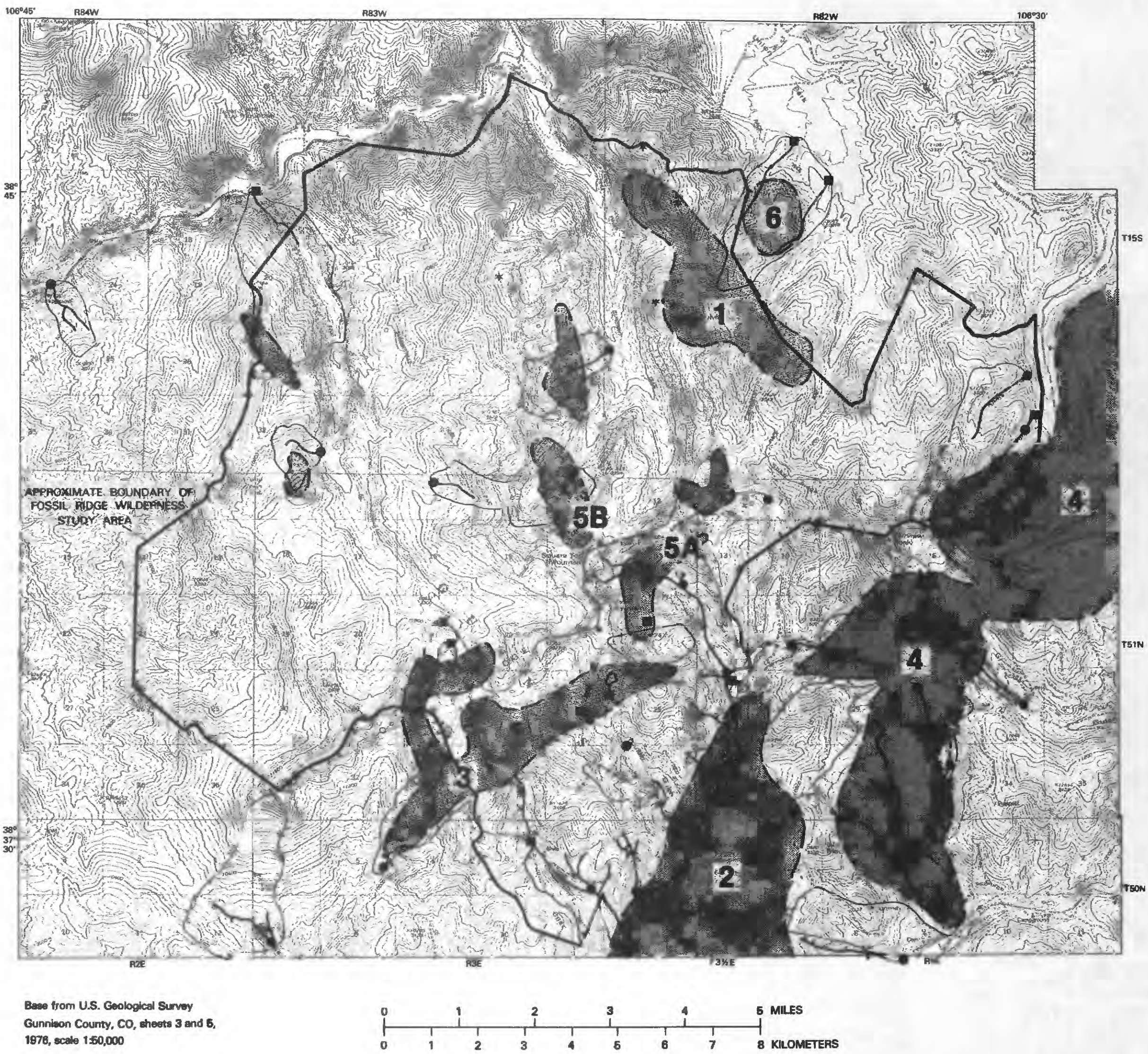
* ROCK SAMPLE LOCALITY--Samples contained anomalous values; analyses reported by Adrian and others (1984) and Kluender and McColly (1983)

/ PART OF STREAM THAT CONTAINS ANOMALOUS CONCENTRATION OF ELEMENT

DRAINAGE AREA THAT COULD HAVE PRODUCED ANOMALOUS STREAM-SEDIMENT OR PANNED-CONCENTRATE SAMPLE--Dashed lines signify drainage basin considered anomalous by data from Maasen (1981), but not corroborated by data from Rocky Mountain Energy (unpub. data, 1982)

AREA MOST LIKELY TO CONTAIN MINERAL OCCURRENCES--Evaluation based on geologic factors. Unnumbered areas are considered to have no mineral resource potential or are outside the wilderness study area

