STUDIES RELATED TO WILDERNESS

MOUNT ZIRKEL WILDERNESS AND NORTHERN PARK RANGE VICINITY, COLORADO

U.S. GEOLOGICAL SURVEY BULLETIN 1554

Mineral Resources of the Mount Zirkel Wilderness and Northern Park Range Vicinity, Jackson and Routt Counties, Colorado

By GEORGE L. SNYDER, U.S. GEOLOGICAL SURVEY,
LOWELL L. PATTEN, U.S. BUREAU OF MINES, *and*
JEFFREY J. DANIELS, U.S. GEOLOGICAL SURVEY

STUDIES RELATED TO WILDERNESS—WILDERNESS AREAS

U.S. GEOLOGICAL SURVEY BULLETIN 1554

An evaluation of the mineral resource potential of the area

Includes Davis Peak Roadless Area and adjacent wilderness established by P. L. 96–560

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STUDIES RELATED TO WILDERNESS

WILDERNESS AREAS AND STUDY AREAS

In accordance with the provisions of the Wilderness Act (Public Law 88-577, Sept. 3, 1964) and related acts, the U.S. Geological Survey and U.S. Bureau of Mines have been conducting mineral surveys of wilderness and primitive areas. Studies and reports of all primitive areas have been completed. 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. This report discusses the results of a mineral survey of some national forest lands in the Mount Zirkel Wilderness and northern Park Range vicinity, Colorado, that are being considered for wilderness designation, and of an equal amount of surrounding land that has not been considered for wilderness designation. Since the initial writing additional wilderness adjacent to the original Mount Zirkel Wilderness has been established by Public Law 96-560, Dec. 22, 1980, and the adjacent Davis Peak Roadless Area was classified as further planning during the Roadless Area Review and Evaluation (RARE II) by the Forest Service, January 1979. Both are shown on the index map figure of this report but are not otherwise referred to herein; the area of each is completely covered by the geologic, geochemical, and geophysical studies contained in this report.

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STUDIES RELATED TO WILDERNESS—WILDERNESS AREAS

MINERAL RESOURCES OF THE MOUNT ZIRKEL WILDERNESS AND NORTHERN PARK RANGE VICINITY, JACKSON AND ROUTT COUNTIES, COLORADO

By GEORGE L. SNYDER, U.S. GEOLOGICAL SURVEY,
LOWELL L. PATTEN, U.S. BUREAU OF MINES, and
JEFFREY J. DANIELS, U.S. GEOLOGICAL SURVEY[1]

SUMMARY

A mineral resource survey of the Mount Zirkel Wilderness and adjacent area (971 km^2 or 375 mi^2) and its surroundings was made by the U.S. Geological Survey and U.S. Bureau of Mines during the summers of 1965–73. The area studied, 2,458 km^2 or 945 mi^2, lies in the northern Park Range along the Continental Divide between Steamboat Springs and Walden, Colorado, immediately south of the Colorado-Wyoming State line. Almost all of this wilderness area is underlain by Precambrian rocks, mainly amphibolitic to felsic high-grade metavolcanic rocks with minor interlayered metashale and marble that have been intruded by bodies of syntectonic gabbro, quartz monzonite, quartz diorite and peridotite, and posttectonic quartz monzonite and granite. All the Precambrian rocks were cut by northeast-trending, largely left-lateral mylonite shear zones. The adjacent area is underlain largely by the same crystalline rocks, although significant Mesozoic and Miocene sedimentary rocks flank both sides of the range. Additional post-Cretaceous compressional faults and post-Miocene tensional faults offset the younger sediments; some of these follow the Precambrian zones of weakness, and some are at a large angle to them.

The mineral resource potential of the area was evaluated by geologic studies including geologic mapping, by detailed examination of rocks and mining claims, by geochemical and geophysical surveys, and by analysis of the derived data. A total of 3,352 samples were collected and studied by petrographic and chemical methods. Known surface deposits of fluorspar veins, base- and precious-metal sulfide veins and manto deposits,

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and uranium-thorium veins have been explored or mined, and may be economically productive in the future, chiefly near the fringes of the adjacent area. Several areas at the surface in the centrally located Gilpin district (figs. 3, 14, 70) have anomalous concentrations of copper, lead, zinc, gold, silver, tin, and mercury and have low to moderate mineral resource potential. Stream-sediment geochemical data indicate that surface ore zones in rugged topography with rapid erosive dispersal of elements (like that of the lower Greenville mine) are unlikely to have escaped detection. However, some small blind veins (like those at the Elkhorn mine), or surface ores in gentle topography with slow erosive dispersal of elements (like the upper Greenville mine) could have escaped geochemical detection. No large high-grade metal deposits are present at the surface in the Mount Zirkel Wilderness or vicinity, but several geologic environments are present that are favorable for the subsurface occurrence of certain types of mineral deposits, some of which may be of substantial value. These include base-metal sulfides along three belts across the wilderness area, fluorspar within the Mount Ethel pluton in the wilderness area, uranium, mercury, and molybdenum deposits associated with possible Tertiary plutons buried beneath the wilderness area, and layered chromium-platinum ores under the northwestern part of the adjacent area. An aeromagnetic survey identified several positive magnetic anomalies that could indicate mineralization at depth within the wilderness area (pl. 1). A search for the platinum group elements in numerous small surface exposures of ultramafic rock has failed to identify economic deposits, but the data indicate some potential. Other commodities investigated have little value because of small volume, poor quality, or unfavorable economic factors. There is no potential for coal, and only a slight potential for oil and gas, largely in undrilled overthrust areas near the western boundary of the adjacent area. Evidence for geothermal resources is present only outside the Mount Zirkel Wilderness and adjacent area.

INTRODUCTION

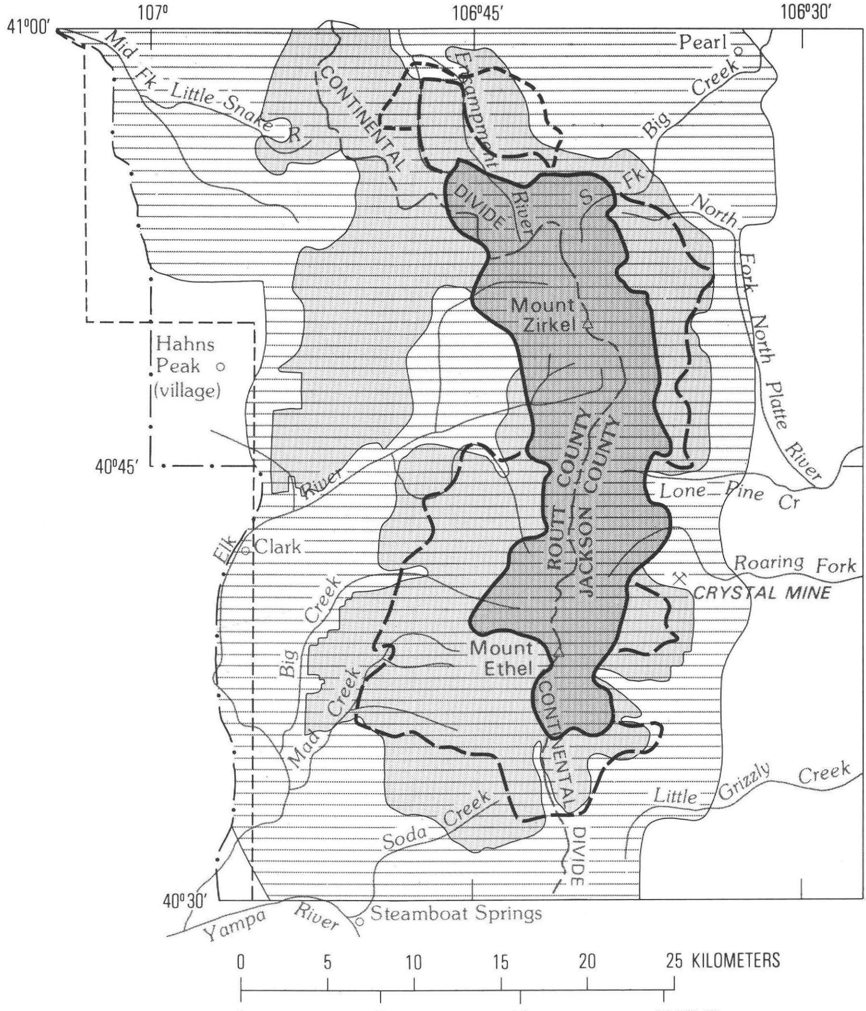
The Mount Zirkel Wilderness and adjacent area covers about 970 km^2 (375 mi^2) of rugged terrain astride the Continental Divide in Jackson and Routt Counties, Colo. (295 km^2 or 114 mi^2 in the Mount Zirkel Wilderness).[2] Geochemical, geophysical, and geological surveys have covered more than twice the area of the Mount Zirkel Wilderness and adjacent area (fig. 1); the surveyed area lies entirely within Routt National Forest. Mean annual precipitation ranges from 30 cm (12 in.) at lower levels to four times this on the highest mountains; most moisture falls in the form of snow, and snowfields persist all summer in the high cirques. (For illustration see figs. 9, 16.) Westward drainage flows into the Little Snake-Elk-Yampa River system, and northward and eastward drainage is part of the Encampment-North Platte River system. Runoff is profuse, especially in the spring; the average Park Range stream has an average discharge of more than an acre-foot of water per day for each square mile of its drainage area (Todd, 1970, p. 139, 140, 167).

[2]For this report, most original measurements were made in inches, pounds, or U.S. customary units and converted to equivalent metric units. The precision of the original measurement or statement as well as of the conversion varies and can best be judged from the context. Elevations taken from topographic maps printed in feet are given first in the map unit, and those numbers are then shown converted to meters.

Scenery in the Mount Zirkel Wilderness is spectacular, especially in the vicinity of Big Agnes Mountain and Mount Zirkel in the north (fig. 2) and Mount Ethel and The Dome in the south (Snyder, 1978, figs. 4, 5*B*). Streams and (former) glaciers have carved deep canyons in Precambrian crystalline rocks; rapids and small waterfalls are prominent along many streams. Some of the tarn, cirque, and paternoster lakes are among the most beautiful anywhere (fig. 3). Total relief is nearly 1,525 m (5,000 ft), ranging from an altitude of less than 7,200 ft (from topographic map; 2,200 m) along Big Creek in the southwest to 12,180 ft (3,712 m) on Mount Zirkel; most of the major peaks rise above 11,400 ft (3,475 m). The barren high ridges expose varicolored resistant Precambrian schist, gneiss, and granofels. Timberline lies at an average of 10,500 ft (3,200 m), but can vary 210 m (700 ft) up or down from this average. Ribbon forests—stable linear stands of evergreens with parallel intervening meadows (fig. 15)—are extensive near timberline especially in the vicinity of Buffalo Pass (Buckner, 1977). An extensive spruce–fir–lodgepole pine–aspen forest blankets most of the intermediate slopes; valleys and lower slopes are locally swampy or choked with brush. Numerous species of wild game share the forests and meadows in summer with grazing livestock and camping people.

Access to the Mount Zirkel Wilderness and adjacent area is by numerous all-vehicle roads. Popular ingress points are Buffalo Pass, Strawberry Park, numerous points along the Elk River and its tributaries (especially Slavonia at the end of the Elk River road), Big Red Park, the Encampment River, Big Creek Lakes, Lone Pine Creek, Norris Creek, and Little Grizzly Creek. More than 140 U.S. Forest Service camp units were available in established campgrounds in 1976 along the border of the area; in addition, numerous State-supported (for example, near Steamboat Lake) or informal campsites are available along the area margins. Movement within the area is necessarily on foot or horseback along the well-established trail system, or overland, except for a very few four-wheel-drive roads. One of these, the historic Ellis Trail, the earliest stage and wagon route between Columbine and Hog Park, Wyo., via Big Red Park, winds across the Continental Divide and along the South Fork Hog Park Creek in the northwest corner of the area. Another four-wheel-drive road crosses the summit of Farwell Mountain between North Fork Elk River and Twin Mountain. Vehicular traffic has been prohibited in recent years along two former jeep roads—up West Fork Encampment River and from Buffalo Pass to Luna Lake.

A variety of maps and aerial photographs covers the area. Part of the U.S. Army's 1:1,000,000 Cheyenne sheet (NK13) covers the area with planimetry and 500-m contours. Likewise, part of the U.S.



EXPLANATION

- Mount Zirkel Wilderness
- Adjacent area
- Area of geochemical survey
- Western boundary of aeromagnetic survey—Entire area to right of line was surveyed
- Western boundary of geological survey—Entire area to right of line was surveyed

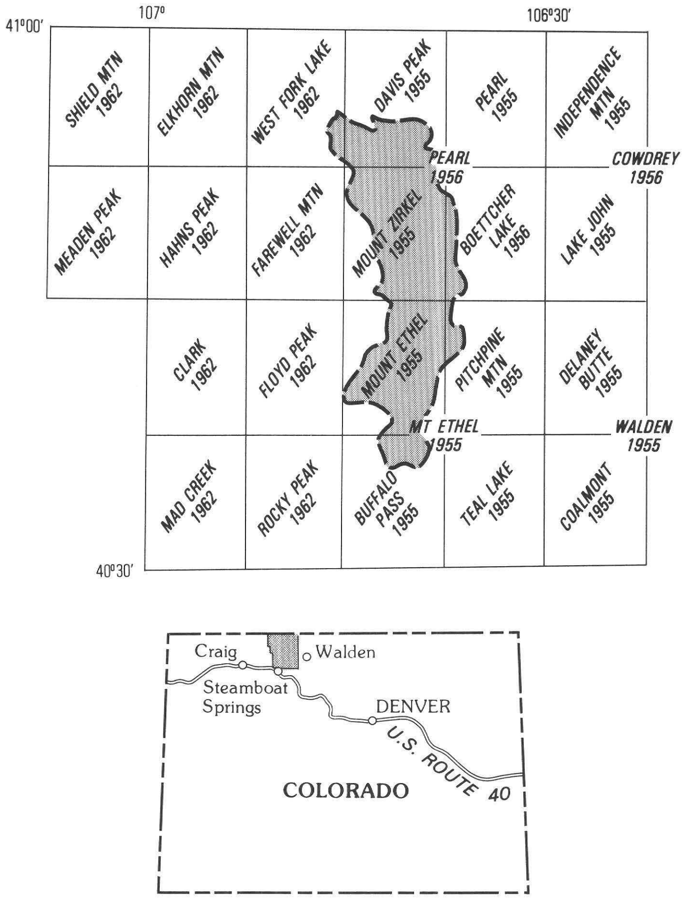


FIGURE 1 (above and facing page).—Index map of Mount Zirkel Wilderness and adjacent area, showing areas surveyed for this report and U.S. Geological Survey topographic maps. Heavy solid line, outline of Mount Zirkel Wilderness; heavy long-dash line, wilderness established by P.L. 96-560; heavy short-dash line, Davis Peak roadless area.

Geological Survey 1:250,000 Craig sheet covers the area with planimetry and 200-ft contours; that part of the map has been enlarged to 1:125,000 and serves as the base for the geologic map (pl. 1). A U.S. Forest Service planimetric map of the Routt National Forest, showing drainages and trails, is available at a scale of 1:126,720. U.S. Geological Survey 7 1/2-minute quadrangle topographic and forest-overprint maps, at a scale of 1:24,000 and with 20- or 40-ft contours, cover the area (fig. 1); a composite of 17 of these maps, reduced to 1:48,000, serves as the base for the sample map (pl. 2). Along the east side of the area, the 7 1/2-minute quadrangles have been series-converted into 15-minute, 1:62,500 quadrangles. U.S. Forest Service aerial photographs, scale 1:20,000, taken during flights in 1957, cover the area. In addition, the entire range is covered by satellite photography, and selected portions are covered by detailed photography at various scales.

GEOLOGIC INVESTIGATIONS BY OTHERS

Most previous geologic investigations in and adjacent to the Mount Zirkel Wilderness have been limited in scope, but the history of investigations stretches back to the reconnaissance geologic exploration of the Colorado Territory in the last half of the nineteenth century. In fact, the earliest petrographic studies of the crystalline rocks were of the granite on Mount Ethel and the hornblende gneisses of Mount Zirkel and the upper Encampment drainage by Ferdinand Zirkel, for whom Mount Zirkel is named (King, 1878, p. 37–40). Turn-of-the-century geologic-economic interest focused on the coal beds on either side of the Park Range (R. C. Hills, 1893; Hewett, 1889; Parsons and Liddell, 1903; Fenneman and Gale, 1906; Gale, 1909, 1910; Ball and Stebinger, 1910; Beekly, 1915), the nodular copper-bearing schists at Pearl (Read, 1903; Spencer, 1903b), the copper deposits of the Encampment district, Wyoming (Spencer, 1903a, 1904), the Hahns Peak gold field (Gale, 1906; George and Crawford, 1909), and the Rabbit Ears region (Grout and others, 1913). Anticlines of western Routt County, some productive of oil and gas, have been summarized by Crawford, Wilson, and Perini (1920); the easternmost mapped anticline, the Trull, extends into the extreme southwestern part of the present map area (Crawford and others, 1920, pl. 1). Geological publications concerned with the northern Park Range abated between 1920 and the early 1950's, with the exception of Atwood's (1937) glaciological and Christensen's (1942) Tertiary igneous studies.

More modern geological studies adjacent to the Park Range began with Steven's thorough coverage of the Northgate fluorspar district east of the area (Steven, 1954, 1956, 1957, 1960). The geology and mineral fuels of a large area west of Steamboat Springs were reviewed by Bass, Eby, and Campbell (1955). Mesozoic and Tertiary stratigraphy and structures along the east side of the range were mapped by Hail (1965, 1968). Buffler (1967) reviewed the distribution and origin of the Browns Park Formation throughout the region. The Hahns Peak–Farwell Mountain area has been the subject of recent detailed studies (Segerstrom and Kirby, 1969; Segerstrom and Young, 1972; Young and Segerstrom, 1973). Numerous university theses have covered smaller areas, generally about 50 square miles per thesis, throughout the northern Park Range and Sierra Madre (Ritzma, 1949; Welsh, 1951; Rollins, 1952; Wakefield, 1952; Walters, 1953; Barnwell, 1955; de la Montagne, 1955; Hunter, 1955; Murphy, 1958; Short, 1958; McConnell, 1960; Wied, 1960; Scott, 1961; Kucera, 1962; Merry, 1963; Walton, 1963; Ferris, 1964; Fenton, 1965; Lackey, 1965; De Nault, 1967; Hill, 1969; Ebbett, 1970; Huang, 1970; Miller, 1971; Ridgely, 1971; and Graff, 1973). The geology and geochemistry of the Sierra Madre of Wyoming have recently been summarized by Houston, Schuster, and Ebbett (1975), Divis (1975, 1976), Houston and Ebbett (1977), Graff (1978), and Houston, Karlstrom, and Graff (1979). Several aspects of the regional geologic, stratigraphic, or tectonic setting of the northern Park Range area or the sedimentary basins on either side of it are covered in numerous recent reports (Oriel, 1954; T. G. Larson, 1955; Osterwald and Dean, 1958, 1961; Tweto and Sims, 1963; Tweto, 1968, 1975a, b, 1976a, b, 1977a, b, c; Barclay, 1968; Behrendt and Popenoe, 1969; Behrendt and others, 1969; Izett and others, 1971; Izett and Barclay, 1973; Izett, 1975; E. E. Larson and others, 1975; Blackstone, 1977; Hedge and others, 1977; Madden, 1977a, b; Park, 1977; Wellborn, 1977; Warner, 1978; and Snyder, 1977a, b, c, 1978, 1980a, b, c, 1984). Landslides on the Craig 1° × 2° quadrangle have been mapped by Colton and others (1975), and other surficial deposits are currently being studied by R. F. Madole (1982, and written commun., 1976).

PRESENT STUDIES AND ACKNOWLEDGMENTS

The purpose of this study was to appraise the mineral resource potential of the Mount Zirkel Wilderness and vicinity. The report is a cooperative effort of the U.S. Geological Survey and the U.S. Bureau of Mines. The USGS (U.S. Geological Survey) fieldwork included geologic mapping and sample collecting and took place from 1965 through 1967 and from 1970 through 1973 (pl. 1). The fieldwork was supervised by G. L. Snyder, working with Warren Hamilton in part of the 1965 field season; Fredric Hoffman, 1966; R. L. Bonewitz, 1967; P. W. Schmidt, 1970 and 1972; and Paul Graff, 1971 and 1972. The

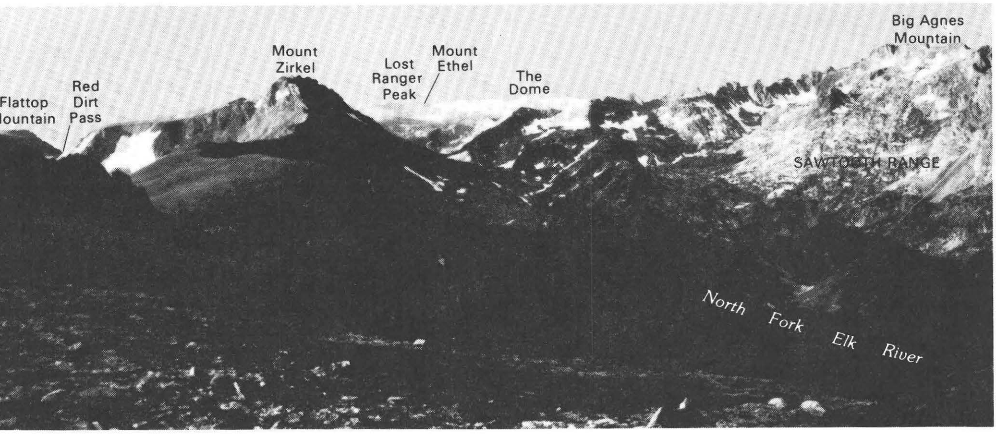
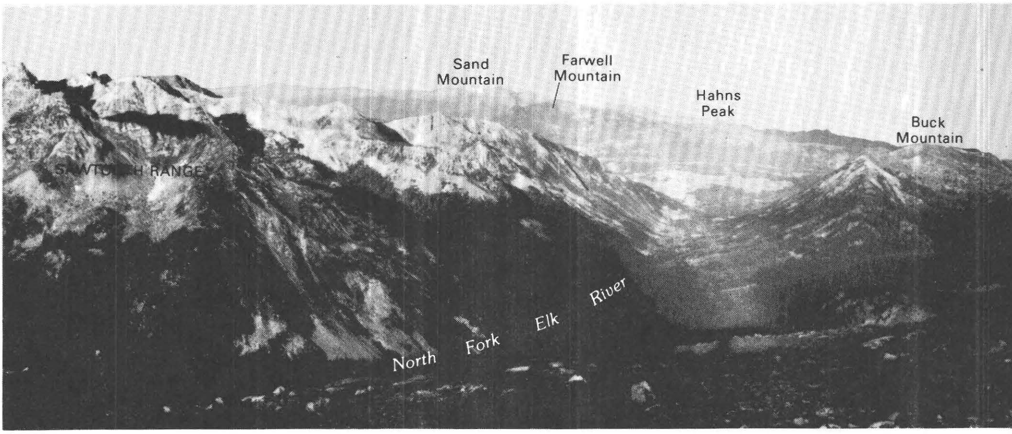


FIGURE 2.—View south to Mount Zirkel and west to Sawtooth Range and North Fork
brian interlayered quartz monzonite, pegmatite, felsic gneiss, amphibolite, and pelitic

area was mapped geologically via foot traverses (with one-quarter-mile or closer spacing). The resulting geologic maps are available in two sheets (Snyder, 1977a, b, 1980a, b), at a scale of 1:48,000, and the geology and aeromagnetics of the entire area are summarized in simplified form on plate 1 at 1:125,000.

The USBM (U.S. Bureau of Mines) work consisted mainly of a records search of Routt and Jackson Counties (including records of Larimer County before 1909, when Jackson County was formed from Larimer) for mining locations, and a field investigation of mining claims, prospect workings, and mineral deposits. These county records contain many mining location notices recorded since the 1870's within and near the subject area, and many of the claims are shown in the illustrations of this report. H. C. Meeves and R. A. Beach assisted with the records search. Assistance received from personnel of the U.S. Forest Service and the Jackson, Larimer, and Routt County Clerks' Offices was most helpful. Fieldwork was done by L. L. Patten with the assistance of R. A. Beach, R. J. Jurt, O. D. Staman, and D. D. Keill during 1971 and 1972. The U.S. Bureau of Land Management provided records of oil and gas leasing and patented mining claims.

In the course of these investigations 3,352 samples were collected, 3,240 by the USGS, and 112 by the USBM. Analyses of most USGS samples are available in Snyder and others (1981); analyses of most USBM samples are available in tables 2, 3, and 4 of this report. Of the USGS samples, 1,255 are stream sediments, which have been analyzed by atomic absorption methods for silver, gold, copper, lead,



Elk River from Continental Divide north of Mount Zirkel. Rocks are mainly Precam- schist; Mesozoic sediments underlie low meadows between viewer and Hahns Peak. August 1970.

and zinc and by standard semiquantitative spectrographic techniques for a suite of 30 elements. The other 1,985 samples are mainly rock specimens (a few are soils), most of which were thin sectioned for petrographic study. Three hundred fourteen of these are potentially mineralized rocks which were analyzed by atomic absorption methods for silver, gold, copper, lead, and zinc; by detector for mercury; and by standard semiquantitative spectrographic techniques for a suite of 30 elements. Atomic absorption analyses of stream sediments or potentially mineralized rocks were made by R. B. Carter, J. G. Frisken, J. D. Hoffman, E. Martinez, A. L. Meier, J. Mitchell, J. M. Motooka, R. M. O'Leary, T. Roemer, Z. Stephenson, R. Tripp, and S. H. Truesdell. Mercury detector analyses were made by W. Campbell, J. G. Frisken, and J. James. Semiquantitative spectrographic analyses were made by R. Babcock, W. D. Crim, G. W. Day, J. H. Domenico, C. Forn, R. T. Hopkins, Jr., E. Mosier, J. M. Motooka, and A. L. Sutton, Jr. In addition, 32 stream sediments and 22 potentially mineralized rocks possessing 20 ppm or greater niobium, were analyzed by delayed neutron technique for uranium and thorium by H. T. Millard, Jr., C. L. Shields, C. M. Ellis, R. L. Nelms, and C. A. Ramsey. Standard chemical analyses have been run on 95 typical crystalline rocks for 14 major oxides (plus chlorine and fluorine for 26, Cr_2O_3 and NiO for 1) by E. L. Brandt, E. Engelman, G. O. Riddle, and V. C. Smith. Ninety-seven ultramafic or related rocks have been analyzed for platinum, palladium, and rhodium by L. B. Breeden, W. D. Goss, Joseph Haffty, A. W. Haubert, H. G. Neiman, and L. B. Riley. One

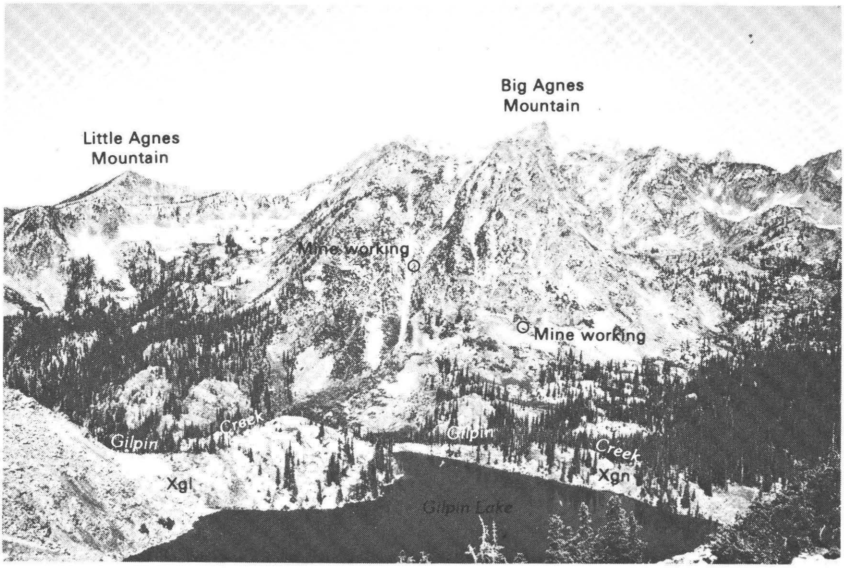


FIGURE 3.—View north over Gilpin Lake to Big Agnes Mountain. Quartz diorite of Gilpin Lake well exposed in glacially polished whaleback left of lake. Two mine portals labeled, across Gilpin Creek on lower slopes of Big Agnes Mountain. Xgl, quartz diorite, and Xgn, felsic gneiss, both of Proterozoic X age. August 1971.

hundred fifty-five of the typical crystalline rocks or the ultramafic rocks have been analyzed by standard semiquantitative spectrographic techniques for a suite of 34 elements by L. A. Bradley, L. D. Forshey, J. C. Hamilton, B. W. Lanthorn, H. G. Neiman, and G. W. Sears, Jr. R.L. Rahill has run colorimetric Cr_2O_3 analyses on nine of the ultramafic rocks; J. G. Crock and G. O. Riddle have run Na_2O_2 fusion-colorimetric Cr_2O_3 analyses on four other mafic rocks. Also, Wayne Mountjoy has run spectrophotometric SiO_2 and Al_2O_3 analyses on two rocks. Eleven hot-spring waters from the Steamboat Springs Group were analyzed for lithium by P. R. Barnett in 1950. Twenty-five USBM ore samples were analyzed in the USGS laboratories by standard semiquantitative spectrographic techniques for a suite of 30 elements by J. H. Domenico and R. T. Hopkins, Jr. G. H. Allcott, T. M. Billings, H. E. Eichler, S. K. McDanal, R. V. Mendes, C. M. McDougal, and L. O. Wilch assisted with computer storage and retrieval of analytical data.

All analyses of ores and stream sediments prepared by the USGS for G. L. Snyder are available on open file (Snyder, 1981). These analyses are summarized in tables 5 and 6, and the geographic distribution of the anomalous chemical data is shown on map figures 52–104. Semiquantitative spectrographic data for unmineralized crystalline rocks are presented in table 7. All analyses prepared for the USBM are given in tables 2–4.

In addition, a geochemical survey using 805 soil samples is available for a 16 mi^2 area centered on Hahns Peak overlapping the northwest edge of the area studied (pl. 2; Young and Segerstrom, 1973, fig. 2, p. 10, 11). Also, 144 modern chemical analyses of several types are available for Tertiary and Precambrian crystalline rocks in southwestern North Park (Hail, 1968, table 3, p. 54–55), the Hahns Peak area (Segerstrom and Young, 1972, tables 1, 5, 7, p. 10, 11, 38, 39, 42; Young and Segerstrom, 1973, table 1, p. 14–15), and the Wyoming Sierra Madre (Divis, 1976, tables 1, 3–7, 9; p. 25, 48, 49, 57, 58, 64, 65, 72, 76, 89). Available radiometric geochronologic data for the vicinity of the northern Park Range are reviewed by Segerstrom and Young (1972), Divis (1977), and Snyder (1978).

Many professional colleagues in the USGS and USBM besides those specifically mentioned also helped with the field, laboratory, manuscript, or illustration work, and we are deeply grateful for their help. Our gratitude is also expressed to the many people outside the USGS and USBM who assisted in some way in the preparation of this report. Walter Metcalf and Gay Weidenhaft of the U.S. Forest Service located the surveyed boundaries of the Mount Zirkel Wilderness and adjacent area on USGS topographic maps (written commun., April 1972). Richard Dirmeyer, Warren Hartman, Melvin Hitchings, and Parker T. Qualls of the U.S. Forest Service were helpful in the field. Joseph Gerrans and James Houston of the Colorado Natural Resources Department were most cooperative in helping maintain order at one campsite repeatedly raided by six bears. The following geologists contributed unselfishly to many geological discussions or educational field trips: W. A. Bowes (Steamboat Springs, Colo.), R. T. Buffler (Galveston, Texas), A. F. Divis (Lakewood, Colo.), A. B. French, Jr. (Houston, Texas), Paul Graff (Casper, Wyo.), J. J. Hill (Colorado State University), R. S. Houston (University of Wyoming), E. E. Larson (University of Colorado), M. E. McCallum (Colorado State University), and A. E. Miller (Steamboat Springs, Colo.). Robert Perry and Alex Paul (Ozark Mahoney Co.) sponsored a private survey of the fluorite veins underground at the Northgate mine. R. R. Ogilby (Minerals Exploration and Development, Ltd.) conducted a tour of several then-active fluorite prospects above the Crystal mine. Numerous local residents extended courtesies throughout the field investigations, often without introduction or identification. The following residents, whose names are known, were especially helpful: Ray Barrows, Donald Hoelzen, Mary Morgan, the late Gerry Truax, and Forrest Warren of Steamboat Springs, Gary Hayter and Luis Nagra of Three Forks Ranch, Mr. and Mrs. Ralph Warrick of Big Creek Ranch

and Craig, Mr. and Mrs. William Bush, then at Clark, and Melvin J. Bradley of Craig.

Geological Appraisal

By GEORGE L. SNYDER, U.S. GEOLOGICAL SURVEY

MINERAL RESOURCES OF THE MOUNT ZIRKEL WILDERNESS AND NORTHERN PARK RANGE VICINITY, JACKSON AND ROUTT COUNTIES, COLORADO

U.S. GEOLOGICAL SURVEY BULLETIN 1554-A

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MINERAL RESOURCES OF THE MOUNT ZIRKEL WILDERNESS AND NORTHERN PARK RANGE VICINITY, JACKSON AND ROUTT COUNTIES, COLORADO

GEOLOGICAL APPRAISAL

By George L. Snyder, U.S. Geological Survey

GEOLOGIC SETTING

The oldest rocks of the northern Park Range were formed in Precambrian time off the shore of a yet older continent to the north and have been added to by continent-building or affected by continent-shattering forces several times since that ancient origin. Some younger deposits or structures were controlled by, or appear to be related to, the oldest Precambrian rocks and stuctures; others are unrelated, or are not presently known to be related, to the rocks and structures of earlier Colorado history. Ironically, the old erosion-resistant Precambrian rocks that guarantee the presence of a mountain range of great scenic beauty are the ones that also guarantee maximum time and opportunity for the development of mineral resources useful to man. The oldest Precambrian rocks of southern Wyoming are 2.6 b.y. (billion years) old (Hills and others, 1968; Divis, 1977; Hills and Houston, 1979) in contrast to the oldest Precambrian rocks of northern Colorado which are 1.8 b.y. old (Peterman and Hedge, 1967; Peterman and others, 1968; Snyder, 1977a, 1978, 1980a). Isotopic evidence indicates that the Colorado rocks overlie new oceanic crust rather than older continental rocks (C. E. Hedge, Z. E. Peterman, R. F. Zartman, oral communs., 1967–77), so the boundary in southern Wyoming between these two provinces must represent the remains of the southern margin of an old continent. The Precambrian rocks discussed in this report include the younger Precambrian metavolcanics or metasediments deposited at the margin of this older northern continental mass, and the even younger rocks that intrude or overlie them. The general trend of Precambrian fold, fault, and intrusive structures south of this boundary is parallel to it, showing that this continental boundary has had a major effect in orienting subsequent Precambrian tectonic events. It is now the site of a major shear zone that trends northeast across the Medicine Bow Mountains and east across the Sierra Madre of southern Wyoming (fig. 4). Another major northeast-trending shear zone cuts the 1.4- to 1.8-b.y.-old rocks between Soda Creek and North Fork Fish Creek northeast of Steamboat Springs in the southern part of the mapped area (fig. 4; Snyder, 1978, fig. 2). Some shearing must have taken place after 1.4 b.y. ago because it affects rocks and structures of this age (Snyder, 1978). Possibly 19 km (12 mi) or more of left lateral offset has taken place along some of the shear zones (Snyder, 1978).

The available geologic record shows that uppermost Paleozoic and Mesozoic rocks (750–3,000 m, or 2,500–10,000 ft, of strata) were deposited next on top of the sheared, folded, and metamorphosed Precambrian rocks. This deposition was interrupted by repeated uplifts, as indicated by the near-source pebbles and boulders of Precambrian lithologies in nearly all the sedimentary deposits nearest the mountains. Folding and faulting intensified near the end of the Cretaceous Period and continued during deposition of sedimentary rocks of Paleocene and Eocene age (as much as 1,000 m, or 3,400 ft). In addition to reactivation of older faults (for example, fig. 18), the range was broken along north to northwest directions into several major fault blocks that today preserve partial Mesozoic sections within downfaulted or overridden parts of the range. Displacement along these faults of the Laramide orogeny (Cretaceous to Eocene age) must have been from a few thousand to several thousand meters, partly in a compressional regime, and partly tensional, at the extreme northernmost wedge-out of the Rio Grande rift zone (Tweto, 1977c). Deposition was also substantial in the Miocene (300 m or more), and this was followed by minor (as much as 300 m) normal faulting of diverse orientations. Late Miocene intrusives and contemporaneous faults cut the Miocene sediments along the west margins of the mapped area. Pleistocene glaciers sculptured the mountain highlands and canyons and left thick morainal deposits near their margins and extensive fluvial gravel terraces beyond their margins. Stream erosion and deposition and minor landsliding continue to this day.

PRECAMBRIAN ROCKS

The most widespread rocks of the Mount Zirkel Wilderness and adjacent area are Precambrian crystalline rocks. They fall into four main types in terms of volumetric importance and into three main groups in order of age. More than 90 percent of the exposed mountain ledges are mafic to felsic metavolcanics, intrusive igneous gabbros, or two types of quartz monzonites (Snyder, 1978). In addition, there are lesser amounts of layered metasedimentary rocks of several types (fig. 5) and ultramafic or intermediate intrusive rocks. Nearly all the Precambrian crystallines are medium to coarse grained, locally porphyritic, porphyroblastic, or augen-containing. Most rocks are resistant to erosion, forming ledges, cliffs, rapids, arêtes, or roches moutonnées. Colors range from light to dark in shades of gray, green, and pink. Metamorphic grade is high: amphibolite or higher, with pyroxene or sillimanite widely distributed as grade-indicator minerals. Extensive metamorphic recrystallization and shearing have eliminated all primary structures from most rocks, but rare exposures of preserved intersertal or coronitic structure in former mafic magmatic rocks and graded beds or crossbedding in former sediments testify that primary structures were once widespread. Generally oligomictic pod-rocks (fig. 6) containing pods, lenses or inclusions from 3 mm to 15 cm (1/8 in. to 6 in.) in diameter are common; they consist either of felsic pods in a mafic matrix or the reverse, and they owe their origins to a variety of causes. Some were definitely caused by sedimentary processes (such as calc-silicate concretionlike structures in layered gneisses; for example, fig. 6*A*), some by igneous extrusion or intrusion (such as agglomerates or contact breccias; for example, fig. 6*B*), and some by metamorphic differentiation (such as sillimanite-quartz-muscovite faserkiesel; for example, fig. 6*C*); some are without discernible genetic clues. Some fine-grained rocks near faults—mylonites—are the result of mechanical milling of originally coarser grained rocks after the peak of metamorphic crystallization.

METAVOLCANIC AND OTHER ROCKS

Most of the northern Park Range is underlain by the oldest Precambrian rocks, mainly medium grained mafic to felsic metavolcanics with smaller amounts of intercalated marine metasedimentary rocks, such as marbles. The rocks interpreted as metavolcanics are prominently to faintly layered pink, gray, or green gneisses of sillimanite grade, about 50 percent mafic and 50 percent felsic, but including rocks of

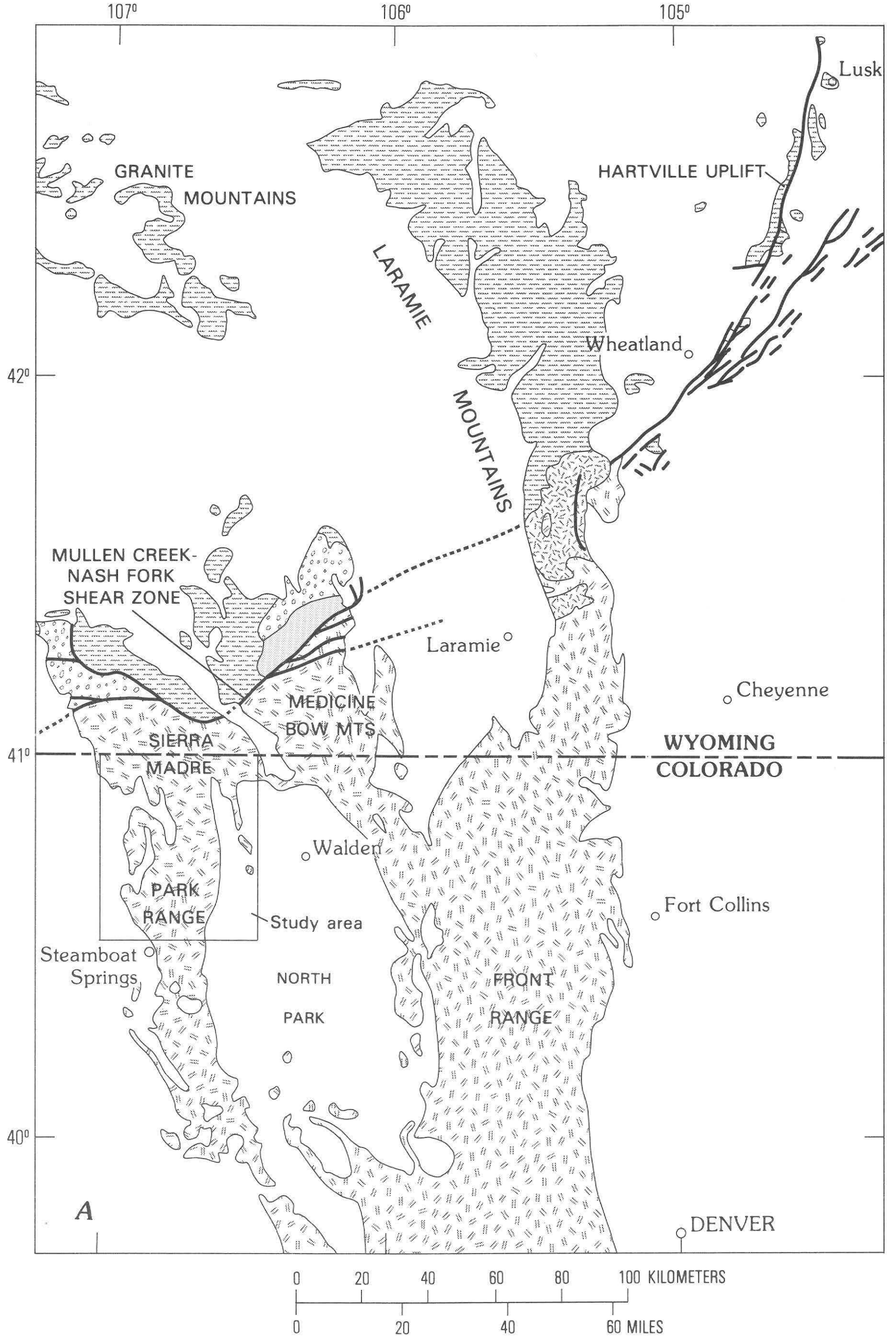
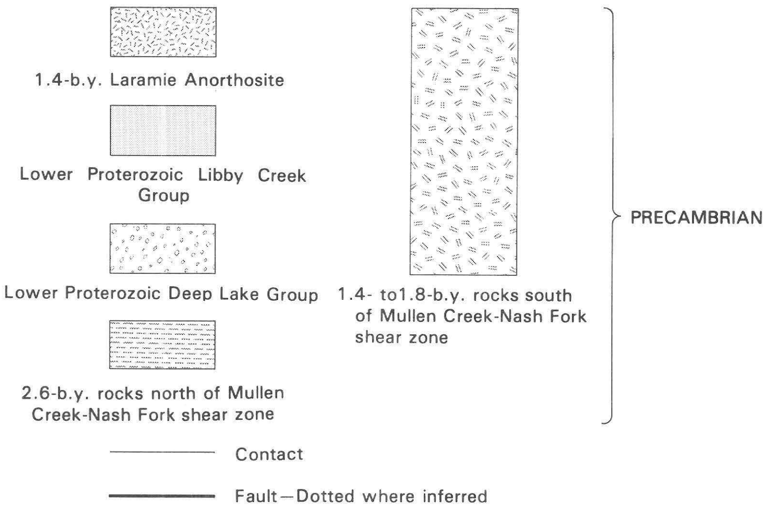


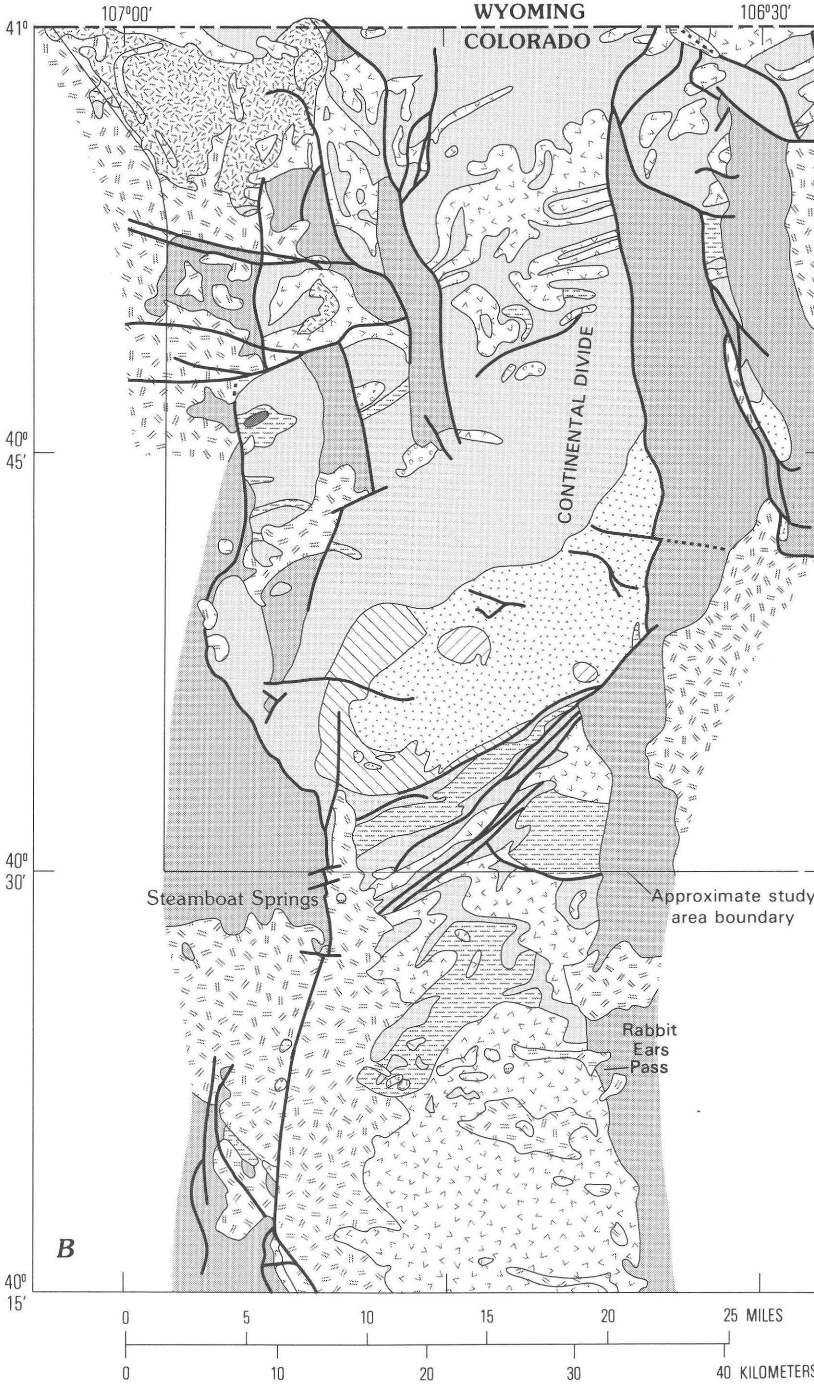
FIGURE 4 (above and next three pages).—Geologic index maps of Precambrian rocks. *A*, southern Wyoming and northern Colorado.

EXPLANATION FOR MAP *A*



a wide spectrum of compositions (figs. 5*A* and 5*B*). Also included but not described here are numerous bodies of pegmatite too small to show on plate 1.

The typical mafic metavolcanic rock is amphibolite consisting chiefly of subequal amounts of hornblende and calcic plagioclase with regionally important concentrations of biotite, garnet, or epidote. Amphibolites grade into mafic amphibolites with decreasing plagioclase or into hornblende gneisses with increasing plagioclase, biotite, and quartz. Amphibolites may be massive and unstructured, probably representing lava flows and near-surface intrusives, or they may be minutely layered, probably representing water-deposited basaltic ash (figs. 5*A*, 15). Layered amphibolites in many places are interlayered with, or contain inclusions or pods of, calc-silicate rock consisting of plagioclase, aluminous epidote, diopside, scapolite, calcite, and other minerals. The interlayered rocks may represent sediments from two sources, perhaps basaltic ash in a carbonate-secreting or carbonate-depositing environment; some interlayered rocks can be observed to grade laterally into pure calc-silicate rocks and eventually marbles. Some pod-rocks may be due to sedimentary processes with tectonic overprinting (fig. 6*A*), but exposures just across the Wyoming State line of amphibolite pillows with recrystallized carbonate mud in their interstices suggest that some similar Colorado pod-rocks without preserved primary structures may also have had a mixed igneous-sedimentary origin. The typical felsic metavolcanic rock is feldspar-quartz-biotite gneiss with sodic plagioclase and minor potassium feldspar. This rock grades



107°00′
WYOMING
106°30′
41°
COLORADO
CONTINENTAL DIVIDE
40°
45′
40°
30′
Steamboat Springs
Approximate study area boundary
Rabbit Ears Pass
B
40°
15′
0
5
10
15
20
25 MILES
0
10
20
30
40 KILOMETERS

DIAGRAMMATIC CROSS SECTION FOR MAP *B*

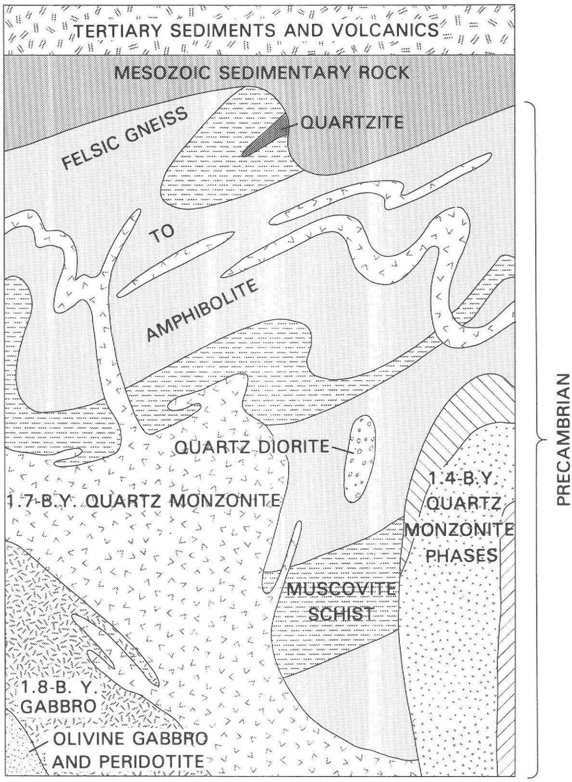


FIGURE 4 (continued).—Geologic maps of Precambrian rocks. *B*, northern Park Range. 1.4 b.y. quartz monzonite phases of the Mount Ethel pluton are coarse grained (diagonal line pattern from top left to bottom right), medium grained (coarse stipple), and fine grained (diagonal line pattern from top right to bottom left). Light line, contact; heavy line, fault (dotted where inferred).

with increasing hornblende into hornblende gneiss and with marked increase of biotite, or biotite with minor hornblende, into several varieties of mafic schist. There are also, in the more felsic terrains, important regional concentrations of garnet, muscovite, magnetite, and quartz-muscovite-sillimanite pods (fig. 6*C*). The felsic pod-rocks grade into massive quartz monzonites with increasing groundmass potassium feldspar and with a decreasing number of pods, and into pelitic schists with increasing groundmass and decreasing size of pods. The magnetite-rich alaskites have a characteristic streaky appearance.