◉ DIAMOND DRILL HOLE

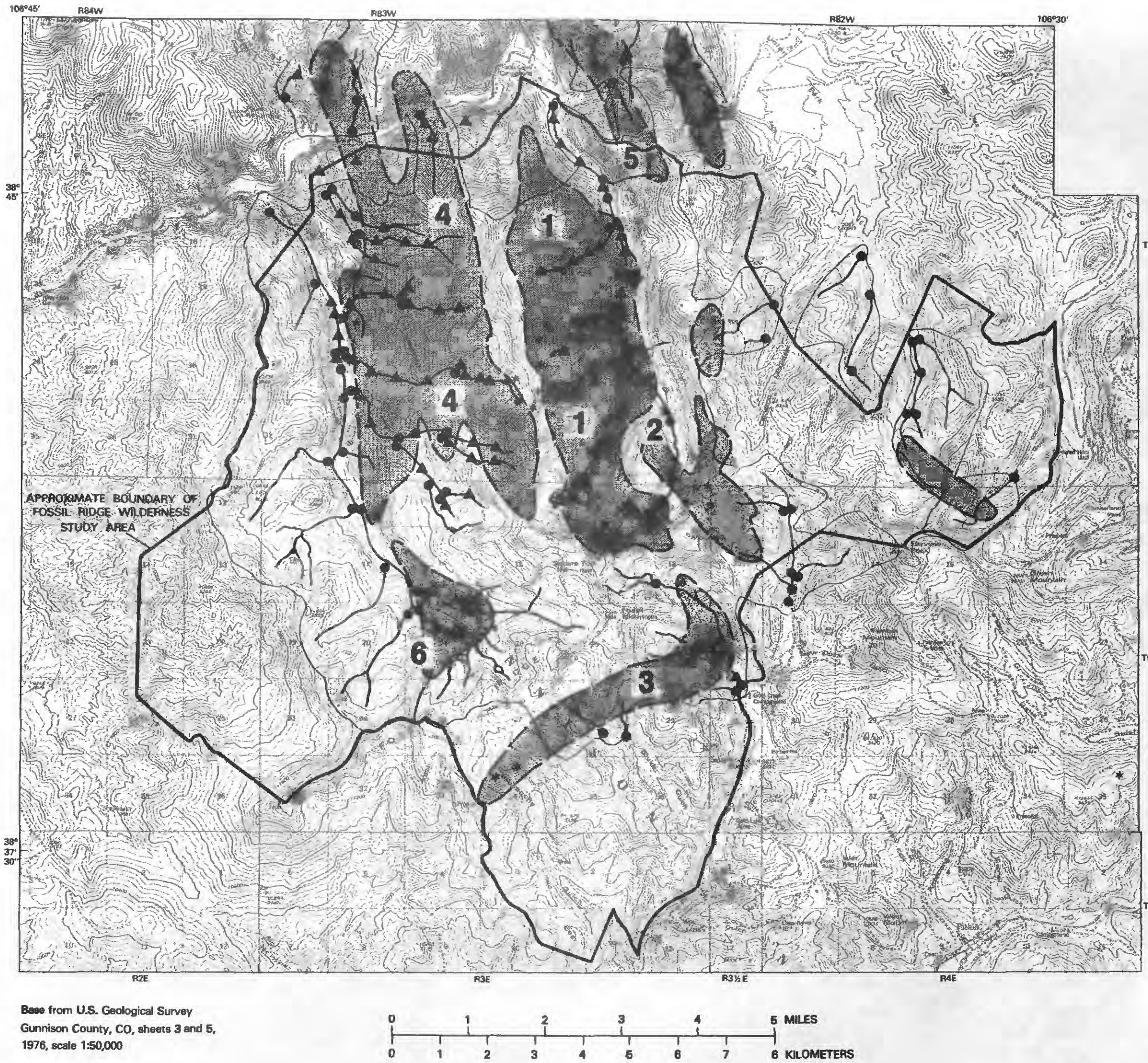


Map area	Resource potential	Commod-ity	Size and type of deposit
1	Moderate	Cu	Small; vein and (or) replacement.
	Low	Pb, Zn	Do.
2*	High	Pb	Medium; vein and (or) shear zone.
2**	Moderate	Pb	Small; vein.
3	Low	Cu, Pb, Zn	Small; vein and (or) fracture.
4**	Moderate	Cu, Pb, Zn	Do.
4* Green Mountain area.	High	Mo	Large; disseminated aud (or) porphyry.
4* Halls Gulch area.	--do	Pb, Zn	Small-medium; replacement and (or) vein.
5A	Low	Mo	Small; vein.
5B	Low	Mo	Small; unknown.
6	Unknown	Mo	Small-medium; disseminated and (or) porphyry.

*Area outside Fossil Ridge Wilderness Study Area.

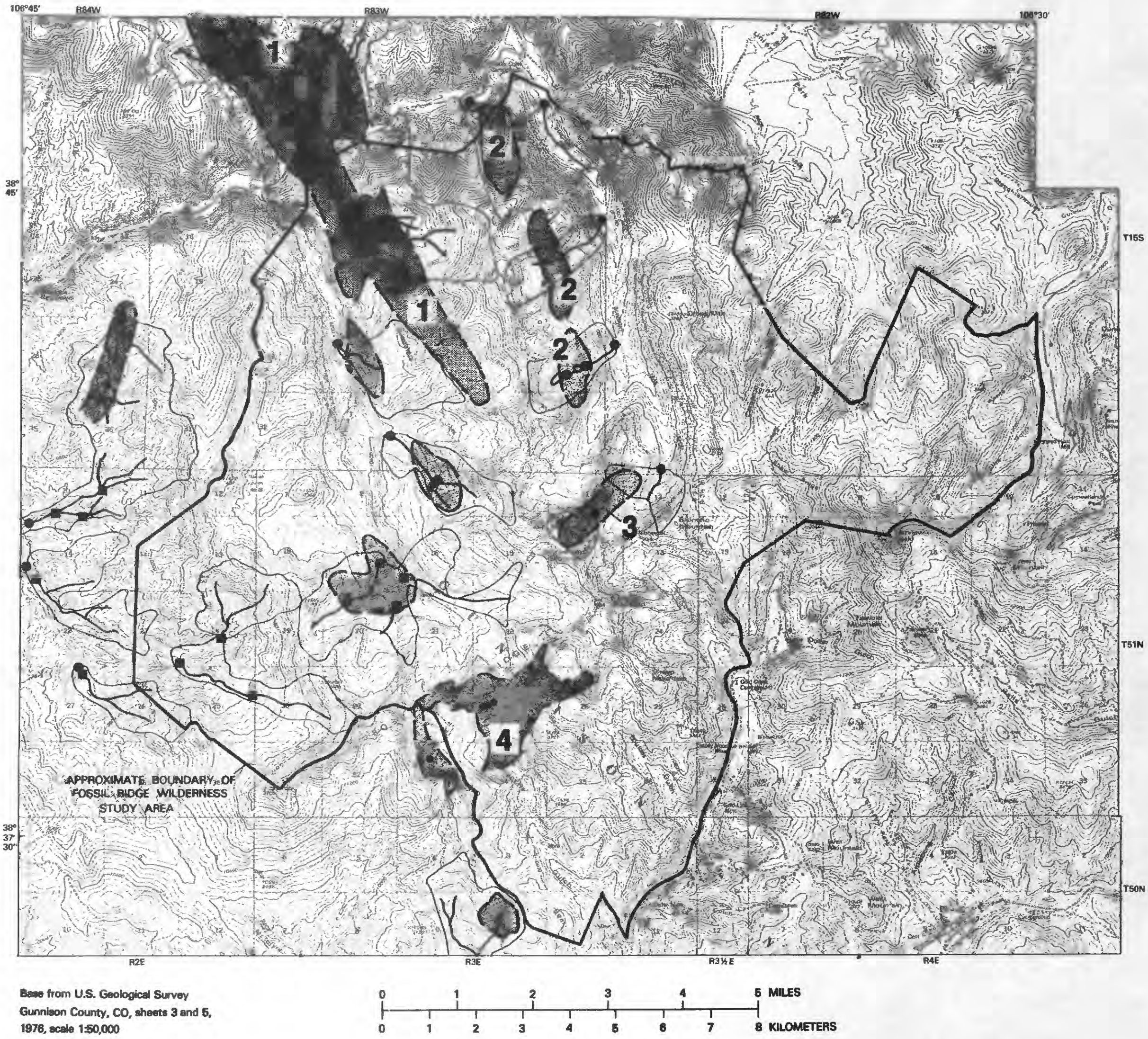
**Area inside Fossil Ridge Wilderness Study Area.

Figure 4.--Map showing mineral resource potential for copper, lead, zinc, molybdenum, bismuth, and cadmium, Fossil Ridge Wilderness Study Area, Colorado. See figure 3 for explanation of symbols.



Map area	Resource potential	Size and type of deposit
1--------	High----------	Medium; shear zone and (or) vein.
2--------	Moderate-----	Small; shear zone.
3--------	--do----------	Small; vein.
4--------	Moderate-high	Medium; vein(?) and (or) shear zone(?).
5--------	Low-moderate-	Small; shear zone.
6--------	Low-----------	Small; unknown.

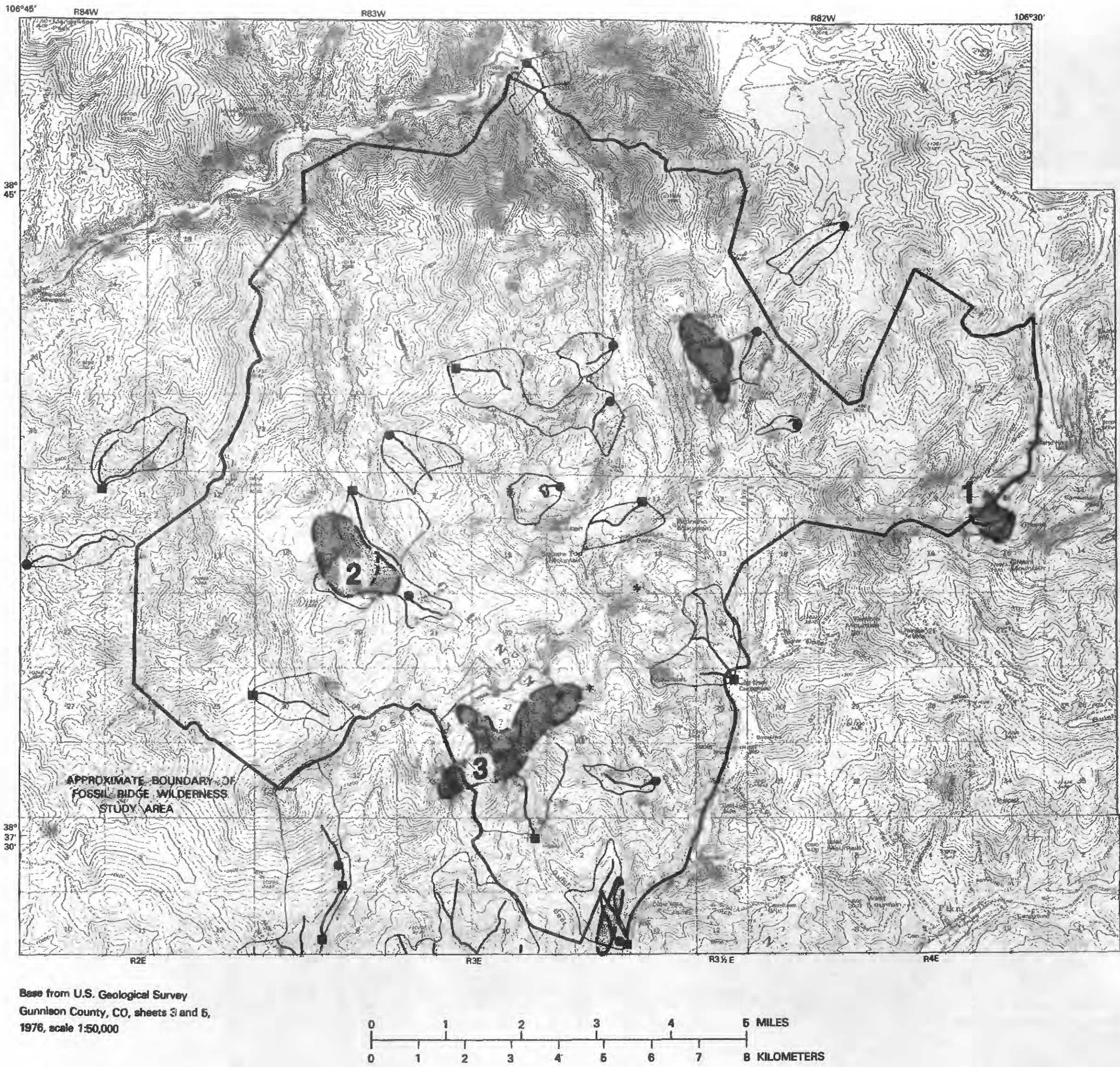
Figure 5.--Map showing mineral resource potential for uranium, Fossil Ridge Wilderness Study Area, Colorado. See figure 3 for explanation of symbols.



Base from U.S. Geological Survey
Gunnison County, CO, sheets 3 and 5,
1976, scale 1:50,000