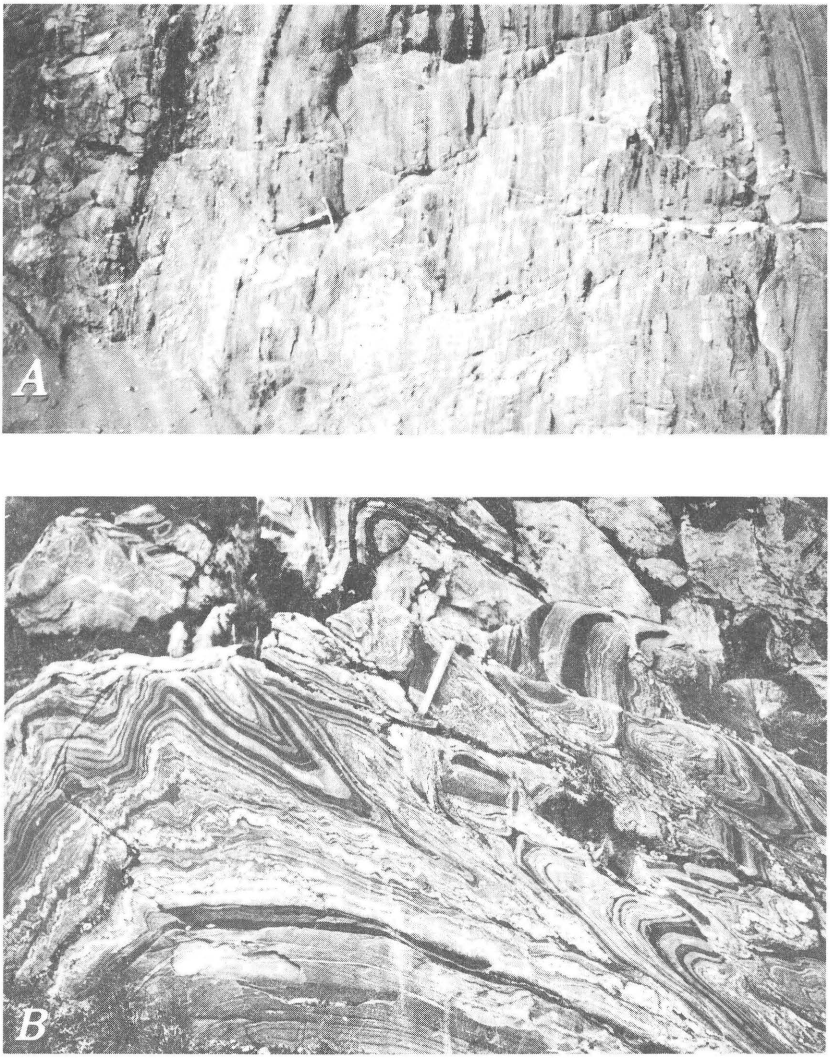
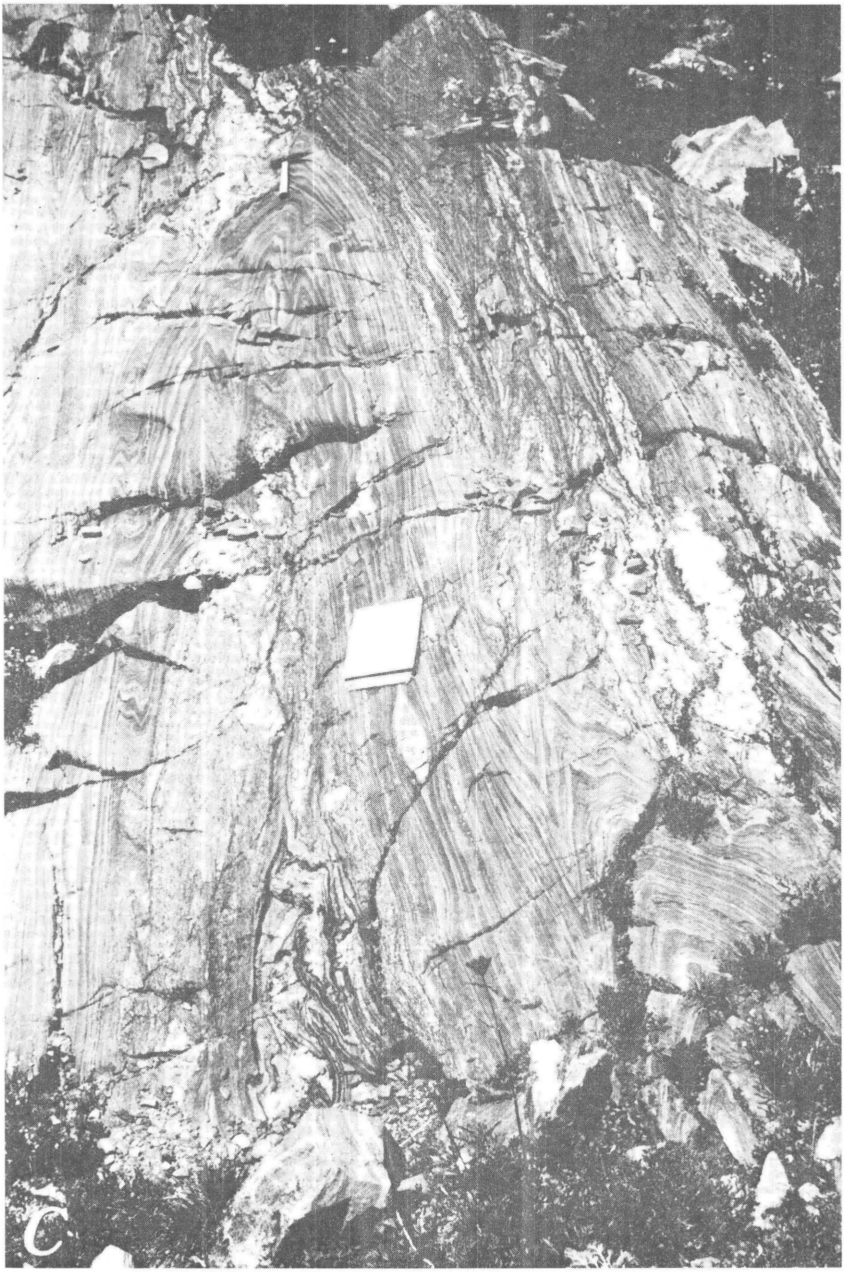
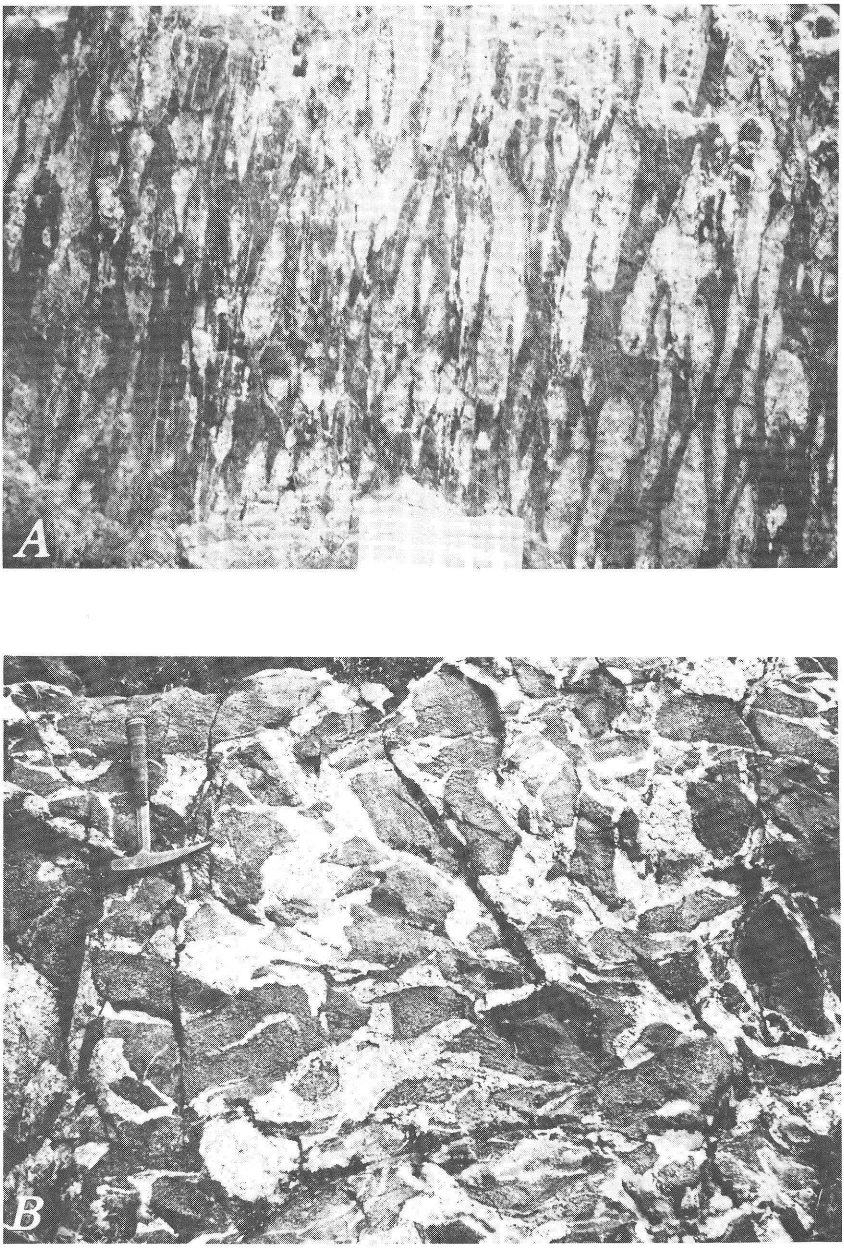


FIGURE 5 (above and facing page).—Precambrian layered metasedimentary rocks of various types from northern Park Range. *A*, Subtly but distinctly layered amphibolite from 7,360-ft elevation (from topographic map; 2,243 m). U.S. Highway 40 cut, south of Steamboat Springs. Probably originally water deposited basaltic ash. *B*, Tightly folded and sheared migmatitic felsic gneiss and biotite gneiss from north of 10,136-ft (3,089-m) saddle on Buffalo Pass road southwest of Buffalo Pass. Possibly originally water deposited ash of intermediate composition. *C*, Isoclinal folds in layered biotite-muscovite-quartz-garnet-sillimanite pelitic schist, originally a shale, from 10,300-ft (3,140-m) elevation south of summit of peak between Soda Creek and South Fork Soda Creek.


C


A
B

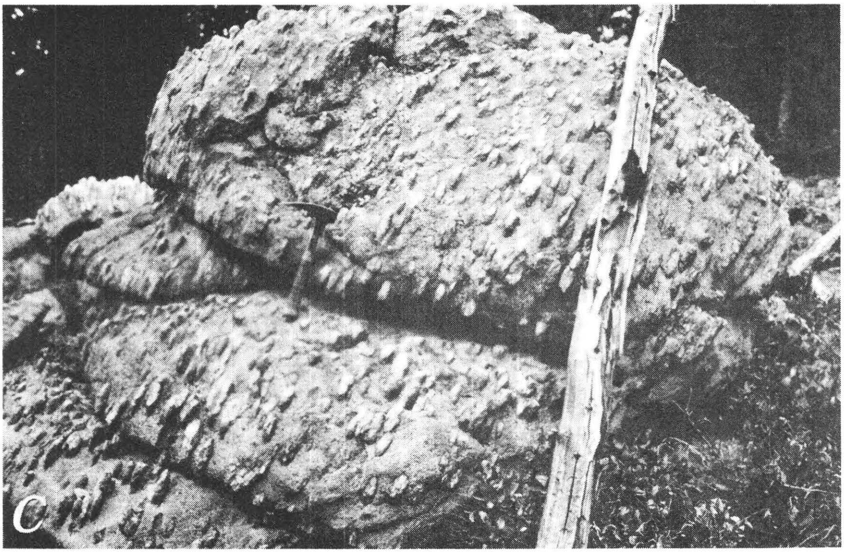


FIGURE 6 (above and facing page).—Precambrian pod-rocks of various origins. *A*, Vertical surface exposure in pod-rock of mixed origin. Light calc-silicate pods in dark amphibolite matrix, probably originated with deposition of basaltic ash in a carbonate-depositing environment followed later by concretionary sedimentary or diagenetic processes, which preserved species distinction, and tectonic stretching, which produced vertical lineation. Rocks of this type are common in the northern Park Range, but details of the structure are seldom this well exposed because of lichen cover on pitted weathering surfaces. These pod-rocks can grade over short distances into pure amphibolite in one direction or pure calc-silicate rocks or marbles in another direction. From 10,200 ft altitude on south end of ridge east of Hogan Creek (Snyder, 1977c, 1980c). Aluminum map holder at base of photo is 20 cm (8 in.) wide. *B*, Pod-rock formed by brecciation near contact of igneous intrusion. Amphibolite wall-rock inclusions in quartz monzonite from 9,900-ft (3,018-m) elevation on south end of Black Mountain northwest of West Fork Lake. *C*, Pod-rock believed to have been formed by mineral segregation during metamorphism. Oriented pods of quartz-sillimanite-muscovite rock in a granitic matrix. Rock may have been emplaced originally as a peraluminous extrusive, perhaps contaminated by shale fragments. From crest of Independence Mountain northwest of Sugar Loaf.

The various types of felsic gneiss may represent compositional variants of several types of silicic extrusives, perhaps in some cases with an admixed arkosic or pelitic detrital component, but the rocks themselves lack primary structures or textures. However, the compositions are appropriate for a variety of silicic ashes or welded tuffs from dacites to alkali rhyolites. The great local thicknesses of particular compositional variants are suggestive of the great local thicknesses of silicic welded tuffs found in many modern calderas, although later tectonism and total metamorphic recrystallization have obscured any traces of bounding caldera faults that may have existed.

The commonest recognizable metasediment intercalated in the metavolcanic sequences is medium-grained aluminous schist or metapelite or metashale, several belts of which are continuously mappable across the range (pl. 1; fig. 5*C*). These rocks vary markedly from belt to belt, but all belts have this in common: their rocks contain aluminous minerals recrystallized from former detrital clays. Minerals present are mainly micas (especially muscovite), sillimanite, sodic plagioclase, potassium feldspar at higher grades, and almandine garnet; rarely present are staurolite, tourmaline, cordierite, chloritoid, or andalusite. Sillimanite occurs either as euhedral crystals or fibrolite pods, either of which may be retrogressively altered to pseudomorphs of pinite or sericite. Quartz is ubiquitous. The more aluminous, schistose, or micaceous rocks are interlayered in many places with less aluminous, more granular, or gneissic layers. Some metapelite belts contain minor but distinctive pods of mafic rocks of unusual composition, for example, garnet amphibolites or biotite-actinolite schist. Although top and bottom criteria are only rarely preserved, the contrasting compositions of adjacent layers are more suggestive of several individual sedimentary beds than of isoclinal fold repetition of a single stratum (despite the fact that isoclinal folds abound on all scales: fig. 5*B*, 5*C*).

The most unusual mapped metasedimentary rocks or mixed metavolcanic-metasedimentary rocks occur mainly near Willow Creek or on Farwell Mountain and consist of clean quartzites and dirty metaconglomerates and meta-agglomerates, respectively. The quartzites contain minor muscovite and hematite. They must have been more resistant to shearing than most rocks because they commonly preserve primary crossbedding, which clearly indicates that the quartzite body north of Willow Creek is an overturned syncline. The Farwell Mountain body is a complex mixture of unusual rocks including gray to gray-green polymictic conglomerate (generally with biotitic matrices), oligomictic agglomerate (generally with hornblendic matrices), and oligomictic pisolitic rocks containing peasized feldspar-quartz-muscovite pods of uncertain origin, some possibly due to metamorphic segregation, some possibly due to metamorphism of nonclastic primary structures, such as amygdules or pumice clots.

The age of the felsic gneisses, and therefore of all intercalated metavolcanic and metasedimentary rocks, is greater than 1.78 b.y., possibly as old as 1.9 b.y. or Proterozoic X. Some felsic gneisses have contributed to Rb-Sr (rubidium-strontium) whole-rock isochrons, or their accessory zircon has been dated by uranium-thorium-lead methods, but some current dating attempts need to be carefully qualified. Unlayered or thickly layered gray felsic gneisses along the east margin of the northern Park Range could be extrusives of compositions ranging from dacite to alkali rhyolite. Three, from Lone Pine Creek to Newcomb Creek, form a Rb-Sr whole-rock isochron, suggesting an age of 1.69 b.y. (Hedge, in Snyder, 1978). Another gneiss, north of Line Creek, possesses zircons giving highly discordant U-Th-Pb ages that are difficult to interpret but are at least 1.58 b.y. (C. E. Hedge, written commun., November 1976). Both these ages must be minima, as the rocks are cut by a gabbro that yields a U-Th-Pb date of 1.78 b.y. (Hedge, in Snyder, 1980a, 1977a) and by quartz monzonites that yield Rb-Sr dates of 1.65–1.70 b.y. (Hedge, in Segerstrom and Young, 1972, p. 16) and 1.80 b.y. (Hedge, in Snyder, 1978). Additionally, felsic gneisses in the adjacent Sierra Madre of Wyoming continuous with these are dated by Rb-Sr at 1.88 b.y. (Divis, 1976, p. 56; 1977, p. 98), but this age is controlled by a single pegmatitic phase. A nearby gneiss in the Sierra Madre contains discordant zircons, giving a minimum age by $^{207}Pb/^{206}Pb$ of 1.73 b.y. (Divis, 1976, p. 56, 60).

MAFIC AND ULTRAMAFIC INTRUSIVE ROCKS

Dark medium-grained gabbro, olivine gabbro, and peridotite are associated in an intrusive body of batholithic dimensions—the gabbro of Elkhorn Mountain—in the northwestern part of the area and in numerous smaller bodies. These rocks normally weather to distinctive chocolate-brown soils containing equidimensional gabbro boulders. Most samples contain subequal amounts of calcic plagioclase and mafic minerals including clinopyroxene, hornblende, and biotite, singly or in various mixtures, invariably occurring in a uniform, unlayered, diabasic or homogeneous rock. Typical rocks in the large gabbro body of Elkhorn Mountain are hornblende-clinopyroxene-biotite gabbro, hornblende-biotite gabbro, hornblende gabbro, and porphyritic feldspar amphibolite; rare dark diorite is exposed at Three Forks. Hornblendic and anorthositic gabbros are prominent on Farwell Mountain.

Olivine gabbro occurs in a single pluton within the gabbro of Elkhorn Mountain between South Fork Hog Park Creek and the Sierra Madre Continental Divide, where it is associated with small peridotite masses and is rarely cut by dikes of olivine-free gabbro of Elkhorn Mountain. This distinctively different rock contains corona structures in which orthopyroxene, clinopyroxene, pargasitic amphibole, and spinel are arranged in concentric shells around olivine grains.

Ultramafic peridotite masses occur either within the gabbro of Elkhorn Mountain or as separate isolated intrusive bodies as much as 2.5 km (1.5 mi) long. These rocks are everywhere black or dark olive gray but may weather to a bright-red soil. They include amphibole peridotite of various types including dunite, wehrlite, harzburgite, and also hornblendite, many containing some spinel and chromite. Pargasitic amphibole occurs in peridotite, either as large poikilitic crystals containing olivine and pyroxene inclusions or as kelyphytic rims around olivine with the amphibole partly alone and partly in complex symplectic intergrowths with spinel.

The gabbro of Elkhorn Mountain is believed to be a composite mafic body intruded in several inhomogeneous batches that carried along solid rafts of peridotite derived from its mantle source area (Snyder, 1984). It is asymmetrically zoned from diorite along the north and south (but not east) margins to predominant gabbro in the center and along the east margin. Olivine and hypersthene are most common in the most mafic central and eastern rocks, and biotite the least common, but many different mineral mixtures occur. Although the gabbro of Elkhorn Mountain is more altered and less magmatically layered than gabbros in the Lake Owens and Mullen Creek Mafic Complexes in Wyoming's Medicine Bow Mountains (McCallum, 1968; Houston and others, 1968), it is similar in age and aeromagnetic signature to these bodies. Lake Owens and Mullen Creek are believed to be layered funnel-shaped intrusives. Intrusives of this type elsewhere in the world contain layered chromium-platinum ores at depth, and this should be considered a possibility here, even though surface evidence of such in any of the bodies is minimal or lacking.

That the gabbro of Elkhorn Mountain is older than the quartz monzonite of Seven Lakes is well shown by numerous dikes of quartz monzonite cutting gabbro and by numerous swarms of lozengelike gabbro inclusions in quartz monzonite near some contacts. Zircons separated by Robert Sperandio from a dark diabasic andesine-clinopyroxene-biotite-magnetite diorite phase of the gabbro of Elkhorn Mountain near Three Forks of the Little Snake River have a highly concordant U-Th-Pb age (C. E. Hedge, written commun., November 1976; analyst Margarita Gallego); the $^{207}Pb/^{206}Pb$ age, usually the best approximation to the true age, is reported as 1.78 b.y., Proterozoic X.

OLD QUARTZ MONZONITE

Red to gray medium- to coarse-grained massive to augen-gneissic biotite granite, quartz monzonite, and granodiorite occur in numerous discordant tabular, lensoid, or irregular bodies in two main belts—one about 12 km (7.5 mi) wide extending in a broad curve from the northeast corner of the mapped area, south of Seven Lakes, to the northwest corner of the mapped area; the other about 1.6 km (1 mi) wide passing through Buffalo Pass near the south margin of the area. Individual bodies of the quartz monzonite of Seven Lakes or Buffalo Pass range in size from small dikes to large plutons; contacts range from sharp (figs. 9, 10*B*, 11) to diffuse. Structure and texture are variable and include: (1) medium grained and equigranular; (2) coarse potassium feldspar augen gneiss; (3) sheared flaser gneiss; (4) fine-grained equigranular leucogranite; (5) complex lit-par-lit zones with pegmatite (figs. 7, 9). Weathering forms vary from resistant ledges, roches moutonnées and monadnocks to less resistant smooth uplands (fig. 8) and eroded badlands. In places near the borders of the plutons, the quartz monzonite is choked with inclusions of country rock (fig. 6*B*), and assimilation of some more mafic inclusions leads to the more mafic granodioritic plutonic phases in these border areas. The plutons were dated at 1.65–1.80 b.y. with Rb-Sr whole-rock techniques by C. E. Hedge (in Segerstrom and Young, 1972, p. 16; Snyder, 1978, p. 17, 18) or Proterozoic X.

QUARTZ DIORITE OF GILPIN LAKE

Medium-grained equigranular speckled gray biotite-hornblende quartz diorite forms several small homogeneous plutons near Gilpin Lake (fig. 3), spanning Hole-in-Wall Canyon (fig. 10*A*) and along South Fork Elk River. The quartz diorites in the northern Park Range have never been radiometrically dated, but they probably fall in the same 1.7- to 1.8-b.y. age span (Proterozoic X) as the other old intrusives. In the field they can be seen to grade into the old quartz monzonites locally, but elsewhere they are also found as angular inclusions both in quartz monzonites (fig. 10*B*) and in some amphibolitic rocks.

YOUNG QUARTZ MONZONITES OF THE MOUNT ETHEL PLUTON

Unsheared postmetamorphic, largely quartz monzonitic intrusive rocks are present in a single large batholith extending from Routt Hot Spring northeast under Mount Ethel to Sheep Mountain and beyond. Although not shown on plate 1, at least five different lithologic phases

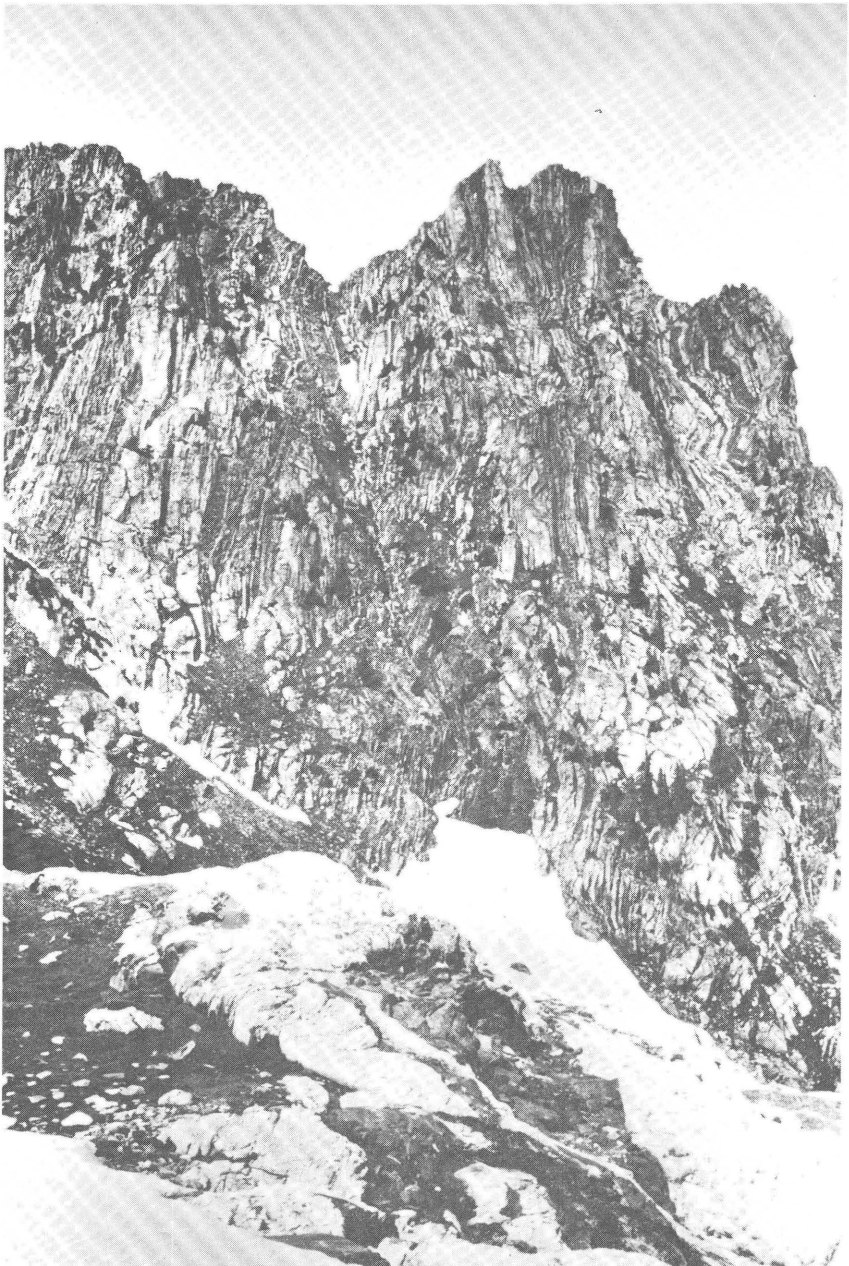


FIGURE 7.—Lit-par-lit quartz monzonite and pegmatite interlayered with amphibolite and pelitic schist in Sawtooth Range near head of North Fork Elk River. Note angular dark-colored amphibolite inclusions in glacially polished light-colored pegmatite ledge in foreground. Vertical span from pegmatite ledge to skyline ridge top is more than 300 m (1,000 ft).

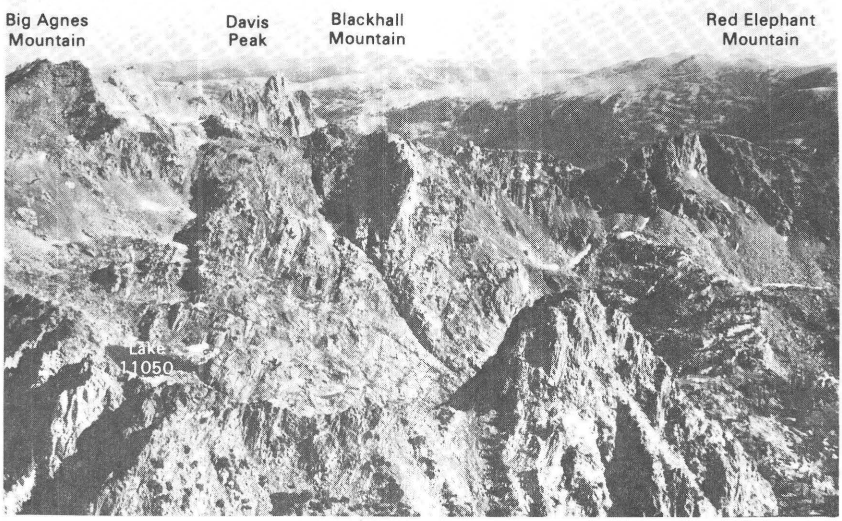


FIGURE 8.—Big Agnes Mountain massif viewed northeast across Gilpin Creek, September 1971. Foreground arêtes are formed on vertical interlayered quartz monzonite, pegmatite, amphibolite, felsic gneiss, and pelitic schist. (For closeup of lake 11,050 area, see fig. 9.) Contrast foreground topography with gentler topography from Davis Peak to Red Elephant Mountain underlain mainly by quartz monzonite of Seven Lakes. Blackhall Mountain (on skyline) is in Wyoming.

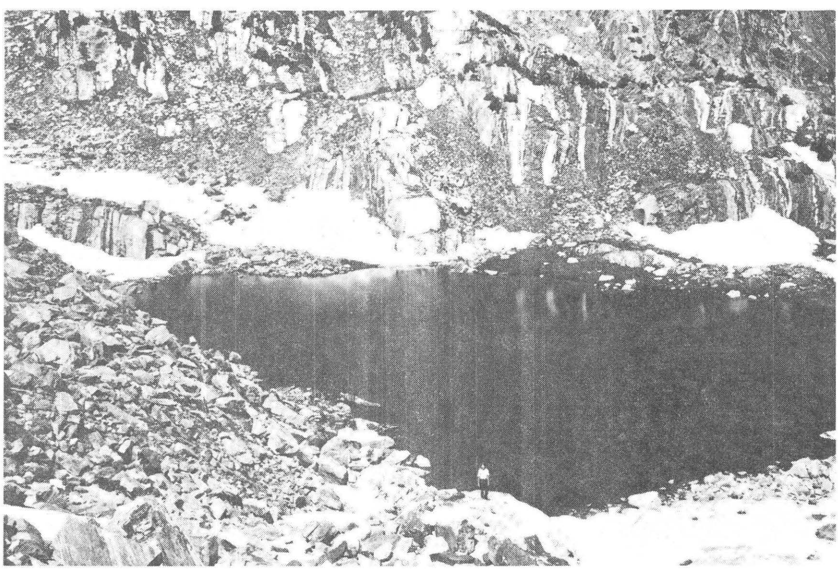


FIGURE 9.—Interlayered Precambrian quartz monzonites and pegmatites (light color) and amphibolites and pelitic schists (dark color) near lake 11,050 near head of Gilpin Creek. August 1971; for snow conditions 2 weeks later, contrast distant view of same area in figure 8.

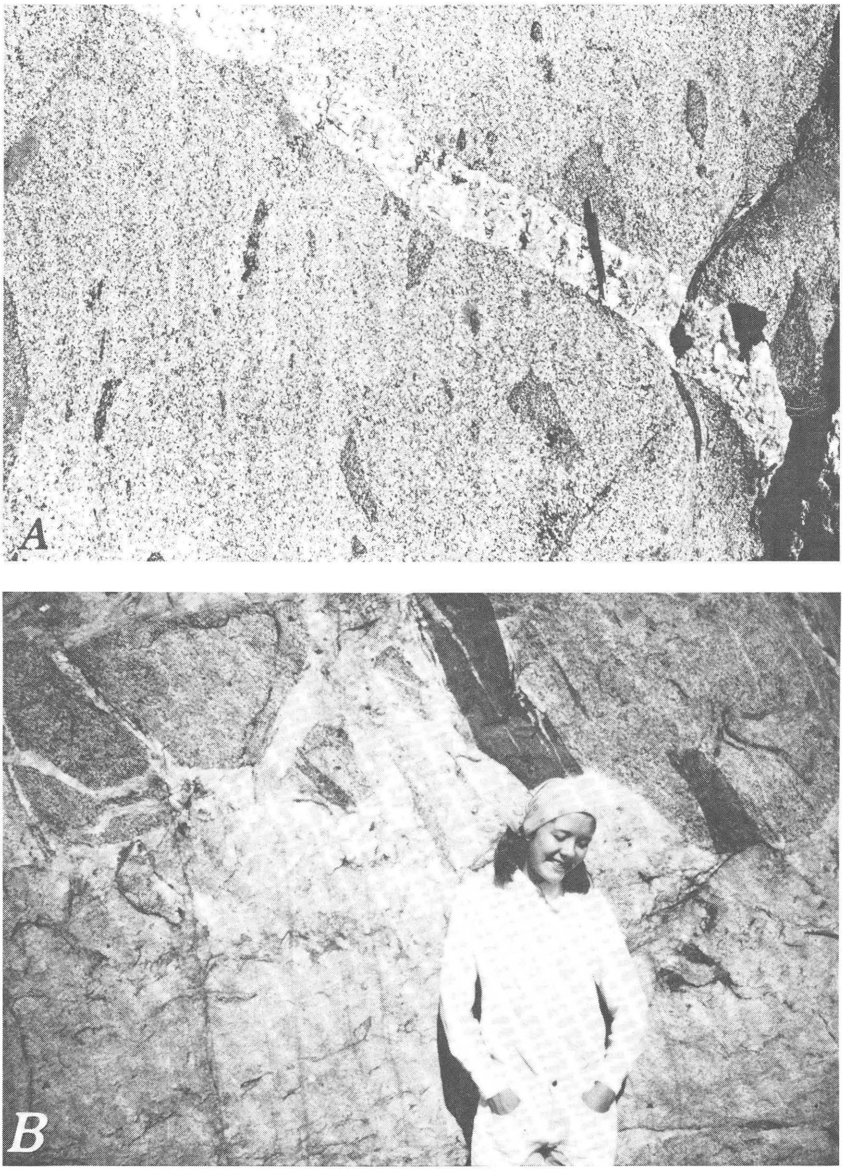


FIGURE 10.—Textures and structures of intrusive igneous rocks. *A*, Pegmatite dike cutting quartz diorite of Gilpin Lake at 8,800-ft elevation (from topographic map; 2,682 m) on southwest rim of Hole-in-Wall Canyon. Irregularly parallel walls of pegmatite dike suggest dilation of walls during emplacement, but biotite concentrations in pegmatite near mafic inclusions and orientation of same inclusion on opposite sides of pegmatite (at pencil) prove that replacement of wall rocks was dominant during emplacement. *B*, Light-colored quartz monzonite or granite containing inclusions of dark-colored quartz diorite or granodiorite, which themselves contain inclusions of darker colored mafic diorite and black amphibolite. From 3-m (10-ft) glacial erratic on ridge top south of Fish Creek Reservoir.

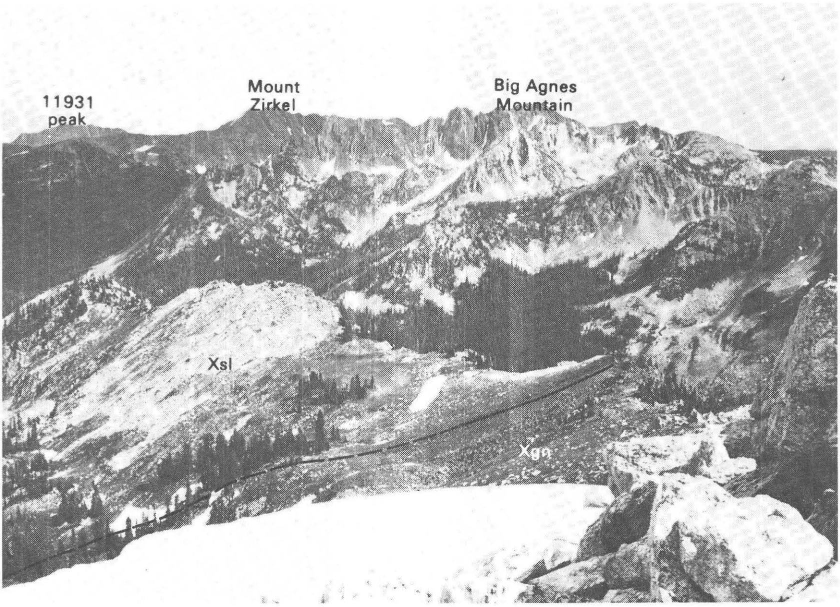


FIGURE 11.—Contact between quartz monzonite of Seven Lakes (Xsl) and amphibolite wall rocks (Xgn) on southeast ridge of Buck Mountain from south summit of Buck Mountain near center of a south-plunging synclinal fold. Light-colored foreground boulders are pegmatite that cuts darker colored amphibolite in center of syncline. View to southeast.

of this Mount Ethel pluton were mapped separately and unequivocal age relations were determined among them. (For photographs and more detailed descriptions see Snyder, 1977b, 1978, 1980b.) The oldest phase is a dark-gray medium-grained hornblende-biotite granodiorite and diorite found mainly in a 1.6-km (1-mi)-long inclusion in the Gunn Creek drainage. The next oldest is a red coarse-grained biotite-hornblende quartz monzonite porphyry containing large microcline phenocrysts and found in a very irregular 5-km (3-mi)-wide carapace around the southwest end of the batholith. The main volume of the batholith is occupied by the middle phase—a gray, variable but mainly medium grained biotite granite and biotite quartz monzonite. This phase was intruded by 3-km (2-mi)-wide and smaller stocks and sheets of pink fine-grained binary (two-mica) granite concentrated near the middle of the batholith. The youngest phase entirely within the batholith is a swarm of pink aplite and leucogranite dikes mainly in the western part of the batholith. All phases have knife-blade-sharp contacts with each other, contain angular inclusions of older phases, and are included in younger phases. The outer contacts of the batholith dip steeply outward and are markedly discordant (Snyder, 1978).

All batholith phases except the granodiorite and diorite have contributed to a Rb-Sr whole-rock isochron which indicates that the batholith was emplaced between 1.37 and 1.47 b.y. ago (Hedge, in Snyder, 1978) in Proterozoic Y time.

PRECAMBRIAN DIKES

Vertical or nearly vertical Precambrian dikes of mafic to silicic composition are present in at least two swarms intruded over perhaps 500 m.y. (million years) of geologic time (fig. 12). The dikes range in width from about 1 cm to 30 m (100 ft). One swarm is blue black, fine grained, and of uniform basaltic composition, and trends mainly northeast and north-northeast in the western part of the gabbro of Elkhorn Mountain and near the summit of Farwell Mountain. These dikes are clearly younger than the gabbro they cut, but they have a complex and apparently contradictory transection relationship with the quartz monzonite of Seven Lakes (some basalt is younger than some quartz monzonite, whereas some quartz monzonite is younger than some basalt), perhaps implying two periods of intrusion of one or the other lithology or a metamorphic remobilization of one or the other rock. Another dike swarm is concentrated within or near the Mount Ethel pluton, but several of these dikes are 8 km (5 mi) and one is 24 km (15 mi) from the pluton. These dikes are generally porphyritic but are diverse in composition with diabases, trachybasalts, trachyandesites, quartz latites, and rhyolites represented in profusion. Some dikes are at least as old as the middle granite and quartz monzonite unit of the Mount Ethel pluton, as they are cut by this unit; other dikes cut the granite and quartz monzonite unit of the Mount Ethel pluton (as well as other rocks). Some dikes are truncated by, and offset along, the Precambrian mylonite shear zones; others were intruded along these zones and were themselves partly mylonitized by repeated fault movements. Most dikes have altered groundmasses, and whatever pyroxene or olivine they originally may have possessed has been completely altered to amphibole.

PALEOZOIC AND MESOZOIC SEDIMENTARY ROCKS

Although consolidated Phanerozoic rocks are exposed in only three places within the Mount Zirkel Wilderness, there are many exposures within the adjacent area, and some evidence of former, more widespread existence within the present wilderness area. Mesozoic and Paleozoic rocks occupy several downdropped or overthrust blocks within the mainly Precambrian range. Because most Mesozoic and

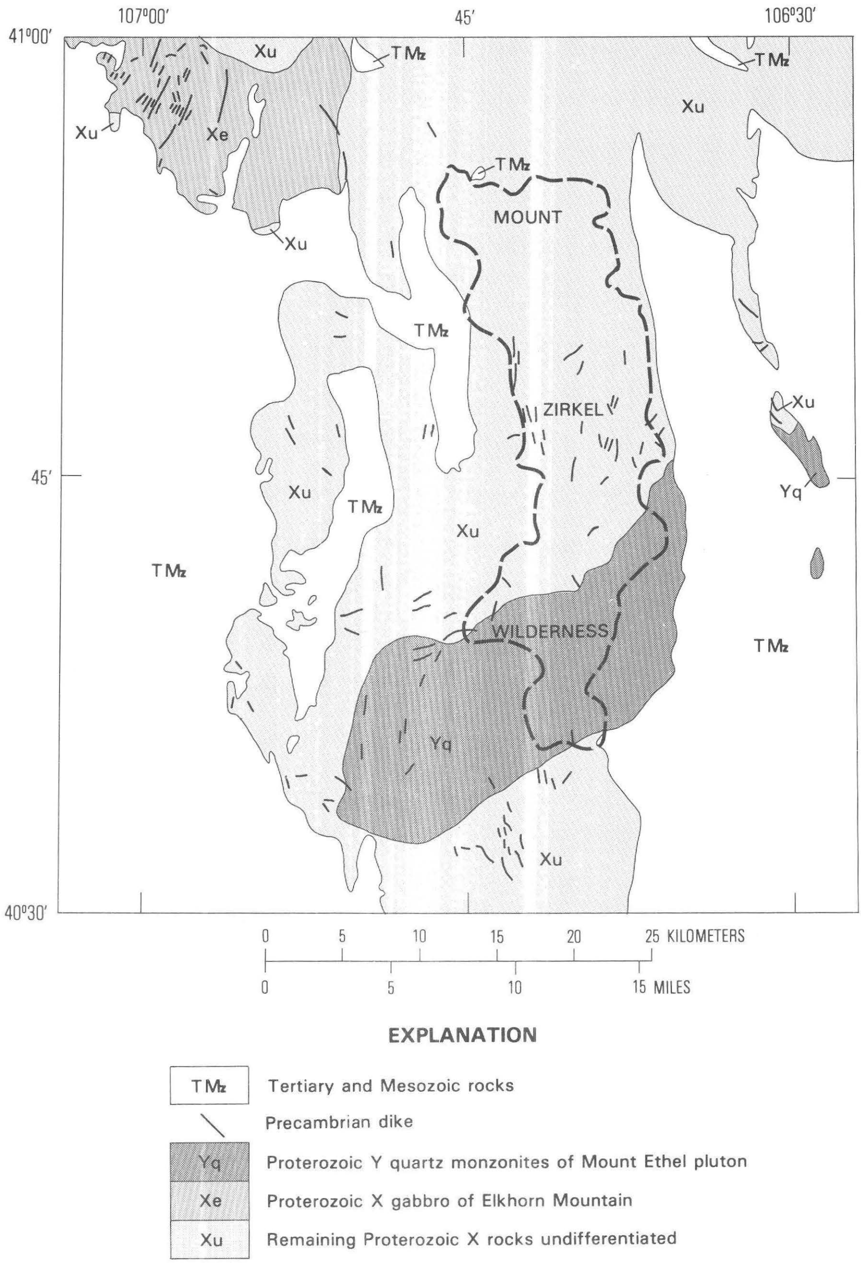


FIGURE 12.—Location of Precambrian dikes. Heavy dashed line, approximate wilderness boundary.

Paleozoic formations contain some easily eroded calcareous shales, they tend to weather down to low grassy meadows between higher surrounding Precambrian hills (fig. 2). The three exposures within the Mount Zirkel Wilderness boundaries are Chugwater red beds on Red Dirt Pass, in the Agnes Creek tributary of the North Fork of the Elk River, and on the ridge northwest of Newcomb Park. The Red Dirt Pass locality is a tiny fault sliver of red beds atypically preserved in the high mountains (fig. 13) (Beekly, 1915, p. 24–26). Near the red bed remnant at Red Dirt Pass, the flat summit planes of Flattop Mountain (figs. 14, 15) and Mount Zirkel (figs. 13, 16) are cut across vertical Precambrian rocks perhaps by the streams that deposited the Chugwater red beds, which may have been recently stripped from these high plateaus.

PERMIAN AND TRIASSIC FORMATIONS

Continental red beds of Permian and Triassic age make up the main part of the unmetamorphosed basal sedimentary section in the northern Park Range. All older Paleozoic rocks, if they ever existed here, were stripped away before the Permian deposition. From lower to upper, the formations present are the Permian Satanka Formation and Forelle Limestone, the Permian and Triassic Chugwater Formation, and the Triassic Chinle Formation. All but the Forelle are red beds. The Satanka Formation consists of red siltstone, red and green calcareous shale, and locally, ocher and red clay. The Forelle Limestone consists of gray to black crystalline, wavy-bedded limestone commonly with 10 to 50 percent quartz pebbles. The Satanka Formation and Forelle Limestone together are as much as 15 m (50 ft) thick; they are recognized only on the outer flanks of the range. The Chugwater Formation consists of thin-bedded red calcareous siltstone and shale 120–240 m (400–800 ft) thick; in the southern part of the area it contains 5 percent quartz pebbles in the lower half of the formation. The Chinle Formation consists of thick-bedded red calcareous siltstone in the upper part, reddish-gray wavy-bedded limestone and pliable ocher and red clay in the middle part, and resistant red calcareous claystone-pebble conglomerate and impure sandstone (Jelm equivalent in Wyoming) in the lower part. The formation is 30–180 m (100–650 ft) thick. Except for a few poorly preserved pieces of petrified wood, none of the above formations is fossiliferous in the area studied.

JURASSIC FORMATIONS

The Middle and Upper Jurassic marine Sundance Formation and the Upper Jurassic continental Morrison Formation are widespread

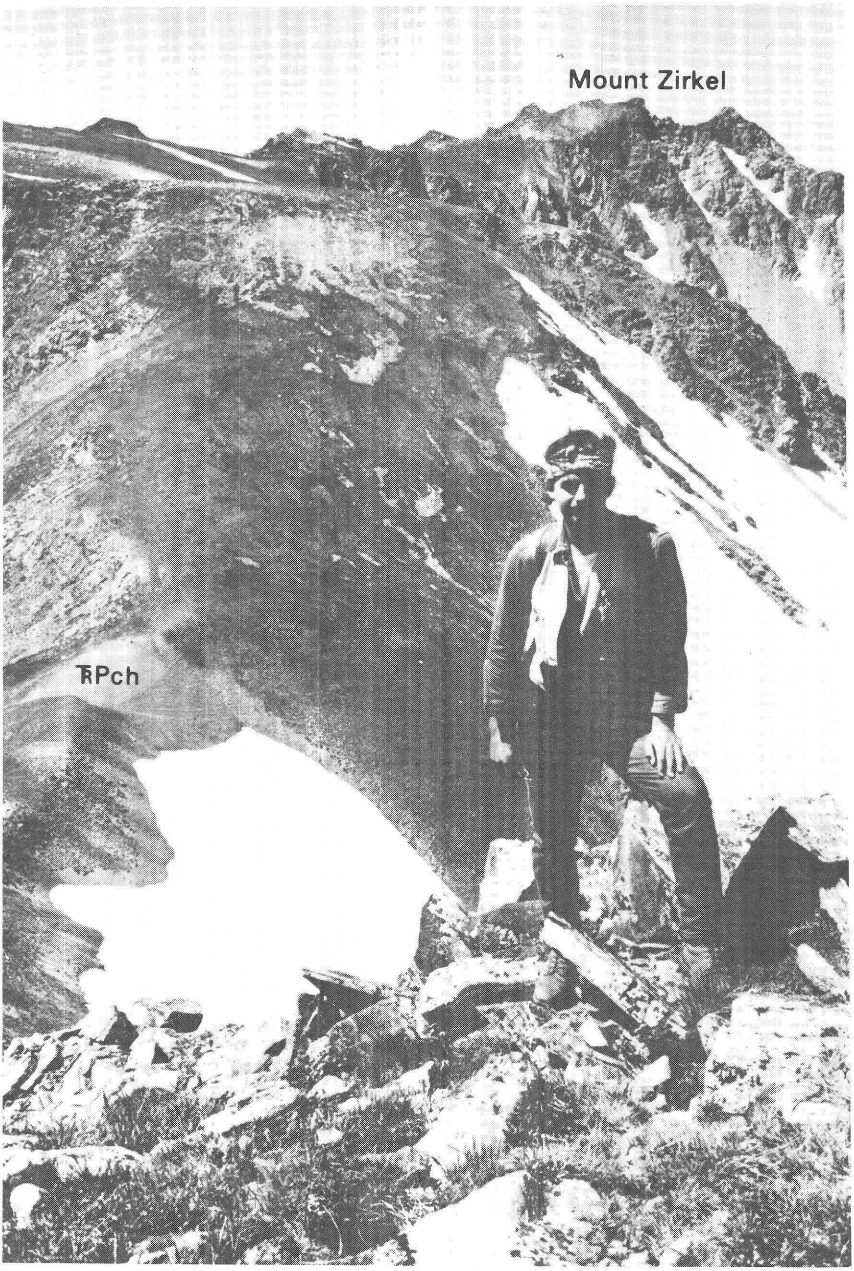


FIGURE 13.—Mount Zirkel and Red Dirt Pass, view to northwest from north end of Flattop Mountain, August 1970. Area of smooth soil above left snowfield is downfaulted sliver of Chugwater Formation (ꞦPch). For earliest description of this locality, see Beekly (1915, p. 24–26). Note flat Mount Zirkel summit plateau.

throughout the mapped area but poorly exposed, owing to their nonresistant character and tendency to landslide. The Sundance Formation consists of very poorly exposed olive-gray calcareous shale and gray glauconitic oolitic limestone with belemnites, mollusks, and foraminiferans in the upper part (which is locally missing), and soft massive salmon-pink (usually), yellow, or white sandstone in the lower part. It has a one-pebble-thick chert-pebble conglomerate at the base. The Sundance Formation is as much as 75 m (250 ft) thick. The Morrison Formation consists of calcareous purple and green shale and claystone, greenish-white sandstone, and gray fresh-water algal limestone; it is 120–275 m (400–900 ft) thick. The Morrison Formation contains charophyte oogonia, ostracodes, and petrified wood locally. Numerous landslides are soled in the Morrison Formation.

CRETACEOUS FORMATIONS

The Cretaceous formations, which begin with a ledge-forming basal conglomerate and sandstone, are mainly nonresistant black to gray calcareous shales. The basal Dakota Sandstone consists of buff siliceous sandstone and quartz- or chert-pebble conglomerate in the lower part and buff siliceous sandstone and minor gray shale in the upper part. It is 30–120 m (100–400 ft) thick and is a persistently mappable horizon to which the discontinuous exposures of all other nearby formations can be related. Above the Dakota, the Benton Shale, 30–180 m (100–600 ft) thick, consists of three locally separable members. The basal or Mowry Shale Member consists of hard siliceous black shale that breaks into angular equidimensional granules (locally used for road topping); it contains abundant chirocentrid fish scales, bones, and fecal pellets. The middle or Graneros Shale Member consists of soft black fissile noncalcareous shale with white clay beds representing former volcanic ash deposits. Its diagnostic fossil, *Acanthoceras amphibolum* Morrow, has been collected by E. A. Merewether (written commun., October 1973) in the structural basin traversed by Silver City Creek. The upper, locally resistant Juana Lopez Member consists of petroliferous calcareous coquina, calcarenite, and fine-grained shaly sandstone containing an abundant distinctive suite of mollusks and ammonites, and rare shark and ray teeth (Snyder, 1977a, b; 1980a, b). The next Cretaceous formation, the Niobrara Formation, consists of distinctive blue-gray calcareous white-spotted shale that weathers into chips and plates and that locally contains abundant *Inoceramus* and oyster fossils and less common fish scales and bones. The uppermost Mesozoic formation exposed in this area, the Pierre Shale, consists of voluminous gray shales in two members. The lower shaly member contains fissile gray shale that is noncalcareous except

FIGURE 14.—View south at flat summit plateau of Flattop Mountain and Red Dirt Pass. (See also fig. 13.) Upper Slavonia mine located above small lake in right middle distance. September 1966.