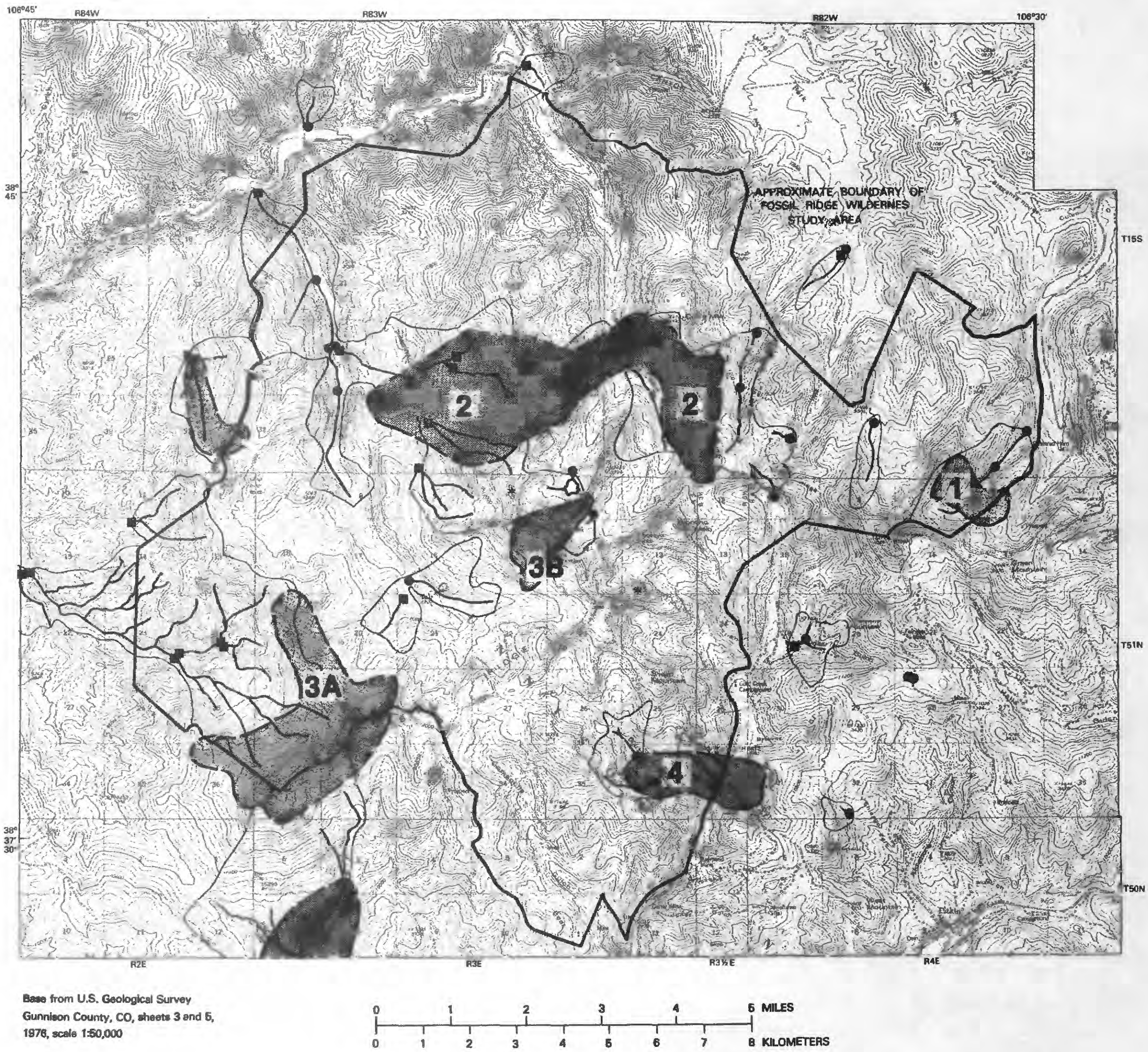
Map area	Resource potential	Commod-ity	Size and type of deposit
1-------	Moderate-high	Th, La, Ce	Small-medium(?); vein and (or) pegmatite(?).
2-------	Low-----------	Sm---------	Medium; shear zone.
3-------	Low-----------	La, Ce----	Small; unknown.
4-------	High----------	Limestone-	Large; sedimentary and (or) bedded.

Figure 6.--Map showing mineral resource potential for thorium, lanthanum, rare-earth elements, and high-calcium limestone, Fossil Ridge Wilderness Study Area, Colorado. See figure 3 for explanation of symbols.



Map area	Resource potential	Commod-ity	Size and type of deposit
1----------	Low-------	W----------	Small; vein.
2----------	Low-------	W, Co, Cr	Small; disseminated.
3----------	Low-------	Cr, Co----	Small; vein.

Figure 7.--Map showing mineral resource potential for cobalt, chromium, and tungsten, and localities of samples containing anomalous amounts of niobium and tantalum. See figure 3 for explanation of symbols.



Map area	Resource potential	Commodity	Size and type of deposit
1--------	Low----------	Sn------	Small; vein.
	Low----------	Sn------	Medium; disseminated and (or) porphyry.
2--------	Low----------	Be, Sn-	Small; disseminated.
3A-------	Low----------	B-------	Small; vein and (or) disseminated.
3B-------	Low----------	B-------	Do.
4-- -----	Low-moderate	Sn------	Small(?); disseminated and (or) porphyry or vein.

Figure 8.--Map showing mineral resource potential for beryllium, boron, and tin, and localities of samples containing anomalous amounts of lithium. See figure 3 for explanation of symbols.

Table 1.--Threshold values of anomalous concentrations of elements in stream-sediment, panned-concentrate, and rock samples, Fossil Ridge Wilderness Study Area

[Values in parts per million]

Element (symbol)	Slightly anomalous	Highly anomalous
Gold (Au)--------	0.1	1.0
Silver (Ag)------	.5	5.0
Arsenic (As)-----	50	500
Antimony (Sb)----	5	1,000
Copper (Cu)------	100	500
Lead (Pb)--------	100	500
Zinc (Zn)--------	200	1,000
Molybdenum (Mo)--	5	50
Bismuth (Bi)-----	2	100
Cadmium (Cd)-----	.5	50
Uranium (U)------	25	250
Thorium (Th)-----	35	150
Lanthanum (La)---	200	500
Cerium (Ce)------	250	1,000
Samarium (Sm)----	35	100
Dysprosium (Dy)--	30	75
Ytterbium (Yb)---	20	40
Cobalt (Co)------	25	200
Chromium (Cr)----	150	500
Niobium (Nb)-----	50	350
Tantalum (Ta)----	8	75
Tungsten (W)-----	30	200
Beryllium (Be)---	5	50
Lithium (Li)-----	100	1,000
Boron (B)--------	500	4,000
Tin (Sn)---------	25	500

Chronicle, Sandy Hook, and McCarty-Clark, are inside the study area. Also, the three largest mines in the Gold Brick district (Crawford and Worcester, 1916), the Gold Links, Raymond, and Carter, are less than 0.2 mi outside the boundary. Only two mines in the Tincup district, the Anna Dedrika and Little Anna, are within the study area. Numerous small mines in the Tincup district adjoin the study area.

At the Gold Bug mine, in the Cross Mountain district, gold, silver, and lead have been produced from a vein deposit in Paleozoic and Proterozoic rocks (table 2; Hill, 1909; Goddard, 1935). The Wahl Lode was described by Goddard (1935) as a replacement deposit in Paleozoic limestone, but R. S. Zech (unpub. mapping, 1983) noted that a vertical vein constitutes most of the deposit. Gold, copper, and manganese were produced from the Wahl Lode. The unnamed workings on the northeast side of Cameron Mountain are similar to the Gold Bug. Deposits in the Gold Brick district are localized along veins and shear zones in Proterozoic metamorphic and plutonic rocks and a small stock of Tertiary(?) rhyolite (Crawford and Worcester, 1916). Gold, silver, and lead were produced in the Gold Brick district mainly from the Carter, Raymond, and Gold Links mines (table 2), all of which were being actively prospected in 1983.

Mines in the Tincup district contain vein deposits of tungsten, molybdenum, and silver in Proterozoic and Tertiary plutonic rocks, and replacement deposits of gold, silver, and lead in Paleozoic sedimentary rocks (table 2; Goddard, 1935). Placer gold has been produced from the Union Park area and the Cameron and Lottis Creek drainages (Goddard, 1935).

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

Parts of the Fossil Ridge Wilderness Study Area have a high resource potential for gold and silver in small deposits, uranium in medium-size deposits, and high-calcium limestone in large deposits. Parts have a moderate to high potential for uranium, thorium, and light rare-earth elements in small- to medium-size deposits, a moderate potential for copper, lead, and zinc in small deposits, a low potential for molybdenum in small deposits, and an unknown potential for molybdenum in deposits of unknown size. Parts of the area have a low potential for cobalt, chromium, tungsten, beryllium, boron, and tin in small deposits. And, depending on the extraction of precious metals, parts of the area could have a low resource potential for arsenic in small deposits. Tungsten, rare-earth elements, and tin could not be considered resources except for coexisting base metals, thorium, and uranium.

Areas that immediately adjoin the Fossil Ridge Wilderness Study Area have a high potential for molybdenum in large deposits, lead in medium-size deposits, and zinc in small- to medium-size deposits. Depending on the extraction of base metals, parts of the adjoining area could have a low resource potential for bismuth and cadmium as byproducts from medium-size deposits.

Assessment of the resource potential is based on studies of the geology (Ed DeWitt, unpub. mapping, 1980-83), stream-sediment and rock geochemistry (Adrian and others, 1984; Kluender and McColly, 1983; Broxton and others, 1979; Maasen, 1981), and production and assay records from mines (Kluender and McColly, 1983). The resource potential classifications of high, moderate, low, and unknown, as used in this paper, are defined by Taylor and Steven (1983). The deposit size classifications of small, medium, and large and grades of low, medium, and high are defined in table 3. A high, moderate, or low resource potential was assigned to parts of the wilderness study area based on the structural framework, stratigraphic succession, chemical composition of rocks, and geologic history of known mineralized areas in the region. This similarity is the basis for the resource classifications, and the statement about similarity is not repeated for each area or commodity.

Gold-silver-arsenic-antimony resource potential

Two areas in the Cross Mountain region have a high potential for gold and silver in two types of deposits (fig. 3). Areas 1A have a high potential for precious-metal resources in small, but high-grade, vein deposits similar to those at the Gold Bug mine and the unnamed mine on the northeast side of Cameron Mountain (fig. 3). Area 1B has a high potential for precious-metal resources in small but exceptionally high grade replacement and (or) vein deposits similar to those at the Wahl Lode. Both deposit types would contain more gold than silver. The vein occurrences contain anomalous amounts of arsenic, bismuth, and cadmium, but the potential of area 1B for resources of these trace elements is low. The replacement and (or) vein deposits contain highly anomalous amounts of arsenic and could be an arsenic resource if the deposits were large enough. Vein mineralization in this area appears to postdate the intrusion of andesite-latite sills, and it is probably early Miocene or younger. The age of the replacement and (or) vein deposits is unknown.

Area 2 east of the Fossil Ridge Wilderness Study Area boundary has a high potential for gold and silver resources in vein and shear-zone deposits similar to those at the Carter, Raymond, and Gold Links mines. The veins and shear zones would contain precious metals in narrow, high-grade zones of moderate size. Silver grades would be approximately three times greater than gold grades. Area 2 inside the boundary has a moderate potential for precious-metal resources in veins similar to those at the Chronicle and Sandy Hook mines. These deposits would contain medium-grade precious metals in narrow, discontinuous veins, and would be small in size. The vein and shear-zone deposits contain anomalous amounts of arsenic and considerable base metals, especially lead (fig. 4). Crawford and Worcester (1916, p. 90-91) believed that the vein mineralization was Precambrian in age. Underground mapping at the Carter, Raymond, and Gold Links mines supports this view (Ed DeWitt, unpub. mapping, 1983). However, Crawford and Worcester noted (p. 102-104) that a porphyritic rhyolite stock south of the Sandy Hook mine (fig. 2) contained mineralized veins similar to those in the Gold Links mine. This stock is likely Tertiary in age (John Thomas, AMAX Exploration, oral commun., 1982), and thus the vein deposits north of the Gold Links mine could be Tertiary.

Area 3, along the Boulder fault (fig. 3), has a low potential for precious-metal resources in veins and

Table 2.--Location and descriptions of mines in or within 0.6 mi of Fossil Ridge Wilderness Study Area, Colorado

Deposit and location	Ore minerals	Geology	Development	Production[1]	Reference
		Cross Mountain district			
Gold Bug mine, secs. 17, 18, T. 15 S., R. 82 W.	Gold, chalcopyrite.	Vertical vein trending N. 40° W. cuts Paleozoic rocks.	300-ft shaft, 400- and 300-ft adits.	Unknown, some indicated.	Goddard (1935).
Wahl mine, sec. 20, T. 15 S., R. 82 W.	Gold, Au-pyrite[2], limonite, chalcopyrite, malachite.	Lenticular replacement deposit in Paleozoic limestone.	Three adits, 100 ft apart.	Small, Au---------	Do.
		Gold Brick district			
Carter mine, sec. 12, T. 50 W., R. 3 E.	Au-pyrite[2], Au-galena[2].	Seven high-angle veins striking N. 15°-20° E. in Proterozoic metamorphic and plutonic rocks.	6,550-ft adit, 1,100 ft of raises with levels at 100-ft intervals.	Large Au, Ag, Pb, small Cu.	Crawford and Worcester (1916)
Raymond mine, sec. 1, T. 50 W., R. 3 1/2 E.	Au-galena[2], Au-pyrite[2].	Seven high-angle veins in Proterozoic metamorphic rocks.	3,000-ft adit, 5 stopes on main level.	Large Au, Ag, Pb, small Cu.	Do.
Gold Links mine, sec. 36, T. 51 N., R. 3 1/2 E.	Au-galena[2], Au-pyrite[2], chalcopyrite, sphalerite.	Six relatively high-angle veins in Proterozoic metamorphic rocks. Some veins grade into shear zones.	3,900-ft adit------	Large Au, Ag, Pb, small Cu, Zn(?).	Do.
Sandy Hook mine, sec. 36, T. 51 N., R. 3 1/2 E.	Au-galena[2], Au-pyrite[2], sphalerite.	Two small veins in Proterozoic metamorphic rocks.	900-ft adit, 2,500 ft of workings.	Small Au, Ag, Cu, Pb.	Do.
Chronicle mine, sec. 36, T. 51 N., R. 3 1/2 E.	Au-pyrite[2], Au-galena[2].	Veins(?) in Proterozoic metamorphic rocks.	75-ft shaft, 188-ft drift.	Unknown, $38,000 in 1889-92.	Do.
Mary A. mine, sec. 36, T. 51 N., R. 3 1/2 E.	Au-pyrite[2], hematite, Au-limonite[2].	Quartz veins in Proterozoic metamorphic rocks.	1,125-ft adit------	Unknown, probably none.	Kluender and McColly (1983).
Carbonate King mine, sec. 33, T. 51 N., R. 3 E.	Smithsonite-----	Veins and fractures in Paleozoic limestone.	200-ft caved incline, 300-ft drift.	Small Zn----------	Crawford and Worcester (1916)
		Tincup district			
Little Anna mine, sec. 10, T. 51 N., R. 4 E.	Au-pyrite[2], galena, limonite, cerussite, cerargyrite.	Vertical vein trending N. 58° E. cuts Proterozoic granodiorite and Tertiary dacite porphyry.	60-ft shaft, 150-ft adit.	Unknown, indicated Au-Ag-Pb.	Goddard (1935).
Anna Dedrika mine, sec. 10, T. 51 N., R. 4 E.	Au-galena[2], cerrusite, cerargyrite.	Vein trending northeast that cuts Proterozoic granodiorite.	Caved prospect shaft.	Unknown, minimum several thousand dollars Ag-Au-Pb.	Do.