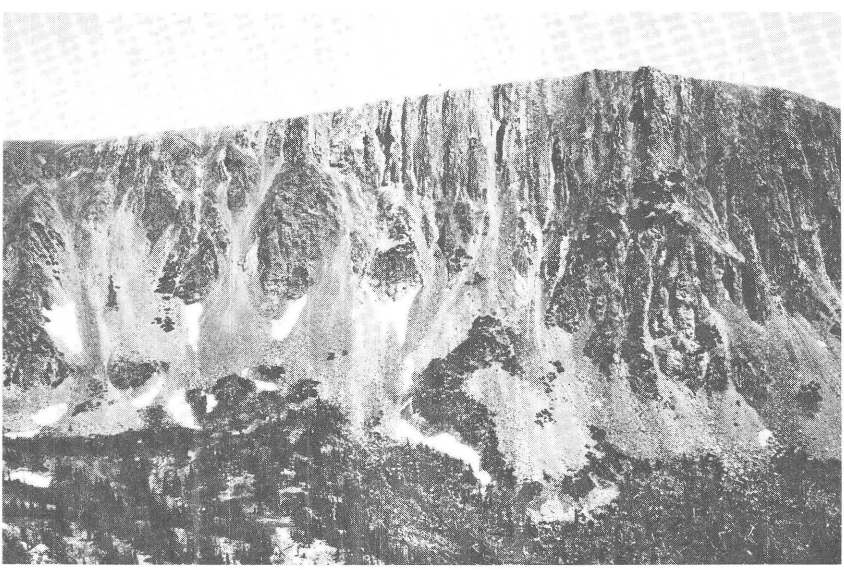


FIGURE 15.—Vertical layered amphibolite truncated by summit plane of Flattop Mountain. (See fig. 14.) View east from near Upper Slavonia mine, August 1971.

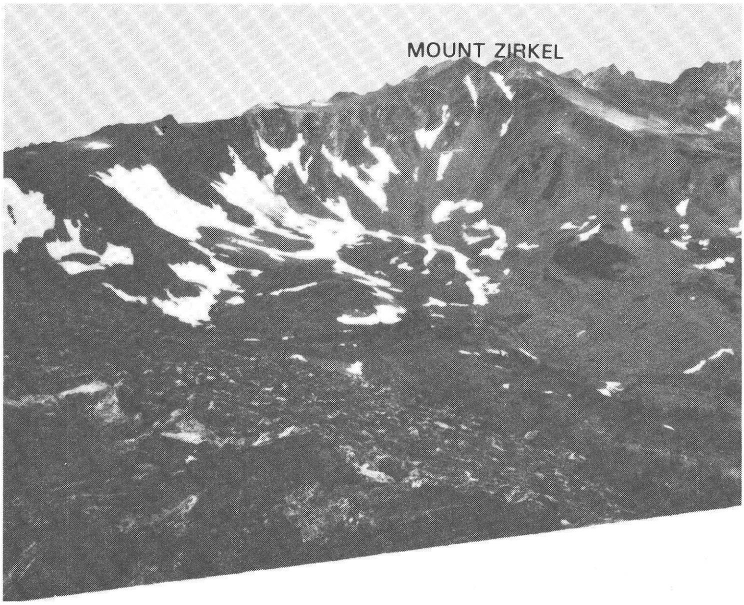


FIGURE 16.—Mount Zirkel and Frying Pan Basin, looking west, August 1970. colored peaks and talus in center and on right are predominantly quartz mon- gneisses. The "frying pan" is a collapsed boulder moraine of earliest snow) at its head. (See also fig. 17.) Note flat summit plateau on south side

near the base and that becomes progressively siltier to sandier in its upper parts. It is 700–850 m (2,300–2,800 ft) thick. The upper sandy member consists of interbedded brown to gray calcareous sandstone, siltstone, and shale with as much as 900 m (3,000 ft) exposed.

TERTIARY ROCKS

The Coalmont Formation of Eocene and Paleocene age is exposed in North Park basin along the east side of the northern Park Range. It consists of buff to olive-green arkosic sandstone and Precambrian-cobble conglomerate, with rare leaf fossils. As much as 1,300 m (3,400 ft) thickness may be present in the mapped area. Coal is present and has been mined just east of the mapped area. Arkosic conglomerate equated with Coalmont Formation is present at an elevation as high as 11,100 ft (3,383 m) on the southeast rim of Red Canyon. The flat summits of several peaks along the Continental Divide southwest of this (for example, Lost Ranger Peak and The Dome: Snyder, 1978, fig. 5*B*) at altitudes between 11,600 and 11,900 ft (3,536–3,627 m) may have been eroded to this level prior to Coalmont

Dark-colored cliffs and talus boulders on left are mainly amphibolite; lighter zonite of Seven Lakes, interlayered with lesser amounts of hornblende Neoglacial or latest Pleistocene age with an active rock glacier (outlined by of summit of Mount Zirkel.

time and stripped recently of Coalmont deposits formerly present upon them. South of this area in the vicinity of Rabbit Ears Peak dated Coalmont Formation is certainly present at an elevation as high as 9,500 ft (2,895 m) and may extend to as high as 10,300 ft (3,140 m) (Snyder, 1977c, 1980c).

Sedimentary rocks of the Browns Park Formation of Miocene age are present locally or as an extensive blanket 335 m (1,000 ft) thick along the west and north margins of the map area. Two lithologies are most prominent, but other less common ones are also present. Most common are buff-colored calcareous or siliceous siltstone or sandstone, and conglomerate. The finer grained siltstone and sandstone units occur mostly in the middle and upper parts of the formation or away from the Precambrian mountains, but they may extend continuously to the base of the formation, even where the formation is surrounded completely by mountains (for example, along the upper Encampment River); conglomerates are mostly near the base of the formation and near the mountains but are interbedded with finer sediments in many places. The siltstones and sandstones are partly eolian and partly alluvial; the conglomerates are mainly alluvial and may be linear in trend, mirroring old stream drainages; a few are colluvial. The fine sediments range from wholly clastic to a mixture of clastic particles and airfall ash shards; either type is interlayered locally with pure white or gray porcellanic ash beds from about 1 cm to 12 m (40 ft) thick. Chert beds are present but rare and may represent ash-derived redeposited silica. Cobbles in conglomerate are predominantly resistant Precambrian rocks and locally resistant Mesozoic rocks, but they commonly contain 1–5 percent nonresistant white clay blebs, probably altered pumice, or more likely, ash-bed fragments. Siltstone and sandstone beds are oxidized extensively to red colors and are silicified locally near some intrusives and faults; such red colors are especially prominent within 2 mi of Columbine and are best seen along the new logging road (not shown on maps) south and west of Iron Mountain. Conglomerate may be as unconsolidated as loose stream gravel or as indurated as concrete; commonly it is partly indurated with indurating carbonate concentrated at bottoms of cobbles. White to gray massive limestone locally is present near the base of the conglomerate or on top of Precambrian outcrops in areas where it is reasonable to infer that Browns Park may once have existed; such limestone may occur as massive unbedded deposits, as clastic dikes within Precambrian rocks, or as the matrix of a breccia of angular Precambrian fragments. Most such limestone has probably been redeposited by ground water near the base of the Browns Park Formation over a considerable period of time; some may be young, hot-spring travertine. Tuffaceous epiclastic volcanic breccia with fragments of silicic porphyry and dark shale is present west of Hahns Peak and may represent the only uneroded extrusive product of a volcano formerly centered on Hahns Peak (Segerstrom and Kirby, 1969, p. B21–B22; Segerstrom and Young, 1972, p. 33–34). Similar near-source pyroclastic deposits are known to be intercalated with the Browns Park sediments farther west in the Elkhead Mountains and south of Steamboat Springs along the Yampa River (Snyder, 1977c, 1980c). No lava flows are known to be intercalated with Browns Park sediments within the present mapped area, but capping lava flows are present on Shield Mountain and Rabbit Ears Peak just outside the study area (shown on pl. 1).

The Browns Park Formation itself has been dated in this general area by a combination of paleontological and radiometric methods. A basal 5- to 60-cm (2-in. to 2-ft) ash bed in the northwest quadrant of the area has been dated, using fission-track methods, as 24.8 ± 2.4 m.y. (C. W. Naeser, written commun., October 1974). A near-basal ash bed on Rabbit Ears Pass has also been dated, using fission-track methods, as 20.1 ± 1.9 m.y. (C. W. Naeser, written commun., July 1976). These figures compare well with the ash in the lowermost part of the Browns Park Formation 40 km (25 mi) northwest of Maybell, dated at 24.8±0.8 m.y. (Izett and others, 1970, p. C150). West of the mapped area on Sand Mountain and Shield Mountain, orange siltstone beds are intercalated with minor white to gray ash beds 180 to 610 m (600 to 2,000 ft) stratigraphically above the highest Browns Park beds mapped on plate 1. The orange siltstone beds contain a vertebrate fossil suite of late Miocene age including two species of camel, and one species each of horse, rhinoceros, and oreodont (Buffler, 1967, pls. 83, 84; G. E. Lewis, written communs., December 1973 and November 1975). Four associated ash beds have been dated, using fission-track methods, at 9.0±2.1 to 15.8±2.6 m.y. (C. W. Naeser, written commun., October 1974).

Small white to gray to black discordant intrusive bodies of several types cut the Tertiary section, mainly along the west margin of the mapped area. The types include pipes, stocks, dikes, and sills, as well as bodies of more irregular aspect. Most rocks are porphyritic; the lighter rocks contain large euhedral feldspar crystals, reacted quartz, or small euhedral biotite crystals, and the darker ones contain small olivine and pyroxene crystals. Compositions range from trachybasalt through intermediate trachyandesites and latites to rhyolite. Many people, including Snyder (1977a, b, c; 1980a, b, c), have mapped mafic and silicic varieties separately, and many have concluded from this that the suite is the usual bimodal one expected of upper Tertiary igneous rocks, but this does not appear to be the case. In the Elkhead Mountains the presently available rock chemistry suggests a completely uniform distribution of compositions, a continuum from the darkest to the lightest colored rocks. (See Snyder, 1978 for a more complete discussion.) In the Elkhead Mountains 10 K-Ar (potassium-argon) igneous rock ages indicate latest Miocene (McDowell, 1966; Buffler, 1967; Segerstrom and Young, 1972); the lone intrusive in the southeast corner of the present area has been mapped as Oligocene(?) (Hail, 1968, pl. 1) but has not been dated directly. An intermediate intrusive 2.4 km (1.5 mi) west of Rabbit Ears Peak has been dated, using fission-track methods, as 17.0±1.5 m.y. (C. W. Naeser, written commun., October 1974; Snyder, 1977c, 1980c).

QUATERNARY DEPOSITS

Five types of unconsolidated Quaternary deposits are depicted on plate 1: till, terrace gravels, modern alluvium, landslide deposits, and travertine. Other surficial deposits, such as talus, rock glaciers (fig. 17), or colluvium, are present but were not mapped because of small area or thickness. (See Snyder, 1977a, b, c; 1980a, b, c.) Till—the jumbled boulders and dirt deposited by former mountain glaciers—is mapped where it is thick enough to obscure older units, and locally

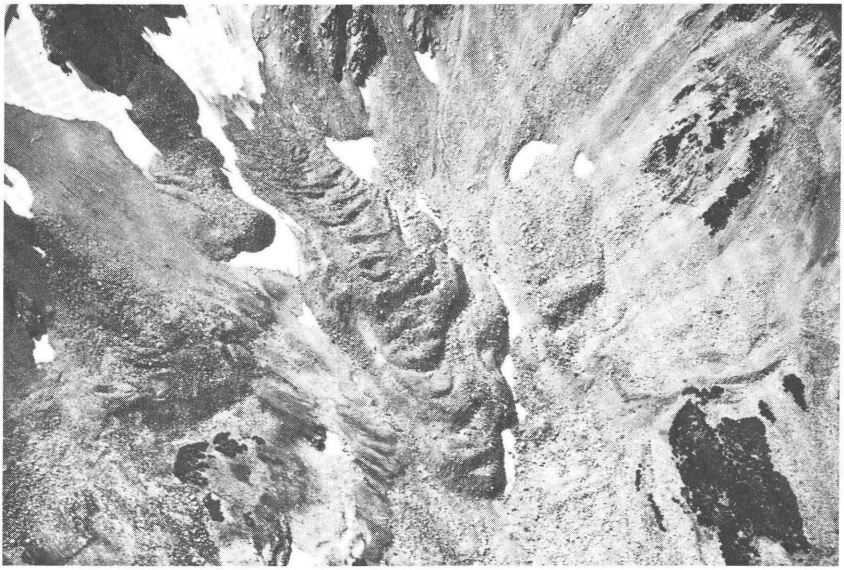


FIGURE 17.—Active rock glaciers in cirque head on east side of Mount Zirkel. Aerial photograph, September 1966. (Compare different snow conditions in fig. 16.)

it is in excess of 60 m (200 ft) thick. Several sets of terminal or lateral moraines can be recognized within this unit; the most extensive ones are of Wisconsin age; others are intermediate in age between these and the presently active rock glaciers (fig. 16). Terrace deposits are rounded alluvial gravels found along the sides of modern drainages but deposited by streams before or during the Pleistocene glaciations. Close to the mountains these deposits can be quite coarse, but the average particle size diminishes rapidly with increasing distance from the mountains. Modern alluvium is simply the latest alluvial or flood deposits of the present streams; it is mappable only in the wider valleys. Landslides are local slumps of bedrock material, as much as several miles long, that usually are soled in weak, slippery rocks like Morrison Formation or Pierre Shale. They may form in response to earthquake shaking, perhaps where weak rocks have been undercut by streams. Several prehistoric landslides have flowed into or across the main course or tributaries of the Elk River, thereby precipitating secondary floods of large magnitude after washouts. Travertine, the porous limestone deposit of warm or hot springs, has been mapped by Hail (1965, pl. 3) on the north side of Delaney Butte. Other small unmapped deposits are present at Routt Hot Spring north of Copper Ridge. Similar but thick travertine deposits are extensive along the Yampa River near Steamboat Springs (Snyder, 1977c, 1980c).

STRUCTURE

The complex structure now present in the rocks of the area is a composite of Precambrian folds and faults, Laramide (Late Cretaceous-early Tertiary) folds and faults, and late Miocene or post-Miocene faults. These structures can be documented on the basis of both direct and indirect evidence; Paleozoic structures, if present, cannot be accurately documented owing to the general lack of rocks of this age. All the known structural movements were complicated by several periods of Precambrian and Tertiary igneous rock emplacement interspersed with the movements.

The widespread Precambrian volcanic and sedimentary rocks were isoclinally folded (and perhaps faulted) and metamorphosed to sillimanite grade about 1.7–1.8 b.y. ago. Hand-specimen- and outcrop-size isoclinal folds are common (figs. 5*B*, 5*C*), and some folds with amplitudes of hundreds of meters or yards can be proven by reversed crossbedding on opposite fold limbs (in the quartzite body north of Willow Creek), by map pattern (in Soda Creek and North Fork Fish Creek), and by map pattern in conjunction with the observation of quartz sillimanite nodules oriented perpendicular to metamorphosed bedding (believed to be near fold crests; on Big Agnes Mountain). Folds having an amplitude or wavelength larger than several kilometers cannot be proven because of a paucity of units mappable at that scale. Some small folds have themselves been isoclinally folded, providing hints of an earlier history more complex than generally assumed or than easily documented elsewhere. Truncation of some metamorphic structures first by gabbro, then by quartz diorite and quartz monzonite, shows that these igneous rocks were intruded after the onset of metamorphism. But the abundance of gneisses and augen gneisses in former magmatic representatives of this igneous suite implies that a high proportion of the suite was intruded well before the close of metamorphism. Some of the tabular bodies of the quartz monzonite of Seven Lakes are today preserved in complex synclinal forms, for example, on Buck Mountain (fig. 11) and Red Elephant Mountain (Snyder, 1977a, 1980a, cross sections *D-D'* and *E-E'*), that may imply considerable folding following emplacement.

Following the earlier Precambrian folding and metamorphism the elongate Mount Ethel batholith was emplaced 1.4 b.y. ago parallel to northeast-trending structure. Some of the porphyry dikes overlap these quartz monzonites in age, and they appear to extend the chemical trends developed by the Mount Ethel rocks (Snyder, 1978, 1984); but some dikes may be much younger than the batholithic rocks. Following batholithic cooling, two extensive northeast-trending Precambrian shear zones were formed, between Soda Creek and North Fork Fish Creek and on Farwell Mountain. The generally medium to coarse-grained rocks in these areas were locally mechanically milled down to excessively fine grained rocks—mylonites—that have never been coarsely recrystallized. The true mylonites are confined to planar sheets as much as a few tens of meters thick and many kilometers long, but within the shear zones many rocks are also partly sheared or partly mylonitized. Some paired porphyry dike sets are offset along some mylonite sheets as much as 400 m (1/4 mi) (for example, northwest of BM 10,088 west of Buffalo Pass), whereas other mylonite sheets include sheared remnants of porphyry dikes, perhaps ones that were intruded along moving faults and that later helped to lubricate the faults (for example, in Soda Creek, south of Round Mountain Lake, and northeast of Big Red Park). The time of shearing and mylonitization has not been directly dated in the northern Park Range, but it must be younger than the Mount Ethel pluton and porphyry dikes and old enough that depth of burial was still sufficient to permit mylonitization. Farther south, northeast-trending shear zones have been inferred to be late Precambrian in age (Tweto and Sims, 1963, p. 991, 1006). To the east mylonites have been dated at 1.2 b.y. (Abbott, 1972). All the mylonites are part of a much broader northeast-trending belt of Precambrian wrench faulting believed by some to be 1,100 km long and 160 km wide (Warner, 1978, p. 161).

Tectonic uplift of the Park Range probably began in the late Paleozoic but was markedly intensified in late Mesozoic and early Tertiary time. Some early or continued uplift is suggested by missing stratigraphic units along the axis of the range (namely, pre-Permian Paleozoic rocks, Forelle Limestone, and Sundance Formation) as well as by the presence of some Precambrian-derived pebbles in most units. But uplift, folding, and faulting culminated in the Laramide orogeny in latest Mesozoic and earliest Tertiary times. The entire range is basically a giant anticline with an eroded crest. Mesozoic hogbacks flank the range and are preserved in isolated synclinal fault blocks within it. The fault blocks are mostly asymmetrical with shallow dipping rocks in depositional contact with Precambrian basement on the west side of the blocks and steep or overturned beds on the east side, overridden by basement thrust blocks. (See Snyder, 1977a, 1980a.) Exposures are incomplete, but there is some evidence of a gradation in dip of the east-margin faults: steep or vertical on the west side of the range to shallow or nearly horizontal on Independence Mountain on the northeast side of the range (Snyder, 1977a, 1980a). If so, this may indicate a cross-range gradation in Laramide tectonic forces: from strongly compressional on the east to less strongly compressional or, locally, tensional on the west. Faults offsetting Mesozoic rocks locally grade into Precambrian mylonite zones, indicating remobilization of earlier crustal weaknesses (fig. 18). The Coalmont Formation

FIGURE 18.—Differentially eroded steeply dipping fault plane crossing Hinman Creek from 9,300-ft lookout point (from topographic maps; 2,835 m) on southeast shoulder of Farwell Mountain. View from 1-m-wide (3-ft-wide) mylonite zone along this fault.

presents evidence of early Tertiary continuation of Laramide uplift and faulting. Mountain margin facies contain large Precambrian boulders, and the formation itself is interleaved in thrust slices on the north side of Delaney Butte (Hail, 1965).

Laramide tectonism died out in the Eocene to be replaced by erosion, sedimentation, and volcanism in the Oligocene and Miocene and by normal faulting in latest Miocene or Pliocene. Volcanic rocks erupted in the Rabbit Ears Range during Oligocene time contributed volcanic boulders to the Miocene North Park Formation just outside the eastern limit shown on plate 1. Lower Miocene lava flows are intercalated with the sparse Browns Park sediments on Rabbit Ears Peak and all across Rabbit Ears Pass (Snyder, 1977c, 1980c). Ash beds, though present in the lower part of the Browns Park Formation, are more numerous and more voluminous in the upper part and were succeeded by capping lava flows and numerous irregular intrusives in the Elkhead Mountains 10–12 m.y. ago (fig. 19; and see Buffler, 1967; Segerstrom and Young, 1972). This episode of intrusion was followed by normal faulting of diverse orientation with offsets of 300 m (1,000 ft) or more: the Browns Park Formation is in knife-blade-sharp fault contact with basement rocks in the valley of the Encampment River northeast of West Fork Lake; significant fault offset can also be demonstrated on the west side of Strawberry Park, on Copper Ridge, northeast of Pearl, and at many localities within 8 km (5 mi) of Hahns Peak. Some of the youngest Elkhead intrusives occupy faults offsetting the Browns Park Formation (for example, the dike on the east side of Little Red Park is K-Ar dated at 10.3±0.3 m.y., Segerstrom and Young, 1972, pl. 1, p. 41). Other faults on Hahns Peak or associated with the Hahns Peak horst cut the Elkhead intrusives. No modern fault scarps have been recognized in the area, but the concentration of recent landslides along linear fault zones from Hinman Park to West Fork Lake suggests their contemporaneity, perhaps because they were triggered by a prehistoric earthquake along a line of structural weakness.

MINERAL AND GEOCHEMICAL SETTING

TIMING OF MINERALIZATION

Rocks of the northern Park Range have been mineralized by introduced ore elements probably four times in the geologic past, twice in the Precambrian, once(?) at the close of the Mesozoic and beginning of the Tertiary (Laramide), and at least once later in the Tertiary. The Precambrian events coincide with the two major episodes of igneous intrusion, 1.7–1.8 b.y. and 1.3–1.4 b.y. (Antweiler, 1966; Antweiler and

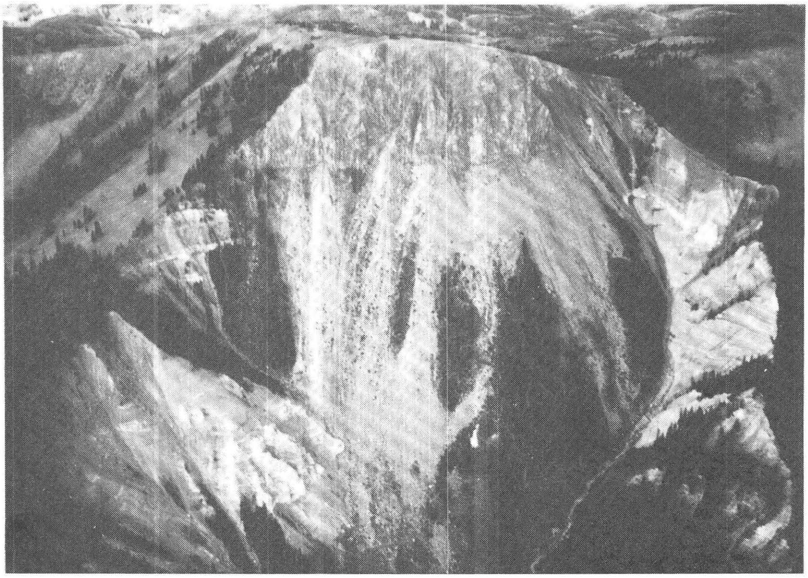


FIGURE 19.—Aerial view looking southwest at northeast face of Sand Mountain, showing bedded silts (gray) and ash-rich beds (light) of Browns Park Formation along right and left ridges of photograph (same covered by talus in center) and silicic intrusive porphyry in cliffs capping Sand Mountain. Area shown has yielded numerous "Barstovian" vertebrate fossils and ash-bed zircon fission-track ages (9–16 m.y.) and is essentially the area mapped in southeast corner of Meaden Peak 7½′ quadrangle in western part of map area of Snyder (1980a). Vertical span from bottom of photograph to top of Sand Mountain is more than 360 m (1,200 ft).

others, 1972; Snyder, 1978, fig. 19), and although not all Precambrian mineralization is definitely assignable to one or the other event, some is directly dated and other assignments are probable, as indicated by the examples in table 1. The reader should note that Antweiler's 1.0-b.y. mineralization (1966, p. 271) in evidence elsewhere in Colorado has not been recognized yet in the northern Park Range. The late and post-Mesozoic mineralization occurred in or was related to Laramide structures, but most deposits have not been directly dated. (See Taylor and others, 1968, for a discussion of this problem.) Some of the Tertiary mineralization was post-Eocene, some was post-Oligocene, and some was late Miocene, but whether one long period of mineralization or three or more short ones took place is not definitely known. Here and elsewhere in the vicinity there is evidence that elements or minerals originally deposited in the Precambrian have been remobilized in the Laramide or Tertiary (Tweto, 1960, p. 1406; Tweto and Sims, 1963; Antweiler and others, 1972, p. 312; Snyder, 1978).

TABLE 1.—*Ages of selected mineralization episodes in the northern Park Range*

Mineralization episode	Reason for age assignment
Greenville district copper-lead-zinc-silver.	Lead isotopes indicate 1.7-b.y. age on a "best-fit" lead evolution curve (Antweiler and others, 1972, p. 310).
Gilpin district copper-lead-zinc-silver (includes Gilpin mines and Upper and Lower Slavonia mines).	Lead isotopes indicate 1.7-b.y. age on a "best-fit" lead evolution curve for Slavonia ore (Antweiler and others, 1972, p. 310).
Farwell district copper-lead-zinc-silver (includes Farwell mines and mines on uppermost King Solomon Creek).	K-Ar age on muscovite from mineralized Farwell pegmatite is 1.68±0.05 b.y. (Segerstrom and Young, 1972, table 3, p. 17).
Copper-lead-zinc-silver ore from Pearl district, Independence Mountain, west side of Buck Mountain, southwest Red Elephant Mountain, and probably most anomalous values in stream sediments in north half of map area.	Intimate association with 1.7- to 1.8-b.y. Precambrian rocks, and by analogy with above.
Seven Lakes beryllium stream-sediment anomaly.	Associated with center of 1.7-b.y. quartz monzonite pluton.
Fish Creek Fair-U claims.	Intimate association with 1.7-b.y. rocks.
Ultramafic chromium-platinum-palladium traces.	Zircons from gabbro of Elkhorn Mountain give $^{207}Pb/^{206}Pb$ age of 1.78 b.y. (C. E. Hedge and Margarita Gallego, in Snyder, 1977a, 1980a).
Elkhorn district lead-silver-zinc-copper ore.	Lead isotopes indicate 1.45–b.y. age on a "best-fit" lead evolution curve (Antweiler and others, 1972, p. 311).
Uranium-niobium traces in prospects in Bear Creek district east of Elk Park, uranium-thorium-rare earth Fielder prospect near Agua Fria Lake, interstitial fluorite in rocks of Mount Ethel pluton, silver trace anomaly in stream sediments south of Horse Thief Peak.	Intimate association with rocks of 1.4–b.y. pluton (Snyder, 1977b, 1980b).
Copper-silver ores south of Lone Pine Creek, copper-silver ores and related stream-sediment anomalies on east side of Silver City Creek basin, minor Northgate fluorite.	"Laramide" because intimately associated with structures cutting Mesozoic rocks (Snyder, 1977a, b, 1980a, b; Steven, 1960, p. 395, 396).
Uranium-fluorite veins, Crystal district; fluorite veins, Northgate.	Post-Coalmont = post-Eocene for Crystal; post-White River = post-Oligocene for Northgate; both could be late or post-Miocene.
Hahns Peak disseminated lead-silver ore; source of Hahns Peak gold placers.	Ore disseminated in or probably derived from porphyry with K-Ar age about 10 m.y. (late Miocene) (Segerstrom and Young, 1972, table 6, p. 41; Young and Segerstrom, 1973; Antweiler and others, 1972).

INTERPRETATION OF ORIGIN OF SULFIDE DEPOSITS

It is worthwhile enlarging upon the description and interpretation of origin of the copper-lead-zinc-silver vein and replacement ores (generally 1.7–1.8 b.y.; table 1) for several reasons:

1. Deposits of this worldwide type are among the most heterogeneous and complex of all ores (Stanton, 1972, p. 598, 610);
2. They occur over a wide area in the northern Park Range, including some centrally located zones within the Mount Zirkel Wilderness and adjacent area;
3. They have generated the most interest in this area in terms of the volume of previous prospecting, albeit without substantial success, but they are judged here to have a real potential for future economic exploitation. Sheridan and Raymond (1977, p. 22) believed that mineable sulfide deposits may occur in the northern Park Range. On the other hand, Tweto, Bryant, and Williams (1970, p. C35, C36) cautioned that the absence of Tertiary porphyries and the offset from the Colorado mineral belt militate against significant Tertiary ore deposits in the Gore Range–Eagles Nest Primitive Area; Mount Zirkel Wilderness and adjacent area has no Tertiary porphyries exposed at the surface and is offset an additional 80–120 km (50–75 mi) from the Colorado mineral belt (Tweto, 1968, fig. 1). However, Doe (1978) has noted that the value of Cretaceous-Tertiary magmatothermal ore deposits is progressively greater in areas where the maximum $^{206}Pb/^{204}Pb$ ratio is toward the low end of the sequence 18–25; in the northern Park Range this ratio has a maximum of 18.7 (Antweiler and others, 1972, p. 310). Certainly rocks of the general 1.8-b.y. age and provenance have the capacity to contain massive sulfide ores in the Jerome area of Arizona (Anderson and Creasey, 1958; Anderson and Nash, 1972). U.S. production from massive sulfide ores is insignificant in comparison to porphyry copper deposits and Mississippi valley type lead-zinc deposits, but in Canada 80 percent of the zinc, 39 percent of the copper, 68 percent of the lead, 62 percent of the silver, and significant amounts of gold came from this type of mineralized rock in 1971 (Sangster and Scott, 1976, p. 129). In Colorado molybdenum, gold, and silver, in that order, constitute 72 percent of the total value of the principal metals produced from 1858 through 1964 (Tweto, 1968, p. 553).

The Park Range ores are variable mixtures of the common iron, copper, lead, and zinc sulfides (mainly pyrite, chalcopyrite, galena, and sphalerite) in places with anomalous silver, tungsten, molybdenum, gold, mercury, and tin, locally with small gossans of iron oxide or hydroxide and copper hydroxide or carbonate, rich in some or all of these elements. The ores commonly occur in disseminated form replacing marble or calc-silicate rocks, but they may also be associated with pelitic schists or the spectrum of metavolcanic rocks from amphibolite to felsic gneiss. Blocks of massive ore with greater than 50 percent sulfides are present on most of the larger dumps, but relations of this ore to the wall rock can only rarely be studied in outcrop. In many dump samples the massive ore appears to be gradational with the disseminated ore, but some sulfides occur in sharp-margined crosscutting veins, possibly reflecting a younger (perhaps much younger) episode of mineralization. Oxide and silicate gangue minerals present in composite aggregates appear to be the same as those present elsewhere in these high-grade wall rocks. Gahnite, a zinc aluminate, is present rarely in the wall rocks of the Pearl and Greenville districts

(Read, 1903; Sheridan and Raymond, 1977, p. 20; Robert Johnson, oral commun., 1977; Snyder, 1984) but has not been observed elsewhere in the range. Alteration zones, if present at all, are narrow; usually the sulfide-silicate assemblage presents the appearance of being emplaced before or during metamorphism (Stanton, 1972, p. 625), certainly not in a much younger, separate event.

Most importantly, many of the base-metal ores seem to occur in the marine metavolcanic-metasedimentary rocks near but outside of the complexly shaped syntectonic bodies of quartz monzonite of Seven Lakes. This observation for the northern Park Range is new with this report, and it has some implications for origin. It is true for most of the prospected ore bodies in the Pearl district and on Independence Mountain, in the Gilpin district (including the Upper and Lower Slavonia and Gilpin mines), on Red Elephant Mountain, on Buck Mountain, on Farwell Mountain, and at the "Chipmunk" claim west of Buffalo Pass. All prospected ore bodies of this type, except Greenville, appear to occur within 3.2 km (2 mi) of a quartz monzonite contact, but none are known either within the quartz monzonite or at its wall-rock contacts. Although, as mentioned above, marble is a favored host (nearly all marbles within 3.2 km (2 mi) of the quartz monzonite contact show some effects of mineralization), marbles outside the 3.2-km (2-mi) range, along the north edge of the mapped area and east of Glen Eden, are not mineralized.

The preceding facts are consistent with a diplogenetic (Lovering, 1963) hypothermal origin of the ores, possibly weakly remobilized by mesogene solutions (Ridge, 1976, p. 190). The following can be visualized. The ore elements are deposited in largely unconcentrated form along with volcanics, volcanic sediments, or sediments. Thus, the country rocks that enclose the deposits are the ultimate source of the metals and gangue elements, an idea that has been advocated since the time of Agricola. (See Amstutz, 1964; Boyle, 1970; Bernard, 1973, for modern summaries.) Some, like Greenville, may have been present in concentrated form, but the evidence either way is meager. (Sheridan and Raymond (1977, p. 17, 18), who have visited the Pearl, Gilpin, and Greenville districts, believed that some deposits may have an exhalative sea-floor origin, whereas other deposits associated with calc-silicate rocks and impure marbles may have been syngenetic or epigenetic stratiform ore deposits in sedimentary rocks before metamorphism.) Following the postulated syngenetic dispersal of the ore elements through the eugeosynclinal rocks, quartz monzonites were intruded prior to or contemporaneous with the height of regional metamorphism, and the outflow of magmatic heat and possible solutions was the agent for magmatothermal (Doe, 1978; see also Jensen and Bateman, 1979, p. 258) concentration of the ore elements. This lithogenic (Lovering, 1963) or laterogenic (Gabelman, 1976, p. 51) concentration of ore elements could be accomplished either by the normal mechanism of migrating interstitial or magmatic water or by the dry "distillation" process of Sullivan (1958). Migration might take place over distances of a few meters to 3.2 km (2 mi), and carbonate hosts along the way would be favored sites of concentration. Many ore bodies resulting from such syngenetic dispersal plus later remobilization might reasonably be expected to be of small subeconomic size, proportional both to the small element amount originally deposited in dispersed form and also to the small size of the concentration "engine" that came along later; but some could be substantial. If the present surface sampling is representative of what is also present at reasonable depth in the crust, this favored remobilization hypothesis does not hold much hope for the existence of a large hidden massive sulfide ore body. However, if the present surface sampling is not representative of what is present at deeper levels, then a valuable subsurface sulfide resource could await more sophisticated prospecting.

Mine Appraisal

By LOWELL L. PATTEN, U.S. BUREAU OF MINES

MINERAL RESOURCES OF THE MOUNT ZIRKEL WILDERNESS AND NORTHERN PARK RANGE VICINITY, JACKSON AND ROUTT COUNTIES, COLORADO

U.S. GEOLOGICAL SURVEY BULLETIN 1554-B

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INTRODUCTION

In 1971, the U.S. Bureau of Mines began a mineral survey of the Mount Zirkel Wilderness in the Routt National Forest in north-central Colorado. In 1972, at the request of the U.S. Forest Service, the survey was expanded to include approximately 170,000 acres (nearly 700 km^2; 68,900 ha (hectares)) of lands adjacent to the 295 km^2 (114 mi^2) of the wilderness area.

The study area, lying along the Continental Divide in Jackson and Routt Counties, has been proposed for inclusion in the National Wilderness System (figs. 20, 21). Altitudes generally range from 2,500 to 3,500 m (8,000 to 11,000 ft) in rough to rolling mountainous terrain. The principal nearby settlements are Walden (population approximately 1,000), east of the wilderness, and Steamboat Springs (population approximately 5,000), immediately southwest of the study area.

PRESENT INVESTIGATION

The U.S. Bureau of Mines investigation of the Mount Zirkel study area included a study of relevant literature; a review of Bureau of Land Management land-status plats; a search for mining-claim location notices recorded in Jackson, Larimer, and Routt Counties; an examination

FIGURE 20.—View east across Mica Basin to Big Agnes Mountain from west boundary of Mount Zirkel Wilderness. Some mica prospects occur on south ridge of Big Agnes Mountain above "Mount Zirkel Wilderness" sign.

of mining claims and prospect workings; and a general reconnaissance of the area. The work was performed by L. L. Patten, assisted by H. C. Meeves, R. A. Beach, R. J. Hurt, O. D. Staman, and D. D. Keill.

Courthouse records show that many mining claims have been located since the 1870's within and near the study area. The records include those of Larimer County, out of which Jackson County was formed in 1909. Claims that could be identified are shown on the illustrations. Many claims are not shown because of uncertainties in descriptions, and those that are plotted may not be accurately shown because of difficulties in interpreting location notices. A determined effort was made to visit and examine all mining claims, prospect workings, and mineralized areas.

During the investigation, 82 samples were taken for analysis by standard methods, from prospect workings and from other localities where there was an indication of mineralization. Most were chip samples, but many grab samples were taken from dumps at regular intervals on lines or rough grids. In addition, alluvium in streams was sampled by panning. Some of the panned samples contained particles of gold that were readily identifiable under a 10-power (×10) hand lens. Because of the sparsity of gold and the relatively small quantity of available placer material, appraisal consisted of a visual estimate of the value of the gold and a search for other minerals of value.

Spectrographic analyses of samples were made by semiquantitative methods in the U.S. Bureau of Mines and U.S. Geological Survey laboratories (tables 2, 3), and some samples were analyzed by a commercial laboratory (table 4). Samples showing significant quantities of potentially valuable elements were analyzed by chemical methods.

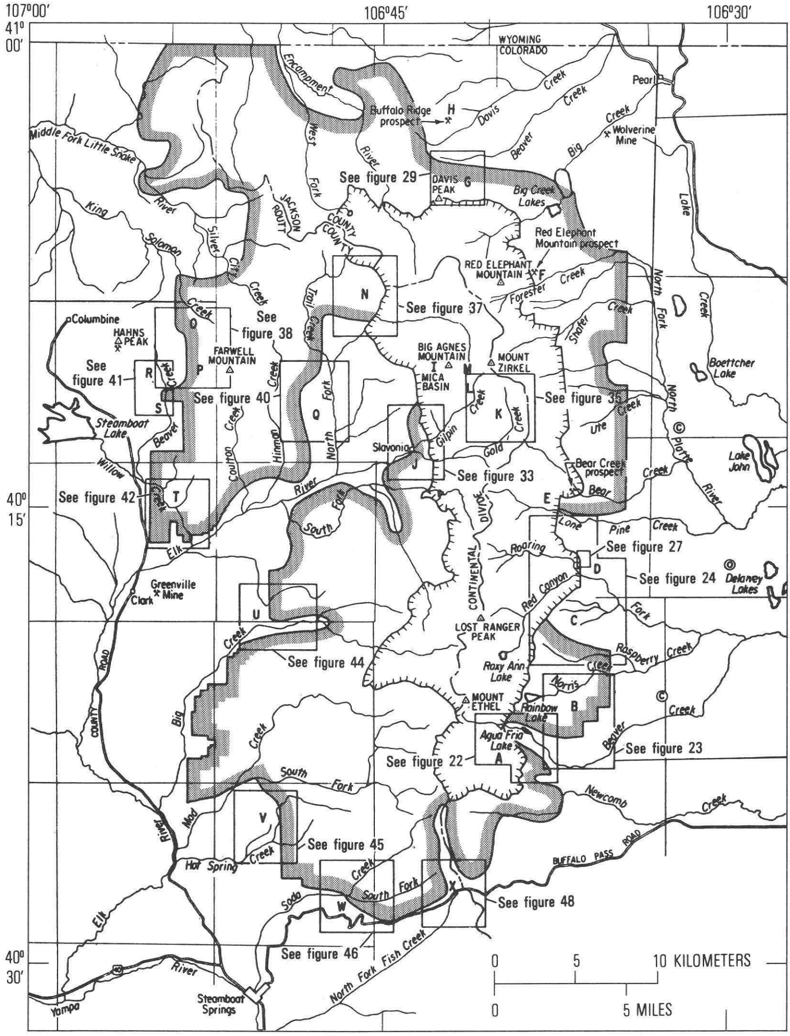
HISTORY AND PRODUCTION

Mining activity began in the Hahns Peak mining district in 1865 with Joseph Hahn's discovery of placer gold (George and Crawford, 1909). The district is approximately 4.8 km (3 mi) west of the study area and about 4 km (2.5 mi) north of Hahns Peak Village. According to USBM (U.S. Bureau of Mines) records, significant quantities of placer gold and silver were produced from the district in 1907, 1909, 1916, 1917, and 1918. The Hahns Peak activity expanded into the area west of Farwell Mountain, where numerous claims were staked; a little production was probably made from prospects about 3.2 km (2 mi) northwest of the mountain.

The Lower Slavonia mining district, at the confluence of Gold and Gilpin Creeks, was the scene of considerable prospecting and claim staking beginning about 1905. The district, outside the wilderness but within the adjacent area, is in the southwest corner of T. 10 N., R. 83 W. The mineral activity evidently was triggered by discovery of an occurrence of lead-zinc-silver with a little copper. There is no record of production from the district.

About 9.7 km (6 mi) up Gold Creek from the Lower Slavonia district, in the west canyon wall, are the remains of workings known locally as the Upper Slavonia mine. The workings are in the heart of the wilderness in the southwest corner of T. 10 N., R. 82 W. It is reported that the property dates from about 1910. No records of production were found, but dumps indicate that the workings were significant, and some production is inferred.

In Mica Basin, about 4.8 km (3 mi) northeast of the Lower Slavonia mining district, pegmatites have been prospected for mica for many years. The prospects are within the wilderness area. Although no records were found, it appears that trial shipments were made from these deposits. The records show considerable claim-staking activity in this area in the 1940's. To facilitate mica prospecting, a road that terminates at the wilderness boundary west of Mica Lake was built in recent years (area of prospects, fig. 20).



EXPLANATION

- × Mine or prospect
- © Abandoned coal mine
- ◎ Oil field
- A Locality examined
- Approximate wilderness boundary
- Adjacent area boundary

In the late 1950's, bulldozer trails and cuts were made in the vicinity of Agua Fria Lake in the southeastern part of the study area. The principal workings are outside the adjacent area in the southwest corner of T. 8 N., R. 82 W. The prospecting was probably a search for radioactive minerals, but no records of production from the area have been found.

Near the eastern boundary of the wilderness, between Raspberry and Roaring Fork Creeks, fluorite-bearing veins have been prospected since 1920. The Crystal mine, east of the study area in north-central T. 8 N., R. 82 W., produced 800 tons[3] (728 t (metric tons)) of fluorspar ore between 1945 and 1949. The mine was reopened in 1970 by the Ozark Mahoning Corp. and produced at the rate of approximately 200 tons (180 t) per day. Mining operations were discontinued in 1973.

Other fluorite-bearing veins have been prospected west and northwest of the Crystal mine by two other companies: Beta Mining Co., of Cañon City, Colo., and Geo Surveys, Inc., of Colorado Springs, Colo. Work by the Beta Co. included an adit, a shaft, and pilot mining from opencuts. Geo Surveys, through a trenching and drilling program, outlined a system of fluorite veins near the wilderness boundary. Geo Surveys, under an agreement with Minerals Engineering Co., of Denver, Colo., planned several thousand feet of drifting, beginning in 1974.[4]

[3]Data from older sources are quoted in their original systems of measurement first.

[4]Use of trade and company names in this report is for descriptive purposes only and does not imply endorsement by the U.S. Geological Survey.

FIGURE 21 (facing page).—Map showing localities examined by U.S. Bureau of Mines in the Mount Zirkel Wilderness and adjacent area, Colorado. Letters identify the following areas: A, Agua Fria Lake area (fig. 22); B, Beaver Creek–Norris Creek area (fig. 23); C, Raspberry Creek–Roaring Fork area (figs. 24, 25, 26); D, Roaring Fork–Lone Pine Creek (includes Pedad-DLB claims in fig. 27); E, Bear Creek prospect (figs. 19, 21); F, Red Elephant Mountain prospect (fig. 28); G, Windy Gulch claims (fig. 29); H, Buffalo Ridge (figs. 19, 21); I, Mica Basin (figs. 30, 31, 32); J, Lower Slavonia district (figs. 33, 34); K, Upper Slavonia mine (figs. 14, 35, 36); L, Upper Gilpin Creek (fig. 35); M, North Fork Elk River; N, Diamond Park area (fig. 37); O, King Solomon Creek area (fig. 38); P, Beaver Creek–King Solomon Creek area (figs. 38, 39); Q, Zinc Mountain claim group (fig. 40); R, Beaver Creek area; S, Grouse Mountain area (fig. 41); T, Willow Creek Canyon area (figs. 42, 43); U, Big Creek area (fig. 44); V, Elk Park area (fig. 45); W, Soda Creek area (fig. 46); X, Buffalo Pass area (figs. 47, 48, 49).

TABLE 2.—*U.S. Geological Survey analyses of samples from the Mount Zirkel Wilderness and adjacent area*

[Samples analyzed by U.S. Geological Survey, Denver, Colo., by semiquantitative spectrographic analysis; reported to the nearest number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, ..., which represent the approximate midpoint of group data on a geometric scale. Arsenic, gold, and tungsten, normally detectable by this process, looked for but not found; >, more than amount shown; >>, much more than amount shown; Tr., trace; leader (-), looked for but not found]

Sample	Semiquantitative spectrographic analyses (ppm)															
	Ag	B	Ba	Be	Bi	Cd	Co	Cr	Cu	La	Mn	Mo	Nb	Ni	Pb	Sb
[1]1	-	70	300	20	-	70	5	50	100	>>1,000	>5,000	15	>>2,000	20	1,500	300
5	-	-	300	3	-	-	-	150	70	-	50	70	30	5	70	-
8	-	-	1,500	2	-	-	5	150	70	50	500	-	10	7	70	-
10	-	20	700	3	-	-	10	100	50	50	500	-	-	20	20	-
11	-	-	200	2	-	-	15	150	70	70	700	-	-	20	10	-
12	-	-	300	1	-	-	20	50	70	50	1,500	-	-	15	15	-
[2]13	-	-	150	7	-	-	-	-	30	-	300	15	20	5	150	-
17	30	-	150	3	-	-	5	70	2,000	50	>5,000	30	-	7	300	-
18	30	-	300	1.5	-	-	-	50	700	70	>5,000	-	-	Tr	1,500	-
[3]19	200	-	150	3	20	70	5	20	1,500	-	>5,000	150	-	5	20,000	200
[4]20	300	-	150	3	20	300	-	-	3,000	-	>5,000	200	-	5	20,000	300
21	5	-	300	3	-	-	-	100	1,500	100	700	-	20	7	300	-
22	10	-	1,500	3	-	50	-	70	700	70	2,000	-	-	15	7,000	-
23	15	-	1,500	3	-	-	-	70	3,000	70	1,500	-	-	5	2,000	-
25	10	-	150	3	-	50	-	-	700	-	>5,000	-	-	5	70	-
26	10	Tr	300	1.5	-	500	30	70	3,000	-	5,000	-	-	20	70	-
27	15	Tr	-	1.5	-	150	5	-	1,000	-	>5,000	-	-	7	70	-
28	-	-	1,500	2	-	-	-	100	700	-	1,000	-	-	5	70	-
29	-	-	300	1	-	-	-	70	200	70	150	-	-	5	-	-
30	-	-	1,500	1.5	-	-	-	100	70	50	70	-	-	15	10	-
31	-	-	300	1	-	-	20	50	20	-	1,500	-	-	10	10	-

Sample	Semiquantitative spectrographic analyses (ppm)							(percent)				Remarks
	Sc	Sn	Sr	V	Y	Zn	Zr	Fe	Mg	Ca	Ti	
[1]1	>>100	300	5,000	70	>2,000	-	>1,000	10	0.5	0.3	0.2	2.0-foot chip.
5	-	-	-	-	10	-	300	0.1	.05	.3	.05	1.0-foot chip.
8	5	-	300	70	30	-	150	2	.7	2	.15	0.4-foot chip.
10	15	-	-	70	30	700	150	3	1.5	2	.15	1.5-foot chip.
11	30	-	-	150	70	-	70	7	1.5	3	.3	2.1-foot chip.
12	30	-	100	300	30	-	70	10	3	7	.5	1.0-foot chip.
[2]13	10	-	Tr	20	70	-	20	1	.2	.5	.07	Do.
17	15	-	-	20	70	7,000	300	10	5	.3	.2	4.0-foot chip.
18	15	-	-	20	70	3,000	300	10	7	.5	.3	2.0-foot chip.
[3]19	7	10	-	10	30	>10,000	100	10	7	3	.2	3.5-foot chip.
[4]20	10	20	-	20	30	>>10,000	150	10	7	3	.15	1.5-foot chip.
21	5	10	-	-	100	>10,000	300	5	3	.3	.1	Do.
22	5	-	-	30	70	>10,000	200	2	3	3	.15	3.0-foot chip.
23	-	-	-	20	70	>10,000	200	2	3	.5	.07	0.5-foot chip.
25	15	70	-	50	150	>10,000	70	10	7	3	.2	3.0-foot chip.
26	5	30	-	15	30	>>10,000	70	10	1.5	1	.1	2.5-foot chip.
27	5	-	-	30	10	>>10,000	30	10	7	10	.03	1.0-foot chip.
28	10	-	200	20	10	700	50	10	1.5	3	.5	3.6-foot chip.
29	5	-	100	20	50	-	150	2	.5	3	.15	3.0-foot chip.
30	10	-	100	10	-	-	200	5	.1	.3	.15	0.5-foot chip.
31	30	-	300	700	50	-	100	10	3	3	1	1.0-foot chip.

[1]Sample 1 contained 300 ppm antimony.
[2]Sample 13 contained 0.001 percent uranium.
[3]Sample 19 contained 200 ppm antimony and 20 ppm bismuth.
[4]Sample 20 contained 300 ppm antimony and 20 ppm bismuth.

TABLE 3.—*U.S. Bureau of Mines analyses of samples from the Mount Zirkel Wilderness and adjacent area*

[Samples analyzed by semiquantitative spectrographic methods and standard fire assay at the U.S. Bureau of Mines laboratory, Reno, Nev. Spectrographic analyses were made using a 3.4-meter Wadsworth spectrograph with a 30-inch plate holder. A margin of error of plus 100 percent and minus 50 percent is assumed. The following elements, normally detectable by this process, looked for but not found: As, B, Cd, Ga, Hf, In, La, Li, Nb, P, Pt, Re, Sb, Sr, Ta, Te, Tl, and W. Selected samples were rerun by chemical methods. >, more than amount shown; <, less than amount shown; leader (-), looked for but not found; blank, not looked for; Tr., trace; M, major constituent; *, results of rerun by chemical methods. Silicon was a major constituent of all samples]

Sample	Fire assay oz/ton	Semiquantitative spectrographic analyses (percent)															Remarks
	Ag	Ba	Be	Ca	Cr	Cu	Fe	Mg	Mn	Mo	Ni	Pb	Sc	Ti	Y	Zr	
2	Tr	–	–	0.4	0.003	<0.002	<1.0	0.4	0.01	–	–	<0.01	–	0.05	0.001	<0.01	1.5-foot chip.
3	–	–	–	.1	.01	.004	2	.4	.05	0.002	0.002	–	–	.2	–	.007	3.0-foot grab.
4	–	–	–	.1	.007	.003	2	.4	.05	.002	.002	–	–	.2	–	.03	Do.
[1]6	Tr	–	–	M	.01	.004	2	.4	.02	<.002	–	.02	–	.05	–	<.007	2.5-foot chip.
[2]7	0.1	–	–	M	.01	.004	2	.2	.03	–	–	.02	–	.05	–	<.007	3.0-foot chip.
14	–	–	–	.3	.01	.03	3	.2	.03	.002	.002	.01	–	.02	–	<.007	1.2-foot chip.
[3]24	.1	–	–	.5	.01	.008	3	2	.05	–	–	–	–	.1	–	.01	5.0-foot chip.
[4]32	Tr	–	–	M	.01	.06	7	2	.2	–	–	.06	–	.2	–	.03	4.5-foot chip.
34	–	–	–	M	.01	.08	4	2	.2	–	–	.01	–	.2	–	.03	1-foot chip.
36	.1	–	–	.5	<.003	.008	7	2	.2	–	–	.02	0.001	.4	<.001	<.01	Dump grab.
[4,5]37	5.1	–	–	.06	<.003	*.27	3	.05	.02	–	–	7.05	–	.001	–	<.01	Do.
[6]38	Tr	<0.1	<0.001	2	.003	*.13	7	2	.2	<.002	<.002	.02	<.005	.4	<.002	.01	1.8-foot chip.
39	.3	–	<.001	4	.003	.004	7	2	.2	<.002	<.002	.02	<.005	.4	<.002	.01	1.5-foot chip.
40	Tr	–	<.001	M	.003	*.11	6	3	.2	<.002	<.002	.01	<.005	.4	<.002	.01	2.2-foot chip.
[7]41	Tr	.1	–	M	.006	.03	M	4	.2	<.002	–	.01	<.005	.2	<.002	.01	1.2-foot chip.
[7]42	Tr	.1	<.001	1	.006	.04	3	.8	.1	<.002	–	.04	–	.2	<.002	<.007	0.2-foot chip.
43	–	–	<.001	.3	.003	<.002	4	.8	.2	<.002	<.002	–	–	.1	<.002	<.007	0.8-foot chip.
44	–	.1	<.001	.3	.006	*.28	6	.8	.1	.002	–	.01	–	.2	<.002	.01	Dump grab.
[8,9]45	–	–	<.001	.3	.01	*.47	4	.4	.05	.03	–	.01	–	.02	<.002	–	Ore pile grab.
46	–	.1	<.001	.5	.003	.03	6	.8	.2	<.002	–	.01	–	.4	.002	.02	Dump grab.
47	.2	<.1	<.001	.2	<.003	*.23	6	.6	.05	.002	–	.01	–	.2	<.002	.01	Do.
[7,10]48	–	–	–	.3	<.003	*.89	4	.05	.01	.04	–	.04	–	.006	<.002	–	Ore pile grab.
[7]49	–	–	<.001	.4	<.003	.03	3	1.5	.1	<.002	–	.01	–	.2	<.002	.01	Dump grab.
[7]50	–	<.1	<.001	.2	<.003	.05	5	.2	.1	<.002	–	.01	–	.1	<.002	.01	Do.
51	–	–	–	.1	<.003	.004	1	.1	.02	–	–	.04	–	.05	.001	<.01	Do.

52	-	-	-	.1	<.003	.004	1	.1	.02	-	-	.08	-	.2	.001	<.01	Do.
53	-	-	-	.2	<.003	.004	1	.1	.1	-	-	.02	-	.05	.001	<.01	Do.
54	-	<.1	-	1	<.003	.004	>7	1	.1	-	-	.02	.003	.6	.003	<.01	Do.
55	-	-	-	.03	.01	.004	1	.2	.02	-	-	.08	-	.1	<.001	<.01	Do.
56	-	-	-	-	<.003	.004	.4	.02	.01	-	-	-	-	.01	-	-	Do.
[9]57	.1	-	<.001	1	.003	*.34	2	.2	.05	<.002	<.002	.02	-	.05	<.002	.01	1.5-foot chip.
[7]58	.1	-	-	.1	<.003	*1.02	2	.2	.01	-	-	-	-	.006	-	<.01	0.5-foot chip.
59	.1	-	.001	.1	<.003	.003	2	.3	.02	-	-	-	-	.02	-	<.01	Do.
[11]60	.2	-	-	2	.03	.008	5	3	.1	-	.007	.01	-	.2	-	.02	Dump grab.
61	.3	-	-	.1	.01	.28	1	.1	.03	-	-	.02	-	.05	-	.01	Do.
[12]62	Tr	-	-	M	<.003	.004	7	.4	.4	-	-	.08	-	.01	-	<.01	3.0-foot chip.
63	-	-	-	1	<.003	.008	3	.8	.05	-	-	.01	-	.2	.001	<.01	Dump grab.
64	-	<.1	-	4	<.003	.006	7	1	.1	-	-	.01	.001	.2	.001	<.01	Grab.
65	-	-	-	.3	<.003	.004	2	.8	.05	-	-	<.01	-	.1	<.001	<.01	Dump grab.
66	.2	-	-	1	.01	.004	5	.8	.05	-	-	.01	.001	.1	<.001	<.01	Do.
67	.2	-	-	.1	.01	.008	2	4	.05	-	-	.01	-	.1	-	.01	6.0-foot chip.
70	-	-	-	M	.003	.002	5	.8	.05	-	-	<.01	.001	.1	-	<.01	3.0-foot chip.
71	-	.1	-	.1	<.003	.13	4	3	.1	-	-	.04	.001	.05	.003	<.01	2.0-foot chip.
72	-	-	-	.4	.01	.008	4	4	.2	.002	.002	.04	-	.2	-	-	Dump grab.
[13]73	-	-	-	.4	.007	*.28	5	4	.2	.002	.002	-	-	.8	-	.007	1.0-foot chip.
74	-	-	-	>4	.02	.02	3	.4	.1	.002	.002	.01	-	.2	-	.01	5.0-foot chip.
[14]75	-	-	-	.1	.01	.02	3	.8	.1	-	.002	.01	-	.2	-	.01	Dump grab.
76	-	-	-	.06	.003	.002	2	3	.1	-	.002	-	-	.1	-	.01	Do.
77	Tr	-	-	.5	.003	.003	1	.05	.02	-	-	.02	-	.1	-	<.01	35.0-foot chip.
78	.1																5.0-foot chip.
79	.1																3.0-foot chip.
80	.1																6.0-foot chip.
81	.1	-	-	.1	.01	.008	>7	3	.2	-	.004	<.01	.003	.2	<.001	<.01	Dump grab.
82	-	-	-	.4	<.003	.008	7	.1	.02	-	-	.01	-	.02	-	<.01	1.5-foot chip.

[1]Sample 6, 16.2 pct CaF_2 (chem. analysis).
[2]Sample 7, 13.0 pct CaF_2 (chem. analysis).
[3]All samples assayed for gold, but sample 24 was only one to contain measurable quantity: 0.01 oz/ton.
[4]Samples 32 and 37 contained 0.05 percent Zn.
[5]Sample 37, 0.05 pct Bi.
[6]Sample 38, 0.01 pct Sn.
[7]Samples 41, 42, 48, 49, 50, and 58 contained 0.01 pct Bi.
[8]Sample 45, less than 0.005 pct Bi.
[9]Samples 45, 57, 0.02 pct Sn.
[10]Sample 48, 0.005 pct Sn.
[11]Sample 60, 0.01 pct V.
[12]Sample 62, 0.1 pct Zn.
[13]Sample 73, 0.003 pct Co and 0.01 pct V.
[14]Sample 75, 0.003 pct Co.

TABLE 4.—*Analyses of samples from the Mount Zirkel Wilderness and adjacent area*

[Gold and silver determinations by atomic absorption (AA) and fire assay, as shown. Atomic absorption determinations by Skyline Labs, Inc., Wheat Ridge, Colo. Fire assays by the U.S. Bureau of Mines laboratory, Reno, Nev. All other determinations by chemical methods by Skyline Labs, Inc. <, less than amount shown; leaders (—), not analyzed; N.F., none found]

Sample	AA (ppm)		Fire assay (oz/ton)		Chemical analysis (percent)				
	Au	Ag	Au	Ag	Cu	Pb	Zn	U	Th
1	--	--			--	--	--	0.22	0.68
5	--	--			--	--	--	.034	--
8	<0.02	<0.2			0.003	--	--	--	--
9	--	2.0			.02	<0.01	<0.01	--	--
10	<.02	<.2			--	--	--	--	--
11	<.02	<.2			--	--	--	--	--
12	<.02	<.2			--	--	--	--	--
13	--	--			--	--	--	.001	--
17	.03	20.0			.15	.04	.32		
18	.04	11.0			.04	.04	.26	--	--
19	.25	87.0			.11	1.8	2.2	--	--
20	.68	170.0			.26	4.2	6.8	--	--
21	<.02	2.4			.17	.02	.48	--	--
22	<.02	5.6			.07	.65	.78	--	--
23	.22	25.0			.32	.38	.75	--	--
25	.17	6.0			.03	.01	.95	--	--
26	.05	6.8			.21	<.01	16.0	--	--
27	<.02	7.0			.05	<.01	2.8	--	--
28	<.02	<.2			.04	.01	.05	--	--
29	<.02	<.2			.03	--	--	--	--
30	<.02	<.2			--	--	--	--	--
31	<.02	<.2			--	--	--	--	--
33			N.F.	N.F.				N.F.	
[1]35			N.F.	N.F.				N.F.	
68			N.F.	N.F.				N.F.	
69			N.F.	N.F.				N.F.	
78			N.F.	0.1				<.01	
79			N.F.	.1				<.01	
80			N.F.	.2				<.01	

[1]Sample 35 contained 0.09 percent Cu.

Beginning in 1963, an extensive drilling and geochemical exploration program was carried on for several years by William A. Bowes and others in the Hahns Peak, Farwell Mountain, Zinc Mountain, and Big Creek areas. The Hahns Peak locality is west of the adjacent area boundary in the north-central part of T. 10 N., R. 85 W. The Farwell Mountain locality is within the adjacent area in the east-central part of T. 10 N., R. 85 W. The Zinc Mountain area borders the adjacent area in the south-central part of T. 10 N., R. 84 W. Exploration work in the Big Creek area was mainly outside the adjacent area.

Several mines at other locations in the immediate vicinity of the study area have produced minor amounts of ore. These include the Greenville and Wolverine mines.

The Greenville mine, near the town of Clark in the southeast corner of T. 9 N., R. 85 W., produced less than 2,000 tons (1,800 t) of ore between 1942 and 1958. The ore contained more than 1 oz silver per ton (34 ppm), a little more than 10 percent zinc, and small amounts of lead and copper. The sulfide mineralization occurred in gneiss and schist.

The Wolverine mine, about 4.8 km (3 mi) northeast of the adjacent area boundary in the northeast corner of T. 11 N., R. 82 W., produced less than 1,000 tons (900 t) of ore between 1902 and 1917. The ore contained more than 5 percent copper, a little more than 2 1/2 oz silver per ton (86 ppm), and less than 0.1 oz gold per ton (3.4 ppm). Mineralized rock consists of sulfides and oxides of copper in gneiss and in pegmatites.

MINING CLAIMS, PROSPECTS, AND MINERAL DEPOSITS

Only one patented mining claim is within the adjacent area. It is near the western boundary of the area in the extreme northeast corner of T. 10 N., R. 85 W. (figs. 21, 38). Numerous unpatented claims have been located within and near the adjacent area; the claims that could be identified are shown on the illustrations.

Eighty-two samples were taken for analysis from 23 localities within and near the adjacent area. For easy reference, all localities discussed in the text of the report have been lettered, and their locations are shown on figure 21. Values generally are discussed in the text of the report only for those samples with significant ore mineral content.

AGUA FRIA LAKE AREA (LOCALITY A)

The Agua Fria Lake area (locality A) is southwest of Agua Fria Lake near the southeastern boundary of the wilderness on the upper drainage of Beaver Creek. The area examined is in the southwest corner of T. 8 N., R. 82 W. (fig. 21). Hail (1965) discussed the geology of this area. Between 1956 and 1970, bulldozer cuts were made in exploring pegmatites in Precambrian quartz monzonite. The workings, on a group of 60 claims, are partly within the Mount Zirkel Wilderness and adjacent area and partly outside (fig. 22). The principal workings are about 0.5 km (1/3 mi) south of the Agua Fria Lake dam where several sidehill cuts were made by bulldozing and blasting. The largest cut is about 30 m (100 ft) long and 6 m (20 ft) deep; it bears S. 15° W. Material exposed consists mainly of quartz, feldspar, and other

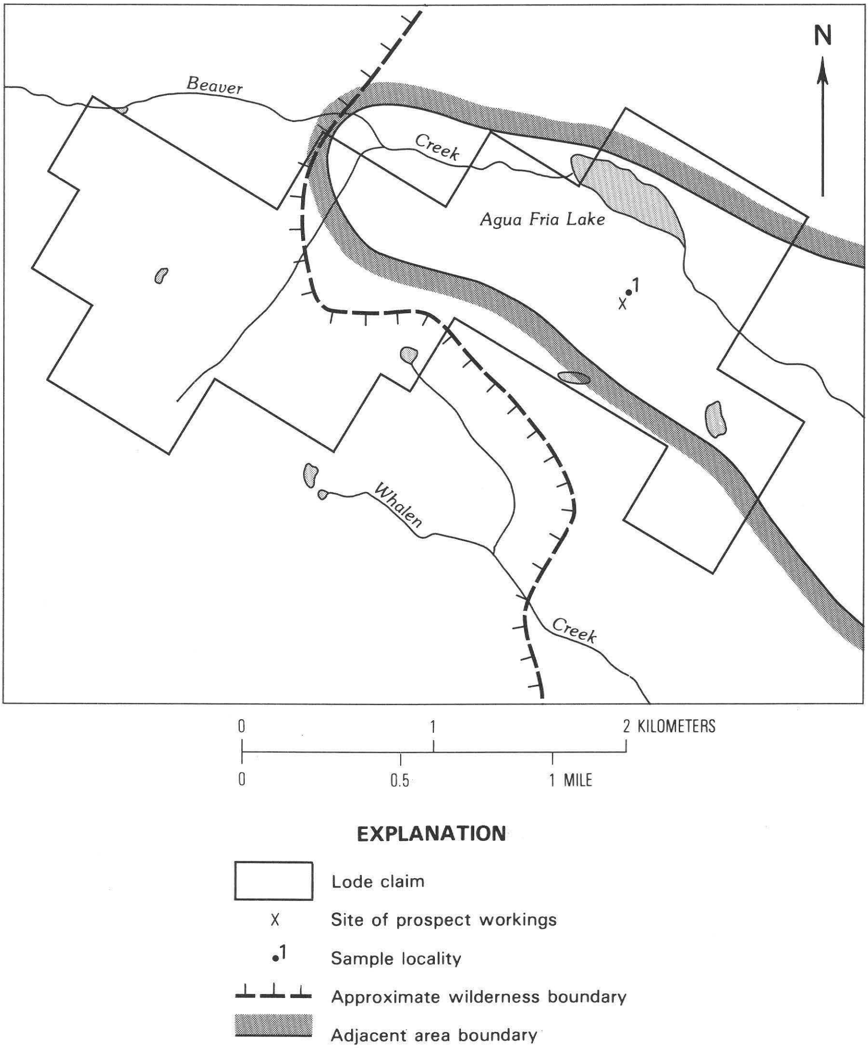


FIGURE 22.—Mining claims and sample locality in the vicinity of Agua Fria Lake (loc. A).

normal pegmatite minerals, together with a very small amount of large biotite crystals (as much as 8 in. in length) and one pod containing biotite and dark-colored, highly radioactive, complex minerals. Analyses of sample 1 from the 60-cm (2-ft) pod showed 0.22 percent uranium and 0.68 percent thorium (tables 2, 4). Significant amounts of lanthanum, niobium, scandium, strontium, and yttrium were detected by spectrographic analysis. (Also see table 9.)

BEAVER CREEK–NORRIS CREEK AREA (LOCALITY B)

Claims and prospects in the Beaver Creek–Norris Creek area (locality B) are in the south-central part of T. 8 N., R. 82 W. (fig. 21), and are shown on figure 23. In west-central section 27, several bulldozer

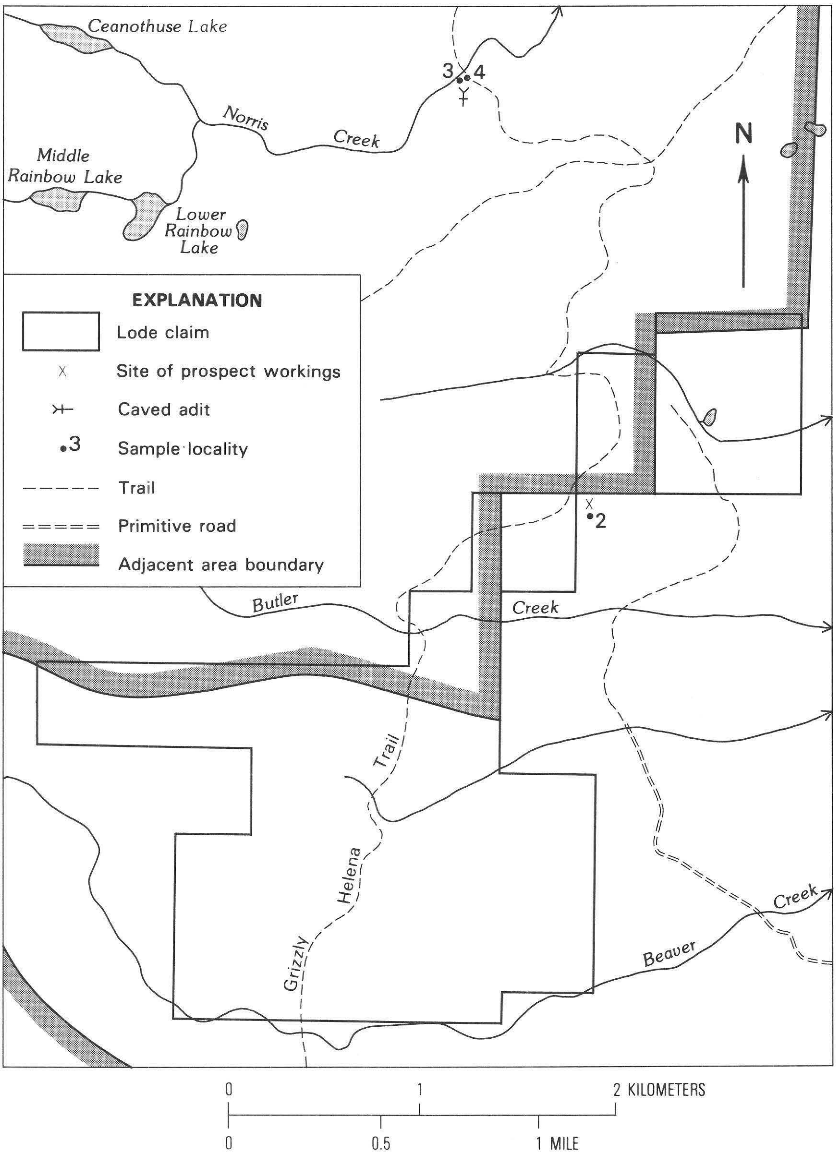


FIGURE 23.—Mining claims and prospects in the Beaver Creek–Norris Creek area (loc. B).

pits have been dug in steeply dipping Morrison Formation. Because the claims were located in the 1950's (a time of widespread uranium prospecting), and because the background reading is somewhat above normal, it is assumed that uranium was the object of the activity. The northernmost of three pits gave a reading of 0.05 milliroentgens per hour. A 45-cm (1.5-ft) chip sample (sample 2) in light-gray shale showed no significant radiometric reading, and the spectrographic analyses showed no anomalous metals (table 3).

About 2.4 km (1.5 mi) north of the three pits, the Grizzly Helena Trail crosses Norris Creek. West of the trail on the south bank of the creek, an adit (now caved) was driven along a north-south fault zone in altered igneous rock containing quartz and pyrite. Remnants of the dump north of the creek indicate that the underground workings may have been extensive. Two samples (3, 4) of material from the fault zone contained no mineral values of consequence (table 3).

RASPBERRY CREEK–ROARING FORK AREA (LOCALITY C)

The Raspberry Creek–Roaring Fork area (locality C) is just east of the wilderness and adjacent area boundaries in the north-central part of T. 8 N., R. 82 W. (fig. 21). Claims and workings within the area are shown on figure 24; most of them are east of the study area. Quartz-fluorite veins are exposed, mostly along north-trending high-angle faults in quartz monzonite; the veins contain traces of uranium. Beginning in the 1920's, numerous excavations were made in this area during fluorspar exploration (Hail, 1965). One of the old workings, known as the Crystal mine, was reopened in 1945 and produced about 800 tons (726 t) of fluorspar ore before it was shut down in 1949. The mine was again reopened in 1970 by the Ozark Mahoning Corp. and produced at the rate of approximately 200 tons (180 t) per day from underground and opencut workings. The ore was shipped to the company's mill at Northgate, Colo. In 1973, production was discontinued because of excessive dilution resulting from weak vein walls. The veins, as much as 4.6 m (15 ft) and more in width, contain bodies of nearly pure fluorite, but an average grade of only about 50 percent calcium fluoride was produced in mining.

About 1.6 km (1 mi) northwest of the Crystal mine, the Beta Mining Co., of Cañon City, Colo., has explored fluorite-bearing veins similar to those of the Crystal mine on a group of approximately 30 claims. Workings include a 240-m-long (800-ft-long) opencut, a 70-m (225-ft) adit, and a shallow shaft (figs. 25, 26).

In the fall of 1971, Geo Surveys, Inc., of Colorado Springs, Colo., located 203 claims of the Spar group adjacent to the Ozark Mahoning and Beta properties, and mostly west and north of them. A trenching

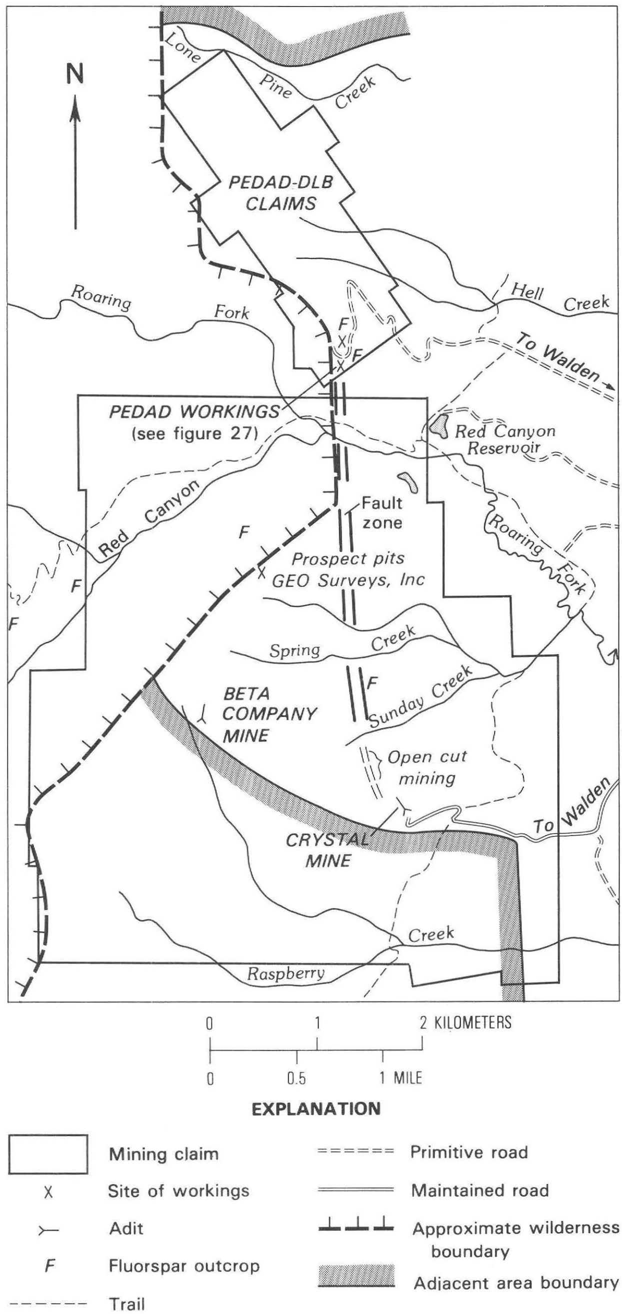


FIGURE 24.—Fluorspar mines, prospects, and occurrences in the Raspberry Creek–Roaring Fork–Lone Pine Creek area (loc. C).

FIGURE 25.—Beta Mining Co. opencut.

FIGURE 26.—Beta Mining Co. headframe.

and drilling program on the property in 1972 and 1973 disclosed significant fluorite-bearing veins, mainly on the ridge east of Red Canyon near the wilderness boundary and north of the Beta property. Plans for future development of the property include an adit to be driven by Minerals Engineering Co., of Denver, Colo.

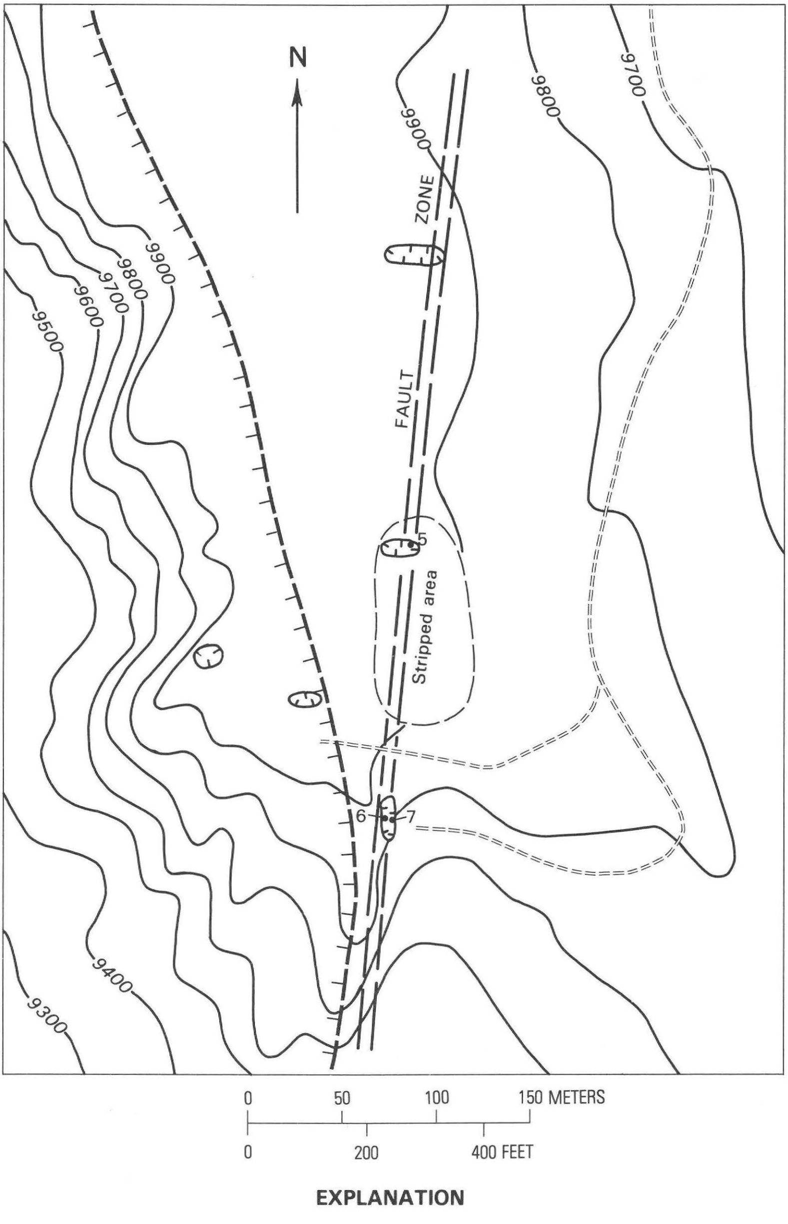
Other minor fluorite occurrences were seen in Red Canyon (as marked "F" on fig. 24). These were veinlets containing up to one-half inch of fluorite.

ROARING FORK–LONE PINE CREEK (LOCALITY D)

The Roaring Fork–Lone Pine Creek area (locality D) straddles the wilderness boundary in south-central T. 9 N., R. 82 W. (fig. 21). Workings are outside the wilderness, but some claims extend into it (fig. 24). Fluorite-bearing veins, similar to those in locality C, were prospected in the 1920's. In the 1950's, the veins were prospected for uranium (Malan, 1957) by bulldozer trenching. Thirty-five claims, the Pedad and DLB groups, were located in the area. The Pedad workings are shown on figure 27. A Geiger counter traverse of the area revealed a substantial count in an 18-m (60-ft) trench at the north end of a stripped area. A narrow fault zone, crossing the east end of the trench, contains small amounts of purple fluorite. A 30-cm (1-ft) chip sample (5) from the north wall of the trench, where the highest Geiger counter reading was obtained, contained 0.03 percent uranium (table 4). A fault zone, presumably the same, has been prospected in the southernmost cut. No significant radioactivity was detected in the cut, but samples contained fluorite. Two chip samples (6, 7) across the fault showed 75 cm (2.5 ft) of 16.2-percent CaF_2 and 90 cm (3 ft) of 13.0-percent CaF_2 (table 3). The owners plan further exploration.

BEAR CREEK PROSPECT (LOCALITY E)

The Bear Creek prospect (locality E) is within the adjacent area in the north-central part of T. 9 N., R. 82 W. (fig. 21). A 15-m (50-ft) adit is in the north wall of the canyon of Bear Creek, a few hundred feet from the canyon mouth and about 30 m (100 ft) above the stream. The adit, bearing N. 60° E., was driven in steeply dipping layered gneiss along an iron-stained layer containing pyrite and traces of copper minerals. A chip sample (8), taken across an altered layer at the face, contained only 70 ppm copper (table 2).



EXPLANATION

Prospect pit — Primitive road

.5 Sample locality — Approximate wilderness boundary

FIGURE 27.—Prospect workings and sample localities on the Pedad-DLB claims (part of loc. D). Contours are in feet; contour interval 100 ft (30.5 m).

RED ELEPHANT MOUNTAIN PROSPECT (LOCALITY F)

The Red Elephant Mountain prospect (locality F) is within the study area just east of the wilderness boundary in the southwest corner of T. 11 N., R. 82 W. (fig. 21), near the canyon of Forester Creek. An adit was driven 18 m (60 ft) S. 75° W. in an iron-stained zone in steeply dipping layered gneiss (fig. 28). A crosscut extends 7.6 m (25 ft) N. 5° W. from the end of the adit. A random sample (9) of loose surface material, rich in pyrite, was analyzed spectrographically. It contained 2 ppm silver and 0.02 percent copper (table 4). Three chip samples (10–12) were taken across the iron-stained zone above the portal of the adit; assay values were of no significance (tables 2, 4). A search for mineral-claim locations showed no claims corresponding to the Red Elephant Mountain site.

WINDY GULCH CLAIMS (LOCALITY G)

The Windy Gulch group of 19 claims (locality G) is within the adjacent area just north of the wilderness boundary in the east-central part of unsurveyed T. 11 N., R. 83 W. (fig. 21). The claims were located in 1957 northeast of Davis Peak (fig. 29). Bedrock in the area consists of gneiss containing numerous pegmatite dikes. A shallow pit is near a small lake in the eastern part of the group. A higher than background

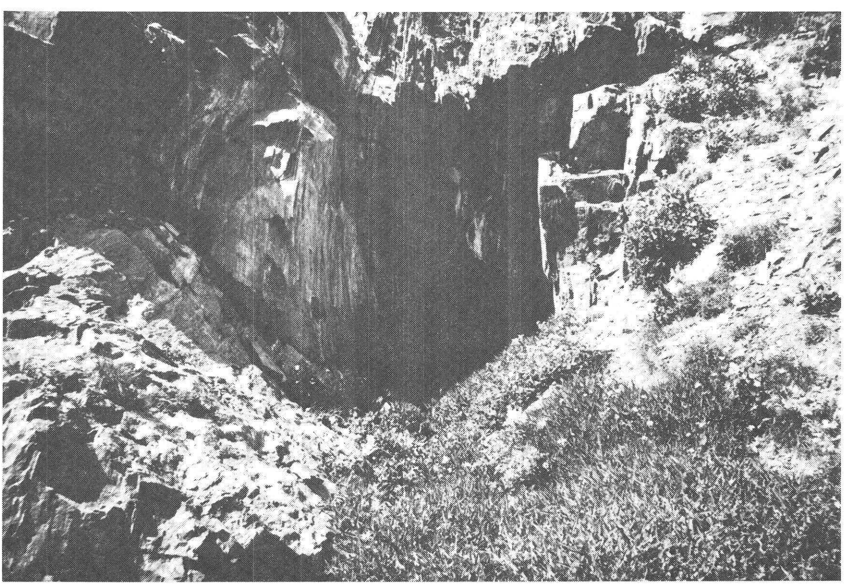


FIGURE 28.—Red Elephant Mountain prospect (F). Height of face about 3–4 m (10–15 ft).

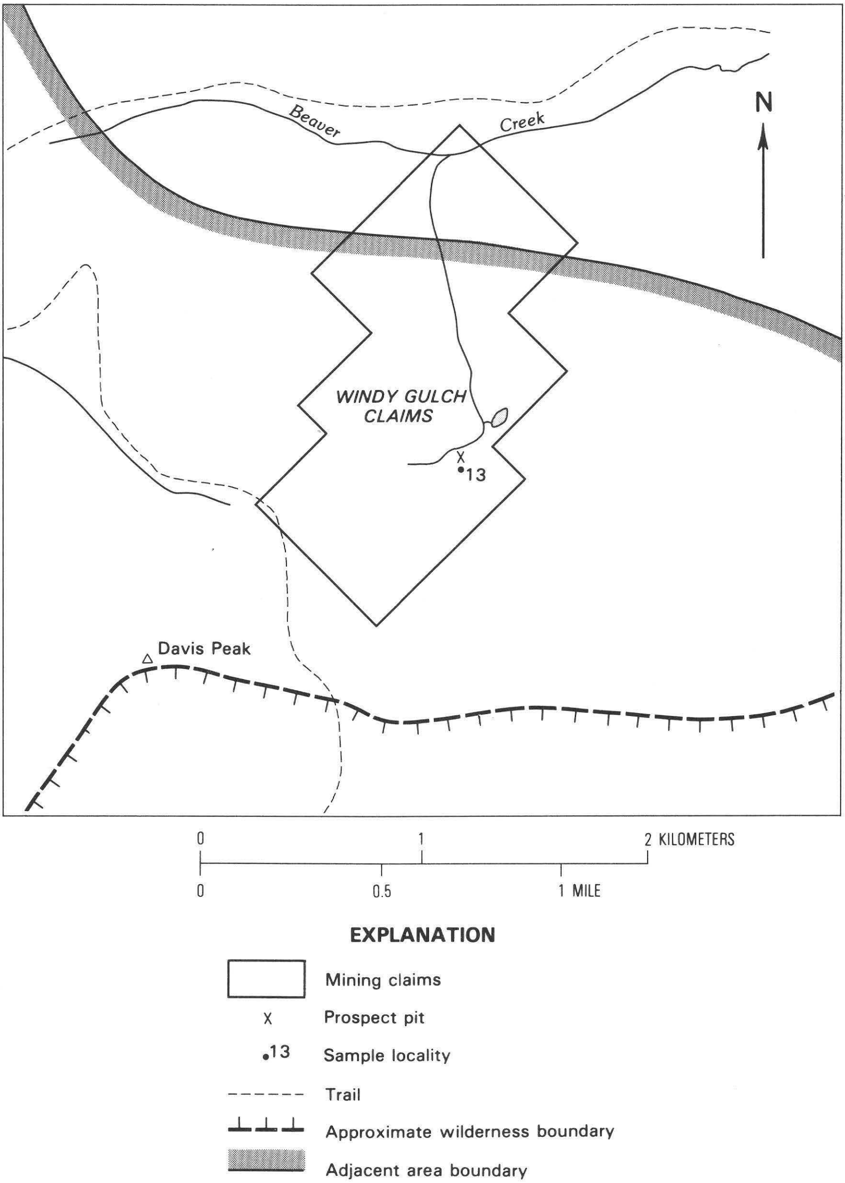


FIGURE 29.—Mining claims and prospect pit near Davis Peak. Part of loc. G.

Geiger counter reading was obtained at the south wall of the pit, but uranium content of a 30-cm (1-ft) chip sample (13) was negligible (table 2).

BUFFALO RIDGE (LOCALITY H)

Buffalo Ridge (locality H) is about 4.8 km (3 mi) north of Davis Peak in the northern part of the area that was investigated. Several mining claims were located at the site, which is east of the study area in the north-central part of unsurveyed T. 11 N., R. 83 W. (fig. 21). About 0.8 km (0.5 mi) east of the ridge, a rusty quartz vein parallels the layering in gneiss. The strike of the steeply dipping vein is N. 70° E. A 40-cm (1.2-ft) chip sample (14), taken across the vein in a shallow prospect pit, contained 0.03 percent copper and 0.01 percent lead (table 3).

MICA BASIN (LOCALITY I)

Mica Basin (locality I), a glaciated bowl bounded on the northeast by Big Agnes Mountain, has been the site of many recorded mining claims dated mostly in 1947 and 1948. Mica Basin is within the wilderness in the central part of unsurveyed T. 10 N., R. 83 W. (fig. 21). Bedrock in the area is a complex mass of schist and gneiss containing many pegmatites. At two shallow prospect workings, the pegmatites contain large mica crystals.

The upper prospect is on the steep southwest slope of Big Agnes Mountain at an elevation of 11,600 ft (3,540 m). Here, a 3.7-m-thick (12-ft-thick) horizontal tabular pegmatite body has been prospected (figs. 30, 31) by a 3-m (10-ft) adit bearing N. 45° E. The pegmatite is near the top of a ridge and crops out on both sides. The outcrops contain quartz, feldspar, and large muscovite crystals. The western outcrop contains crystals as wide as 30 cm (12 in.); the eastern one has smaller crystals. Traces of copper minerals were found on the adit dump, but there has been no significant copper mineralization. Although some of the crystals are quite large, the mica is of scrap quality because of parting planes.

The lower prospect is about 0.8 km (0.5 mi) southeast of Mica Lake (fig. 32). An irregularly shaped pegmatite, composed mostly of quartz and feldspar, contains crystals of muscovite and biotite at least 38 cm (15 in.) across. The pegmatite has been prospected by a shallow 7.6-m-wide (25-ft-wide) cut. The mica crystals contain parting planes that make the material scrap grade.

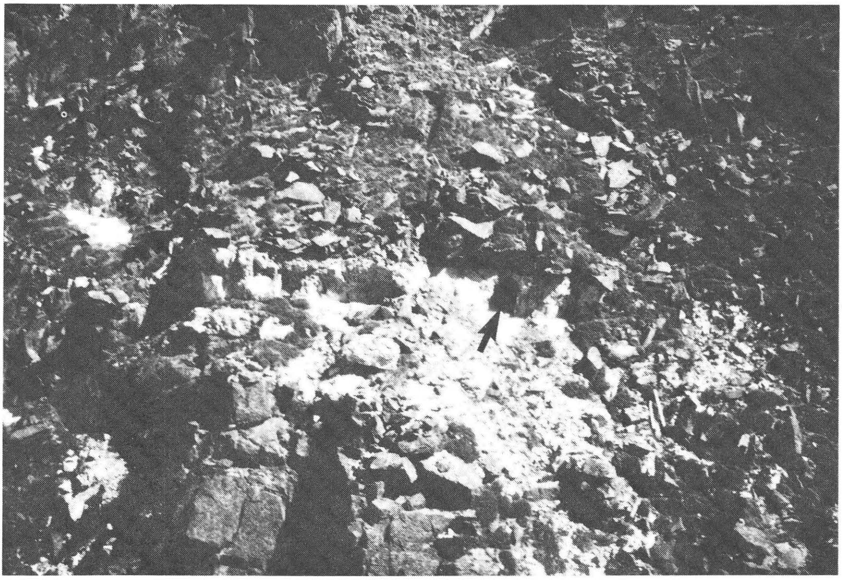


FIGURE 30.—Big Agnes Mountain mica prospect. Part of loc. I. Adit (arrow) about 5 ft high.

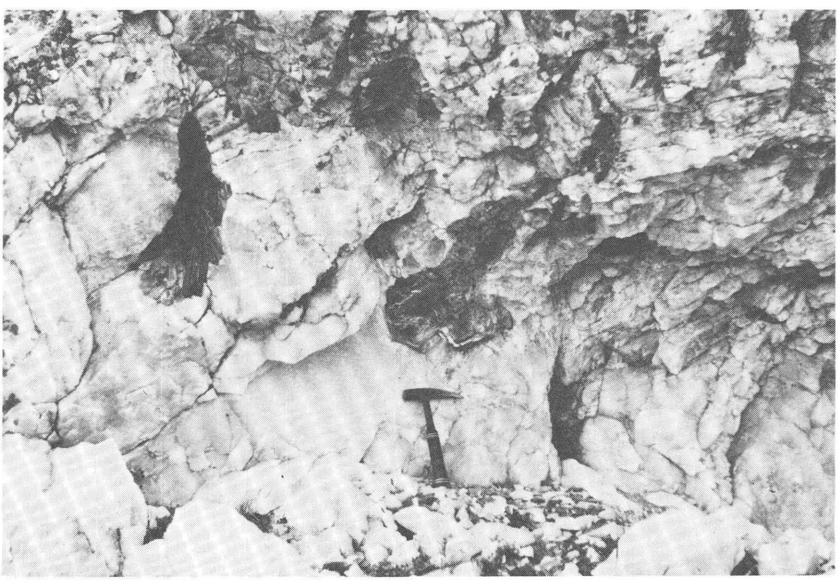


FIGURE 31.—Big Agnes Mountain mica prospect, showing mica crystals in pegmatite quartz.

FIGURE 32.—Lower mica prospect, Mica Basin.

LOWER SLAVONIA DISTRICT (LOCALITY J)

The Lower Slavonia district (locality J) is on the west-central wilderness boundary at the junction of Gold and Gilpin Creeks in the southwest corner of unsurveyed T. 10 N., R. 83 W. (fig. 21). Several old buildings remain of a settlement known as Slavonia, probably built in the late 1800's during a prospecting "rush." Several prospect workings lie in the immediate vicinity, but most are outside the wilderness.

Sulfide mineralization in the Lower Slavonia district appears to have resulted in replacement of limy layers in banded gneiss. The limy mineralized zones are thin and contorted and show little evidence of continuity. Therefore, although the Precambrian gneiss contains a number of such mineralized deposits, they all appear to be small and erratic.

Three prospects were examined in the Lower Slavonia district (fig. 33).

SITE OF SAMPLES 17–20

An opencut above a caved adit is about 0.8 km (0.5 mi) west of the junction of Mica and Gilpin Creeks and a few hundred feet inside the wilderness boundary at an elevation of about 9,300 ft (2,840 m).

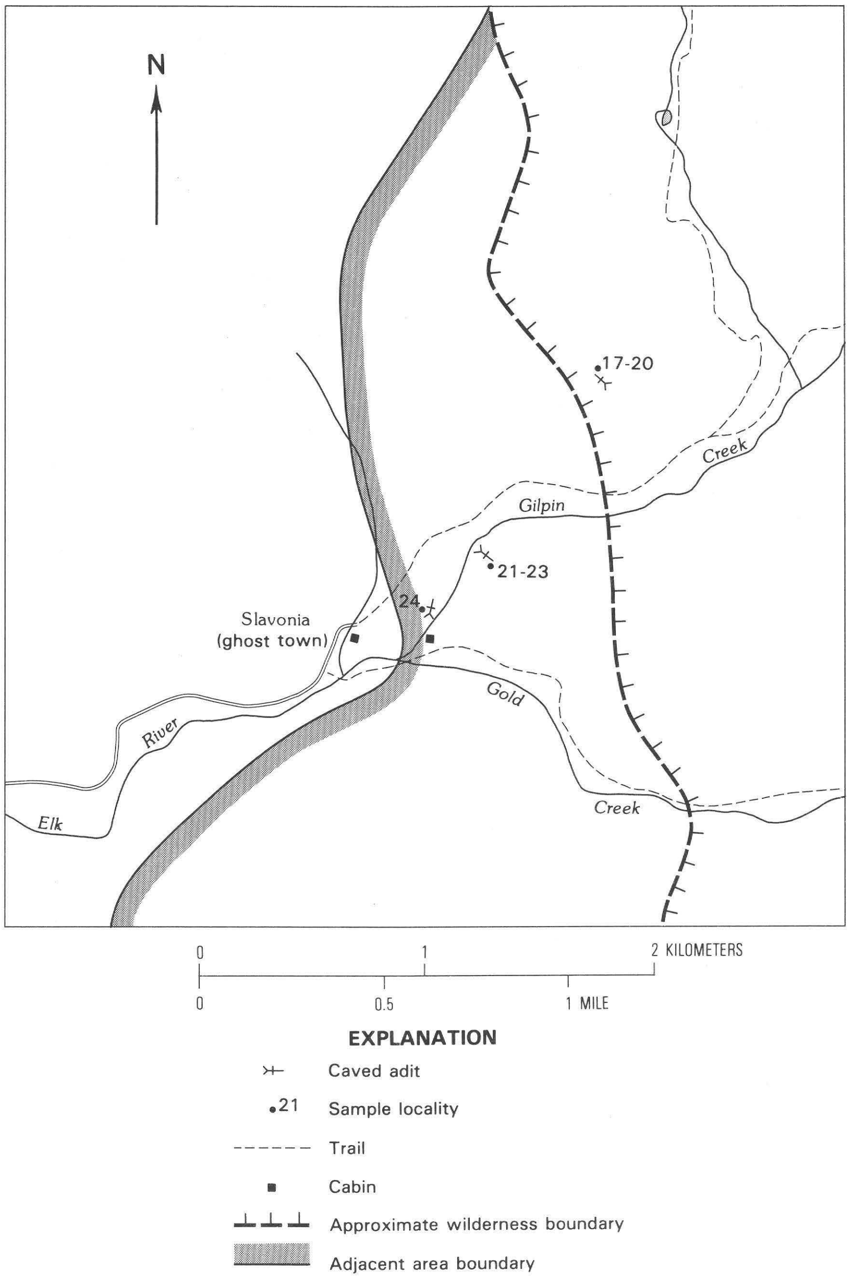


FIGURE 33.—Prospect workings in the Lower Slavonia district (loc. J).

Although the dump is scattered down the mountainside, it probably represents several hundred feet of drifting. The opencut is about 6 m (20 ft) deep (fig. 34) and exposes a steeply dipping iron-stained sulfide-bearing zone in layered gneiss. The zone strikes N. 70° W. and contains visible galena, sphalerite, and pyrite. Chip samples were taken across 2.9 m (9.5 ft) of the mineralized zone with results shown here (sample 20 was a resample of the most mineralized part of sample 17):

Sample	Width		Au	Ag	Pb	Zn	Cu
	Feet	Meters	(ppm)			(percent)	
17	4.0	1.2	0.03	20	0.04	0.32	0.15
18	2.0	.6	.04	11	.04	.26	.04
19	3.5	1.1	.25	87	1.8	2.2	.11
20	1.5	.5	.68	170	4.2	6.8	.26

Spectrographic analyses are listed in table 2, chemical analyses in table 4. The mineralized zone is exposed for about 50 ft. The zone pinches out in a rocky ridge to the northwest. Any southeastern extension of the zone below the adit would be covered by debris and vegetation.

SITE OF SAMPLES 21–23

A caved adit and a cavelike excavation are on the east bank of Gilpin Creek, about 0.5 km (1/3 mi) upstream from its junction with Gold Creek and about 150 m (500 ft) west of the wilderness boundary. The adit, reportedly 45 m (150 ft) long, has a dump that has been partly washed away by Gilpin Creek. These excavations penetrate a steeply dipping narrow sulfide zone in layered gneiss. The zone strikes S. 65° E. and contains visible galena, sphalerite, and chalcopyrite. Analyses of three chip samples (21–23) taken across the zone are shown:

[Leaders (--), not looked for]

Sample	Width		Au	Ag	Pb	Zn	Cu
	Feet	Centimeters	(ppm)		(percent)		
21	1.5	45	--	2.4	0.02	0.48	0.17
22	3.0	90	--	5.6	.65	.78	.07
23	.5	15	0.22	25	.38	.75	.32

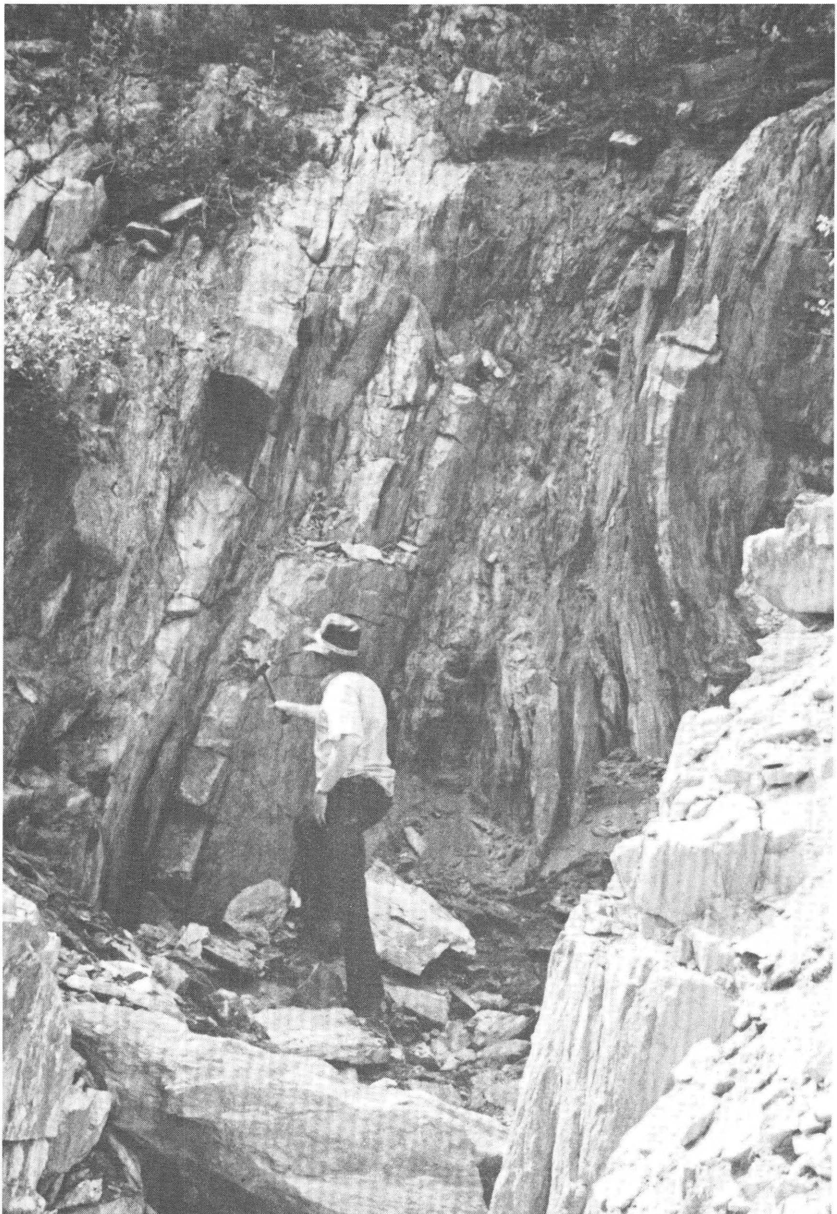


FIGURE 34.—Opencut north of Gilpin Creek, site of samples 17-20.

Spectrographic analyses are listed in table 2, chemical analyses in table 4.

The sulfide zone pinches out a short distance above the excavation, and any extension of the zone below is covered by debris. There is no indication of the zone in the exposed bedrock on the west bank of the creek.

SITE OF SAMPLE 24

A caved adit that penetrates a fault zone bearing N. 5° E. in altered gneiss is on the west bank of Gilpin Creek about 215 m (700 ft) above its junction with Gold Creek. The nearby ruins of a building contain the remains of water-driven machinery. A 1.5-m (5-ft) chip sample (24) taken across the fault zone above the portal contained (table 3) 0.01 oz gold per ton (0.3 ppm) and 0.1 oz silver per ton (3 ppm).