[1]Small: Ag, less than 1,000 oz; Au, less than 100 oz; Cu, Pb, Zn, less than 100,000 lbs.
Medium: Ag, 1,000-10,000 oz; Au, 100-1,000 oz; Cu, Pb, Zn, 100,000-1 million lbs.
Large: Ag, more than 10,000 oz; Au, more than 1,000 oz; Cu, Pb, Mo, Zn, more than 1 million lbs.
[2]Au-pyrite, auriferous pyrite; Au-galena, auriferous galena; Au-limonite, auriferous limonite.

Table 3.--Size and grade categories used in assessing mineral resource potential, Fossil Ridge Wilderness Study Area

[>, more than; pct, percent]

Commodities	Estimated grade of deposit*			Estimated size of deposit (short tons)		
	Low	Medium	High	Small	Medium	Large
Gold (Au)----------	0.001-0.05	0.05-0.30	>0.30	1,000-10,000	10,000-500,000	>500,000
Silver (Ag)--------	0.03-1.50	1.50-10.0	>10.0	1,000-10,000	10,000-500,000	>500,000
Copper (Cu)--------	0.1-2.0	2.0- 5.0	>5.0	5,000-50,000	50,000-1,000,000	>1,000,000
Molybdenum (MoS_2)--	0.01-0.1	0.0- 2.0	>2.0	10,000-100,000	100,000-1,000,000	>1,000,000
Lead, zinc (Pb,Zn)-	0.1-3.0	3.0-10.0	>10.0	5,000-50,000	50,000-1,000,000	>1,000,000
Uranium (U_3O_8)-----	0.01-0.05	0.05-0.50	>0.50	1,000-10,000	10,000-50,000	>50,000
Thorium (ThO_2)+----	0.1-0.5	0.5- 2.0	>2.0	1,000-20,000	20,000-200,000	>200,000
Rare-earth elements (combined rare-earth oxides).	0.4-0.5	0.5-1.0	>1.0	1,000-10,000	10,000-500,000	>500,000
Tin (SnO)----------	0.5-1.0	1.0-2.0	>2.0	500-5,000	5,000-50,000	>50,000
Tungsten (W)-------	0.2-0.8	0.8-5.0	>5.0	25,000-75,000	75,000-500,000	>500,000
Cobalt (Co)--------	0.75-1.0	1.0-2.5	>2.5	20,000-50,000	50,000-500,000	>500,000
Chromium (Cr_2O_3)---	30-35	35-45	>45	10,000-20,000	20,000-100,000	>100,000
Tantalum (Ta_2O_5)---	0.1-0.3	0.3-0.5	>1.0	5,000-50,000	50,000-200,000	>200,000
Niobium (Nb)-------	0.05-0.2	0.2-0.5	>0.5	20,000-50,000	50,000-500,000	>500,000
Beryllium (BeO), pegmatitic.	0.04-0.1	0.1-0.2	>0.2	10,000-30,000	30,000-2,000,000	>2,000,000
Lithium (Li_2O), pegmatitic.	0.75-1.0	1.0-2.0	>2.0	10,000-30,000	30,000-2,000,000	>2,000,000
Limestone----------	Must have less than 1.0 pct MgO and contain less than 2.0 pct insoluble residue.			10,000-100,000	100,000-10,000,000	>10,000,000

*Values in percent, except gold and silver, which are in oz/ton.

+No thorium is currently marketed in the United States; its classification as a resource is therefore slightly different from the other commodities.

fracture zones that contain anomalous amounts of arsenic and base metals (fig. 4). Base metals would probably be considered a resource if these small deposits were exploited for their precious metals. These deposits along or parallel to the Boulder fault appear to postdate the andesite-latite porphyry (unit Ta), as the Boulder fault truncates the body of porphyry (fig. 2).

Area 4, centered on Green Mountain, has a moderate to low potential for precious-metal resources in small vein deposits of medium grade similar to those at the Little Anna mine in that part of the area inside the Fossil Ridge Wilderness Study Area boundary. Silver would probably predominate over gold in these deposits. Outside the boundary, area 4 has a high potential for precious-metal resources in replacement deposits in Paleozoic rocks such as those at the Fairview-Cleopatra mine and in veins such as those at the Swiss Bell mine in the Quartz Creek mining district (Kluender and McColly, 1983; Hill, 1909). The replacement deposits would be of medium size and high grade, and would probably contain much more silver than gold. Data on the vein deposits is incomplete. Inside the boundary, the precious-metal deposits contain anomalous amounts of base metals. Outside the boundary, especially in the replacement deposits in Paleozoic limestone, highly anomalous amounts of arsenic, antimony, bismuth, and cadmium were found, all of which might be recovered as byproducts if the precious metals were extracted. The vein deposits near the wilderness study area boundary cut the latite porphyry stock at Green Mountain (unit Ta, minimum age of 34 m.y.; Naeser and Cunningham, 1976) and are probably genetically related to the stock. The replacement deposits south of the boundary are undated and could be either Paleozoic or Tertiary in age. The vein deposits are localized along the Athens fault and are probably Tertiary.