UPPER SLAVONIA MINE (LOCALITY K)

The Upper Slavonia mine (locality K) is in the central part of the wilderness just west of the Continental Divide in the southwest corner of T. 10 N., R. 82 W. (fig. 21). The workings are shown on figure 35.

The main adit of the mine was driven into the west wall of the canyon of Gold Creek, about 9.7 km (6 mi) above its confluence with Gilpin Creek. The adit, now caved, is reported to have been 105 m (350 ft) long, and the size of the dump appears to confirm this (fig. 36). At the minesite are the ruins of several cabins and the remains of a hydraulically powered compressor. The original wagon road to the property is now used as a pack trail. The area has been covered by several groups of mining claims since 1910, which is probably about the time that most of the work was done. There is no record of production. The adit was driven into a steeply dipping west-striking iron-stained zone in layered gneiss that crops out above the caved portal. The zone includes a layer of hornblende gneiss containing visible sphalerite. A chip sample (25) taken across the zone above the adit contained 0.95 percent zinc and 0.03 percent copper (table 4). About 60 m (200 ft) west, also on the steep mountainside, is a caved stope. The working is in an iron-stained zone, probably the same as that of the adit; the walls contain visible sphalerite. A 75-cm (2.5-ft) chip sample (26) across the iron-stained zone in the east wall of the open stope contained 16 percent zinc and 0.21 percent copper (table 4).

About 0.4 km (¼ mi) northwest of the main adit at an elevation of approximately 11,000 ft (3,350 m), a 4.6-m (15-ft) shaft has been sunk

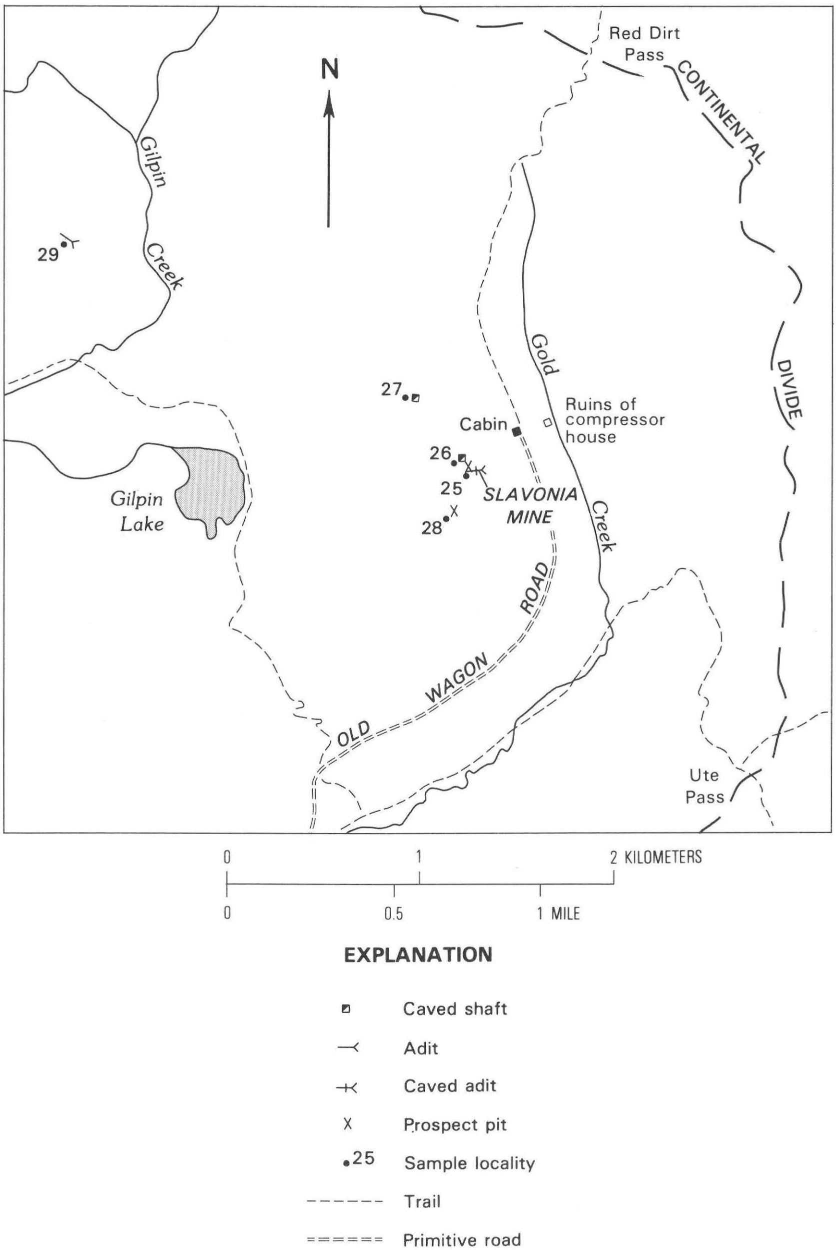


FIGURE 35.—Mine workings and sample localities in the Gold Creek-Gilpin Creek area, in loc. K.

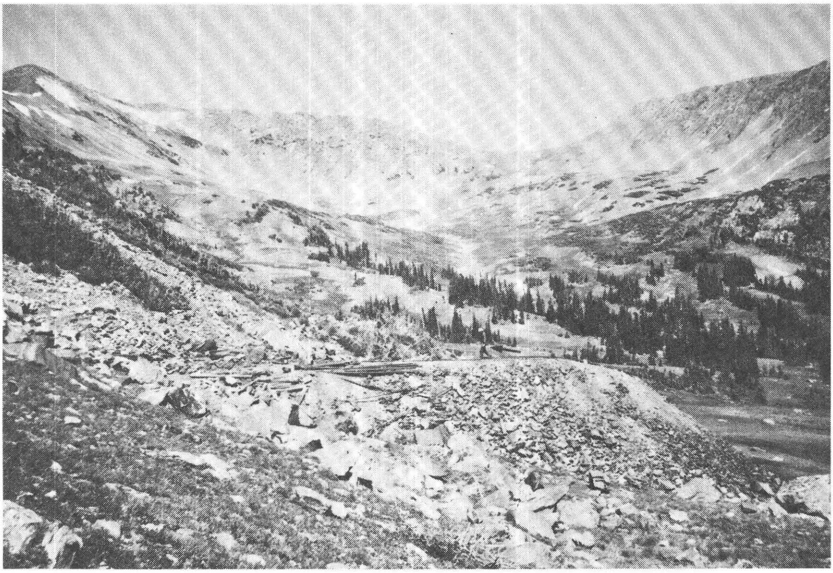


FIGURE 36.—View north of Upper Slavonia mine dump area. Man gives scale.

in an iron-stained sulfide-bearing zone in layered gneiss that strikes N. 40° W. A 30-cm (1-ft) chip sample (27), taken across the zone in the north wall of the shaft, assayed 2.8 percent zinc and 0.05 percent copper (tables 2, 4).

The mineralized zones exposed in the separate workings have a similar appearance and mineralogy, suggesting that the zone is continuous. Verification of continuity, however, is not possible because of surface debris, including a rock slide between the open stope and the shaft.

About 250 m (800 ft) south of the main adit, another steeply dipping, westward-bearing iron-stained zone in gneiss has been prospected by a small pit. A 1.1-m (3.6-ft) chip sample (28) contained 0.04 percent copper (tables 2, 4).

UPPER GILPIN CREEK (LOCALITY L)

Several groups of mining claims were located in the upper drainage of Gilpin Creek in the late 1940's and early 1950's (fig. 35). The claims of upper Gilpin Creek (locality L) are within the wilderness in the southeastern part of unsurveyed T. 10 N., R. 83 W. (fig. 21). The only working observed in the area is an adit about 1,220 m (4,000 ft) northwest of Gilpin Lake at an elevation of approximately 10,500 ft

(3,200 m). The adit bears N. 20° W. for 9 m (30 ft) and then N. 40° E. for 5.5 m (18 ft). Traces of copper minerals were seen on the dump. A 90-cm (3-ft) chip sample (29), taken across the face in light-colored gneiss, contained 0.03 percent copper (table 4).

A 15-cm (0.5-ft) chip sample (30) was taken across the outcrop of an iron-stained band in gneiss on the east-sloping mountainside, approximately 1,850 m (6,000 ft) northwest of Gilpin Lake at an elevation of approximately 10,800 ft (3,300 m). Metal content was not significant (tables 2, 4).

NORTH FORK ELK RIVER (LOCALITY M)

Several groups of claims, located in 1947 and 1948, were described as being in the upper drainages of North Fork Elk River (locality M). The area is in the wilderness just west of the Continental Divide in the east-central part of unsurveyed T. 10 N., R. 83 W. (fig. 21). Reconnaissance of the area revealed no workings. A 30-cm (1-ft) chip sample (31) was taken across the outcrop of a black iron-stained layer in gneiss about 1,070 m (3,500 ft) east of Big Agnes Mountain. An assay for gold and silver was negative (tables 2, 4).

DIAMOND PARK AREA (LOCALITY N)

The Diamond Park area (locality N) is well within the adjacent area near the western boundary of the wilderness in the extreme northeast corner of T. 10 N., R. 84 W. (fig. 21). All the workings are within 1.6 km (1 mi) of the wilderness boundary (fig. 37). Diamond Park, an open meadow at the mouth of the Precambrian part of the canyon of North Fork Elk River, has been the site of a number of mining-claim locations. A traverse of the area, however, revealed no workings, claim monuments, or mineralized rock.

About 1.6 km (1 mi) north of Diamond Park, near the southern headwaters of Stevens Creek, a 2.4-m-deep (8-ft-deep) trench bearing S. 55° E. has been excavated on a fault zone in iron-stained gneiss containing abundant garnet with a little copper stain. A 1.4-m (4.5-ft) chip sample (32) across the north wall contained 0.06 percent copper (table 3). About 610 m (2,000 ft) N. 30° E. of the trench, a prospect pit has been sunk on what may be the same fault zone in gneiss; the zone shows a little copper stain. A grab sample (33) from the pit dump contained no metal values of consequence (table 4). Two other workings

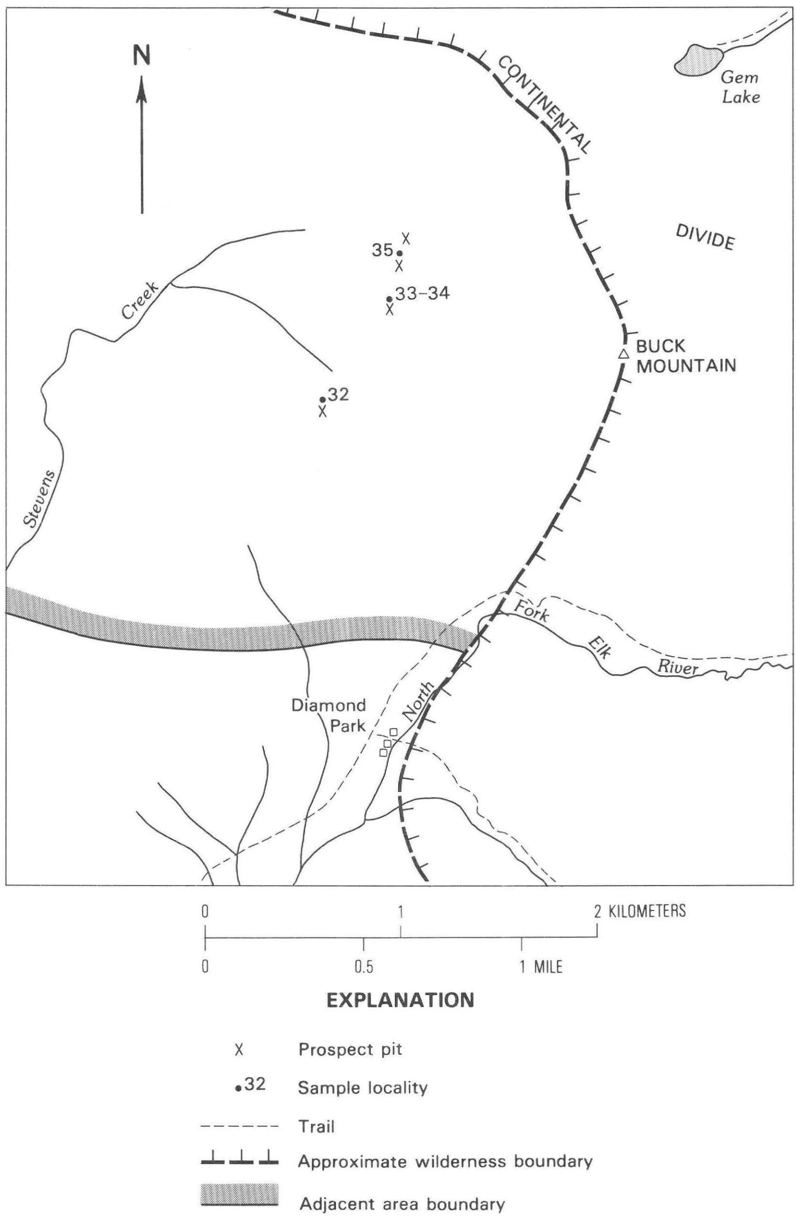


FIGURE 37.—Prospect workings and sample localities north of Diamond Park (loc. N).

were examined at points about 60 m (200 ft) and 360 m (1,200 ft) north of sample site 33. The first is a pit that exposes a 30-cm (1-ft) quartz-calcite vein. A chip sample (34) across the vein contained 0.08 percent copper (table 3). At the second site, two trenches were cut in an iron-stained zone consisting mainly of quartz and garnet with a little chalcopyrite. A 1.8-m (6-ft) chip sample (35) across the zone in the southern trench contained 0.09 percent copper (table 4). Molybdenite was identified in one 15-cm (6-in.) rock fragment from the dump, but no more of the mineral was found in the area.

KING SOLOMON CREEK AREA (LOCALITY O)

Two workings were examined in the King Solomon Creek area (locality O), which is within and near the western boundary of the adjacent area in the northeast corner of T. 10 N., R. 85 W. The workings are shown on figure 38. The first working is a caved adit that bears N. 25° E. in gneiss. A dump grab sample (36) contained no mineral values of consequence (table 3).

About 430 m (1,400 ft) southeast of sample site 36, another caved adit approximately 15 m (50 ft) in length bears S. 50° E. in dark gneiss. A patented claim described in this locality seemingly does not coincide with this working, although the original claim probably included it. Vein material on the dump consists of iron-stained quartz with considerable galena and malachite. A grab sample (37) of the dump contained 5.1 oz silver per ton (175 ppm), 7 percent lead, 0.3 percent copper, and 0.05 percent bismuth (table 3). Bedrock is exposed southeast of the caved adit, but no vein is evident. The northwestern extension of the vein, if it exists, is covered by alluvium. On the basis of the values contained in sample 37, the working warrants further investigation as a mineral prospect.

BEAVER CREEK–KING SOLOMON CREEK AREA (LOCALITY P)

Since about 1895, there has been considerable prospecting in the Beaver Creek–King Solomon Creek area (locality P), which lies along the western boundary of the adjacent area in the east-central part of T. 10 N., R. 85 W. (fig. 21). Numerous workings were examined in secs. 11, 13, 14, and 23, as shown on figure 38.

SECTION 11

Section 11 contains numerous prospect workings, and most of the section has been covered by mining claims (figs. 38, 39). Fourteen

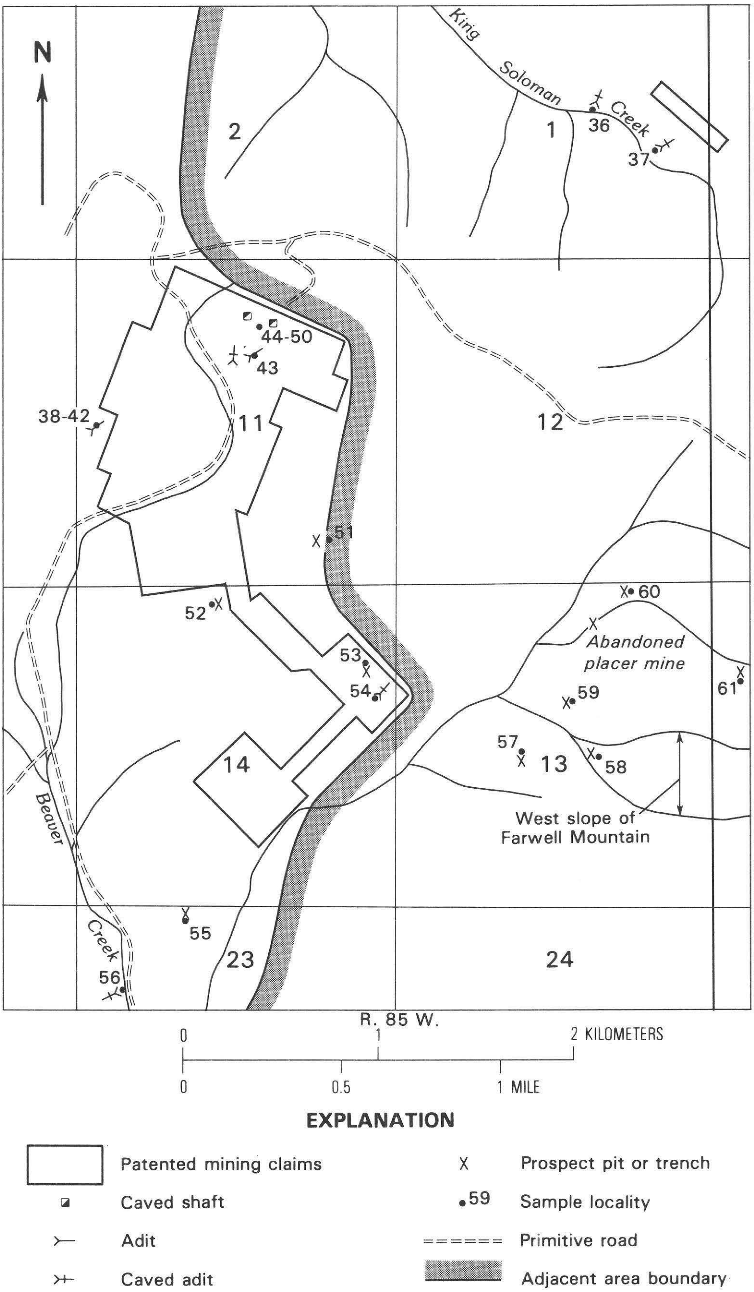


FIGURE 38.—Patented mining claims and prospect workings in the Beaver Creek-King Solomon Creek area (locs. O and P).

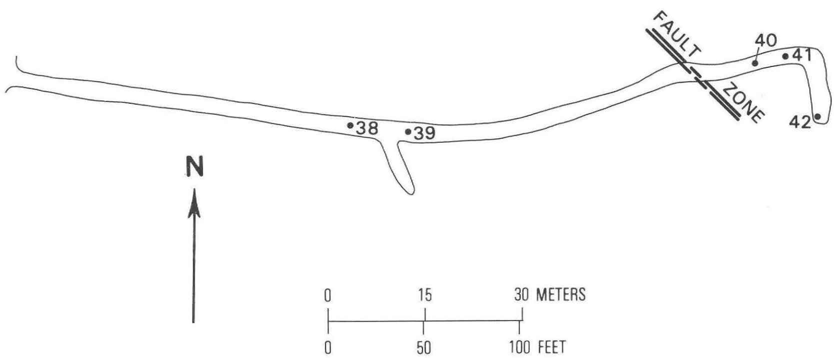


FIGURE 39.—Adit in west-center sec. 11, T. 10 N., R. 85 W., site of samples 38–42.

samples were taken at four workings within the section but outside the adjacent area.

38–42: At this locality, a 120-m (400-ft) adit partly caved at the portal was driven on a granite dike (fig. 39). Samples 38–42 (table 3) contained only small amounts of copper (less than 0.20 percent) and minor lead (less than 0.05 percent).

43: This working is a 20-m (67-ft) adit driven N. 70° E. in Precambrian schist. Sample 43, taken in a fault zone 15 m (50 ft) in from the portal, contained nothing of interest (table 3).

44–50: Samples 44–50 (table 3) are from the dumps of caved shafts and adits in the north-central part of the section. Gold and silver values were negligible, copper values ranged from 0.03 to 0.89 percent, and lead from 0.01 to 0.04 percent. Two samples (45, 48) contained 0.47 and 0.89 percent copper, respectively. They were from ore(?) piles.

51: A grab sample (51) was taken from the dump of a prospect pit in light-colored gneiss with quartz and muscovite. The sample contained 0.04 percent lead (table 3).

SECTION 14

Three samples were taken at three workings in section 14 (fig. 38). The workings are west of the adjacent area boundary.

52: Sample 52 was a grab sample from a dump at a shallow prospect pit in gneiss with quartz. It contained minor (0.08 percent) lead (table 3).

53: The dump of a shallow prospect pit in pegmatite was sampled (53) at this site. Assay results showed no significant metal concentration (table 3).

54: A grab sample (54) from the dump of what appears to be a caved adit did not contain anomalous metal values (table 3), although the dump, composed of gneiss and quartz, showed some copper stain.

SECTION 23

Two workings were examined and sampled in section 23 (fig. 39). The prospects are west of the adjacent area boundary.

55: At this site, a grab sample (55) from near a prospect pit in sandstone yielded 0.08 percent lead (table 3).

56: Sample 56 assayed traces of gold and silver (table 3). It was taken from the dump of a caved adit driven in quartz-bearing sandstone.

SECTION 13

In section 13 within the adjacent area, five samples were taken at five workings (fig. 38).

57: This working is a trench in gneiss with quartz veinlets and copper stain. A dump sample (57) contained 0.1 oz of silver per ton (3 ppm), 0.34 percent copper, and 0.02 percent lead (table 3).

58: At this locality, two pits about 3 m (10 ft) deep have been sunk on erratic quartz veins containing small amounts of bornite; the country rock is gneiss. A 15-cm (0.5-ft) chip sample (58) across one of the more heavily mineralized zones contained 1.02 percent copper (table 3).

59: At this site, a trench in gneiss has exposed a narrow quartz vein. Assay values from a 15-cm (0.5-ft) chip sample (59) were negligible (table 3).

60: A grab sample (60), taken from a dump at a pit in gneiss, contained anomalous metal values (table 3). Southwest of the sample site, the remains of a small placer operation are in the bottom of a small draw that drains the northwestern slope of Farwell Mountain. The material that was worked from the stream bed is very coarse and of small volume. Very little loose material remains undisturbed in the area; no sampling was attempted.

61: Near the eastern boundary of section 13 a 4.6-m (15-ft) pit has exposed a copper-stained quartz vein in gneiss. A dump grab sample contained traces of gold and lead, 0.3 oz (10 ppm) silver per ton, and 0.3 percent copper (table 3).

ZINC MOUNTAIN CLAIM (LOCALITY Q)

Locality Q is west of the wilderness and partly within the adjacent area in the south-central part of T. 10 N., R. 84 W. (fig. 21). This claim group, named Zinc Mountain by local prospectors, is on a prominence west of North Fork Elk River between Hole-In-Wall Canyon and Scott Run. The ZM claim group was located in 1967 by William A. Bowes; it covers the north half of the mountain, as shown on figure 40. The old prospect pits (shown by a single symbol on fig. 40) are of unknown origin. Both workings are in gneiss containing marble and garnet, and exhibiting a little copper stain. A 90-cm (3-ft) chip sample (62) from one of the pits contained no metal values of consequence (table 3). Bowes built a road to the property and dug four north-trending bulldozer cuts, 45 to 60 m (150 to 200 ft) long, across the northern part of the prominence in an attempt to crosscut a suspected east-trending mineralized zone; his efforts were unsuccessful. Grab samples (63–66), taken from each of the four pits, contained very low metal values (table 3).

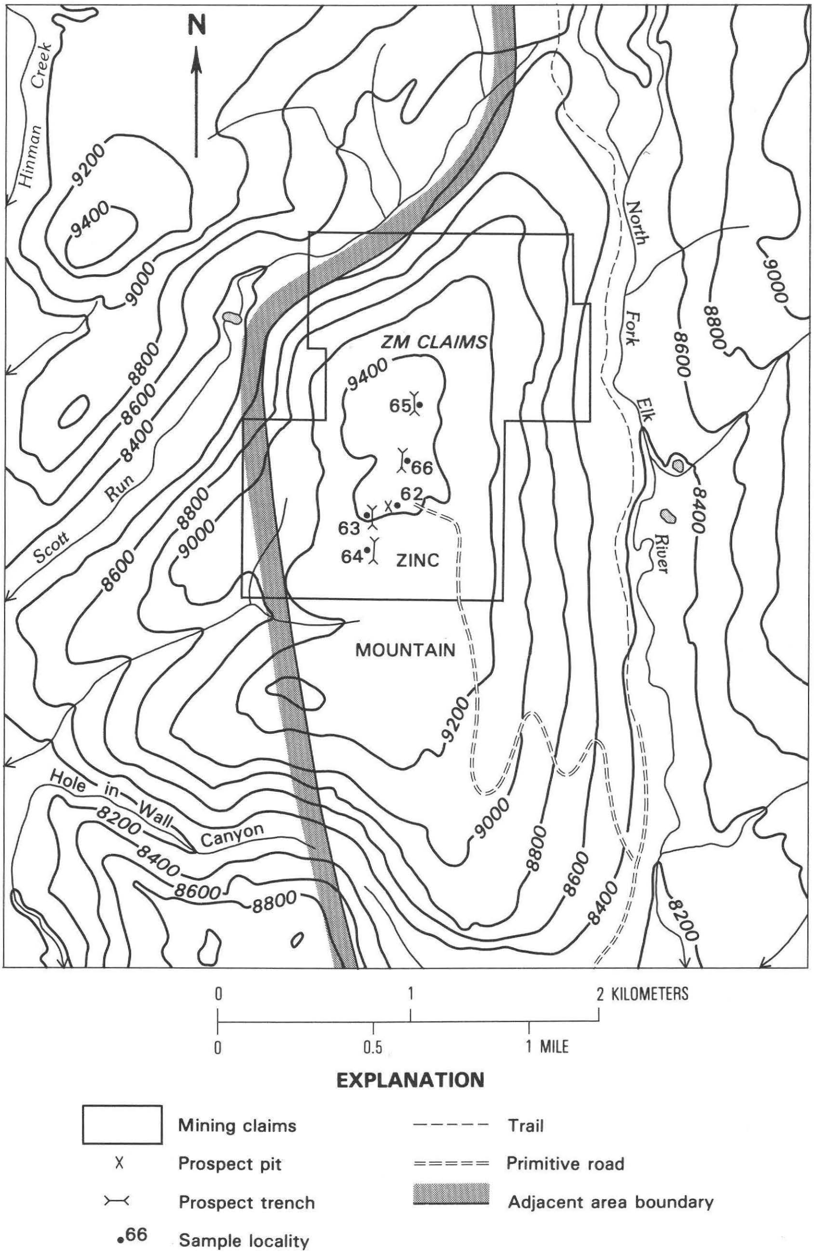


FIGURE 40.—Claims and prospect workings in the Zinc Mountain claim area (loc. Q). Contour interval 200 ft; 1 ft = 0.3 m.

BEAVER CREEK AREA (LOCALITY R)

The Beaver Creek area (locality R) lies along the western boundary of the adjacent area in the eastern part of T. 10 N., R. 85 W. (fig. 21). Land paralleling Beaver Creek, which flows south between Hahns Peak and Farwell Mountain, has been covered by numerous placer mining claims over a period of many years. Placer mining has been conducted at a number of locations in the vicinity, including Ways Gulch (south of Hahns Peak), Little Red Park (north of Hahns Peak), and near Hahns Peak Village (George and Crawford, 1909). The placer gold appears to have originated near Hahns Peak (Segerstrom and Young, 1972). During this investigation, samples of gravel were panned at a number of locations along Beaver Creek just west of the study area boundary. Only sparse fine flakes of gold, estimated at less than 0.01 ppm of the gravel, were found in the panned concentrates.

GROUSE MOUNTAIN AREA (LOCALITY S)

The Grouse Mountain area (locality S) is just west of the adjacent area in the southeastern part of T. 10 N., R. 85 W. (fig. 21). The area has been the site of mining-claim activity and some prospecting (fig. 41). Three samples (67–69) from a trench and two prospect pits contained only low metal values (tables 3, 4).

WILLOW CREEK CANYON AREA (LOCALITY T)

The Willow Creek Canyon area (locality T) lies within the adjacent area in the northeastern part of T. 9 N., R. 85 W. (fig. 21). Willow Creek Canyon has been the site of placer mining claims, as shown on figure 42, located mostly in 1966. The upper end of the canyon was mined many years ago by placer methods for several hundred feet (fig. 43). Water was brought in by a ditch that tapped Beaver Creek. The stream appears to have been mined to bedrock. Placer gold obviously was recovered, but no record of production was found. Four samples were taken from the banks of Willow Creek, as shown on figure 42. The samples were panned, and the quantity of gold estimated. Although fine flakes of gold are common in material on or near bedrock, both the quantity of the placer material and its estimated grade are insignificant. No indication of recent work was found.

Opposite the mouth of Lester Creek and a little downstream, a 6-m (20-ft) trench, bearing N. 75° W., was excavated in layered gneiss and quartzite. A 90-cm (3-ft) chip sample (70) from the trench wall contained no anomalous metal (table 3).

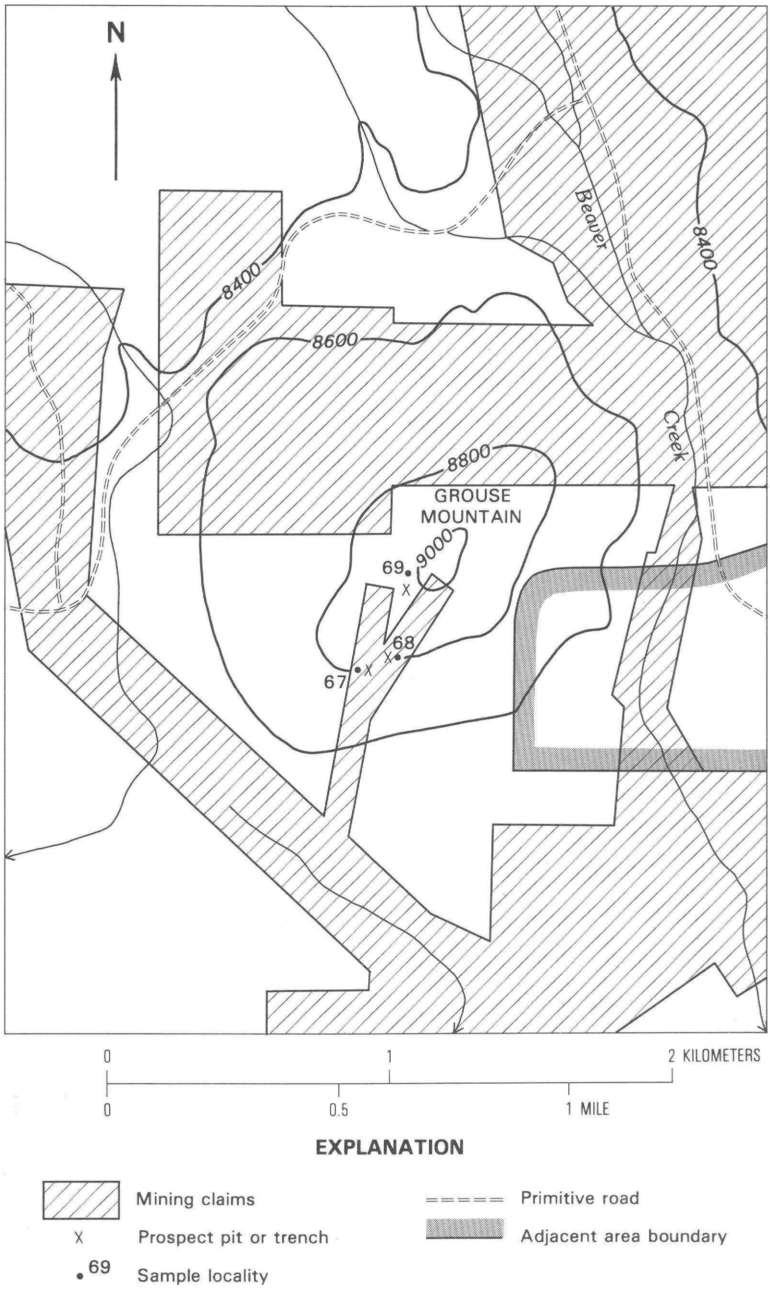


FIGURE 41.—Mining claims and prospect workings in the Grouse Mountain area (loc. S). Contour interval 200 ft.

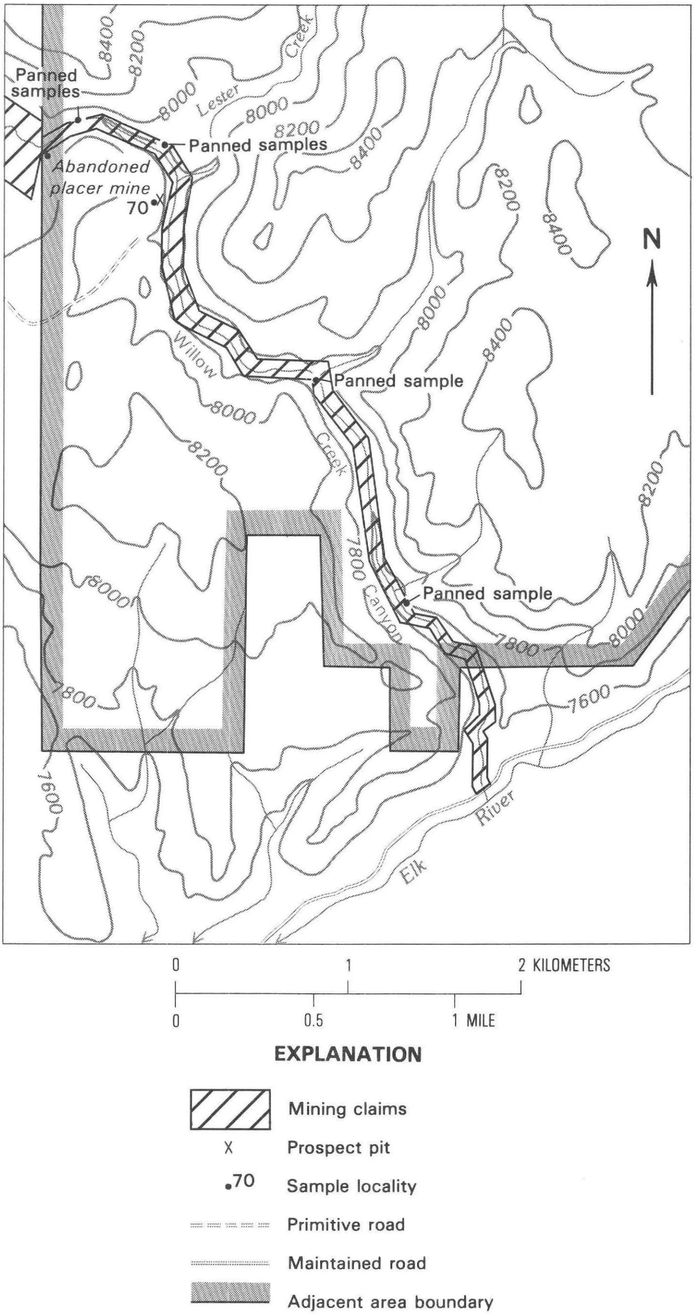


FIGURE 42.—Mining claims and sample localities in Willow Creek Canyon (loc. T). Contour interval 200 ft.

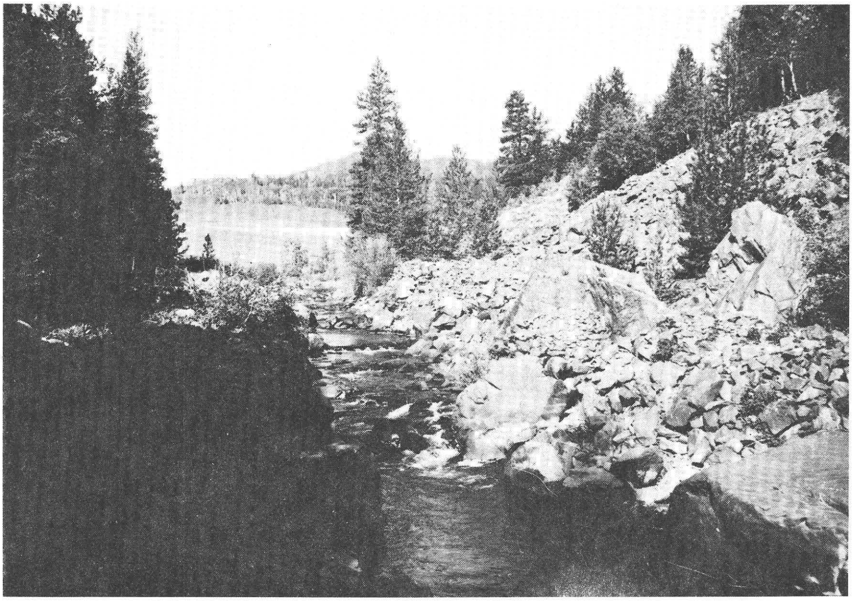


FIGURE 43.—Abandoned placer workings at the upper end of Willow Creek Canyon.

BIG CREEK AREA (LOCALITY U)

The Big Creek area (locality U) is near the western adjacent area boundary in the south-central part of T. 9 N., R. 84 W., and the north-central part of T. 8 N., R. 84 W. (fig. 21). One group of 14 claims (the Haskell claims) was located in the drainage of Big Creek, as shown on figure 44. Three old workings were examined and sampled in the area.

Just inside the study area in the southwest corner of section 33, a 24-m (80-ft) adit was driven in layered gray gneiss that carries some copper mineralization. A 0.6-m (2-ft) chip sample (71), taken across a copper-stained zone above the portal, contained 0.13 percent copper (table 3).

Just outside the adjacent area in the southeast corner of section 33, a grab sample (72) was taken from the dump of a caved adit that had been driven north in schist. The sample yielded 0.04 percent lead on analysis (table 3).

About 90 m (300 ft) north and up the hillside from the caved adit, a 30-cm (1-ft) copper-stained zone in gneiss was sampled (73). The sample contained 0.28 percent copper (table 3). This sample site is probably just inside the adjacent area boundary.

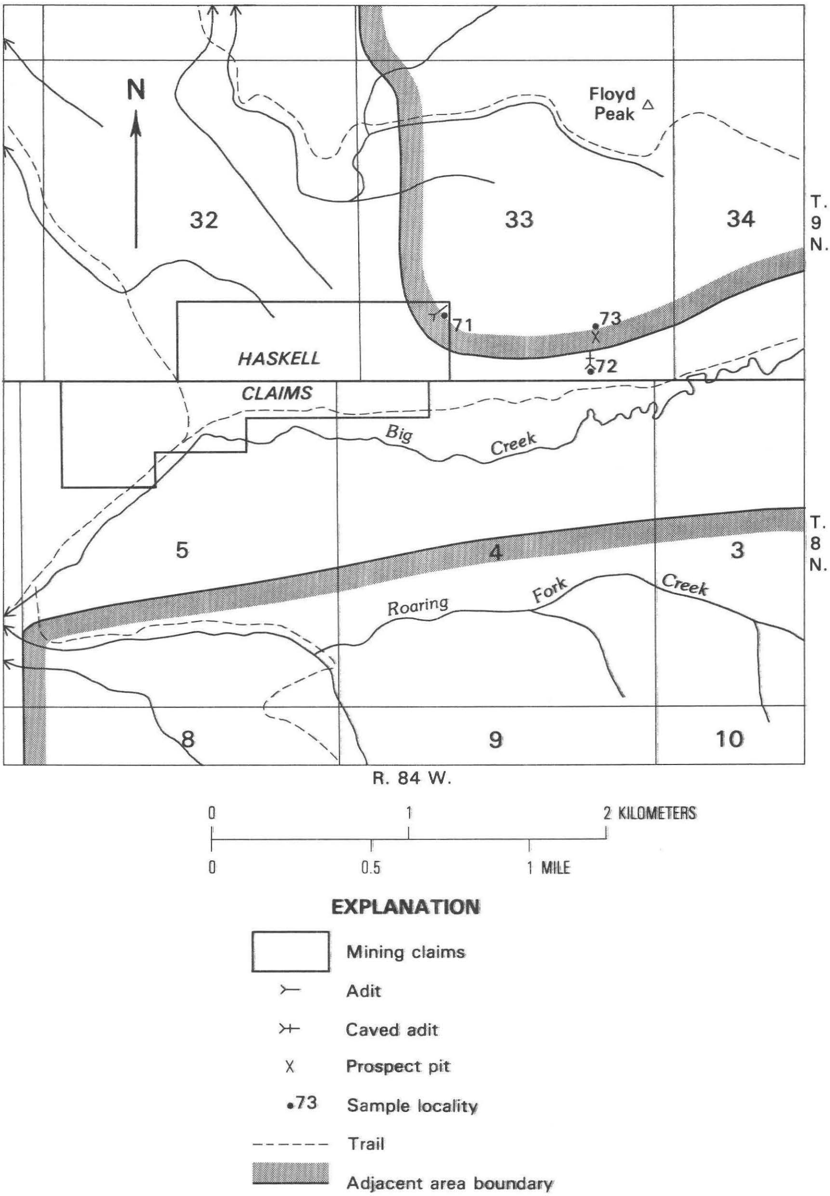


FIGURE 44.—Mining claims and prospect workings in the Big Creek area (U).

ELK PARK AREA (LOCALITY V)

The Elk Park area (locality V) straddles the southwestern boundary of the adjacent area in the northwestern part of T. 7 N., R. 84 W.

(fig. 21). In 1903, several claims were located west of the adjacent area boundary (fig. 45). Three prospect workings, all in section 9, were examined. The workings are prospect pits that were sunk in altered igneous rock. A 2-m (6-ft) chip sample (74) was taken at the northernmost pit; the other samples (75, 76) were grab samples from dumps. Only low metal values were contained in the samples (table 3).

SODA CREEK AREA (LOCALITY W)

The Soda Creek area (locality W) straddles the southern boundary of the adjacent area in the southeast corner of T. 7 N., R. 84 W. (fig. 21). Routt County records show that 14 mining claims were located in 1954 in the Soda Creek area. Six of the claims are shown on figure 46.

Because of the date of location and the fact that there is slightly anomalous radioactivity in the area, it is assumed that the claims were located for uranium. The area contains numerous large pegmatite dikes that have a somewhat high background radiation, possibly owing to their potassium content. One of the dikes east of the Dry Lake Campground has a high feldspar content, nearly pure in places. Although Colorado feldspar deposits presently have little or no market, the dike may have value as a future source of feldspar. A chip sample (77) taken at 30-cm (1-ft) intervals across 11 m (35 ft) of another pegmatite dike contained nothing of interest (table 3).

A bulldozer trail leads from the Buffalo Pass road to a prospect that is on a knoll south of and above South Fork Soda Creek (fig. 47). Here, a nearly vertical dark layer in gneiss strikes N. 85° W.; it has been prospected by a series of shallow pits about 3.6 m (12 ft) apart for a distance of about 23 m (75 ft). Trace amounts of a highly radioactive yellow mineral, probably carnotite, gave a high Geiger counter reading. Chip samples (78–80) were taken at the middle and both ends of the outcrop. The samples contained 0.1 oz silver per ton (3 ppm), but less than 0.01 percent uranium (table 3).

BUFFALO PASS AREA (LOCALITY X)

The Buffalo Pass area (locality X) is at the southeastern boundary of the adjacent area in the south-central part of unsurveyed T. 7 N., R. 83 W. (fig. 21). Two prospect pits, in the vicinity of Buffalo Pass, have been sunk on a northeast-trending fault zone (fig. 48). The pits are outside the adjacent area and are about 450 m (1,500 ft) apart.

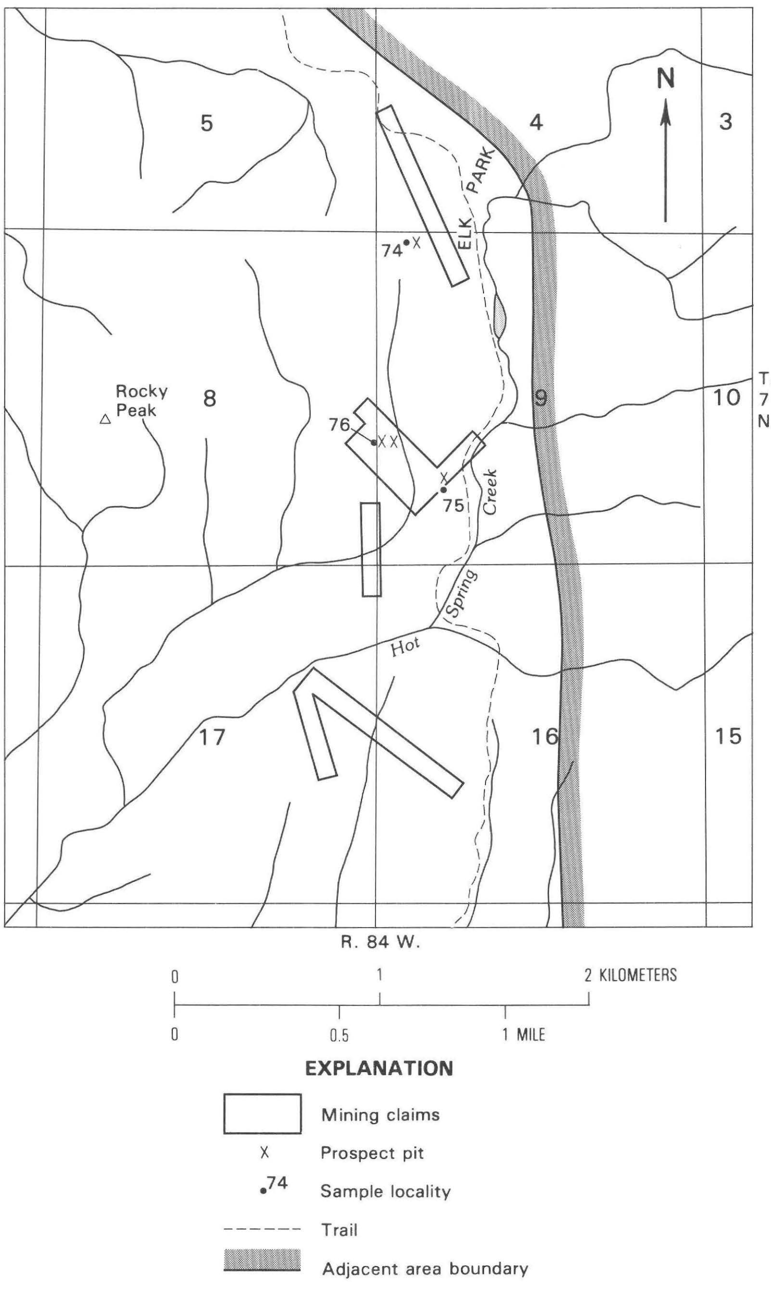


FIGURE 45.—Mining claims and prospect workings in the Elk Park area (V).

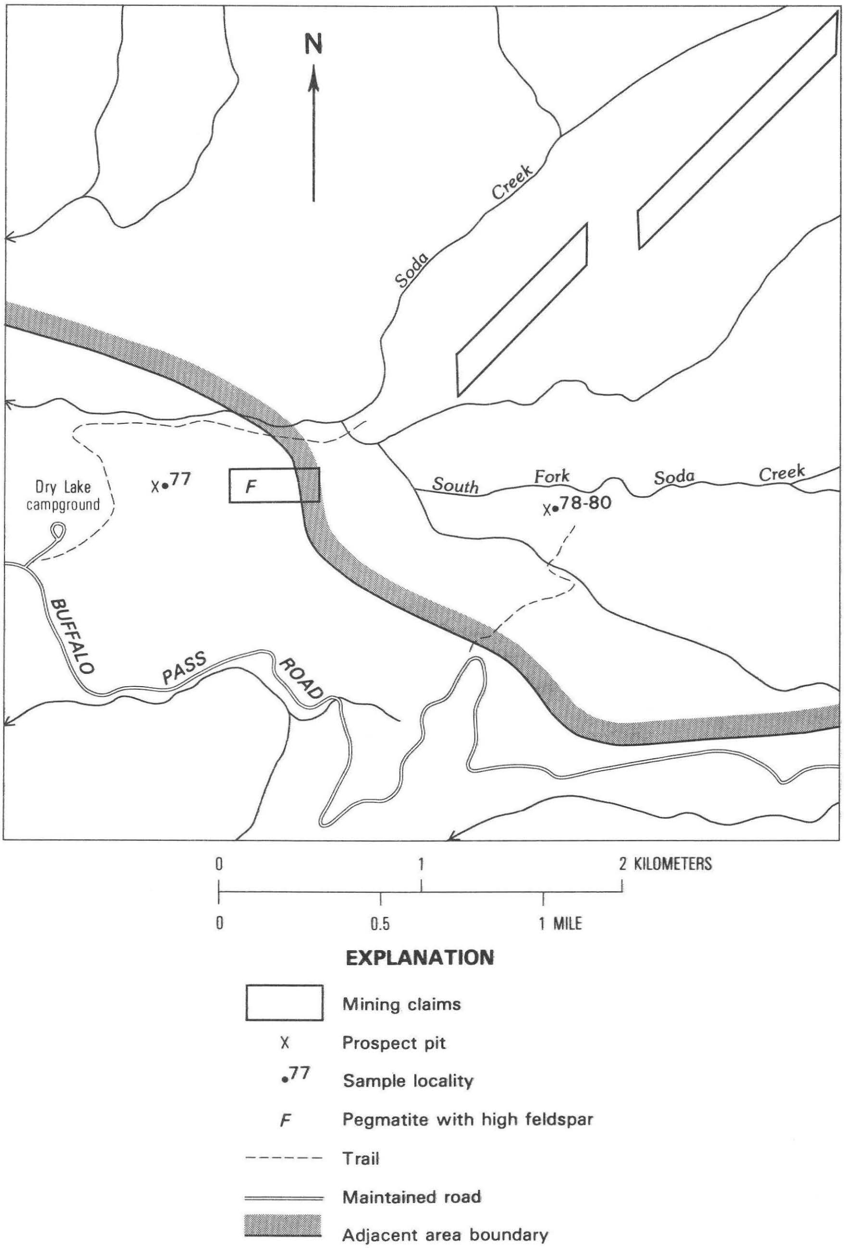


FIGURE 46.—Mining claims and prospect pits in the Soda Creek area (W).

FIGURE 47.—Prospect near South Fork Soda Creek.

A grab sample (81) from the dump at a pit that was sunk on a steeply dipping iron-rich bed in gneiss contained 6 percent iron (table 3). Figure 49 is a photograph of the working. The other pit exposes light-colored schist, part of which is impregnated with pyrite. A 45-cm (1.5-ft) chip sample (82) across the heaviest pyrite zone contained negligible metal values (table 3).

FOSSIL FUEL LEASES

During the past 50 years, oil and gas leases have been issued covering land along the eastern boundary of the adjacent area. The leased areas include the uplifted western edge of the sedimentary rocks of the North Park basin, but the formations have not been found to contain significant oil and gas deposits. Nearest production to the study area is from the recently discovered Lone Pine field (marked by a circled O, fig. 21) near Delaney Lakes, about 8 km (5 mi) east of the adjacent area.

West of the adjacent area in Tps. 7, 8, and 9 N., R. 85 W., there has been sporadic leasing for oil and gas since 1925, also without discovery of oil and gas deposits.

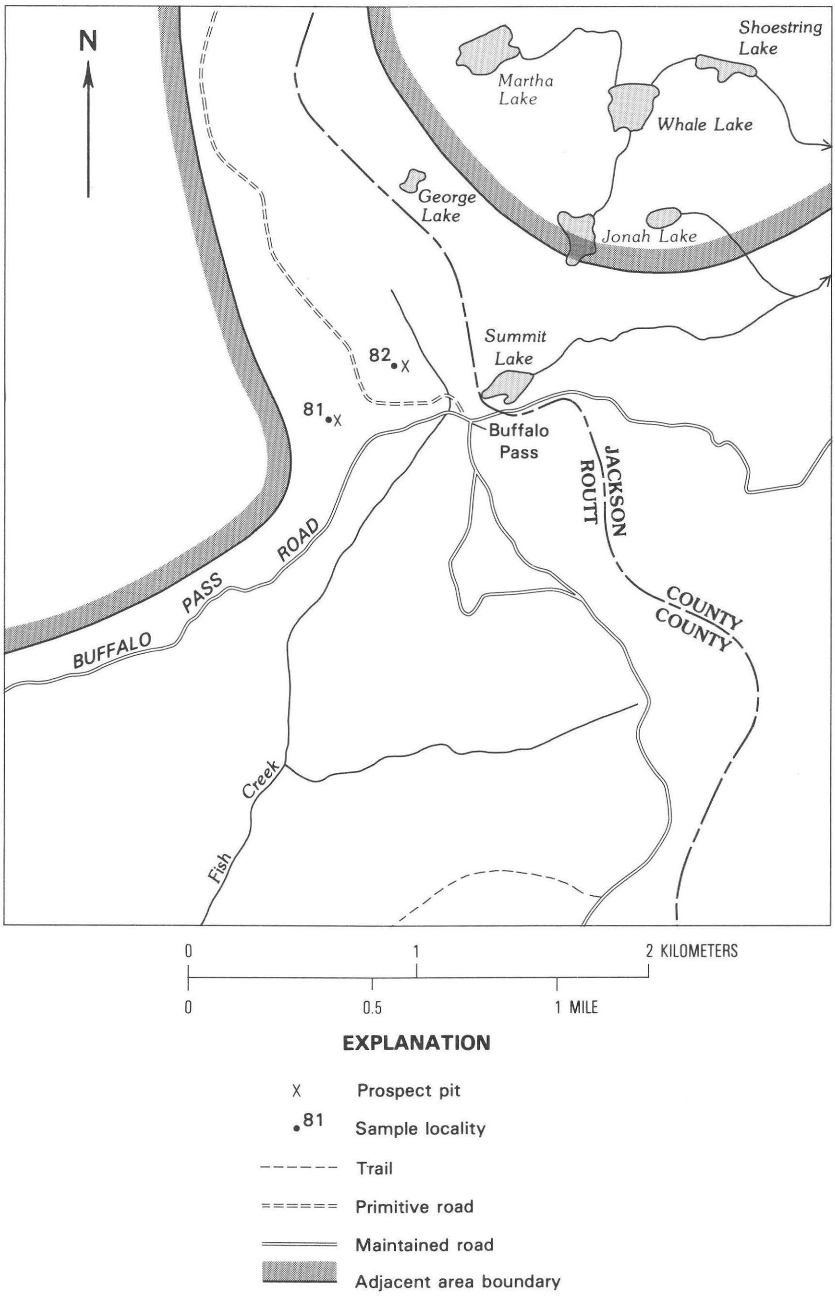


FIGURE 48.—Prospect pits and sample localities in the Buffalo Pass area (X).

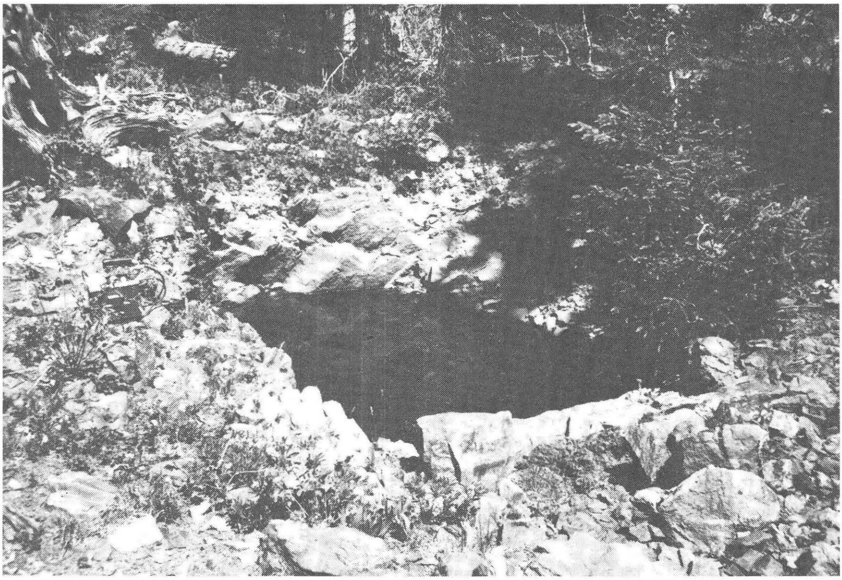


FIGURE 49.—Prospect pit near Buffalo Pass.

Small amounts of coal have been produced from two locations (marked by a circled C, fig. 21) both about 3.2 km (2 mi) east of the study area (Hail, 1965). The Mitchell mine (T. 8 N., R. 82 W.) is in the Coalmont Formation of Tertiary age, and the Monahan coal mine (T. 10 N., R. 81 W.) is in the Pierre Shale of Cretaceous age. Both mines are now abandoned. The Coalmont Formation contains abundant coal in other parts of the basin (Madden, 1977a, b); the Pierre Shale contains a small amount of coal. Very little of the adjacent area is underlain by these formations.

Evaluation of Surface Metallic and Nonmetallic Resource Potential

By GEORGE L. SNYDER, U.S. GEOLOGICAL SURVEY

MINERAL RESOURCES OF THE MOUNT ZIRKEL WILDERNESS AND NORTHERN PARK RANGE VICINITY, JACKSON AND ROUTT COUNTIES, COLORADO

U.S. GEOLOGICAL SURVEY BULLETIN 1554-C

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By GEORGE L. SNYDER, U.S. GEOLOGICAL SURVEY

GEOCHEMICAL APPRAISAL OF SURFACE METALLIC RESOURCE POTENTIAL

PROCEDURE

To evaluate mineral resources near the land surface, the U.S. Geological Survey collected 1,985 rock samples, and most of these were studied in thin section. A total of 314 rock samples were collected specifically for geochemical studies, many from now-abandoned mine dumps, mine faces, or prospect pits. Of these, 45 percent contain visible ore minerals, 38 percent came from altered rocks, and 17 percent represent rock without visible evidence of mineralization. Ore samples were characterized by green to blue copper minerals but also included iron-manganese sulfide-oxide gossan, as well as chalcopyrite, galena, sphalerite, fluorite, and rare molybdenite. The non-ore altered rocks contain quartz, chalcedony, carbonate, magnetite, or hematite veins, iron-stained joints, or rocks variously chloritized, argillized, sericitized, silicified, epidotized, feldspathized, or limonitized; some are sheared to mylonite or fault breccia. Other analyzed rocks included basal conglomerate, tuffaceous sandstone or siltstone, and basal limestone or limestone breccia of the Browns Park Formation, coarsely crystalline pegmatites, marble or calc-silicate rocks, or ultramafic rocks, and a few Precambrian or Tertiary porphyry dikes and their contained wall-rock inclusions. The geochemical samples were crushed, split, and routinely analyzed by six-step semiquantitative emission spectrographic methods for 30 elements (Fe, Mg, Ca, Ti, Mn, Ag, As, Au, B, Ba, Be, Bi, Cd, Co, Cr, Cu, La, Mo, Nb, Ni, Pb, Sb, Sc, Sn, Sr, V, W, Y, Zn, and Zr; some also analyzed for Ga), by atomic absorption photospectrometric methods for Ag, Au, Cu, Pb, and Zn, and by instrumental detector for Hg. Twenty-two of these samples were anomalously high in niobium and were subsequently analyzed by delayed neutron determination for thorium and uranium. Ninety-seven ultramafic and related rocks were analyzed by chemical methods (as in Talanta, 1968, v. 15, p. 111–117) for platinum, palladium, and rhodium (no rhodium found); many of these contain chromite and 14 were analyzed by chemical or colorimetric methods for Cr_2O_3.

Samples of stream sediments from 1,255 localities were analyzed in an effort to identify key elements characterizing individual drainage areas. Weathering, erosion, and soil movement constantly change patterns of rock outcrops and surficial cover, first exposing, then hiding potential bedrock ore deposits, with the result that the present surface evidence for some smaller ore deposits may consist exclusively of downstream detritus. The preferred sample type consisted of about 140 cubic centimeters (22 $in.^3$) of typical fine sand, silt, or clay collected in a special water-permeable metal-free paper bag. Some samples from cascading mountain streams were necessarily coarser. A few panned heavy mineral concentrates also were collected and analyzed. All samples were dried and sieved, and the minus-80-mesh fractions were mixed and split. Splits were then routinely analyzed by six-step semiquantitative emission spectrographic methods for 30 elements (same elements as analyzed for in rock samples) and by atomic absorption photospectrometric methods for silver, gold, copper, lead, and zinc. Splits of 33 selected samples were analyzed later by delayed neutron determination for thorium and uranium.

DEFINITION OF GEOCHEMICAL ANOMALY

The amount of an analyzed element that is "background," that is, within normal expectations, or "anomalous," that is, anomalously higher than background, varies for every element of either rock or sediment and for every geologic host and environment. Theoretically, any host that has been partially replaced or added to by variable amounts of ore solutions of much different overall composition should demonstrate bimodal or polymodal frequency distributions for appropriate elements from multiple analyzed samples. The trough(s) between the modal peaks would then be a convenient threshold class for distinguishing most background from most anomalous element values. In reality, the populations of data are seldom simple (for example, here it was deemed impractical to try to separate the data for all the Precambrian lithologies concerned), and it is often difficult to distinguish a bimodal distribution from an unevenly skewed single distribution. On R. L. Earhart's advice, the writer found it easier to pick the background-anomalous threshold by plotting the cumulative frequency data on semilogarithmic percentage paper. Two of the best examples are shown on figure 50, where the elbow of the cumulative curve defines the background-anomalous threshold. The system also works satisfactorily with less linear (more irregular) cumulative distributions or those with a less elongate distribution. In case of any remaining uncertainty, a conservatively low threshold value was chosen. In a few cases (examples, gold, tungsten), only a few unqualified values were reported, and it was assumed in these cases that the threshold was below the limit of analytical detection. Conveniently, therefore, all the background values (most of the data) can be dropped from further consideration in this surface mineral resource assessment.

Two qualitative checks on the approximate validity of the anomaly thresholds are available. First, the lowest anomalous value chosen is listed for every element in tables 5 and 6 and on each of the detailed element map figures. These can be compared with the average element values for the different types of crystalline rocks as presented in the compilation of semiquantitative spectrographic analyses of 136 unmineralized crystalline rocks in table 7. In general, the elemental values considered anomalous by this technique in the Park Range rocks or stream sediments are equal to or greater than the average values for the various types of unmineralized crystalline rocks listed in this table, but there are several exceptions, and the reader should compare the data sets for details. Second, the anomalous element value limits can be compared with the known crustal abundances of various elements that are available in the professional literature. When this is done, all the analyzed elemental values considered anomalous in Park Range rocks or stream sediments are equal to or many times greater (as much as 6,000 times greater) than the average amounts of these elements as reported in common crustal rocks and sediments (Goldschmidt, 1954; Turekian and Wedepohl, 1961, table 2; Clark and others, 1966, p. 528–538; Solomon, 1976, table 1, p. 45), with the exception of chromium and nickel in ultrabasic rocks. It seems reasonable to conclude that these different determinations of anomalous chemistry generally reinforce each other.

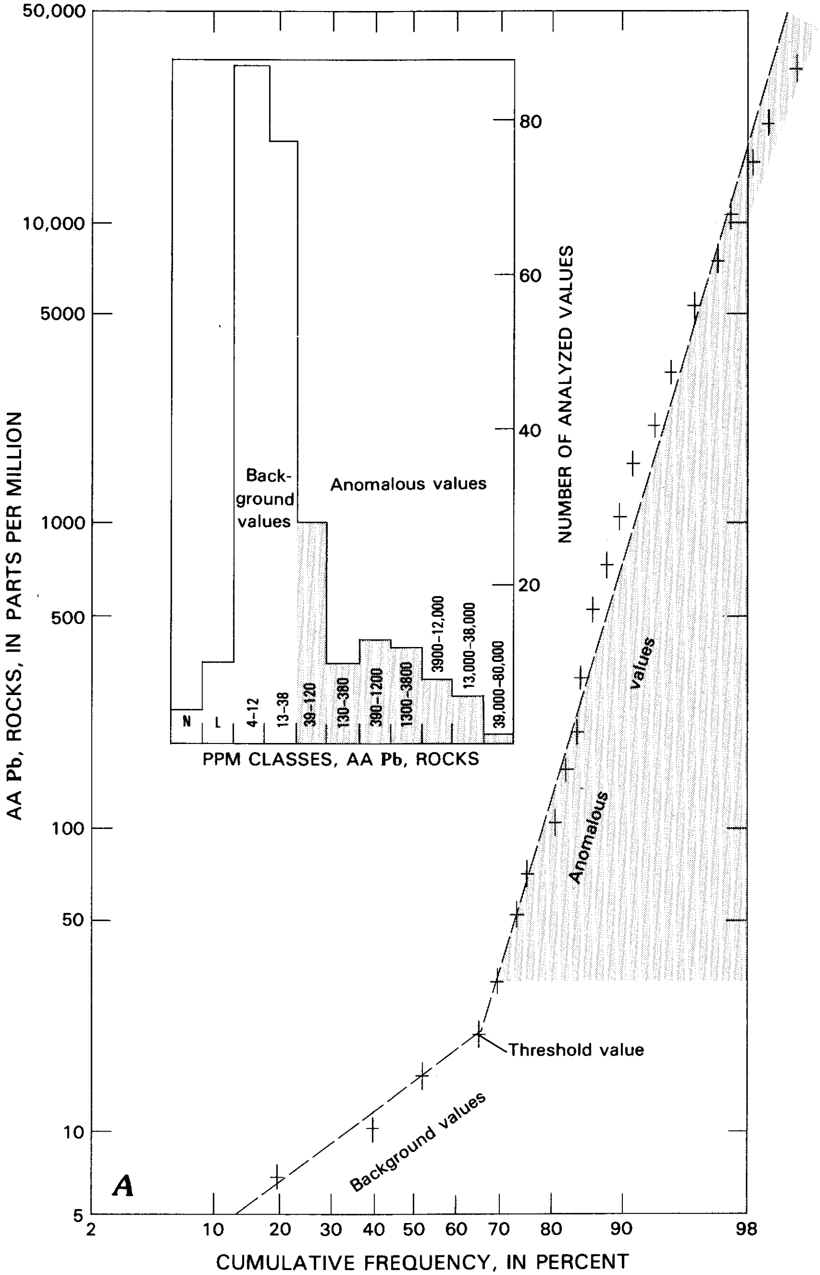
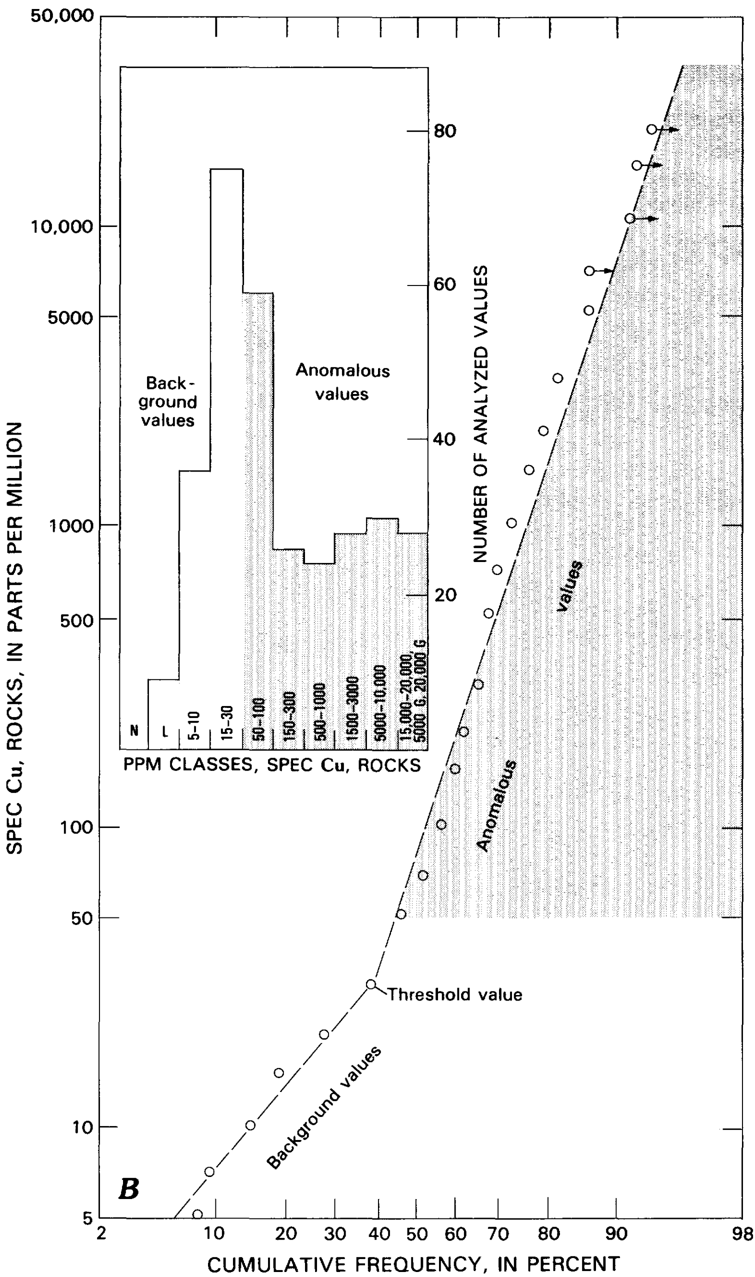


FIGURE 50.—Typical cumulative frequency plots of the population of rocks ana- (crosses) and *B*, six-step semiquantitative emission spectrographic methods for insets of frequency distributions for the same analyses. Anomalous values (pat- quency curve, are the only values shown on detailed map figures of these and mal semilogarithmic Spec scale by approximations shown. On Spec Cu diagram, 5,000G analyses were remeasured in later 20,000G mode.



lyzed by *A*, atomic absorption photospectrometric methods for lead (AA Pb)
copper (Spec Cu) (open circles), on semilogarithmic-percentage paper, and with
terned), defined as those higher than major deflection of percent cumulative fre-
other elements. The arithmetic-scale AA values are computer adapted to the nor-
highest four values shown would be expected to move right if an earlier set of

TABLE 5.—*Summary of anomalous rock geochemical data shown on individual element maps in the vicinity of the Mount Zirkel Wilderness*

[Spec, analysis obtained by standard semiquantitative spectrographic techniques; AA, analysis by atomic absorption techniques; Inst, analysis by instrumental techniques. L, less than; G, greater than. Because these analyses were performed over a period of years during which the L and G limits varied for many different elements, symbol boundary values are chosen to eliminate the effect of these variations. Total number of analyses (shown in parentheses; below concentration) given for each symbol may vary slightly from actual totals on element maps because some samples lie outside the area of the element maps and were therefore excluded from them. Localities of individual analyses of particular interest should be checked against plate 2 (where their positions are accurately shown); individual element maps frequently distort the locations slightly in order to alleviate crowding. For rock geochemistry: anomalous single highs or prominent clusters of data are mentioned where pertinent for each analyzed element selected. Note that presence of anomalous concentrations of an element, although providing targets in any search for economic concentrations, does not guarantee that economic concentrations are present. Areas within present boundaries of Mount Zirkel Wilderness or adjacent area are italicized. Lack of anomalous atomic absorption (AA) data near Greenville district is due to lack of AA analyses in this area]

Map symbol key for selected geochemical data of Mount Zirkel Wilderness					Rock geochemistry
Rock sample data (coded "A")	Symbol code, in parts per million				
Element with chosen values	Smallest symbol	Next to smallest	Next to largest	Largest symbol	
Spec Ag: All 153 unqualified values + 23 L values.	0.5L, 0.5–3 (86)	5–30 (55)	50–300 (31)	500–3,000 (4)	Spec Ag: Maximum 3,000 ppm, from Elkhorn mine galena sample. Data clusters: Elkhorn, Farwell, *Gilpin*, Greenville, and Pearl districts, *west side Buck Mountain*, Lone Pine Creek area, *southwest of Red Elephant Mountain*.
AA Ag: 5 ppm and greater -----------	0.5–0.7 (55)	7.5–54 (27)	55–250 (13)	500–2,600 (4)	AA Ag: Same maximum and clusters, except Greenville lacking.
Spec As: All 9 unqualified values + 63 L values.	200L (63)	(None)	200–1,500 (7)	2,000–5,000 (2)	Spec As: Maximum 5,000 ppm at Master Key mine north of Columbine; secondary highs at Crystal mine-Pedad claim area. Prominent cluster of trace amounts in Greenville district.
AA Au: 0.05 ppm and greater --------	0.05–0.3 (25)	0.35–1.5 (10)	3–5.5 (4)	20 (1)	AA Au: Maximum 20 ppm from Fe-cemented quartz breccia at

					mine north of Gilpin Creek and Gilpin Lake. 5.5 ppm in sulfide ore Wolverine mine, Pearl district; 3 and 4 ppm in quartz-galena veins, Elkhorn mine. Clusters: Elkhorn, Farwell, *Gilpin* and Pearl districts, *Buck Mountain, Red Elephant Mountain.*
Spec Ba: 3,000 ppm and greater (13) ---	3,000 (5)	5,000 (6)	5,000G (1)	(None)	Spec Ba: Maximum >5,000 ppm in copper-iron pegmatite ore south of Republic Creek, Pearl district.
Spec Be: 5 ppm and greater (36) ------	5, 7 (25)	10, 15 (9)	20, 30 (2)	(None)	Spec Be: Maximum 30 ppm in iron-stained breccia south of Lone Pine Creek. Clusters: Farwell and Pearl districts.
Spec Bi: All 57 unqualified values + 56 L values.	10L, 20L, 10, 15 (79)	20–100 (19)	150–700 (11)	1,000, 1,000G (4)	Spec Bi: Maximum >1,000 ppm in sulfide ore Wolverine mine, Pearl district. Important clusters: *Buck Mountain* and Farwell and Pearl districts. Lesser clusters: *Gilpin*, Greenville, *west of Buffalo Pass.*
Spec Cd: All 22 unqualified values + 56 L values.	20L, 50L, 20, 30 (59)	50–100 (9)	150–300 (3)	500, 500G (7)	Spec Cd: Maximum >500 ppm from galena veins Elkhorn mine, sulfide ore at both *Lower and Upper Slavonia mines*, and iron-manganese ore Independence Mountain. Clusters: Elkhorn, *Gilpin*, Greenville, Pearl districts.

TABLE 5.—*Summary of anomalous rock geochemical data shown on individual element maps*—Continued

Map symbol key for selected geochemical data of Mount Zirkel Wilderness					
Rock sample data (coded "A")	Symbol code, in parts per million				Rock geochemistry
Element with chosen values	Smallest symbol	Next to smallest	Next to largest	Largest symbol	
Spec Co: 50 ppm and greater (20) -----	50, 70 (11)	100, 150 (6)	200 (3)	(None)	Spec Co: Maximum 200 ppm *Bear Creek peridotite*. Cluster in *olivine gabbro phase of gabbro of Elkhorn Mountain*; other associations with mafic or ultramafic rock bodies too small to map.
Spec Cr: 100 ppm and greater (35) ----	100–200 (20)	300–700 (9)	1,000, 1,500 (5)	2,000, 3,000 (1)	Spec Cr: Maximum 3,000 ppm in Troutman Draw malachitic hornblendite, Pearl district. Also associated with ultramafic rocks south Farwell, *Three Island Lake*, *Bear Creek*, and *Elkhorn olivine gabbro*.
Spec Cu: 50 ppm and greater (173 + 22G values).	50–300 (85)	500–3,000 (52)	5,000–20,000, 5,000G–20,000G (58)	(None)	Spec Cu: All of numerous >20,000 ppm analyses from malachitic ores of the Pearl or Farwell districts, but a large suite of >5,000 ppm analyses are from an early suite of Greenville rocks. Other clusters: Elkhorn, *Gilpin*, *Buck Mountain*, *south of Lone Pine Creek*, *west of Buffalo Pass* and *Round Mountain*.

AA Cu: 280 ppm and greater (87)	280–2,100 (32)	2,500–15,000 (41)	18,000–146,000 (13)	152,000–210,000 (3)	AA Cu: The five highest analyzed values (140,000–210,000 ppm) are all from the Farwell or Pearl districts. Clusters similar to Spec Cu, except for lack of Greenville analyses.
Spec Ga: All 35 unqualified values + 24 L values (very incomplete data).	10L, 20L, 10 (30)	15, 20 (22)	30, 50 (6)	70, 100 (1)	Spec Ga: Maximum 100 ppm in Greenville ore. Data very limited, but anomalies at Greenville district, Strawberry Park–Copper Ridge, in Willow Creek, and at head of landslide south of Hinman Park.
Inst Hg: 0.09 ppm and greater (70 + 3 G values).	0.04–0.24 (40)	0.28–0.8 (21)	0.85–5.5 (8)	10, 10G (4)	Inst Hg: Maximum >10 ppm in *botryoidal iron-gossan at Gilpin mine*, and iron-silica boxwork, Crystal mine.
Spec La: 50 ppm and greater (62) -----	50, 70 (44)	100, 150 (14)	200, 300 (3)	500 (1)	Spec La: Maximum 500 ppm iron-stained pegmatite northeast of Red Hill Ranch. Cluster *Bear Creek district*.
Spec Mo: All 66 unqualified values + 48 L values.	2L, 5L, 2, 3 (57)	5–30 (39)	50–300 (15)	500–1,500 (1)	Spec Mo: Maximum 1,000 ppm from malachitic garnet rock *west side Buck Mountain*. Clusters: Pearl, Farwell, *Gilpin*, and Greenville districts, Crystal-Pedad claim area.
Spec Nb: 20 ppm and greater (22) -----	20 (11)	30 (7)	50, 70 (3)	100, 150 (1)	Spec Nb: Maximum 150 ppm malachitic muscovite pegmatite, Farwell. Other highs: *Soda Creek*, south Lone Pine Creek.

TABLE 5.—*Summary of anomalous rock geochemical data shown on individual element maps*—Continued

Map symbol key for selected geochemical data of Mount Zirkel Wilderness					
Rock sample data (coded "A")	Symbol code, in parts per million				Rock geochemistry
Element with chosen values	Smallest symbol	Next to smallest	Next to largest	Largest symbol	
Spec Ni: 20 ppm and greater (61) -----	20, 30 (35)	50–100 (15)	150–300 (6)	500, 700 (5)	Spec Ni: Maximum 700 ppm in *Bear Creek peridotite* and *dunite segregate of gabbro of Elkhorn Mountain.*
Spec Pb: 50 ppm and greater (109 + 15 G values).	50–300 (63)	500–3,000 (35)	5,000–15,000, 5,000G, 20,000G (6)	(None)	Spec Pb: Maximum >20,000 ppm from Greenville soil; Independence Mountain iron-manganese ore; and quartz-galena or quartz-pyrite veins in or near the Elkhorn mine. 15,000 ppm *Gilpin mine*; >5,000 ppm cluster at Greenville. Other clusters: *Lower Slavonia to Red Dirt Pass*, Pearl, *Bear Creek.*
AA Pb: 30 ppm and greater (89) ------	30–120 (39)	130–1,000 (23)	1,300–10,000 (20)	14,000–68,000 (7)	AA Pb: Maximum 68,000 ppm quartz-galena vein Elkhorn mine. Other maximums and clusters similar except Greenville and Lower Slavonia analyses lacking, and *King Solomon Creek* high is new with AA data.
Spec Sb: All 18 unqualified values + 51 L values.	100L (51)	100–200 (11)	300–500 (5)	700, 1,000 (2)	Spec Sb: Maximum 1,000 ppm and highest cluster Elkhorn mine. Second highest cluster Greenville mine.

Spec Sc: 20 ppm and greater (57) -----	20 (29)	30 (22)	50 (4)	70, 100 (2)	Spec Sc: Maximum 100 ppm in pyritic gabbro near Dudley Creek. Concentrated in epidote or hornblende rocks.
Spec Sn: All 58 unqualified values + 43 L values.	10L, 10, 15 (69)	20, 30 (17)	50, 70 (12)	100, 150 (3)	Spec Sn: Maximum 150 ppm in *Upper Slavonia* and Farwell ore; 100 ppm in iron-gossan at Gilpin mine. Clusters: *Upper Slavonia*, Farwell, southwest Pearl, and Greenville districts.
Spec Sr: 1,000 ppm and greater (9 + 1 G).	1,000 (3)	1,500 (2)	2,000 (4)	5,000G (1)	Spec Sr: Maximum >5,000 ppm epidote rock *Soda Creek*. All concentrations associated with epidote.
Spec V: 30 ppm and greater (163) -----	30–70 (73)	100, 150 (59)	200, 300 (27)	500, 700 (4)	Spec V: Maximum 700 ppm in epidote-veined amphibolite near a shear zone, *Black Mountain*. Commonly concentrated in epidote amphibole rocks. Many clusters in north half or southwest corner of area.
Spec W: All 10 unqualified values + 62 L values.	50L (62)	50–100 (4)	150–300 (3)	500–1,000 (3)	Spec W: Clusters: Pearl (includes maximum 1,000 ppm in malachite ore), Farwell, and Greenville districts.
Spec Y: 50 ppm and greater (61) ------	50, 70 (44)	100, 150 (14)	200, 300 (2)	500 (1)	Spec Y: Maximum 500 ppm in malachitic muscovite, Farwell; most in 150–300 ppm range in association with fluorite.

TABLE 5.—*Summary of anomalous rock geochemical data shown on individual element maps*—Continued

Map symbol key for selected geochemical data of Mount Zirkel Wilderness					
Rock sample data (coded "A")	Symbol code, in parts per million				Rock geochemistry
Element with chosen values	Smallest symbol	Next to smallest	Next to largest	Largest symbol	
Spec Zn: All 100 unqualified values + 27 L values and 32 G values.	100L, 200L, 100–700 (77)	1,000–7,000 (42)	10,000 (8)	10,000G (32)	Spec Zn: Prominent clusters in the Greenville and Elkhorn districts, in an east-west zone across the Pearl district, and at both the *Lower and Upper Slavonia mines*.
AA Zn: 30 ppm and greater (196)	30–260 (131)	280–2,500 (34)	2,900–25,000 (22)	40,000–200,000 (9)	AA Zn: Maximum 200,000 ppm from galena-quartz vein at the Elkhorn mine; 190,000 ppm from ore both at Independence Mountain and *Upper Slavonia mines*. Clusters same as Spec Zn except Greenville and Lower Slavonia analyses lacking, and additional small cluster present in northern Farwell district.

TABLE 6.—*Summary of anomalous stream-sediment geochemical data shown on individual element maps in the vicinity of the Mount Zirkel Wilderness*

[Spec, analysis obtained by standard semiquantitative spectrographic techniques; AA, analysis by atomic absorption techniques; L, less than; G, greater than. Because these analyses were performed over a period of years during which the L and G limits varied for many different elements, symbol boundary values are chosen to eliminate the effect of these variations. Total number of analyses (shown in parentheses below concentration) given for each symbol below may vary slightly from actual totals on element maps because some samples lie outside the area of the element maps and were therefore excluded from them. Localities of individual analyses of particular interest should be checked against plate 2 (where their positions are accurately shown); individual element maps frequently distort the locations slightly in order to alleviate crowding. In right column, anomalous single highs or prominent clusters of data are mentioned where pertinent for each analyzed element selected. Note that presence of anomalous concentrations of an element, although providing targets in any search for economic concentrations, does not guarantee that economic concentrations are present. Areas *within* present boundaries of Mount Zirkel Wilderness or adjacent area are italicized]

Map symbol key for selected geochemical data of Mount Zirkel Wilderness					Stream-sediment geochemistry
Sediment sample data (Coded "B")	Symbol code in parts per million				
Element with chosen values	Smallest symbol	Next to smallest	Next to largest	Largest symbol	
Spec Ag: All 16 unqualified values + 34 L values.	0.5L (34)	0.5, 0.7 (12)	1 (2)	2 (2)	Spec Ag: Maximum 2 ppm *1 mile west-southwest of Stump Park* in unmapped tributary of Encampment River, and in Greenville Creek just below lower Greenville mine. Clusters (mostly trace amounts) in the northwest part of area in streams below Tertiary intrusives, *south of Horse Thief Peak,* and *in Silver City basin.*
AA Ag: 14 ppm and greater (9).	0.4 (4)	0.5 (3)	1 (1)	2 (1)	AA Ag: Maximum 2 ppm and cluster in Greenville Creek just below lower Greenville mine. 1 ppm in Beaver Creek tributary draining the east side of Hahns Peak. Besides other lesser values, three of less than 0.5 ppm (not shown on map) in vicinity of Hahns Peak.

TABLE 6.—*Summary of anomalous stream-sediment geochemical data shown on individual element maps*—Continued

Map symbol key for selected geochemical data of Mount Zirkel Wilderness					
Sediment sample data (Coded "B")	Symbol code in parts per million				Stream-sediment geochemistry
Element with chosen values	Smallest symbol	Next to smallest	Next to largest	Largest symbol	
AA Au: All 7 unqualified values.	(None)	(None)	0.05–0.1 (5)	0.2 (2)	AA Au: Maximum 0.2 ppm from *head of Silver City Creek*, and *east of Bear Mountain*. Not much detectable gold in stream sediments.
Spec Be: 5 ppm and greater (13).	(None)	(None)	5 (9)	7 (4)	Spec Be: Maximum 7 ppm and a notable cluster in streams near the type locality of the quartz monzonite of *Seven Lakes*; a few others within the Mount Ethel pluton.
Spec Co: 50 ppm and greater (31).	(None)	(None)	50 (29)	70 (2)	Spec Co: Two maximum values of 70 ppm; one *east of Three Island Lake*; the other associated with a tight cluster from streams issuing from beneath rock glaciers *north of Ute Lake*. Other clusters *on Buck Mountain*, and *in the northeast part of the gabbro of Elkhorn Mountain*.
Spec Cr: 500 ppm and greater (48 + 1 G value).	500 (33)	700 (8)	1,000, 1,500 (6)	2,000, 5,000G (2)	Spec Cr: Isolated maximum of greater than 5,000 ppm in a tributary of Silver City Creek south of Big Red Park. Most anomalous values, including a secondary maximum of 2,000 ppm and an associated tight cluster, are within 5 miles of *Twin Lake*. Another tight cluster on *east side Buck Mountain*.

Spec Cu: 50 ppm and greater (324).	50 (159)	70 (144)	100, 150 (17)	200, 300 (4)	Spec Cu: Maximum 300 ppm in Greenville Creek just below lower Greenville mine, and in Silver City Creek; 200 ppm in *unmapped tributary of Silver City Creek east of Silver City basin*. Except for a Greenville cluster, nearly all the anomalous values are located in the north half of the map area, concentrated in a 5-mile-wide belt stretching *from Lone Pine Creek to west of Elkhorn Mountain*, with only scattered values in the Pearl district.
AA Cu: 30 ppm and greater (305).	30–35 (169)	40–55 (105)	60–120 (27)	200–250 (4)	AA Cu: Maximum 250 ppm and next two values (230 and 220 ppm) confirm three Spec Cu maximums mentioned above. Silver City Creek anomalies may be related to mineralization along faults cutting rocks of Silver City basin. Overall anomalous pattern confirms Spec Cu pattern, especially in *Gilpin district*, but with additional clusters on *Farwell Mountain* and in Whiskey Creek, and fewer values near Pearl.
Spec La: 100 ppm and greater (74).	100 (44)	150 (21)	200 (7)	300 (2)	Spec La: Maximum 300 ppm *west of Seven Lakes* (in center of cluster), and *along Encampment tributary west of Buffalo Ridge*. Additionally, there is a loose cluster centered on the *Gilpin district*, and a tight cluster along a quartz monzonite contact west of Battle Ridge.

TABLE 6.—*Summary of anomalous stream-sediment geochemical data shown on individual element maps*—Continued

Map symbol key for selected geochemical data of Mount Zirkel Wilderness					
Sediment sample data (Coded "B")	Symbol code in parts per million				Stream-sediment geochemistry
Element with chosen values	Smallest symbol	Next to smallest	Next to largest	Largest symbol	
Spec Mo: All 21 unqualified values + 1 L value.	5L, 5 (5)	7, 10 (13)	15, 20 (3)	30, 50 (1)	Spec Mo: Maximum 50 ppm and cluster *east of Ceanothuse Lake* (northeast of Rainbow Lake). Another cluster near Farwell mine.
Spec Nb: 20 ppm and greater (36).	20 (28)	30, 50 (6)	(None)	70, 100 (2)	Spec Nb: Maximum 100 ppm from two localities in *South Fork Mad Creek* above the junction with the main stem of Mad Creek. One linear cluster extends from *Seven Lakes to Black Mountain.*
Spec Ni: 50 ppm and greater (327).	50 (178)	70 (112)	100 (23)	150–300 (14)	Spec Ni: Maximum 300 ppm in stream issuing from rock glacier *between Twin and Ute Lakes*; 200 ppm in Encampment tributary *southwest of Gem Lake.* Anomalous pattern broadly parallel to that of copper with a wide *belt between Lone Pine Creek and west of Elkhorn Mountain*, but with the absence of a maximum in the Greenville district.
Spec Pb: 50 ppm and greater (159).	50 (110)	70 (38)	100, 150 (10)	700 (1)	Spec Pb: Maximum 700 ppm and 150 ppm cluster in Greenville Creek below lowest Greenville mine; 150 ppm in *Gilpin Creek tributary below Gilpin mine.* Broad concentration of anomalous values in *triangular area*

					with Lone Pine Creek, Silver City basin, and Seven Lakes near corners of triangle. No apparent stream-sediment anomaly below Elkhorn mine!
AA Pb: 30 ppm and greater (168).	30–35 (88)	40–55 (66)	60–100 (9)	130–570 (5)	AA Pb: Maximum 570 ppm and other similar values below Greenville and *Gilpin mines*. Similar overall anomaly pattern to Spec Pb, especially with tight Greenville cluster and broad *Gilpin* cluster, but with more anomalous values in *Damfino and lower Encampment drainages*.
Spec Sc: 50 ppm and greater (116).	(None)	50 (99)	(None)	70 (17)	Spec Sc: Maximum 70 ppm at 17 localities in north half of map area. Anomalous values fall in broad belt reminiscent of copper and nickel, but with nothing west of Whiskey Creek.
Spec Sn: All 9 unqualified values + 7 L values.	10L (7)	10, 15 (5)	20, 30 (2)	50, 70 (2)	Spec Sn: Maximum 70 ppm in tributary of South Fork Hog Park Creek just *southeast of where the Continental Divide passes into Wyoming*; 50 ppm *northwest of Dome Peak*; 30 ppm in a tributary of the Encampment River *southeast of the Guard Station*; 20 ppm in a tributary of Middle Fork Little Snake River *east of Big Red Park*. Small cluster *near Rainbow Lake*.

TABLE 6.—*Summary of anomalous stream-sediment geochemical data shown on individual element maps*—Continued

Map symbol key for selected geochemical data of Mount Zirkel Wilderness					
Sediment sample data (Coded "B")	Symbol code in parts per million				Stream-sediment geochemistry
Element with chosen values	Smallest symbol	Next to smallest	Next to largest	Largest symbol	
Spec Sr: 500 ppm and greater (88).	(None)	500 (71)	(None)	700 (17)	Spec Sr: Maximum 70 ppm at 17 localities, mainly in the north half of the map area. Main cluster *Three Island Lake to Bear Mountain*; another *southwest of West Fork Lake*; another along Soda Creek–Fish Creek shear zone.
Spec V: 300 ppm and greater (97).	(None)	300 (89)	500 (7)	700 (1)	Spec V: Maximum 700 ppm from natural magnetite concentrate in Big Creek southwest of Floyd Peak. Other highest anomalous values from magnetite concentrates or streams draining Mesozoic rocks. Main cluster in north half of map area similar to that for copper and nickel.
Spec Y: 70 ppm and greater (407).	70 (297)	100, 150 (98)	200 (10)	300 (2)	Spec Y: Maximum 300 ppm in Beaver Creek northwest of Big Creek Lake, and *Mica Creek above Gilpin Creek*. Most anomalous values scattered throughout north half of map area.

Spec Zn: All 31 unqualified values + 26 L values.	200L, 200, 300 (48)	500, 700 (4)	1,000, 1,500 (4)	2,000, 3,000 (1)	Spec Zn: Maximum 3,000 ppm in Greenville Creek below lowest Greenville mine, with next four highest values (1,000–1,500 ppm) successively downstream from this. Smaller cluster *around Bighorn Lake.*
AA Zn: 125 ppm and greater (61).	125–170 (29)	180–260 (20)	270–480 (9)	850–2,700 (3)	AA Zn: Maximum 2,700 ppm and same concentration of highest values in Greenville Creek. Clusters from *Bighorn Lake to Gilpin Lake*, and east of Hahns Peak.
Spec Zr: 500 ppm and greater (110 + 5 G values).	500 (47)	700 (44)	1,000 (19)	1,000G (5)	Spec Zr: Maximum greater than 1,000 ppm from mouth of Hot Spring Creek; above Twisty Park; *east of Seven Lakes*; in South Fork Big Creek above the Pearl smelter; and in a tributary of Silver City Creek south of Big Red Park (same sample with highest chromium). Many samples clustered in east-west belt in northernmost quarter of map area.

TABLE 7.—*Summary of semiquantitative spectrographic*

[Data values for all columns: top, low; boldface, average; bottom, high. Average is generally the *mode*; average is collected by George L. Snyder, 1965-72. Semiquantitative spectrographic analyses by J.C. Hamilton (USGS lab B. Wayne Lanthorn (USGS lab numbers D141154-D141162, Jan. 8, 1970); Leon A. Bradley (USGS lab numbers D103027-D103060, Feb. 1, 1972); and Harriet G. Neiman (USGS lab numbers D103296-D103319, Apr. 25, 1973). detected in amount greater than shown; L, detected in amount less than shown]

Number of samples analyzed	Number of rocks represented	Sample types	Fe (weight percent)	Mg (weight percent)	Ca (weight percent)	Ti (weight percent)	Mn	B
8	5	Tertiary intrusives (of intermediate composition).	3 **5** 7	1 **3** 5	2 **5** 7	0.3 **0.7** 1	300 **700** 700	10N **10N** 10L
13	13	1.4-b.y. felsic plutonic rocks (mainly quartz monzonite and granite).	0.7 **2** 3	0.03 **0.3** 0	0.15 **1.5** 1.5	0.02 **0.15** 0.3	20 **200** 500	- **10N** -
4	4	1.4-b.y. mafic plutonic rocks (granodiorite, diabase).	5 **7** 7	1 **1.5** 2	1.5 **3** 5	0.5 **0.7** 0.7	500 **700** 700	- **10N** -
14	14	1.7-b.y. felsic plutonic rocks (mainly quartz monzonite and granite).	0.7 **3** 7	0.1 **0.5** 0.7	0.2 **(1)** 3	0.05 **0.15** 0.3	70 **200** 500	- **10N** -
13	13	1.7-b.y. mafic plutonic and volcanic rocks (tonalite, gabbro, amphibolite).	1 **7** 10G	0.3 **7** 7	2 **7** 10	0.005 **0.3** 1	200 **1000** 5000	- **10N** -
45	38	1.7-b.y.(?) ultramafic rocks (peridotite, dunite, hornblendite).	3 **(10)** 10G	3 **10** 10G	0.03 **3** 10G	0.01 **0.1** 0.3	300 **1000** 2000	10N **10N** 20
2	2	1.7-b.y.(?) pegmatite dikes.	0.15 **(0.5)** 1	0.015 **(0.05)** 0.1	0.2 **(0.5)** 1	0.03 **(0.05)** 0.07	70 **(100)** 100	- **10N** -
5	5	1.7-b.y. felsic gneiss country rock.	1 **3** 10	0.015 **(0.7)** 2	0.3 **(1.5)** 3	0.05 **0.3** 0.5	150 **(500)** 1500	- **10N** -
19	8	1.7-b.y. pelitic schist or felsic sillimanitic pod-rock.	0.5 **1.5** 10	0.2 **0.7** 1.5	0.03 **0.5** 1	0.05 **0.2** 0.3	100 **(500)** 1000	10N **10N** 30
5	5	1.7-b.y. marble and calc-silicate rock.	1.5 **2** 10G	1 **1.5** 3	10 **10G** 10G	0.05 **0.1** 0.15	700 **1500** 7000	- **10N** -
1	1	1.7-b.y. quartzite ---	**(2)**	**(0.2)**	**(0.05)**	**(0.3)**	**(50)**	**(10N)**
7	7	Conspicuously reddish soils (mostly overlying dunite).	10 **10G** 10G	0.7 **5** 7	1 **2** 3	0.1 **0.15** 0.3	700 **1500** 1500	10N **10N** 10L
136	115							

data for unmineralized crystalline rocks, Park Range, Colorado

the *mean*—in parentheses—where the data are bimodal or where there are too few data for mode. All samples numbers D101275-D101279, Jan. 20, 1966); G.W. Sears, Jr. (USGS lab numbers D101640-D101658, Mar. 3, 1967); D102923-D102926, April 22, 1971); Larry D. Forshey (USGS lab numbers D154815-D154855, Dec. 3, 1971, and Looked for but not found: Ag, As, Au, Bi, Cd, Pd, Pt, Sb, Sn, Te, U, W, Zn. N, not detected at limit shown; G,

Ba	Be	Co	Cr	Cu	La	Mo	Nb	Ni	Pb	Sc	Sr	V	Y	Zr
						(parts per million)								
1500	1N	15	50	30	30	3N	10	70	20	10	1500	70	15	70
3000	**1**	**30**	**200**	**30**	**100**	**5**	**20**	**150**	**30**	**20**	**1500**	**150**	**20**	**150**
5000	2	50	300	70	150	5	20	300	50	30	3000	300	30	200
50	1N	3	1	1N	30N	3N	10	3N	20	5N	20	10	10	30
1500	**2**	**5**	**5**	**3**	**150**	**3N**	**10**	**3N**	**30**	**5**	**200**	**30**	**20**	**150**
2000	3	10	20	20	300	3	50	10	50	10	500	100	50	300
1000	1	10	15	20	100	-	10	10	10	15	500	100	30	150
2000	**1.5**	**20**	**(50)**	**(50)**	**150**	**5L**	**10**	**30**	**15**	**20**	**500**	**200**	**30**	**(200)**
2000	2	30	100	70	200	-	10	50	15	20	1000	200	30	300
500	1N	3N	1N	1N	30N	-	10L	3N	10N	5N	100	7N	10N	70
1500	**2**	**5**	**5**	**(3)**	**50**	**3N**	**10**	**3N**	**20**	**5**	**(200)**	**50**	**20**	**150**
3000	5	10	30	10	200	-	15	7	50	15	700	70	70	200
20	1N	3N	2	3	30N	3N	10N	3N	10N	5N	50	10	10N	10N
(100)	**1N**	**50**	**300**	**70**	**30N**	**3N**	**10N**	**100**	**10N**	**30**	**700**	**(100)**	**10N**	**10N**
1000	1.5	50	700	150	70L	7	20L	150	15	70	1500	300	30	150
5	1N	20	100	1	-	3N	10N	100	10N	5	5N	20	10N	10N
50	**1N**	**50**	**1500**	**50**	**30N**	**3N**	**10N**	**(500)**	**10N**	**15**	**70**	**70**	**10**	**10N**
700	1.5	150	5000	300	-	10	20L	1000	30	100	300	200	15	50
150	1N	-	1	1	30N	-	-	-	20	-	20	5N	10L	10N
-	**(1)**	**3N**	**(2)**	**(3)**	**-**	**3N**	**10L**	**3N**	**(30)**	**5N**	**-**	**(5)**	**-**	**-**
2000	1.5	-	2	7	70	-	-	-	50	-	300	7	10	70
30	1	3N	1N	1	30	-	10N	3N	10N	5N	5	5N	20	100
1500	**1**	**3N**	**(2)**	**(2)**	**70**	**3N**	**10L**	**3L**	**10N**	**5N**	**200**	**5N**	**(50)**	**100**
1500	3	20	20	200	70	-	30	10	30	50	500	300	100	300
700	1N	3N	1N	1N	30N		10L	3N	15	5N	30	5N	10	100
1000	**2**	**3N**	**1**	**(2)**	**70**	**3N**	**10**	**3N**	**15**	**(5)**	**150**	**5L**	**50**	**100**
2000	3	20	150	20	70	-	15	30	50	20	200	150	100	500
15	1N	3N	1	2	30N	-	10N	3N	10N	5N	20	5N	10	20
(200)	**(1.5)**	**3N**	**1**	**(5)**	**30N**	**3N**	**10L**	**3N**	**20**	**7**	**(150)**	**5N**	**50**	**70**
700	3	50	500	300	100	-	10	150	150	20	1500	100	70	200
(150)	**(1N)**	**(3N)**	**(30)**	**(3)**	**(30N)**	**(3N)**	**(15)**	**(3N)**	**(10)**	**(5)**	**(10)**	**(30)**	**(10)**	**(150)**
200	1N	7	70	20	30N	-	10N	20	15	10	100	50	10	50
200	**1N**	**100**	**1500**	**150**	**30N**	**3N**	**10L**	**300**	**20**	**15**	**150**	**100**	**10**	**70**
700	1.5	100	1500	150	70	-	10L	700	30	20	300	150	30	100

GENERAL EVALUATION OF SURFACE ANOMALIES

Attempt was made to evaluate the reliability of geochemical sampling of stream sediments under local conditions as a guide to ore deposits that crop out at the surface. Would sediment samples reflect anomalous values downstream from known ore deposits? The attempt was made on Greenville Creek in the vicinity of the Greenville mine, an area of known geology, variable topography, and easily accessible sediments. (See fig. 51.) Conditions were purposely chosen to minimize extraneous variables. Most collections were made in one-half day; all were collected by one person; most samples were analyzed in a single batch by a single analyst using comparable analytical techniques. Stream sediments were collected in Greenville Creek at intervals of 150 to 300 m (500–1,000 ft), providing much closer control than the average spacing elsewhere throughout the mapped area.[5] The results illustrate both the strengths and weaknesses of the Park Range sampling system. Under favorable topographic conditions the sampling net is probably adequate, but, under unfavorable conditions, there is no assurance that an ore deposit of a certain type could not slip undetected through the net spacing. The reader should note that, with the elements indicated in figure 51, under high-transport conditions zinc is detectable farthest downstream, silver least far, and copper and lead for intermediate distances, averaging about 1.2 km (3/4 mi). Conditions are less favorable in rolling upland topography, where, despite visible ore in outcrop and a clear contribution to the nearby soil, speed of transport is apparently low enough that this soil has not moved very far (less than 0.5 km, 1/3 mi) from its site of origin. Other things being equal, therefore, geochemical analysis of stream sediments has a greater chance of detecting an exposed ore deposit in environments with rugged topography than in subdued topography situations. Partially offsetting this topographic effect is the fact that tributary density, and hence sampling density, is often greatest in high-basin subdued-topography environments, where the drainage patterns are in the process of being established.

[5]Reference to plate 2 will show that the sediment-sample spacing has varied along streams from intervals of 0.15–3 km (0.1–2 mi) and with an average of about 0.8 km (0.5 mi). The sampling net is less dense in the south half of the map area, where the work began and where visible shows of ore were less numerous. As the work progressed to the north half of the map area and as shows of basement ore became more numerous, the sediment sampling density increased commensurately, with the result that sampling control is most complete in the area of greatest surface mineral potential.