The Union Park area, Cross Creek, Cameron Creek, and Lottis Creek drainages (areas 5, fig. 3) have a moderate potential for gold in small- to medium-size placer deposits. Kluender and McColly (1983, table 2) documented placer gold in nearly all gravels sampled in Union Park, but the grade was low. Silver would be a byproduct if gold were produced from these placers.

Area 6, near the head of Bear Gulch, has a moderate potential for gold in a very small but high-grade quartz vein deposit in Proterozoic metamorphic rocks. Other areas of mineralized material shown in figure 3 but not discussed have anomalous concentrations of precious and associated metals but are either outside the wilderness study area or have no resource potential.

Copper-lead-zinc-molybdenum-bismuth-cadmium resource potential

The area around Cross Mountain (area 1, fig. 4) has a moderate potential for copper and a low potential for other base metals in small precious-metal vein and replacement deposits. Copper would be considered a resource primarily because it is associated with precious metals. Area 1 also contains anomalous amounts of molybdenum, an element not associated with anomalous amounts of base and precious metals in other parts of the wilderness study area.

The Gold Creek precious-metal vein and shear-zone deposits (area 2, fig. 4) contain lead as their predominant anomalous base metal and do not have associated bismuth or cadmium anomalies as do other precious-metal veins in the Fossil Ridge Wilderness Study Area. Area 2 outside the wilderness study area boundary has a high potential for lead associated with precious metals in medium-size, medium-grade deposits. Area 2 inside the boundary has a moderate potential for lead in small, lower grade deposits than to the east. All of area 2 has a low potential for other base-metal resources.

The Boulder fault zone and adjacent mineralized Paleozoic strata (area 3, fig. 4) contain all base metals in about equal amounts, but none in highly anomalous concentrations. The area has only a low potential for base metals in small, medium-grade deposits due to the limited width of the fault zone and the lack of hydrothermally altered rocks.

Area 4 inside the study area has a moderate potential for copper, lead, and zinc in small veins similar to but more widespread than the precious-metal veins. These vein deposits would be narrow and discontinuous, and of only a medium grade. Area 4 outside the study area boundary has a high potential for molybdenum in a porphyry deposit related to the Tertiary latite porphyry intrusive at Green Mountain (Tweto, 1943; Kirkemo and others, 1965; AMAX Exploration and Union Oil Co., unpub. reports, 1976-82). This deposit would be large but low grade compared to known molybdenum deposits in Colorado. Area 4 southeast of Green Mountain contains more anomalous amounts of lead and zinc than of copper, and it has highly anomalous amounts of bismuth and cadmium associated with replacement deposits in Paleozoic strata. This part of area 4 has a high potential for lead and zinc in all deposits in the Paleozoic rocks. These deposits would generally be small to medium in size, and the lead and zinc would be low to medium grade. This part of area 4 also has a moderate to low potential for bismuth and cadmium in the medium-size replacement deposits. The bismuth and cadmium would be byproducts of silver if these deposits were mined.

Area 5A has a low potential for molybdenum in quartz veins related to the granite of Taylor River (Crawford and Worcester, 1916). The quartz veins are discontinuous and are within a small area but are locally very rich in molybdenum. Area 5B has a molybdenum potential of similar magnitude, but the source of the anomalous values is unknown.

Area 6, northeast of Cross Mountain, has an unknown potential for molybdenum. Anomalous amounts of molybdenum were found in samples from Cross and Cameron Creeks. The source of these anomalous amounts is apparently not area 1, because these streams do not receive sediment from area 1, and anomalous amounts of molybdenum were not found in the parts of the streams that drain area 1. More study is needed to determine the source and extent of the anomalous values. The geochemical signature of area 6 is similar to area 4 east of Green Mountain; a buried porphyry of unknown size could underlie area 6.

Uranium resource potential

Much of the northern half of the Fossil Ridge Wilderness Study Area contains highly anomalous concentrations of uranium in stream-sediment and rock samples (fig. 5). Rocky Mountain Energy Co. and Exxon USA have drilled uranium prospects in areas 1, 2, and the northeastern part of 3 (fig. 5), and much of the following information was obtained from their unpublished reports (1979–81).

Area 1, which includes the high cirques west of South Lottis Creek, has a high potential for uranium in shear zones and veins. These medium-size, low- to medium-grade deposits are in narrow (10–100 ft wide), altered and brecciated zones that extend as much as 0.6 mi along strike and cut the granite of Taylor River and porphyritic andesite-latite dikes and sills (units Yt and Ta, fig. 2). Veins in this area contain minor pitchblende, uranothorite, brannerite, and apatite in a gangue of dolomite, pyrite, and rhodochrosite. In many samples of brecciated granite, the matrix is crystalline apatite that contains much uranium. Altered rock peripheral to the veins and shear zones consists of granite and porphyritic andesite-latite replaced by sericite and dolomite, and clay minerals developed on fracture planes. Negligible amounts of base and precious metals and thorium accompany the uranium. Mineralized material is mostly concentrated along a north-trending shear zone, 3,300 ft west of South Lottis Creek, and postdates or is a late stage of emplacement of the porphyritic andesite-latite sills and dikes.

Area 2, along the Broncho Mountain fault, has a moderate potential for uranium in small shear-zone deposits in the granite of Taylor River (unit Yt). Autunite was recognized in drill core from one of the mineralized zones, but surface details are obscured by glacial cover. Uranium anomalies also extend northward along the thrust fault on Cross Ridge (an informal name for the ridge between Cross Mountain and Broncho Mountain). The age of this mineralization is unknown, but it is probably middle Tertiary and related to movement on the Broncho Mountain fault.

Area 3, along the Boulder fault, has a moderate potential for uranium in small vein deposits associated with base metals along the fault and in the Paleozoic limestone (A. J. Pansze and B. O. Brodsky, Cruson and Pansze Associates, written commun., 1982). Area 3, in the Lamphier Creek drainage, has a moderate potential for uranium in an ill-defined zone trending northwest near Lamphier Lake that cuts Precambrian metasedimentary rocks (H. G. Brown, III, Exxon USA, oral commun., 1982).

Area 4, the region between Crystal Creek and Tranquility Ridge, has a moderate to high potential for uranium in a geologic setting similar to that of area 1. Area 4 has not been as well studied as area 1, primarily because of the extensive glacial cover, and no mineralized targets have been drilled. However, the anomalous amounts of uranium in samples probably indicate that mineralized material is concentrated along the Crystal Creek fault and in a parallel shear zone 1.5 mi to the east. Uranium deposits in these shear zones are probably similar in size and grade to those in area 1. The age of mineralization is unknown but is probably middle to late Tertiary.