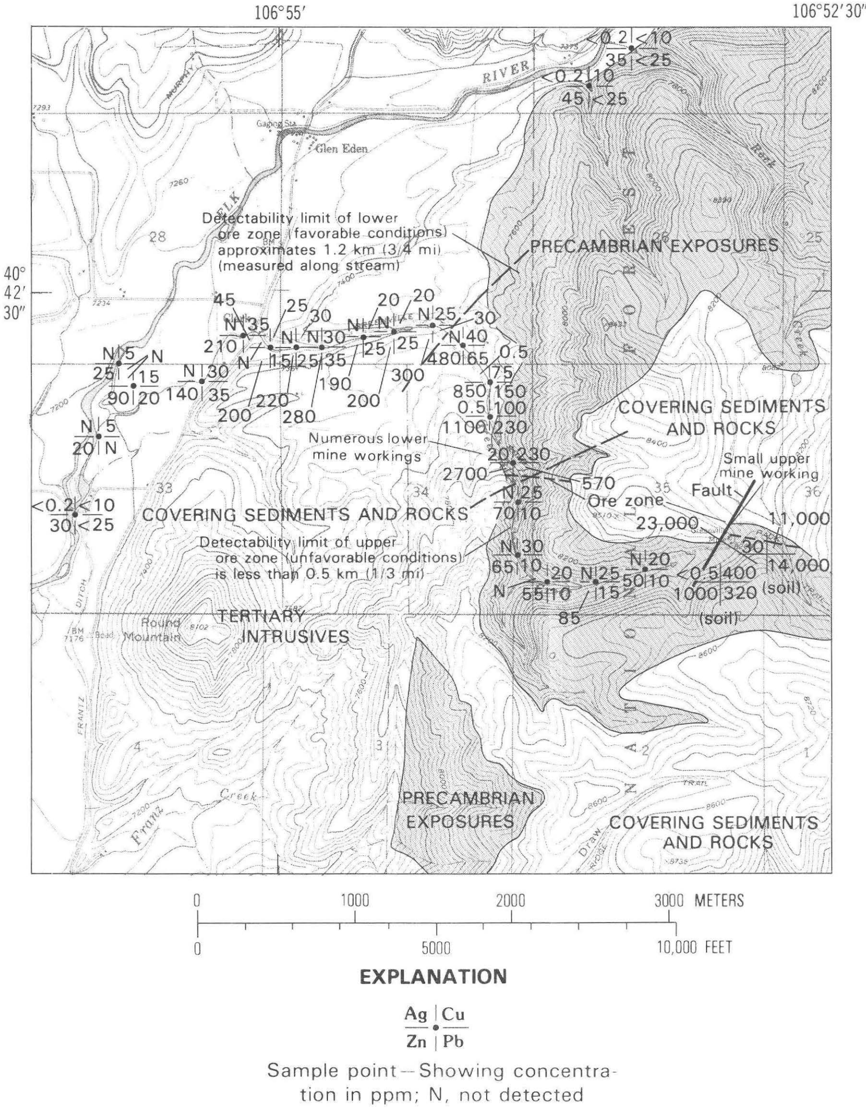


FIGURE 51.—Test, under both favorable and unfavorable conditions, of detectability of selected elements near known Greenville mine ore zone(s) by AA (atomic absorption) analysis of stream sediments. Note that steep canyon topography creating rapid-transport environment apparently favors detection over stable-upland environment. All samples are stream sediment unless shown as "(soil)."

Stream-sediment geochemical analysis can have very positive results, indicating anomalously high target areas that might warrant more assiduous search by private interests. It can narrow or pinpoint targets and, conceivably, save exploration expenses. However, lack of a geochemical anomaly does not by itself guarantee lack of an exploitable deposit at depth. Negative evidence can never be equivalent to complete mathematical proof; it is merely statistical. Whatever deposits are found as a result of this or other geochemical studies, others will certainly be missed; some "blind" deposits may eventually be found by other techniques, whereas some may never be found.

A potentially economic deposit may fail to create a significant geochemical anomaly for any of the following reasons:

1. The deposit may be under sufficient cover to prevent guide elements from reaching the surface in detectable amounts.
2. The deposit may consist of materials too light or too soluble to linger in stream sediments (for example, chlorine, sodium, carbon dioxide).
3. The local conditions of topography may not favor transport away from the site. (See fig. 51.)
4. Evidence of a small source can be flooded out if it is near a large volume of sediment that can rapidly dilute its detritus.
5. The definition of an economic deposit varies with time. Economic conditions in the society at large have a definite effect. There are numerous examples where yesterday's gangue is today's ore, or where yesterday's conditional resources are today's demonstrated reserves (Brobst and Pratt, 1973a, p. 4; 1973b, p. 4; U.S. Geological Survey, 1975, p. 4).

All the above negative provisions, and probably others unmentioned, are pertinent in an evaluation of the present geochemical survey of the Mount Zirkel area. It is estimated that 20 percent of the area is under thick cover, near large sources of diluting alluvium, topographically gentle, or otherwise unsuitable, so that only minimum benefit would be derived from collection of geochemical samples. Of the 80 percent of the area where the sampling is most valid, perhaps 90 percent of this has been sampled, the remaining 10 percent missed due to sampling inefficiencies, mainly the thinner coverage early in the program. If these estimates are anywhere near correct, this means that one-fourth, or slightly more, of the area could harbor anomalous geochemistry undetected or undetectable by this stream-sediment sampling program. However, the sediment geochemical survey is supplemented by the field observations of the surveyors and by the rock-sample geochemical survey. The reader should note that the coverage net of traverses walked by the field mappers was substantially the same throughout the area from south to north and from beginning to end of the work. Covering or diluting detrital sediments, soil, colluvium, or till may contain fragments of mineralized rock undetectable by analysis of downstream detritus but physically observable by surveyors at or near the site of origin, especially by surveyors actively looking for such signs of mineralized rock. Also, in addition to the 426 samples of potential ore analyzed, more than 1,671 additional rock samples were collected of the more typical unmineralized rocks of the area, and these have provided additional chemical data useful for evaluating the surface mineral potential of the area.

The following tabulation gives the best current appraisal of the likelihood of various types of ore deposits being present near the surface in the Mount Zirkel area:

Large high-grade deposits.—Except for elements like Si, Al, Fe, Mg and Ca locked in silicates, deposits of this type are not known to be present at the present ground surface and none are likely to have been missed.

Large low-grade deposits.—Some of these are certainly present, several discovered as a result of this survey, and it is unlikely that any were missed. For example, the presence of copper and chalcophile elements in metavolcanics near quartz monzonite contacts in the north half of the mapped area, the concentration of interstitial fluorite in rocks of the Mount Ethel pluton, and the occurrence of beryllium in the vicinity of Seven Lakes are either newly discovered or better understood as a direct result of this survey. The large area covered by each of these mineral concentrations makes it virtually impossible for similar deposits to exist undetected within the current net of samples and observations.

Small high-grade deposits.—Some of these were detected in several ways or by several techniques; others were detected by some but missed by other techniques; some may have been missed altogether. For example, the Greenville mine(s) ore zone varies from 0.3 m (1 ft) to several meters or yards wide and is more than a mile long; malachitic bloom is readily observable in outcrop or underground, but evidence of the zone is missing where it totally disappears beneath younger cover rocks. Nevertheless, the topographically most favorable exposures of this zone were detectable in nearby stream sediments at least as close as 1.2 km (¾ mi) away. (The exact distance varies slightly for different elements; see fig. 51.) One can say with confidence that not many lower Greenvilles could have slipped undetected through this survey. In contrast, the Elkhorn mine ore zone was not readily observable in outcrop or underground, but the dump yielded 2.5- to 10-cm chunks of simple galena veins that were the highest sources of rock silver, lead, and zinc in this study. The stream sediment nearest to the Elkhorn mine was collected less than 260 m (900 ft) directly downhill from the mine, and this was supplemented by four other stream sediments downdrainage at successively greater intervals to Whiskey Park. *None* of these sediments provided analytically anomalous silver, lead, or zinc! On this basis, it seems clear that many undiscovered Elkhorns could exist undetected throughout the Mount Zirkel area. Although the Elkhorn mine has been only submarginally economic, the distinct possibility of thin "blind" veins containing economically precious metals like silver or gold cannot be discounted.

Small low-grade deposits.—Several of these are known to be present and many others may have been missed, but, in either case, they appear to be of minimal economic interest. Small low-grade deposits could be marginally economically interesting for at least two reasons: (1) They could lead to something bigger. With the publication of the data contained in this report, it is presumed that other parties will pursue this possibility. (2) They could be low-grade in many elements (multicommodity) so that the aggregate element value makes exploitation possible. No small low-grade multielement deposits of economic interest are known in the Mount Zirkel Wilderness and vicinity, but they were carefully searched for in at least one type of deposit, the ultramafic rocks, which are potential sources of cobalt, chromium, nickel, platinum, palladium, and other elements. To summarize here, it seems unlikely that these small low-grade surface ultramafic deposits will soon be economic even with a multielement consideration.

METALLIC DEPOSITS

The distribution of various metallic elements will be described herein emphasizing unusual or anomalous concentrations and utilizing the geochemical surveys of both rocks and stream sediments. The geochemical survey data are summarized in tables 5 and 6 and on individual element maps (figs. 52–104, 107, 108) that group the anomalous data using no more than four sizes of map symbols (largest symbol equals largest anomaly). (Symbols are explained in tables 5 and 6.) The elements are grouped here in the following categories:

1. Copper-lead-zinc-silver plus gold, mercury, antimony, arsenic, tungsten, tin, cadmium, bismuth, and gallium;
2. Uranium-thorium plus molybdenum, niobium, lanthanum, yttrium, and other rare earths;
3. Chromium-platinum plus palladium, cobalt, and nickel;
4. Major elements, iron, magnesium, calcium, titanium, and manganese plus minor elements boron, barium, beryllium, scandium, strontium, vanadium, and zirconium.

The reader should note that each element map purposely separates data from that of all other elements, that rock and stream-sediment data are separated, and that spectrographic, atomic absorption, and instrumental data are also separated. This permits not only independent scrutiny of each body of data but also the dual comparison of whatever individual sets of data are desired to be compared. Because, for reasons of analytical technique, sampling variance, mineral distribution, or other unknown factors, no two of the data sets are completely identical[6] (see comments in tables 5 and 6), it is believed that this ability to make independent comparisons will be useful to most readers. This separate portrayal of individual elements encourages maximum freedom in following individual geochemical insights toward mineral resource exploration or assessment.

COPPER, LEAD, ZINC, SILVER, AND RELATED ELEMENTS

The detailed distribution of anomalous rock and stream-sediment copper, lead, zinc, silver, gold, mercury, antimony, arsenic, tungsten, tin, cadmium, bismuth, and gallium are shown, in order, on figures 52–78. Chosen anomaly limits plus observed locations of maximum values and prominent clusters of anomalous data are summarized in tables 5 and 6 and figures 107–109. Some other elements grouped for convenience with later sets of data also have some geochemical patterns analogous to those of the elements grouped here. For details, the reader should refer to the detailed data, but, in general, most of the *multielement* anomalies found or indicated have been from five districts:

1. Elkhorn: Rock maxima for silver, cadmium, lead, antimony, and zinc. Includes Elkhorn mine.
2. Farwell: High rock copper, lead, tin, tungsten, and zinc, not to mention rock maxima in niobium and yttrium and a molybdenum cluster in stream sediments. Includes mines north and west of Farwell Mountain, some within present adjacent area boundary.
3. Gilpin: Rock maxima in gold, mercury, and tin, plus high rock zinc and high rock and stream-sediment lead. Includes Lower and Upper Slavonia mines (figs. 14, 36), scheelite reported from here by Tweto (1960, p. 1408); two mines referred to herein as the Gilpin mines (fig. 3), all of which had their main activity after the turn of the century; and other unnamed prospects near the head of Gilpin Creek. This is the only major district entirely within the wilderness. In fact, it could hardly be more centrally located (see figs. 3, 14), and it appears that, if a valuable mineral resource is eventually proven here, it will be most difficult to resolve both economic exploitation and preservation of wilderness values.
4. Greenville: Rock lead and gallium maxima, high rock copper, tungsten, and zinc, and stream-sediment maxima for silver, copper, lead, and zinc. Includes Greenville mine, the only mine known to have shipped base metal ore recently; according to local authority six truck loads of ore were taken to smelter from the Greenville mine during World War II. Greenville has been the site of much sophisticated geophysical prospecting and drilling during the 1960's and 70's and was the study site of a detailed Colorado State University thesis being prepared in 1976 (Johnson, 1979).

[6]When spectrographic and atomic absorption analyses measured for identical samples are compared, for example, on rock Cu, 63 percent (or five out of eight) of the sample points are within two steps of equivalence.

5. Pearl (for a historical account of the turn-of-the-century copper mines, see Spencer, 1903): Rock maxima in bismuth, copper, and tungsten, plus high rock gold, lead and zinc. Multielement anomalies in each of five separate centers within the Pearl district, each of which has had extensive mining or prospecting. Mining in the Pearl district flourished just after the turn of the century and ceased about 1908. The Wolverine was said to have been the oldest and richest mine with a vein of ore containing 10 to 40 percent copper, and minor silver and gold values. A smelter was finished in 1905, but it was never operated; the chimney still stands near the Pearl townsite (Ryan, 1976, p. 12, 13). The Cap Rock mine, on Independence Mountain east of Wheeler Creek, was in an active exploration phase in 1977 (W. H. Raymond, oral commun., 1977); other company explorations were conducted in the Pearl district at least through 1979.

Several smaller copper-lead-zinc-silver-gold and related multielement anomalies with some mineral resource potential occur within the Mount Zirkel Wilderness and adjacent area (fig. 109). Two anomalies which apparently are unprospected are worth mentioning. An area just inside the adjacent area boundary on the east side of Silver City Creek basin (pl. 2) has contributed the stream-sediment gold maximum and high stream-sediment copper values. These may be related to mineralization along the Laramide thrust on the east side of the basin. The other area, between Big Horn Lake (pl. 2) and the Continental Divide, has an anomalous zinc cluster in stream sediments.

Marginally profitable gold placers have been worked in the past in gravels flanking the mountain range (outside the Mount Zirkel Wilderness and adjacent area). Those on Independence Mountain have been described by Beekly (1915, p. 117) and Hail (1965, p. 123, 124), and those on Hahns Peak have been discussed by Gale (1906), George and Crawford (1909), Antweiler, Doe, and Delevaux (1972), and Young and Segerstrom (1973, p. 3–6). There is no indication of appreciable amounts of placer gold within the area of present interest.

URANIUM, THORIUM, AND RELATED ELEMENTS

Grouped together by reason of preferred association are uranium, thorium (fig. 79), molybdenum (figs. 80, 81), niobium (figs. 82, 83), lanthanum (figs. 84, 85), and yttrium (figs. 86, 87). Nevertheless, there is much overlap among the elements of this group and those of other groups. The molybdenum rock maximum of 1,000 ppm is associated with sulfide ore on the west side of Buck Mountain (pl. 2), and a prominent molybdenum sediment cluster is associated with niobium and yttrium in sulfide ores of the Farwell district. The molybdenum sediment maximum is east of Ceanothuse Lake (pl. 2) in the 1.4-b.y. Mount Ethel pluton, a preferred host for other elements of this group—for example, the niobium sediment maximum in South Fork Mad Creek (pl. 2). However, some uranium, thorium, niobium, and lanthanum are associated with the sediment beryllium cluster in 1.7-b.y. quartz monzonites near Seven Lakes (pl. 2). And uranium, molybdenum, and yttrium are associated with Tertiary fluorite veins, especially in the Crystal-Pedad claim area (figs. 24, 27; pl. 2). None of the elements of this group has been the source of economic deposits, although the elements are believed to have been actively prospected in the Bear Creek district and other areas. Elsewhere in Colorado, vanadium is an accessory element locally associated with uranium that enabled the extraction of uranium ores which otherwise would have been uneconomic to develop (Morse and Curtin, 1977, p. 10), but this association does not appear to be prominent in the northern Park Range.

URANIUM AND THORIUM

Uranium and thorium are not known to be present in the northern Park Range in significant amounts except for small specimens notable as mineralogical curiosities rather than as parts of ore deposits (0.176 percent U_3O_8 was the average grade of uranium ore mined in the United States in 1974 (Woodmansee, 1974, p. 1327) whereas 0.15 percent U_3O_8 was projected as minable by 1979 (Morse and Curtin, 1977, fig. 12, p. 31)). Selected Park Range minerals may contain uranium and thorium in amounts of 1 percent (10,000 ppm) or more. A survey of a handful of old analyses reported in the literature and 61 new analyses indicates minor concentrations (generally a few tens or less, rarely hundreds or thousands, of parts per million) associated with several types of geological environments, which will be recounted herein. Detailed searches in the vicinity of known deposits or in these relatively favorable environments will possibly turn up larger buried uranium and thorium deposits than are now known, but there is little evidence to encourage the belief that large, economically exploitable ore deposits will be found at the ground surface. A recent compilation of uranium districts in Colorado shows none in Jackson or Routt Counties (Morse and Curtin, 1977, fig. 4, p. 56–58). The new analyses are contained in tables 2, 4, and 8. About half of the new analyses are on stream sediments and half on rock samples; most are mixtures of common silicate minerals, many with an indication that they are rich in iron (sulfide, oxide, or silicate). All the new analyses plus all the old ones that could be located are shown on figure 79.

Higher than normal radioactivity measured in the northern Park Range has been attributed to a variety of primary or secondary uranium- or thorium-containing minerals or to mineralogic environments. Reported radioactive minerals include uraninite or pitchblende, zircon, xenotime, allanite, fergusonite, euxenite, carnotite, black chalcedony or dark-purple fluorite, as well as secondary alteration

TABLE 8.—*Delayed neutron determinations of thorium and uranium in stream sediments and rocks of the northern Park Range, Colorado, that contain 20 ppm or greater niobium*

[Average sample size 8 g (range 1-13 g) except where marked "insufficient sample." For description of analytical technique see Millard, 1976. Do., entry same as preceding; for localities see plate 2]

Field No.	Lab. No.	Nb (ppm)	Th (ppm)	U (ppm)	Remarks
			Stream sediments		
71	ADS 123	20	13.97	3.98	Hot Spring Creek above Elk Park.
84	ADS 136	20	22.21	5.44	Southwest of Horse Thief Peak.
89	ADS 141	100	22.64	9.43	South Fork Mad Creek.
194	ADW 023	20	6.64	3.79	Newcomb Creek at toe of landslide in Morrison Formation.
203	ADW 032	20	9.05	5.34	Head of Whalen Creek.
3	AMT 485	20	6.99	6.04	North Three Island Creek.
6	AMT 488	20	30.79	8.29	Mouth of Hot Spring Creek.
20	AMT 502	20	7.95	4.02	Natural magnetite concentrate, Big Creek.
23	AMT 505	20	21.98	8.04	Do.
26	AMT 508	20	9.70	4.37	Mucky sediment northwest of Moon Hill.
32	AMT 514	20	36.15	19.94	Panned heavy minerals, North Fork Elk River near Seedhouse.
33	AMT 515	20	29.40	9.76	Mouth of Mad Creek.
42	AMT 524	100	146.01	24.68	South Fork Mad Creek at trail.
43	AMT 525	30	25.65	20.93	7,800-ft altitude Mad Creek.
45	AMT 527	30	48.48	13.66	Soda Creek above Gunn Creek.
46	AMT 528	30	52.90	9.05	Gunn Creek above Soda Creek.
47	AMT 529	20	13.37	5.22	Soda Creek.
50	AMT 532	20	30.26	8.68	Gunn Creek tributary.
52	AMT 534	20	47.33	9.70	Hot Spring Creek.
53	AMT 535	20	52.24	14.23	Bear Creek.
57	AMT 539	20	26.19	9.56	East fork Gunn Creek.
58	AMT 540	20	30.89	17.13	Soda Creek above South Fork.
674	BFM 952	20	Insufficient sample		Encampment River tributary from Seven Lakes area.
682	BFM 960	20	19.65	17.82	9,460-ft altitude Encampment River.
688	BFM 966	20	8.15	5.88	East of West Fork Lake.

TABLE 8.—*Delayed neutron determinations of thorium and uranium in stream sediments and rocks of the northern Park Range, Colorado, that contain 20 ppm or greater niobium*—Continued

Field No.	Lab. No.	Nb (ppm)	Th (ppm)	U (ppm)	Remarks
			Stream sediments—Continued		
694	BFM 972	20	Insufficient sample		North of West Fork Lake.
697	BFM 975	20	Insufficient sample		West of West Fork Lake.
698	BFM 976	20	7.68	11.30	Northwest of West Fork Lake.
266	BFN 167	20	19.13	18.66	Stream draining Seven Lakes area.
288	BFN 189	30	22.35	19.06	Do.
289	BFN 190	20	12.11	10.15	Do.
293	BFN 194	30	12.60	12.15	Do.
388	BFN 288	20	Insufficient sample		Stream draining Seven Lakes area.
786	LAA 432	20	40.65	9.29	Silver City Creek tributary below Dakota Sandstone.
902	LAA 548	20	5.87	5.52	Middle Fork Little Snake River tributary.
1057	LAA 704	30	12.90	4.46	Lester Creek tributary below Browns Park Formation.
			Rock samples		
250	ADS 518	30	16.95	6.08	Chloritized pelitic gneiss near fault.
263C	ADS 523	30	46.37	4.89	Hematitic granite from prospect pit above head of Bear Creek.
289	ADS 530	30	13.96	8.57	Mylonite below pegmatite, Soda Creek.
322	ADS 533	20	12.57	34.38	Epidote rock north of head of Soda Creek.
411	ADS 540	20	6.26	2.03	Plagioclase-augen mylonite from north-northeast of Buffalo Mountain.
607	ADV 984	50	34.43	258.11	Yellow ferrous breccia from Pedad claim north of Roaring Fork.
736	BFO 744	20	2.72	3.56	Malachitic amphibolite from pit near head of Republic Creek.
793	BFO 762	20	1.05	12.96	Porous ferrous amphibolite, Wolverine mine upper dump.

TABLE 8.—*Delayed neutron determinations of thorium and uranium in stream sediments and rocks of the northern Park Range, Colorado, that contain 20 ppm or greater niobium*—Continued

Field No.	Lab. No.	Nb	Th	U	Remarks
		(ppm)			
		Rock samples—Continued			
845	BFO 771	30	6.79	2.58	Epidotitic pyritic granite dike, 11,400-ft altitude Bear Ridge.
1130	BFO 810	20	14.03	7.69	Iron-stained granite gneiss, Mica Basin.
1180	BFO 830	30	8.56	1.64	Iron-stained gneiss from pit on ridge north of Agnes Creek.
1385	LAA 979	20	3.66	1.33	Altered granite gneiss east of Ryan Park.
1404	LAA 981	20	7.38	3.94	Mylonitized trachyandesite dike, Ellis Trail, South Fork Hog Park Creek.
1565	LAA 994	150	18.56	3.17	Malachitic pegmatite, central Farwell mine.
1566	LAA 995	30	1.67	12.42	Malachitic dump rock, west Farwell mine.
1573	LAA 997	20	14.41	8.08	Malachite, east Farwell mine.
1574	LAA 998	20	6.12	2.95	Malachite, central Farwell mine.
1594	LAB 004	20	4.26	1.55	Pegmatite from pit east of Crane Park.
1596	LAB 005	30	6.93	7.16	Mylonitized trachyandesite dike along thrust fault northeast of Big Red Park.
1607	LAB 009	70	5.30	10.78	Pegmatite with green ferrous mineral from gully on southwest shoulder of Farwell Mountain.
1608	LAB 010	70	3.26	3.76	Pegmatite with red ferric mineral from gully on southwest shoulder of Farwell Mountain.
1817	LBH 993	20	17.15	6.33	Baked shale inclusion in City Mountain Tertiary intrusive.

products like autunite, uranophane, gummite, and a suite of unidentified yellow-orange efflorescent incrustations commonly labeled as uranium and radium sulfates. Uraniferous spring waters and peat have been described west of Lake John in northwestern North Park (Malan, 1957, p. 129–133). The association of radioactivity with iron enrichment, alteration, or staining, noted in the preceding paragraph, has also been noted in the vicinity by others (E. P. Beroni, written commun., August 1950; Beroni and Derzay, 1955; Grutt and Whalen, 1955, p. 128), but not all iron-rich areas are radioactive. The Ace High No. 1 claim or Upper Slavonia mine is characterized by numerous iron-rich zones in Precambrian gneiss. These were extensively examined by J. W. Adams (written commun., July 31, 1951) both underground and on the surface, and no significant radioactivity was detected.

The present study shows that anomalously high uranium and thorium are preferentially associated with several varieties of Precambrian rocks or structures and less commonly with Mesozoic or Tertiary rocks. Precambrian pegmatites or plutonic granites seem to be more favorable than mafic intrusives or the metasedimentary and metavolcanic rocks. Among the plutonic granites, those of 1.4-b.y. age contain more uranium and thorium localities than those of 1.7-b.y. age, but the 1.7-b.y. granite contains one notable concentration.

Pegmatites of various ages have been the source of the richest deposits of both uranium and thorium in the northern Park Range, but the volumes of all known deposits are small and uneconomic. A few large specimens of uraninite or euxenite are reported to have been collected from a mica-beryl pit in pegmatite at the E. C. Ellis property in Mica Basin (pl. 2). One such specimen approximately 7 inches in diameter and weighing 26 pounds assayed 86 percent U (E. P. Beroni and F. A. McKeown, written commun., September 1960). A less unusual sample of radioactive biotite from the Mount Zirkel area was reported to contain 0.1 percent (1,000 ppm) uranium (Beroni and McKeown, 1952, p. 39). The Mica Basin pegmatites contain book muscovite and beryl as well as uraninite (Adams, 1964, p. 171). Besides containing greater than 20 percent rare earths and yttrium, the Fielder prospect in pegmatite near Agua Fria Lake (pl. 2) also contains as much as 1.5 percent (15,000 ppm) Th and 0.7 percent (7,000 ppm) U (table 9 with rare earth prospect description follows). E. R. Mabes (written commun., September 14, 1950) reported 0.3–0.7 percent (3,000–7,000 ppm) U in samples described as pegmatite from the Fair-U claims area in North Fork Fish Creek (eastern locality below south edge of area of fig. 79). Beroni and McKeown (1952, p. 24–30) reported uranium analyses of nine samples from this area (0.002–0.054 percent U) (20–540 ppm) and constructed an isoradioactivity map (Beroni and McKeown, 1952, fig. 5) of the Fair-U claims area, showing "pod-shaped radioactive zones 1 to 20 feet in length—highest along the gradational contacts between the granitic rocks and the schist" (Beroni and McKeown, 1952, p. 27). They reported that "the deposits are not now of commercial interest" (Beroni and McKeown, 1952, p. 30). Beroni and Derzay (1955) later reported that selected samples from the Fish Creek district contained as much as 0.3 percent (3,000 ppm) U. In the present study (table 8), pegmatites on Farwell Mountain (samples 1565, 1566, 1573, 1574, 1607, 1608), along Middle Fork Little Snake River (sample 1594) and along Soda Creek (sample 89) contain as much as 19 ppm Th and 12 ppm U. Pegmatite muscovite from the Farwell mine has a reported K-Ar age of 1.7 b.y. (Segerstrom and Young, 1972, p. 17), but the pegmatite at Agua Fria Lake that cuts rocks of the 1.4-b.y. Mount Ethel pluton, though not dated directly, must be 1.4 b.y. or younger in age.

The 1.4-b.y. granitic rocks have supplied many uraniferous stream sediments and several anomalous outcrops. Most important of these are the Pedad and James Bird claims and Crystal mine, where as much as 3,400 ppm U (Malan, 1957, p. 126) and 34 ppm Th (pl. 3, sample 607) are known. However, within the 1.4-b.y. Mount Ethel pluton, these deposits are associated with much younger (Tertiary?) fault breccias and associated fluorite veins that crisscross the northeastern part of the pluton. Sample 607 was one of four samples collected by Snyder from the Pedad claim area. One was a red breccia, one, a yellow breccia (607); one, a white breccia; and one a fluorite vein. Only the yellow breccia (607) contained anomalous niobium, and, therefore, it was the only one of Snyder's samples from this area analyzed for uranium and thorium. The Agua Fria Lake rare earth prospect is within the Mount Ethel pluton also, as is stream-sediment sample 203, over the ridge from Agua Fria Lake. The uraniferous spring waters and peat west of Lake John (Malan, 1957, p. 129–133) must be derived from waters passing through Mount Ethel rocks. A large assemblage of anomalous stream sediments and rocks is present in the southwestern part of the Mount Ethel pluton (fig. 79). These samples contain as much as 146 ppm Th and 34 ppm U and include sediment samples 42, 43, 47, 50, 52, 53, 57, 71, 84, and 89 and rock samples 263C and 322. In addition, three rock samples are from possible 1.4-b.y. dikes outside the Mount Ethel pluton: sample 845 on Bear Ridge, and samples 1404 and 1596 from two localities in a single porphyry dike northeast of Big Red Park.

Although covering a much greater area, the remaining Precambrian rocks have given rise to a proportionately smaller number of anomalous samples. One notable anomalous area in the vicinity of Seven Lakes coincides with a beryllium high in 1.7-b.y. granite (fig. 97). There, stream sediments 266, 288, 289, 293, and 682 have as much as 22 ppm Th and 19 ppm U. A few other scattered samples are also related to 1.7-b.y. granite (688, 698, 736, 1130, 1385) or metasedimentary or metavolcanic rocks (20, 23, 58, 89, 250, 411, 793, 902, 1180). Three of the latter (89, 250, 411) are related to Precambrian faults in the Soda Creek–Fish Creek mylonite zone. Beroni and McKeown (1952, p. 40) listed 20 ppm U from "granite taken from road cut, north of Steamboat Springs, Colo.," but with exact locality or type of granite otherwise unidentified.

As much as 53 ppm Th and 14 ppm U in this study can be related to Mesozoic or Tertiary rocks. Malan (1957, p. 135, 136) reported uranium mineralization associated with Dakota Sandstone south of Rabbit Ears Pass. The only evidence of similar mineralization in this area might come from stream sediments 26, 194, and 788. Other anomalous sediments from streams draining Mesozoic rocks are samples 6, 32, and 33. Beroni and McKeown (1952, p. 39) reported 20 ppm uranium from Mancos Shale northwest of Hahns Peak. Analyzed rock sample 1817 is of a shale inclusion, presumably Mancos, in the Tertiary City Mountain intrusive northwest of Hahns Peak. McConnell (1960, p. 64) reported two small uranium prospects in Mesozoic rocks on the northeast side of Hinman Park. Grutt and Whalen (1955, p. 128) regarded the Miocene Browns Park Formation as the most favorable formation to prospect for uranium, but the only known prospect in the Browns Park Formation in this vicinity is east of the northeast corner of the area of figure 79 (U.S. Geological Survey and Colorado Geological Survey, 1977). S. J. Luft (oral commun., 1980) reported that, although generally a favorable horizon for uranium deposits, the Browns Park Formation in the vicinity of the northern Park Range is here considered unfavorable for uranium deposits. However, there are four anomalous sediments from streams draining the Browns Park Formation: three in Strawberry Park (45, 46, 47) and one in Lester Creek (1057). In addition, Beroni and McKeown (1952, p. 38, 40) reported 30 ppm U from a post-Browns Park intrusive at Hahns Peak, and 20 ppm U from post-Browns Park tufa at Steamboat Springs.

RARE EARTH PROSPECT

Rare earth elements are concentrated in a few cubic meters of a pegmatite at the Fielder prospect near Agua Fria Lake. Samples from this locality have been analyzed both by the U.S. Geological Survey (J. W. Adams, written communs., March 13, 1966 and February 13, 1974) and the Bureau of Mines (see discussion on p. 65, 72; table 1). Although the volume of the known deposit is miniscule, its unique chemistry (>10 percent rare earths) and mineralogy are interesting. Adams reported (table 9) the following six-step spectrographic analysis of the ore (results reported in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15, and 0.1, ...) (Field No. JA-66-1, Lab. No. D121579).

TABLE 9.—*Analysis of Agua Fria Lake rare-earth ore, in percent*

[Bastnaesite, fergusonite, xenotime, and zircon were identified by Adams in methylene iodide-heavy magnetic and nonmagnetic mineral fractions of sample JA-66-1, apparently a first observation of this assemblage in Jackson County (Eckel, 1961; Vanderwilt, 1947)]

Si	>10	Ag	<0.0002	Cr	<0.0015	Hg	0	Pr	0.3	Te	0
Al	>10	As	0	Cu	<0.001	In	0	Pt	0	Th	1.5
Fe	5	Au	<0.005	Dy	1	La	1.5	Re	0	Tl	0
Mg	0.7	B	0.015	Er	1	Lu	0.15	Sb	0	Tm	0.2
Ca	1.5	Ba	0.1	Eu	0.02	Mo	0	Sc	<0.1	U	0.7
Na	5	Be	0.005	Ga	0.01	Nb	0.3	Sm	0.7	V	0.01
K	<1.5	Bi	0	Gd	0.3	Nd	1.5	Sn	0	W	0
Ti	0.1	Cd	<0.01	Ge	0	Ni	0	Sr	0.05	Y	>10
P	3	Ce	1.5	Hf	0.3	Pb	0.15	Ta	<0.02	Yb	1.5
Mn	0.7	Co	0.02	Ho	0.3	Pd	0	Tb	0.15	Zn	<0.1
										Zr	7

CHROMIUM, PLATINUM, AND RELATED ELEMENTS

Chromium, platinum, palladium, cobalt, and nickel are clearly associated in the study area; their distributions are illustrated on figures 88–94, respectively. These elements, and perhaps also some of the chalcophile elements and some vanadium, are concentrated in ultramafic rocks present in numerous small alpine-type bodies throughout the crystalline rocks of the northern Park Range. All are "anomalous" by the definition accepted for the other elements, but none are present in amounts exceptionally large for ultramafic rocks as a class; most of these elements are the products of normal igneous differentiation rather than late ore introduction. Economic platinoid concentrations are not found elsewhere in any alpine-type ultramafic intrusions (Stanton, 1972, p. 326).

CHROMIUM, COBALT, AND NICKEL

Chromium, cobalt, and nickel were analyzed routinely by the usual semiquantitative spectrographic methods in the samples submitted as potentially mineralized rock. The maximum rock chromium in these analyses was 3,000 ppm in the Troutman Draw malachitic hornblendite that also had the maximum platinum plus palladium. However, ultramafic rocks analyzed for platinum and palladium were also analyzed routinely by the same technique for chromium, and two of these showed 5,000 ppm Cr—a giant orthopyroxene crystal out of a Sawtooth Range peridotite and a dunite phase from the gabbro of Elkhorn Mountain. The maximum rock cobalt and nickel were both measured in the Bear Creek[7] peridotite, the largest single ultramafic body in the range. A northern extension of this body may be largely covered by rock glaciers, as streams issuing from beneath rock glaciers between Ute and Twin Lakes provided the highest measured stream-sediment cobalt and nickel. The highest sediment chromium, >5,000 ppm, came from a tributary of Silver City Creek south of Big Red Park that drains Mesozoic sedimentary rocks; the same sediment sample provided the highest Zr, an association possibly explained as an assemblage of heavy minerals. The correlation of chromite observed in thin section with analytically determined rock Cr_2O_3 is shown in table 10.

[7]This Bear Creek is north of Lone Pine Creek on the east side of the range, not the Bear Creek for which the previously mentioned Bear Creek district is named on the west side of the range north of Steamboat Springs.

TABLE 10.—*Association of measured chromite and* Cr_2O_3 *in ultramafic rocks*

[Do., same as entry preceding]

Sample No.	Rock type	Volume percent chromite (by point counting)	Weight percent Cr_2O_3	Analytical method
116	Dunite	0.25	0.19	Wet chemical.
1078	Chromite peridotite	2.1	.49	Colorimetric.
1194	Orthopyroxene crystal (with 5 percent magnetite).	0	.73	Spectrographic.
1410	Olivine gabbro	0	.048	Colorimetric.
1411	Olivine gabbro	0	.089	Do.
1412	Lherzolite	1.1	.36	Do.
1413	Olivine gabbro	0	.054	Do.
1428	Harzburgite	.34	.23	Do.
1472	Dunite	≈ 1	.73	Spectrographic.
1501-A	Norite	0	.042	Colorimetric.
1606	Anorthositic gabbro	0	<0.029	Do.
1685	Gabbro	0	.051	Do.
1765	Gabbro	0	.02	Do.
1781	Diorite phase of gabbro of Elkhorn Mountain.	0	<0.02	Do.
1927	Pargasite peridotite	0	.08	Do.
1985	Basalt dike in gabbro	0	.03	Do.

PLATINUM AND PALLADIUM

Platinum and palladium are present in minute quantities in some mafic and ultramafic Precambrian rocks, generally of small volume, in the northern Park Range, but no convincing evidence exists of a significant economic resource near the ground surface. Both maximum total platinum plus palladium and average total platinum plus palladium are at least two orders of magnitude less at all northern Park Range localities than at the New Rambler mine, Medicine Bow Mountains, Wyo. (Theobald and Thompson, 1968), where the volume of mineralized rock is large and where there are also significant values of copper, gold, silver, and arsenic. The most interesting body for further prospecting, the 2.7-km-long (1.7-mi-long) pargasite peridotite between Lone Pine Creek and Bear Creek on the east side of the range (pl. 1), contains an observed maximum of 0.05 ppm Pt plus Pd.

Ninety-seven samples from 33 localities of mafic and ultramafic rock were searched for platinum, palladium, and rhodium (analyzed for as in Talanta, 1968, v. 15, p. 111–117); of these, 35 samples (includes some duplicates) from 14 localities contained measurable platinum and (or) palladium (none contained measurable rhodium, reported as <0.005 ppm Rh in all samples). The measurable platinum and palladium are listed here in table 11 and figure 90. The average *measured* platinum plus palladium from the 14 localities is 0.02 ppm, but half of the localities also contained one or more samples without measurable platinum or palladium, and these are not entered into the averages. The maximum, 0.09 ppm Pt plus Pd, is from a single prospected outcrop of malachitic hornblendite at the Troutman locality near the road southeast of Pearl. This compares with a maximum of 10 ppm Pt plus Pd and an average of 1 ppm Pt plus Pd at the New Rambler mine (Theobald and Thompson, 1968) and a maximum of 0.28 ppm Pt plus Pd and an average of 0.04 ppm Pt plus Pd from mafic amphibolites of the Sierra Madre of Wyoming (Houston and others, 1955). Only one sample, of several analyzed, from the normal gabbro of Elkhorn Mountain contained a measurable trace of Pd, that from the Whiskey locality (table 11). This compares with a trace of Pt and 0.010 ppm Pd measured in a typical norite from the gabbro body near Lake Owen, Wyo. (Theobald and Thompson, 1968).

Of the known platinum-palladium localities, most are either too small in volume or too lean in grade to be worth further prospecting. Most of the ultramafic bodies sampled are single outcrops or small areas measured in feet or tens of feet. A few of the larger bodies have dimensions in thousands of feet and several of these, especially the Bear Creek locality, may reward more detailed prospecting efforts. Except for the Troutman locality with 10,000 ppm Cu, most have a maximum of 300 ppm Cu, and nothing else known to be of economic interest.

TABLE 11.—*Measured platinum and palladium in mafic and ultramafic Precambrian rocks of the northern Park Range*

[Tr., trace; Do., entry same as preceding]

Figure 90 locality	Field No.	Lab. No.	Pt (ppm)	Pd (ppm)	Remarks
Whiskey ---	1685	D160907	<0.010	Tr.	Gabbro of Elkhorn Mountain.
Olivine ----	1412	D160884	<0.010	0.007	Coronitic lherzolite with chromite (0.36 percent Cr_2O_3).
	1441	D160895	.021	.010	Foliated peridotite.
	1472	D160899	<.010	.024	Coronitic peridotite.
Damfino ---	1049	D154837	<0.010	.006	Amphibole peridotite with spinel.
	1050	D154838	Tr.	.011	Serpentinite.
Buffalo ----	1041	D154836	<0.010	.008	Carbonatite or marble associated with hornblendite.
Troutman	910	D154833	0.060	.026	Actinolite-chlorite-magnetite-malachite rock.
	910	D160878	.028	.022	Do.
Sawtooth	1193	D154851	0.016	.010	Tremolite-chlorite matrix of sample 1194.
	1193	D160881	.020	.011	Do.
	1194	D160882	.012	.004	10 cm (4 in.) hypersthene crystal.
Gilpin -----	1202	D154852	<0.010	.004	Hornblende-hypersthene-spinel peridotite.
Big Agnes	1112	D103055	<0.010	.007	Talc-biotite-tremolite-anthophyllite-chlorite rock.
Wapiti ----	116F	D141158	0.014	.014	Fresh dunite.
	116W	D141159	.017	.017	Weathered dunite.
	117	D141160	.012	.014	Fresh dunite.
	1116	D103056	.014	.015	Do.
	1116	D160880	.013	.012	Do.
	1117	D154842	Tr.	.006	Dunite soil.
	1118	D154843	.015	.008	Do.
	1119	D154844	.011	.005	Do.
	1120	D154845	Tr.	.007	Do.
	1121	D154846	.012	.009	Do.
South Fork	74	D154815	<0.010	.006	Hornblendite.
	75	D154816	.013	.019	Do.
Three Island	1070	D103047	<0.010	.004	Pargasite peridotite.

TABLE 11.—*Measured platinum and palladium in mafic and ultramafic Precambrian rocks of the northern Park Range*—Continued

Figure 90 locality	Field No.	Lab. No.	Pt (ppm)	Pd (ppm)	Remarks
Bear Creek	752	D154832	0.037	.011	Poikilitic pargasite peridotite.
	1016	D154834	.031	.008	Pargasite-chlorite-magnetite rock.
	1017	D103036	.018	<0.004	Pargasite serpentinite.
	1018	D103037	.024	.012	Poikilitic pargasite peridotite.
	1018	D160879	.017	.010	Do.
Boettcher	672	D154825	<0.010	.009	Actinolite-talc rock.
Spring -----	273	D154817	<0.010	.006	Peridotite with chromite.
	1078	D103050	<0.010	.004	Peridotite with chromite (0.49 percent Cr_2O_3).

The Bear Creek locality consists of a long, linear intrusive that crosses a rugged mountain ridge (mapped on pl. 1). The body is 2.7 km (1.7 mi) long and as much as 430 m (1,400 ft) wide; it is exposed over a vertical distance of 440 m (1,450 ft), and it probably projects yet another 170 m (550 ft) deeper than this under the center of the mass (Snyder, 1977a, 1980a, section *E–E'*). Where freshest, as on the north side of the ridge between Bear Creek and Lone Pine Creek, the exposed rock has a curious poikilitic structure with olivine phenocrysts set between pargasite oikocrysts containing clinopyroxene chadacrysts. Elsewhere, the olivine and clinopyroxene are extensively altered to chlorite, magnetite, and serpentine. The peridotite at the Bear Creek locality is completely within the present boundary of the Mount Zirkel Wilderness.

Some peridotites within the mapped olivine gabbro phase of the gabbro of Elkhorn Mountain contain as much as 0.03 ppm Pt plus Pd. (See the Olivine locality, table 11.) The peridotites are believed to be a volumetrically minor part of the olivine gabbro mass, but the mass is well exposed only on peak 9,731 along the Continental Divide; most of the olivine gabbro is covered by humic tundra soil supporting dense grasslands or forests that could hide more extensive ultramafic rocks. If so, the volume of the olivine gabbro, more than a cubic mile (Snyder, 1977a, 1980a, section *A–A'*), might mean that peridotites could increase with depth. Peak 9,731 may be reached via a jeep road along the Continental Divide that branches off the old Ellis Trail. The olivine gabbro is well outside the present Mount Zirkel Wilderness boundary but within the adjacent area.

Another ultramafic rock of barely conceivable economic interest lies astride the Mount Zirkel Wilderness boundary on the ridge southwest of Three Island Lake (the Three Island locality of table 11 and fig. 90).

Here an irregular pargasite peridotite with minor malachite occupies a body as much as 1.45 km (0.9 mi) long by 0.9 km (0.6 mi) wide. This rock contains as much as 700 ppm Cu and 0.004 ppm Pd, not in itself of much economic interest. However, nearby marble (sample 1069, pl. 2) contains 15 ppm Ag, 1,000 ppm Cu, 3,000 ppm Pb, and 1,000 ppm Zn. The marble, unprospected except for this sample, is presumed to be in contact with the peridotite under a covered zone, but nothing is known about the contact.

OTHER ELEMENTS

The other elements whose highlights of distribution are summarized here are the "majors," iron, magnesium, calcium, titanium, and manganese, and the other analyzed "minors," boron, barium (fig. 95), beryllium (figs. 96, 97), scandium (figs. 98, 99), strontium (figs. 100, 101), vanadium (figs. 102, 103), and zirconium (fig. 104). None of these elements occurs in amounts or combinations even approaching economic deposits, but some have been or could be useful guides to other metal concentrations.

The major elements—iron, magnesium, calcium, titanium, and manganese—show some definite associations. Almost all rock analyses that show maxima of 20 percent or greater Fe (12 samples) are from rocks with introduced pyrite or containing hematite-limonite gossan, many from the Gilpin mines or Upper Slavonia. All rock analyses that show maxima of 10 percent Mg (24 samples) are from mafic, ultramafic, or calc-silicate rocks, some mineralized. All rock analyses that show maxima of 20 percent or more Ca (35 samples) are from introduced or original carbonate or fluorspar rocks. Rock maxima of greater than 1 percent Ti are from two samples of sheared or veined granite at the Elkhorn mine; eight rock samples with 1 percent Ti are epidotized rock or porphyry dikes. Excluding monomineralic rocks, the Mn rock maxima of greater than 5,000 ppm (35 samples) occur in garnetiferous rocks or ores, particularly ores from the Pearl district, or the Upper Slavonia or Greenville mines. The stream-sediment analyses show the following maxima: 20 percent Fe (1 sample) and 15 percent Fe (47 samples); 7 percent Mg (5 samples); 10 percent Ca (3 samples); >1 percent Ti (37 samples); >5,000 ppm Mn (2 samples) and 5,000 ppm Mn (6 samples). Excluding the few panned heavies or visible magnetite stream concentrates, the highest iron, magnesium, and titanium favor the streams draining the *northern part* of the gabbro of Elkhorn Mountain or the quartz monzonite north of this, whereas the highest Ca and Mn are apparently scattered without discernible areal preference.

Boron has different rock and stream-sediment affinities, unlike other elements that show similar affinities for both rock and stream-sediment samples. The rock highs of 30 to 100 ppm B (15 samples) occur in chloritized or mylonitized rock near the north side of the Soda Creek–Fish Creek mylonite zone, in mineralized rock (commonly quartz veined) from the Bear Creek district, near the Elkhorn mine, and on the Master Key mine dump (near Columbine), or from weathered or serpentinized peridotite either in the Bear Creek ultramafic body or within the olivine gabbro phase of the gabbro of Elkhorn Mountain. The anomalous stream sediments show values of 30 ppm B (65 samples), 50 ppm B (34 samples), 70 ppm B (6 samples), and 100 ppm B (6 samples); and the data furnish one of the best geologic correlations in the area: 84 percent of the values 30 ppm or greater, 89 percent of those 50 ppm or greater, and 92 percent of those 70 ppm or greater drain areas of Mesozoic rocks, mainly shales. Apparently the boron attached to sedimentary clays is mobile enough to be a good indicator of Mesozoic sedimentary rocks updrainage. Several alluvial basins with Precambrian rocks on one side and Mesozoic rocks on the other infallibly show more boron in the sediment of the tributaries from the Mesozoic rocks.

The distribution highlights of the remaining minor elements are summarized in tables 5 and 6 and following. Eight samples showing high rock barium (5,000 ppm or greater) are from various potentially mineralized rocks in the northeast quarter of the mapped area. The stream-sediment barium maximum of 1,500 ppm (24 samples) is partly scattered without discernible pattern, partly clustered (9 samples) in the Beaver Lake–Three Island Lake–Gold Creek area; the latter cluster may be related to a crosscutting porphyry dike swarm in this area; other Ba sediment samples may be related to Elkhead Tertiary intrusives updrainage or the hot spring effluents near Steamboat Springs. The beryllium concentration in all stream sediments derived from the Seven Lakes area (fig. 97) is truly remarkable, especially in view of the fact that no bedrock minerals or anomalous rock samples have been identified as the source of the anomaly. Possibly beryllium, known to be concentrated in the residual phases of magmatic sequences (Goldschmidt, 1954, p. 206), is here concentrated in beryl or another late magmatic mineral near the central, last-crystallizing part of the complex pluton of the quartz monzonite of Seven Lakes, but in amounts too tiny for it to be recognized yet in thin sections of the rocks of this area. Later erosion set loose subtle alluvial concentration processes that permitted the anomaly to be discovered. A pronounced sediment beryllium *low* is associated with the gabbro of Elkhorn Mountain. Scandium, strontium, and vanadium are all concentrated in epidotitic rocks of the Mount Zirkel area, and strontium sediments especially may show some association with shear zones. Scandium and vanadium sediment distribution patterns show some similarities to copper and nickel patterns, but some sediment vanadium also mirrors some sediment boron associations. Zirconium, though present in most, does not have a very wide spread of values in rocks; the rock maximum of 1,000 ppm occurs in a porphyry dike on Bear Ridge, and two other zirconium rock highs (of six with 500 ppm or greater) are from separate samples of another porphyry dike caught up along the Laramide thrust northeast of Big Red Park.

EVALUATION OF SURFACE NONMETALLIC RESOURCES

The principal nonmetallic resource of the northern Park Range is fluorspar, but other rock commodities have been mined sporadically or are potentially available. Energy resource potential and the "mineral," water, are also discussed.

FLUORSPAR

Veins of sometimes-economic fluorspar (defined as 30-percent CaF_2 in 1974; Wood, 1974, p. 570) are present just outside the east boundary of the Mount Zirkel Wilderness south of Red Canyon, and some of these veins are known to extend into the wilderness area. Others may be present well within the wilderness near the center or north margin of the Mount Ethel pluton, where microscopic and mapping evidence indicates an abundant supply of suitable 1.4-b.y. source rocks (fig. 105), but these areas have not been prospected in detail for fluorite. However, reconnaissance geologic mapping by Snyder throughout the area of the 1.4-b.y. Mount Ethel pluton from 1965 to 1967 showed significant vein fluorite only in the area just outside the east boundary of the wilderness south of Red Canyon, and on Delaney Butte, and it is believed that concentrated fluorite resources are slight at the ground surface within the present wilderness boundary (fig. 109).

Fluorspar has been mined sporadically from veins at Northgate on the north side of North Park since 1922; production has been erratic in periods of 1–9 years, some in each decade since mining began (Steven, 1960; Van Alstine, 1964; Brady, 1975; Shawe, 1976). During the last period of production, 1968–73, considerable interest was developed also in Park Range fluorite within trucking distance of the Northgate mill. The Crystal mine was reopened south of Red Canyon, and much prospecting was done on other adjacent properties and on Delaney Butte. However, only the Crystal mine produced ore for the Northgate mill before it closed in 1973 (Brady, 1975, p. 10; Smith, 1974, p. 158; Wood, 1974, p. 570).

The Park Range fluorspar occurs as mammillary or euhedral-crystal veins or fluorite-cemented fault breccias and contains silica, locally grading out into high-silica low-fluorite veins. The fluorite is purple, green, or white. The veins are poorly dated but, by analogy with Northgate, are probably mainly late or post Oligocene in age. All veins occur within 1.4-b.y. granite or thin Oligocene sediments overlying such granite. Granites in the Mount Ethel pluton preferentially contain interstitial fluorite (absent in most other Precambrian rocks in the northern Park Range), especially the quartz monzonite of Roxy Ann Lake (Snyder, 1978, table 7, figs. 17, 18, p. 26–33; fig. 17 is repeated herein as fig. 105). Most of this fluorite is magmatic and was deposited contemporaneously with the other Mount Ethel mineral grains, but some has been demonstrated to have been mobile in the Precambrian since its first deposition. More may have become mobile in the Tertiary (some nearby fluorite has been mobile in the Quaternary: Tweto and others, 1970, p. C69), becoming concentrated during redeposition in open veins or breccias near its inferred source of supply in the 1.4-b.y. Precambrian granites. If so, data like that presented in figure 105 will be a useful guide for further prospecting. (Such a conclusion is consistent with fluid inclusion studies at Northgate which indicated that the fluorite-depositing solution was predominantly meteoric water (Shawe, 1976, p. 58).)