Areas 1, 2, and 4 have a high potential for uranium in small but possibly high-grade surficial deposits in lake-bottom sediments, glacial bogs, and alluvial material along stream drainages. Reconnaissance radiometric surveys by J. K. Otton (oral commun., 1983) of the alluvial material that overlies the granite of Taylor River suggests the presence of young (Holocene?) uranium deposits on the west side of Tranquility Ridge, along South Lottis Creek and its western tributaries north of Henry Lake, and northeast of Broncho Mountain. Geochemical samples from these areas have been collected, but the analyses are not yet available.

Area 5, along the Lottis Canyon fault, has a moderate to low resource potential for uranium in small, low-grade deposits associated with shear zones parallel to the fault or in the adjacent Paleozoic rocks. Uranium mineralization here is related to movement on the fault and is likely Tertiary in age.

Area 6, in the upper reaches of Crystal Creek, has a low resource potential for uranium. The source of mineralized material is unknown, but the anomalous amounts of uranium could indicate concentrations of zircon or other detrital minerals in the glacial material.

Thorium-lanthanum-rare earth element resource potential

Anomalous concentrations of thorium, lanthanum, and the light rare-earth elements, especially cerium, were found in stream-sediment samples from area 1, the region along and east of Gandy Gulch and Summerville Creek (fig. 6). The source of mineralized material is unknown, but because the anomalous samples outline a linear area in the granite of Taylor River (unit Yt), a shear zone or pegmatite body may be the source. The abundance of cerium and light rare-earth elements suggests that fluocerite, monazite, or cerite could account for the anomalous amounts of these elements. Even though the type of mineralization is unknown, the extent of the anomalous area and size of the anomalous values suggests that this area has a moderate to high potential for thorium and rare-earth elements. The grade of the deposit is probably low, but the amount of low-grade material could be large.

Area 2, along the north-trending shear zone that contains much anomalous uranium, contains slightly anomalous amounts of samarium. Apparently, some uranium minerals may be accompanied by minor amounts of rare-earth minerals. However, this area has only a low potential for rare-earth elements due to the low concentrations of samarium and the limited extent of the anomalous area.

Area 3, along the upper reaches of South Lottis Creek, also has a low potential for rare-earth elements associated with an unidentified deposit. Rare-earth elements in areas 2 and 3 would not be considered resources except for the coexisting uranium.

Cobalt-chromium-niobium-tantalum-tungsten resource potential

Samples from parts of the Fossil Ridge Wilderness Study Area have slightly to moderately anomalous concentrations of cobalt, chromium, niobium, tantalum, and tungsten (fig. 7), but only three areas are considered to have a low resource potential for any of these elements. Area 1, north of Green Mountain, is on the western edge of an area of tungsten-molybdenum veins in the Tincup district

(Goddard, 1935; Tweto, 1943); it has a low potential for tungsten in small, discontinuous vein deposits of medium grade. Veins in this area are related to the Tertiary latite porphyry at Green Mountain. Area 2, west of Crystal Creek, may have minor amounts of tungsten, cobalt, and chromium associated with the Proterozoic diorite (unit Xd), but it has a low resource potential for any of the elements due to the small size of the anomalous area. Area 3, along the Boulder fault, probably has chromium and cobalt associated with the base-metal elements in the vein deposits and, hence, has a low resource potential for these elements. However, chromium and cobalt could not be considered resources except for the coexisting base-metal elements.

Beryllium-lithium-boron-tin resource potential

Area 1 (fig. 8), north of Green Mountain, has a low potential for tin in either vein or disseminated deposits related to the latite porphyry at Green Mountain. The veins would be narrow, discontinuous, and of medium grade. A disseminated deposit would be in the latite porphyry, and the tin would be a resource only because of coexisting molybdenum and tungsten. Area 2, a large area between Cross Ridge and Crystal Creek, has a low potential for beryllium and tin related to disseminated beryl(?) and accessory tin minerals(?) in the granite of Taylor River (unit Yt). Areas 3A and 3B, along Fossil Ridge and south of Henry Mountain, respectively, have a low potential for boron related to tourmaline deposits in the granite of Henry Mountain (unit Xh). Tourmaline veins are most numerous along Fossil Ridge in the Proterozoic metasedimentary rocks, but as much as 2 percent disseminated tourmaline occurs in the granite at least 1.4 mi inside the margin of the intrusion. The resource potential for boron is low because of the difficulty in beneficiation of boron from tourmaline. Area 4, between Gold Creek and Boulder Gulch, has a low to moderate potential for tin that may be present as disseminated accessory tin minerals(?) in the Tertiary rhyolite (unit Tr) exposed along Gold Creek. However, because the anomalous tin is noted in sediment samples from streams that drain Proterozoic metavolcanic rocks above and adjacent to the rhyolite stock, another unknown source for the tin could exist.

High-calcium limestone resource potential

The Mississippian Leadville Limestone on Fossil Ridge (area 4, fig. 6) is a relatively pure calcium carbonate limestone, whereas the composition of the Leadville in surrounding areas is dolomitic (Johnson, 1944). Samples from a 12.6-m-thick interval of the Leadville, drilled in four places along Fossil Ridge, averaged 0.02 percent SiO_2, 0.05 percent Al_2O_3, 55.79 percent CaO, and 0.44 percent MgO, with less than 0.02 percent total of TiO_2, Na_2O, K_2O, and MnO, and 0.07 percent Fe_2O_3 (George Apostalos, Colorado Minerals Corp., written commun., 1983). This limestone contains more than 99 percent $CaCO_3$ and less than 1 percent $MgCO_3$, and is therefore a commercially valuable high-calcium limestone. Area 4 (fig. 6) contains many million tons of the Leadville Limestone, and if a large proportion of it is comparable to that sampled by the drill holes, the area has a high potential for high-calcium limestone that is not readily available outside the Fossil Ridge area.

Volcanogenic massive sulfide (copper-zinc-gold-silver) resource potential

Most of the rocks between Fossil Ridge and Gold Creek are Proterozoic metamorphosed mafic and felsic volcanic rocks (fig. 2), which in most places would be considered excellent hosts for volcanogenic massive sulfide (copper-zinc-gold-silver) deposits. However, the metavolcanic rocks in this area lack many of the features associated with such deposits. In particular, there is no banded iron-formation, ferruginous chert, or other chemically precipitated rock such as chert or limestone interbedded with the volcanic rocks. Also, the felsic volcanic rocks appear to be subaerial tuffs, not the submarine flows and pyroclastic rocks commonly associated with such deposits. Because of these differences, the Proterozoic metavolcanic rocks in the Fossil Ridge Wilderness Study Area have a low potential for copper, zinc, gold, or silver resources related to volcanogenic massive sulfide deposits.

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