Apparently, the geologic environment just cited is common, perhaps preferred, for Colorado fluorspar. Eleven (one-third) of the Colorado fluorite deposits compiled by Brady (1975) are associated with 1.4-b.y. intrusive plutons as mapped by Tweto (1976b). (Four are associated with the 1-b.y. Pikes Peak Granite, nine with younger sedimentary or volcanic cover, nine with all other Precambrian rock.)

Geologic associations other than those previously cited have also been cited for North American fluorspar deposits, including Crystal and Northgate. Van Alstine (1976) has noted that North American fluorspar districts are localized near continental rift zones (for this area, specifically, the Rio Grande graben and its northern projections), and he believed that large volumes of fluorine have leaked upward from the lower crust or mantle along and near these rifts. This interpretation has been disputed by Lamarre and Hodder (1978), who preferred to derive their fluorine by melting phlogopite during the production of alkalic magmas along the deepest parts of two imbricate subduction zones. Their model has fluorine carried in the alkalic magma as SiF_4, which reacts with crustal water to produce HF and SiO_2, and then with Ca^{+2} to precipitate CaF_2 and SiO_2 along surface tension fractures. Shawe (1979) has noted that the timing and composition of Tertiary magmas associated with fluorite deposition in the Western United States are different from that proposed by Lamarre and Hodder's model. Although Tertiary alkalic magmas are not associated at the surface with the northern Park Range fluorspar, fluorite is present in the nearby molybdenum-containing alkalic stocks at Climax and Urad-Henderson (Wallace and others, 1968). Furthermore, Popenoe and others (1970) have speculated that Tertiary plutons may have formed in north-central Colorado from the older 1.4-b.y. granites, and some Tertiary plutons could occur in the Park Range subsurface.

OTHER ROCK COMMODITIES

Included under this heading are mica, feldspar, cement rock, aggregate, riprap, and ornamental stone. Sheet mica (muscovite) has been quarried from several small pits in pegmatite in Mica Basin and on the south ridge of Big Agnes Mountain (fig. 20), and feldspar could be concentrated from some of the same deposits. However, the small size of the pegmatites and poor grade of these resources, coupled with the rugged topography and long distance from market, make it certain that this product will never be important in this area. Possibly some of the marble rock units and certainly the lower half of the Niobrara Formation are suitable for use as a source of cement rock within the confines of the adjacent area. However, the Niobrara Formation is present throughout Colorado and the main factor in its utilization as a cement-rock source is a high-volume market nearby. Other sources will always be more appropriate than the Niobrara within the adjacent area. (However, during 1977, wet cement was trucked daily from the Fort Collins area over two high mountain passes for use in the Hayden area.) At least four lithologies have been used in the area for sized aggregate for concrete construction or dirt-road top-dressing: Precambrian crystalline rock, Cretaceous shale, Tertiary porphyry, and alluvial gravels. One or another is readily available outside the adjacent area near any place it is likely to be needed. Precambrian bedrock or large erratic boulders in till have been used locally for riprap or ornamental stone. Again, the demand is unlikely to exceed the exterior supply.

COAL, OIL, AND GAS

Hydrocarbon resources have never been searched for within the Mount Zirkel Wilderness and adjacent area, and they are certainly not present anywhere near the present land surface. However, besides coal mines, there are paying oil fields in suitable trapping structures in Mesozoic rocks on both sides of the range (northwest of Delaney

Butte and west of Steamboat Springs) so the geological environment may be suitable. If the thrust fault nearly everywhere present on the west side of the range could be proven to dip shallowly eastward for several miles, this would mean that surface Precambrian rocks could overlie subsurface Mesozoic rocks, with the intervening thrust fault as a capping seal for any hydrocarbons trapped in underlying Mesozoic rocks. But neither oil nor gas has been found in the anticlines nearest this thrust, and there has been no incentive to attempt drilling through such a hypothetical crystalline caprock. Nor have hydrocarbons ever been discovered in seeps anywhere within the wilderness and adjacent area. For the present, then, it should be stated that it is not impossible (just unlikely) that some oil and gas could be trapped locally at great(?) depth below the western boundary of the adjacent area.

GEOTHERMAL RESOURCE APPRAISAL

No evidence of a significant geothermal resource was found anywhere within the bounds of the Mount Zirkel Wilderness or adjacent area, even though a well-known geothermal resource lies just outside this area. The external evidence of a possible geothermal resource consists of hot springs, travertine deposited by former hot springs, or recent volcanic deposits, such as lava flows or cinder cones. Hot springs and travertine deposits are present just outside of the adjacent area. One hot spring, Routt hot spring, is located in Hot Spring Creek near the end of the road north of Copper Ridge. A much larger group of hot springs is located along the Yampa River in the village of Steamboat Springs just southwest of the southwest corner of the area of plate 1. One spring supplies hot water to a local bathing pool, but the others are not utilized as a thermal source. There are three main areas of active springs, one with numerous small active areas, and five areas of mapped travertine deposits, some without modern spring activity. These hot springs and travertine deposits occur near the intersections of perpendicular normal faults (Snyder, 1977c, 1980c). Routt hot spring and the Steamboat Springs group are linked by a zone of epidote and chlorite alteration in the bedrock along Copper Ridge (Snyder, 1977b, 1980b) and this whole area, a north-south elongate zone about 16 by 5 km (10 by 3 mi) should, on present criteria (Godwin and others, 1971, p. 6), be considered as suitable for a detailed study of the potential utilization of geothermal energy (Price and Arnow, 1974, fig. 24, p. C36). Some limestone near the base of the Browns Park Formation in this area may also be hot-spring travertine (this report, p. 44; Snyder 1977b, 1980b). In the Routt hot spring–Steamboat Springs system, the springs have a maximum surface temperature of 66 °C, an estimated subsurface temperature of 129°–195 °C, a maximum discharge of 250 gallons per minute, and an estimated reservoir heat content of 0.2×10^{18} cal (Renner and others, 1975, p. 32, 33; Grim, 1977; U.S. Geological Survey and Colorado Geological Survey, 1977). Water collected from 11 springs in this system was found to contain 0.1 to 6.5 mg/L of lithium in 1950, the lowest amount from Routt hot spring. Another small area of travertine has been mapped on the north side of Delaney Butte (Hail, 1965, pl. 3), but, so far as is known, no other travertine deposits or any other active hot springs are within the area shown on plate 1. Nor are there any recent volcanic deposits or other evidence of magmatic activity recent enough to retain residual heat in the upper crust. The potential for any geothermal resource within the Mount Zirkel Wilderness or adjacent area appears to be minimal (fig. 109).

WATER

Liquid water is seldom thought of as a mineral resource, but the crystalline solid, snow, from which most Park Range water is derived, is more easily considered as such. The fact is that water may be the greatest mineral resource of the Mount Zirkel area, renewable at that! Because of the great distance to high terrain west and northwest of the range, these mountains, despite their lower crestal elevations than the Front Range to the east, receive a disproportionately larger share of the precipitation from storm systems migrating eastward from the Pacific than does the Front Range. Melting snow ensures abundant year-round runoff that is consumed by people, animals, and crops in numerous ways downstream from the Mount Zirkel Wilderness source areas.

This water is also a potential resource in another way that has never been utilized in the northern Park Range. If large retention dams were constructed in any of numerous suitable narrow mountain-front canyons (for example, on the Elk River east or west of Hinman Park, on the Encampment River near the Wyoming State line, or Red Canyon, Big Creek, or Mad Creek near their mouths), the resultant reservoirs could be the sources of hydroelectric power, as well as additional irrigation potential and sport and recreational activities. This recounting of the obvious should not be construed as a recommendation that retention dams be constructed, but simply as a reminder that the dams are feasible and, as such, are part of the total resource potential afforded by the Mount Zirkel area. Park Range water *is* a mineral resource; it *is* being used and reused all the way downstream now, and this will continue in the future. Whatever balance between economic and wilderness values is chosen for Mount Zirkel, its water resource will doubtless enter into this decision in many ways.

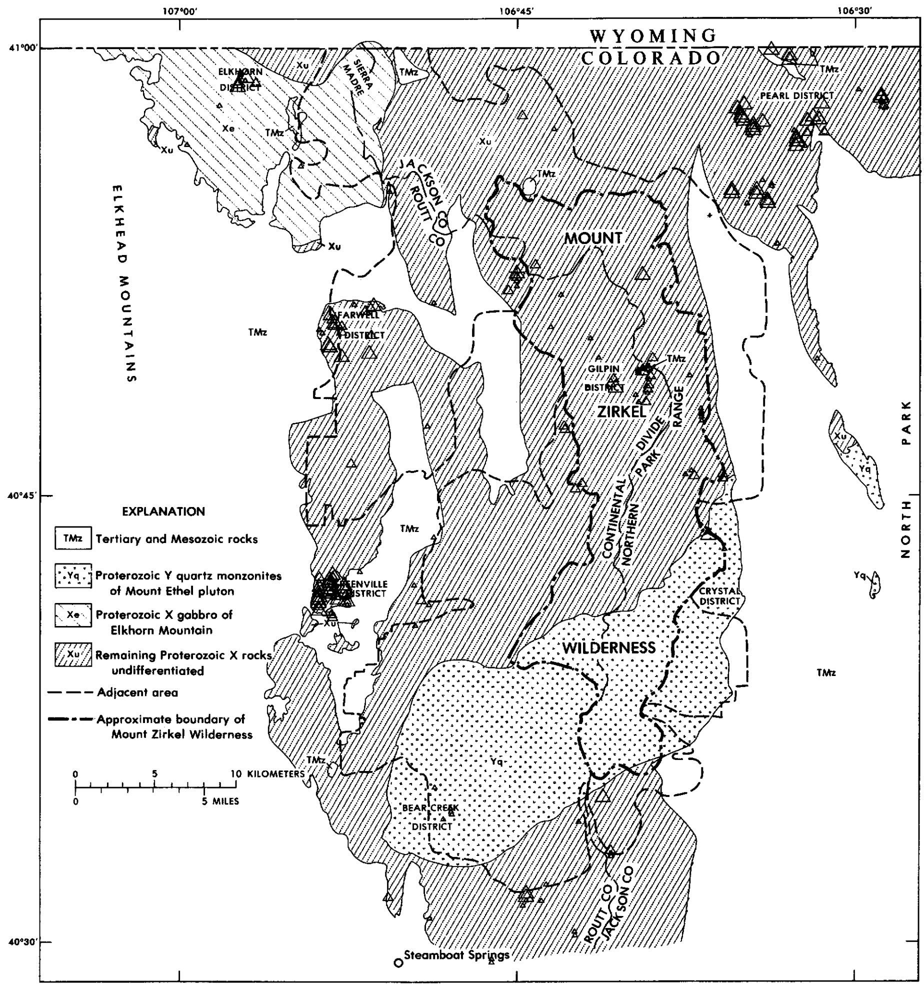


FIGURE 52.—Anomalous rock Spec Cu (spectrographic copper), Mount Zirkel area. Smallest symbol 50–300 ppm; intermediate 500–3,000 ppm; largest 5,000–20,000, >5,000, >20,000 ppm.

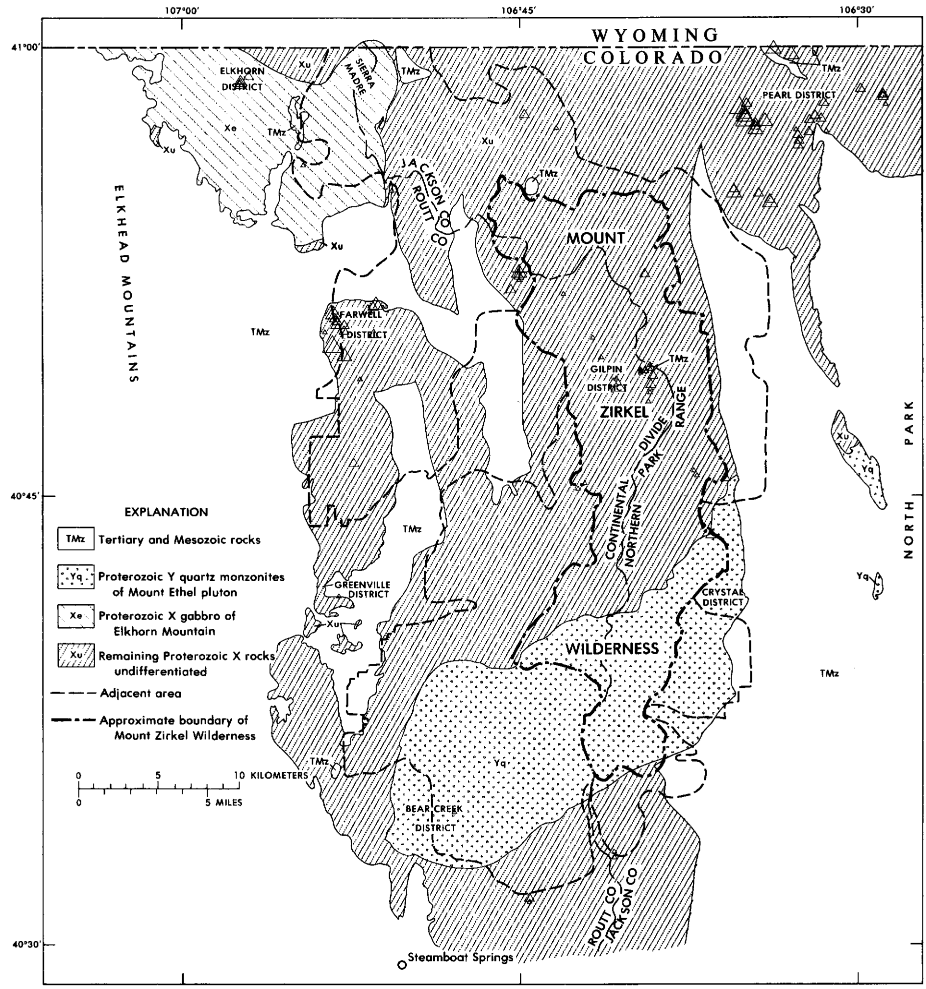


FIGURE 53.—Anomalous rock AA Cu (atomic absorption copper), Mount Zirkel area. Smallest symbol 280–2,100 ppm; next to smallest 2,500–15,000 ppm; next to largest 18,000–146,000 ppm; largest symbol 152,000–210,000 ppm.

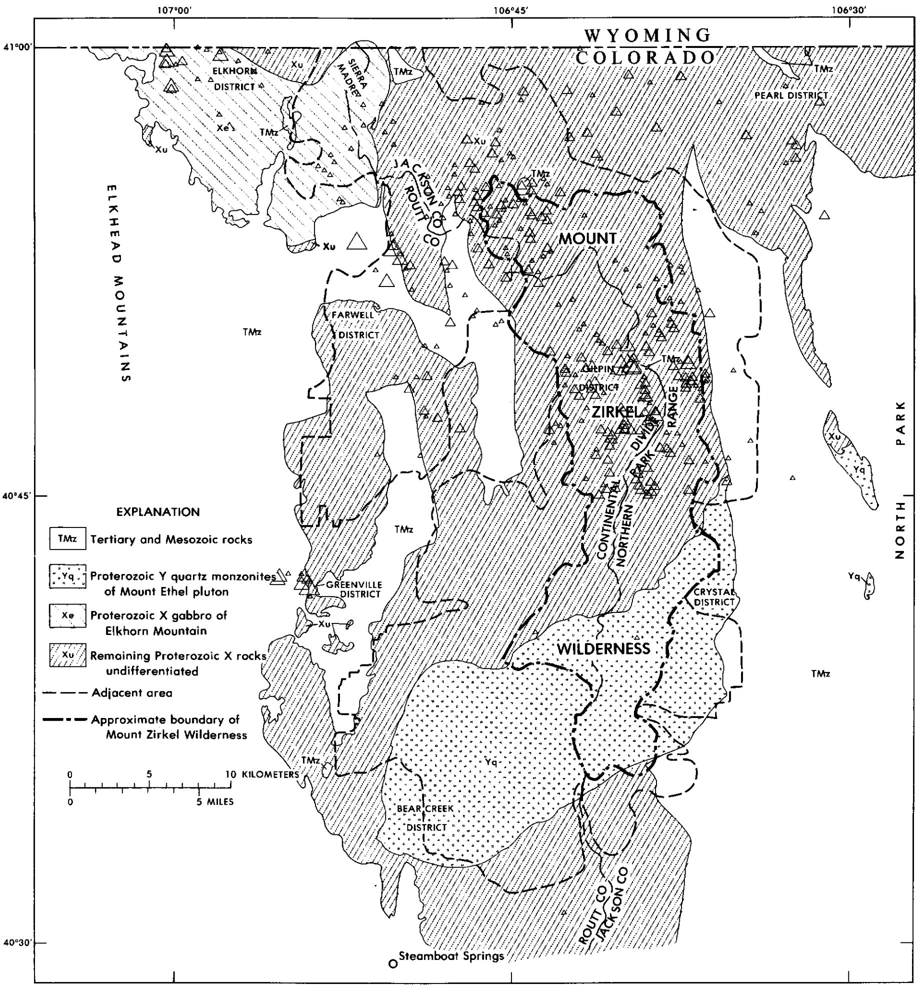


FIGURE 54.—Anomalous stream-sediment Spec Cu (spectrographic copper), Mount Zirkel area. Smallest symbol 50 ppm; next to smallest 70 ppm; next to largest 100–150 ppm; largest symbol 200–300 ppm.

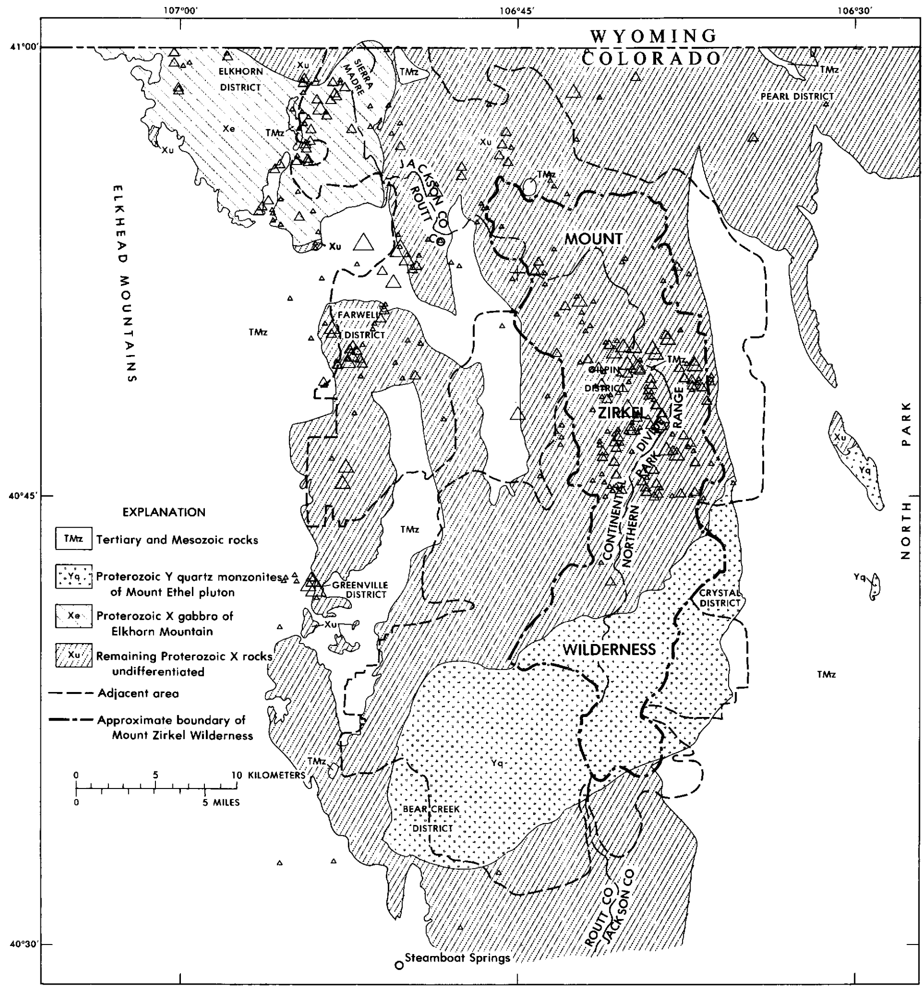


FIGURE 55.—Anomalous stream-sediment AA Cu (atomic absorption copper), Mount Zirkel area. Smallest symbol 30–35 ppm; next to smallest 40–55 ppm; next to largest 60–120 ppm; largest symbol 200–250 ppm.

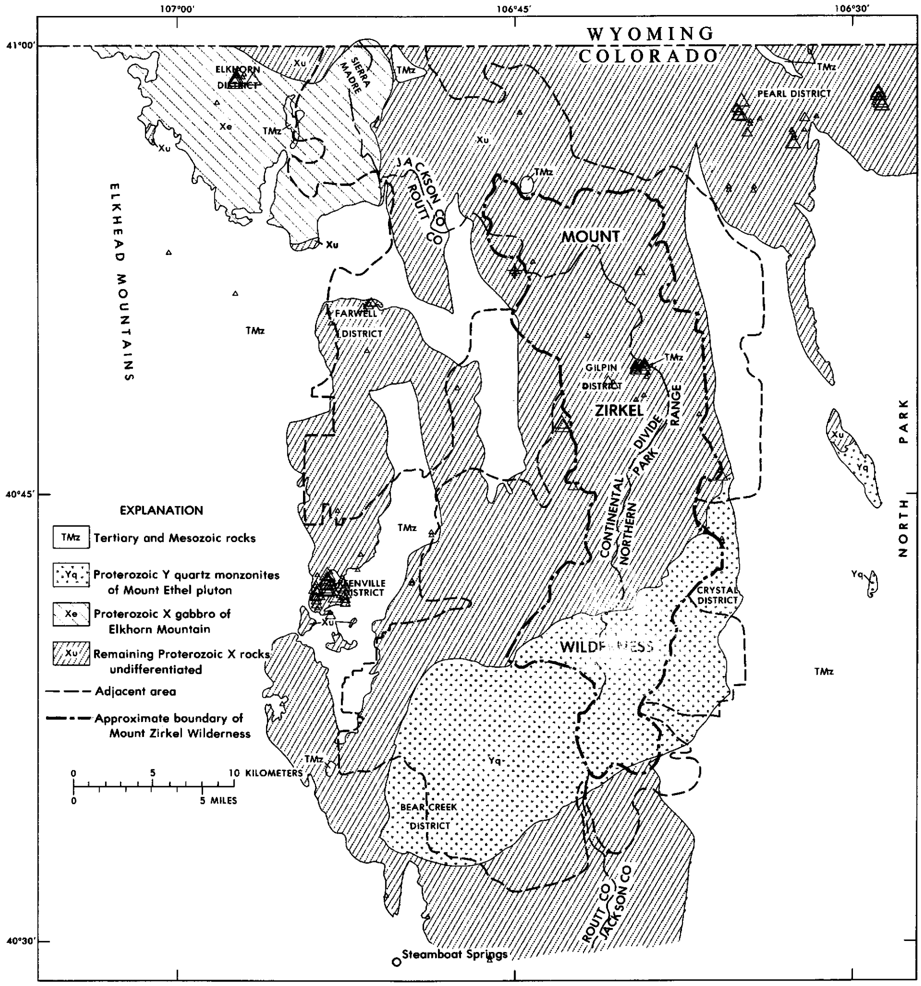


FIGURE 56.—Anomalous rock Spec Pb (spectrographic lead), Mount Zirkel area. Smallest symbol 50–300 ppm; intermediate 500–3,000 ppm; largest 5,000–15,000, >5,000, >20,000 ppm.

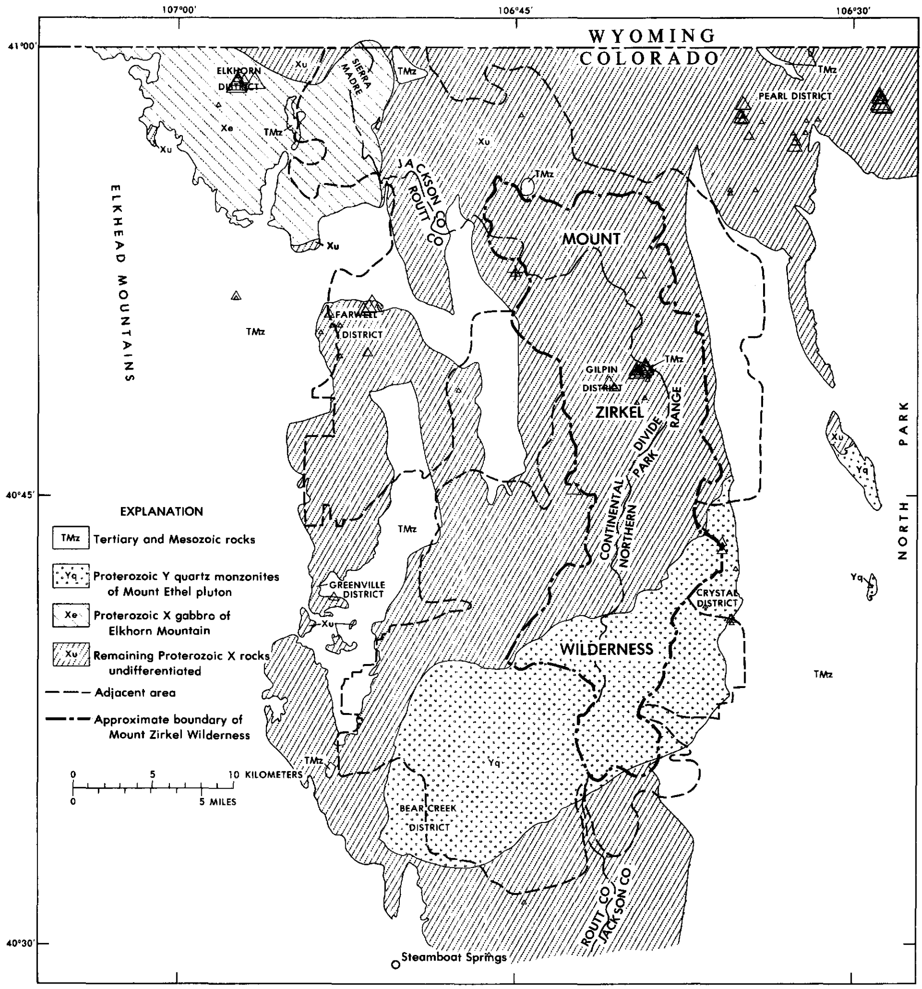


FIGURE 57.—Anomalous rock AA Pb (atomic absorption lead), Mount Zirkel area. Smallest symbol 30-120 ppm; next to smallest 130-1,000 ppm; next to largest 1,300-10,000 ppm; largest 14,000-68,000 ppm.

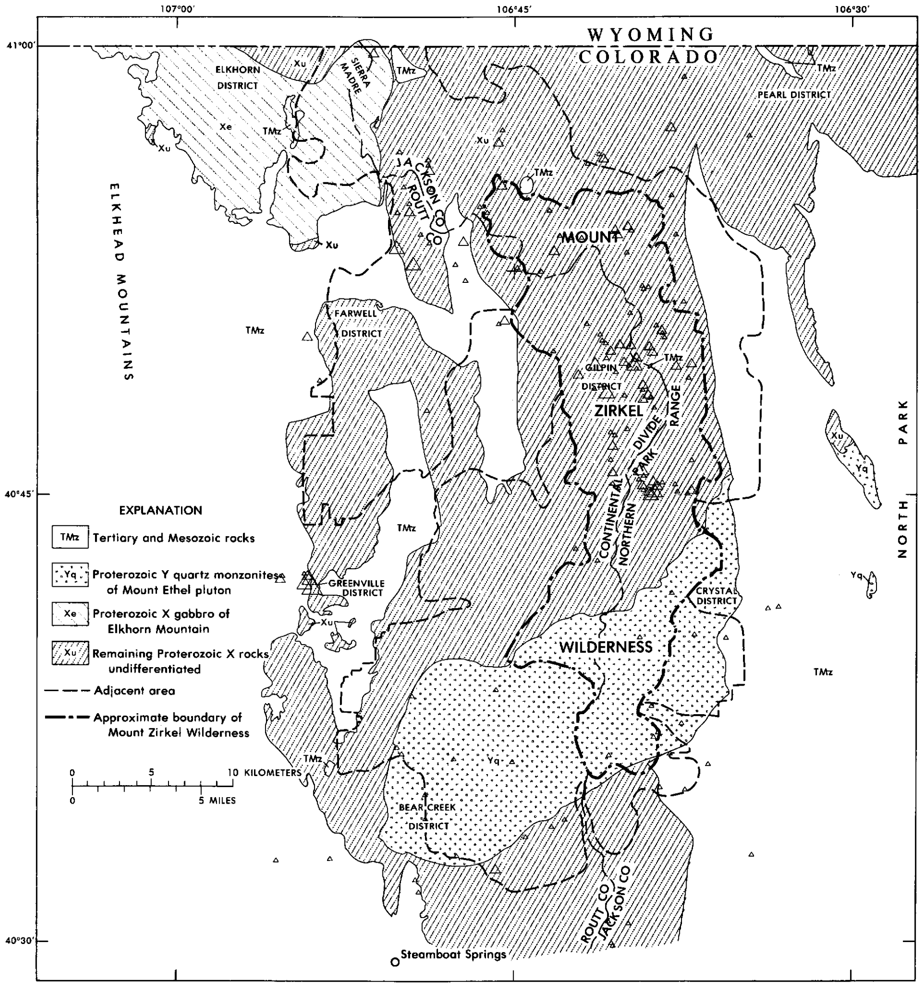


FIGURE 58.—Anomalous stream-sediment Spec Pb (spectrographic lead), Mount Zirkel area. Smallest symbol 50 ppm; next to smallest 70 ppm; next to largest 100–150 ppm; largest 700 ppm.

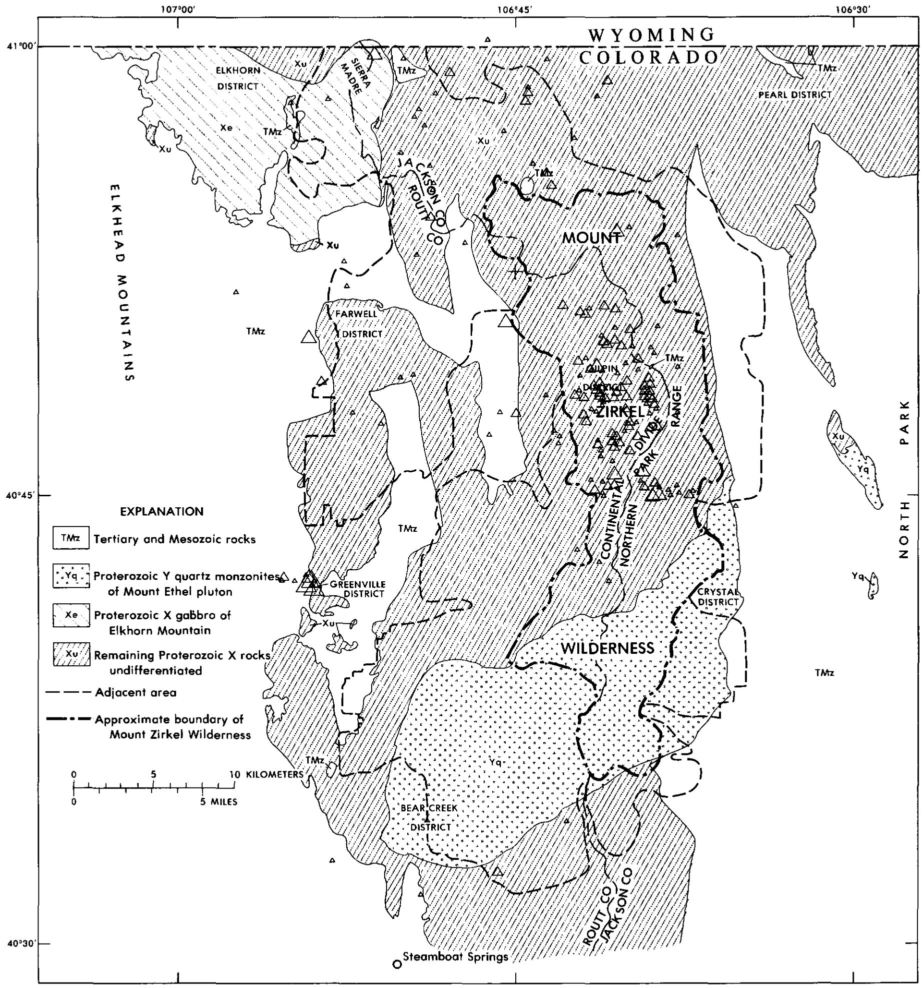


FIGURE 59.—Anomalous stream-sediment AA Pb (atomic absorption lead), Mount Zirkel area. Smallest symbol 30–35 ppm; next to smallest 40–55 ppm; next to largest 60–100 ppm; largest 130–570 ppm.

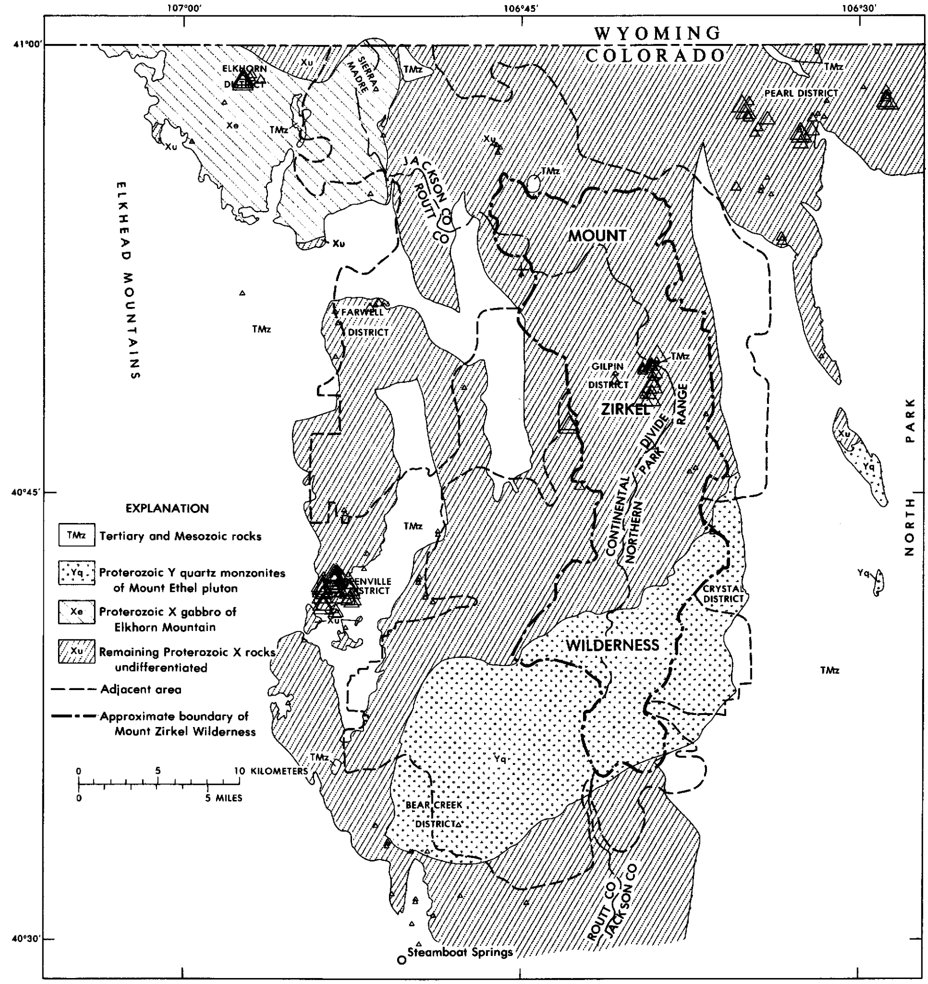


FIGURE 60.—Anomalous rock Spec Zn (spectrographic zinc), Mount Zirkel area. Smallest symbol <100, <200, 100–700 ppm; next to smallest 1,000–7,000 ppm; next to largest 10,000 ppm; largest >10,000 ppm.

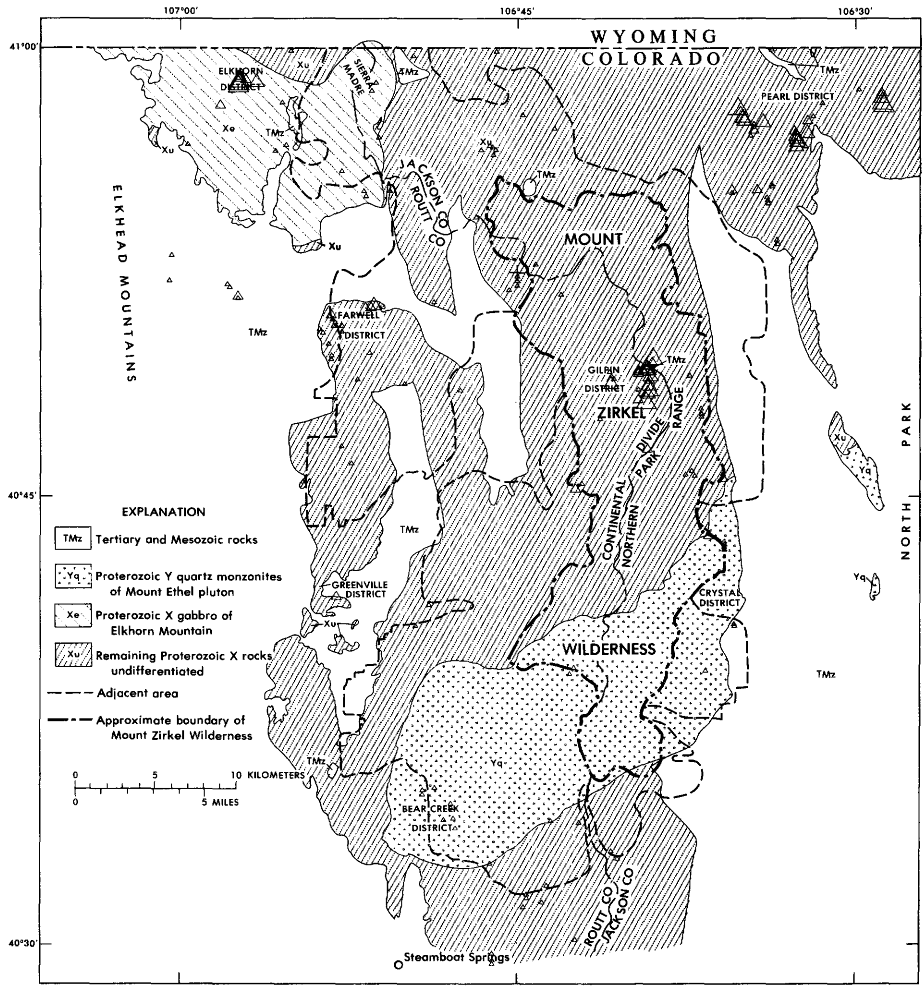


FIGURE 61.—Anomalous rock AA Zn (atomic absorption zinc), Mount Zirkel area. Smallest symbol 30-260 ppm; next to smallest 280-2,500 ppm; next to largest 2,900-25,000 ppm; largest 40,000-200,000 ppm.

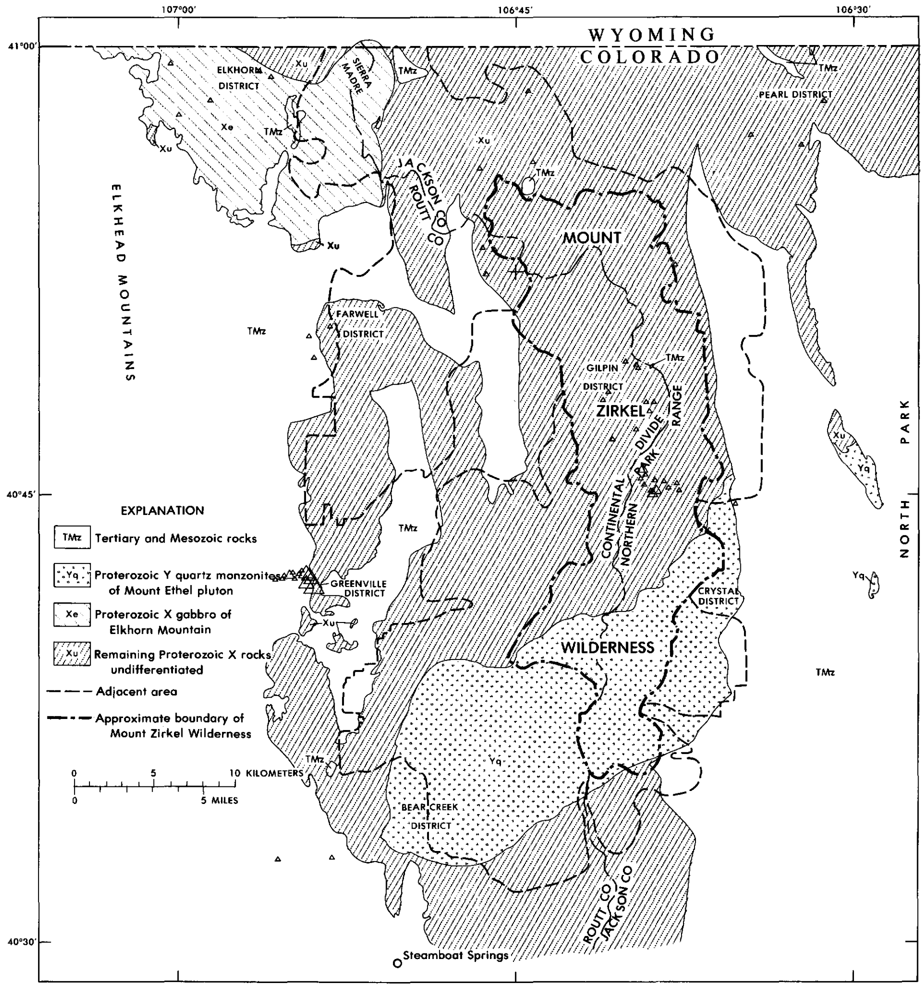


FIGURE 62.—Anomalous stream-sediment Spec Zn (spectrographic zinc), Mount Zirkel area. Smallest symbol <200, 200, 300 ppm; next to smallest 500–700 ppm; next to largest 1,000–1,500 ppm; largest symbol 2,000–3,000 ppm.

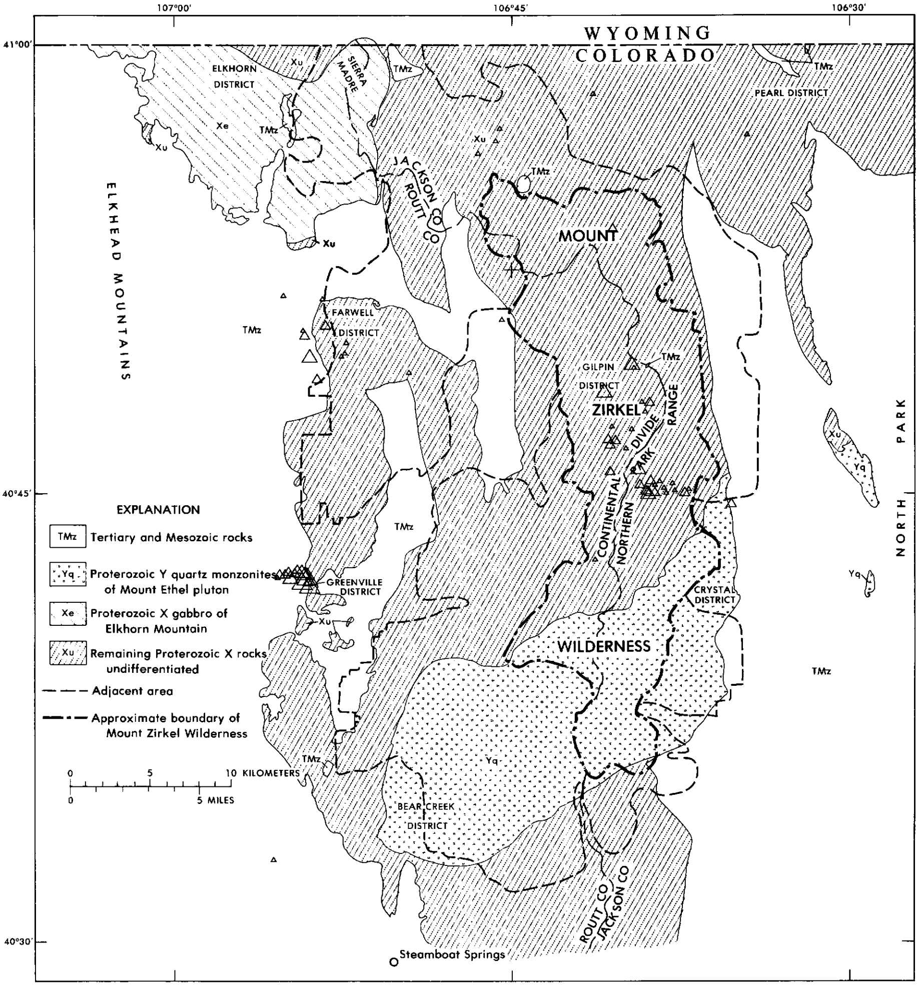


FIGURE 63.—Anomalous stream-sediment AA Zn (atomic absorption zinc), Mount Zirkel area. Smallest symbol 125–170 ppm; next to smallest 180–260 ppm; next to largest 270–480 ppm; largest 850–2,700 ppm.

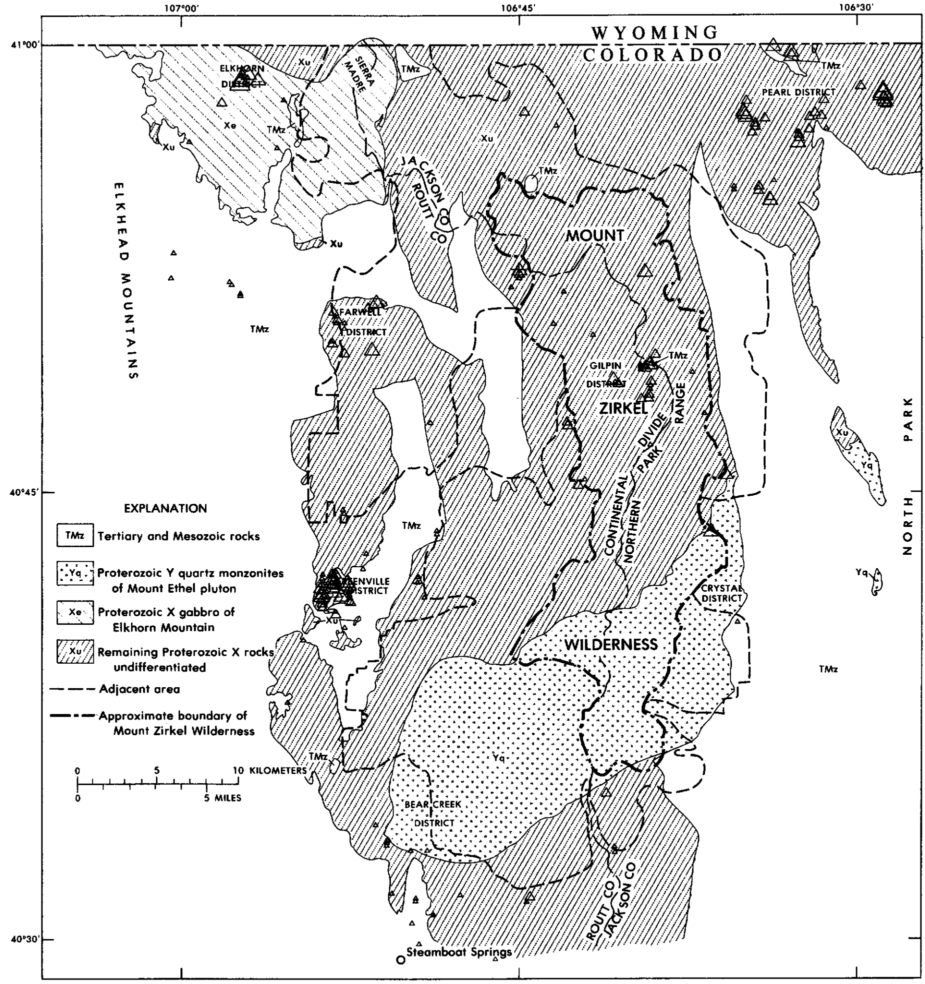


FIGURE 64.—Anomalous rock Spec Ag (spectrographic silver), Mount Zirkel area. Smallest symbol <0.5, 0.5–3 ppm; next to smallest 5–30 ppm; next to largest 50–300 ppm; largest 500–3,000 ppm.

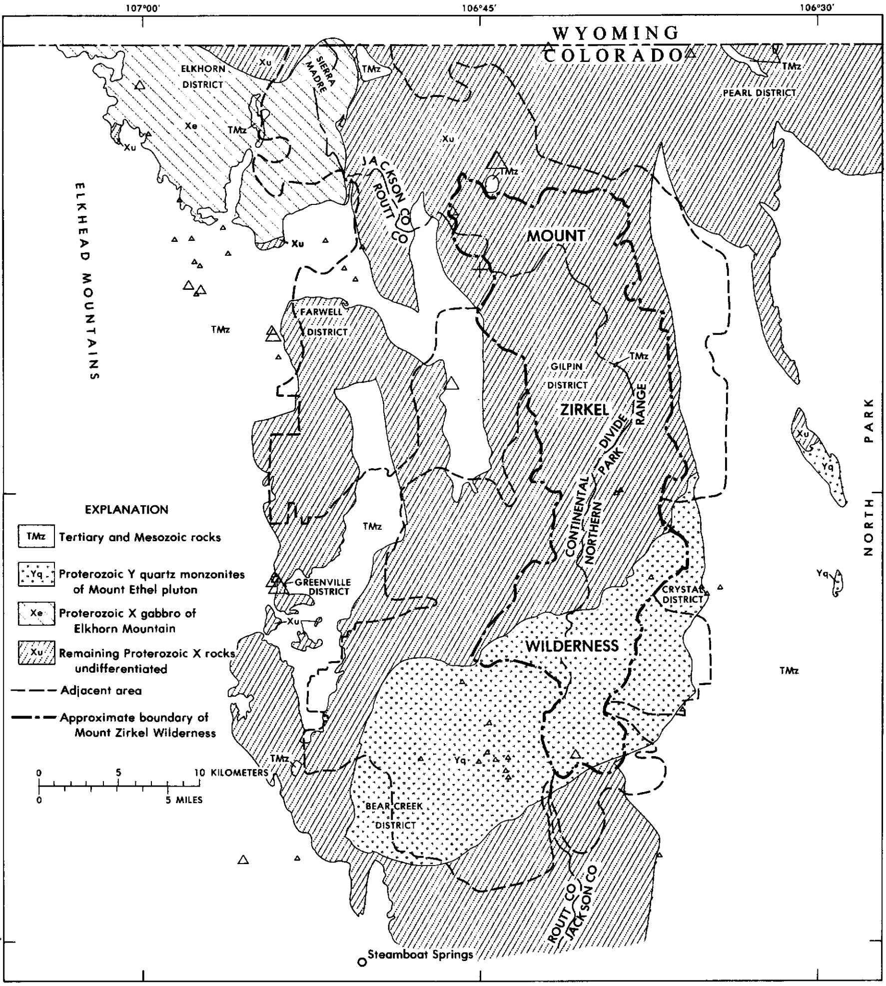


FIGURE 65.—Anomalous rock AA Ag (atomic absorption silver), Mount Zirkel area. Smallest symbol 0.5–0.7 ppm; next to smallest 7.5–54 ppm; next to largest 55–250 ppm; largest 500–2,600 ppm.

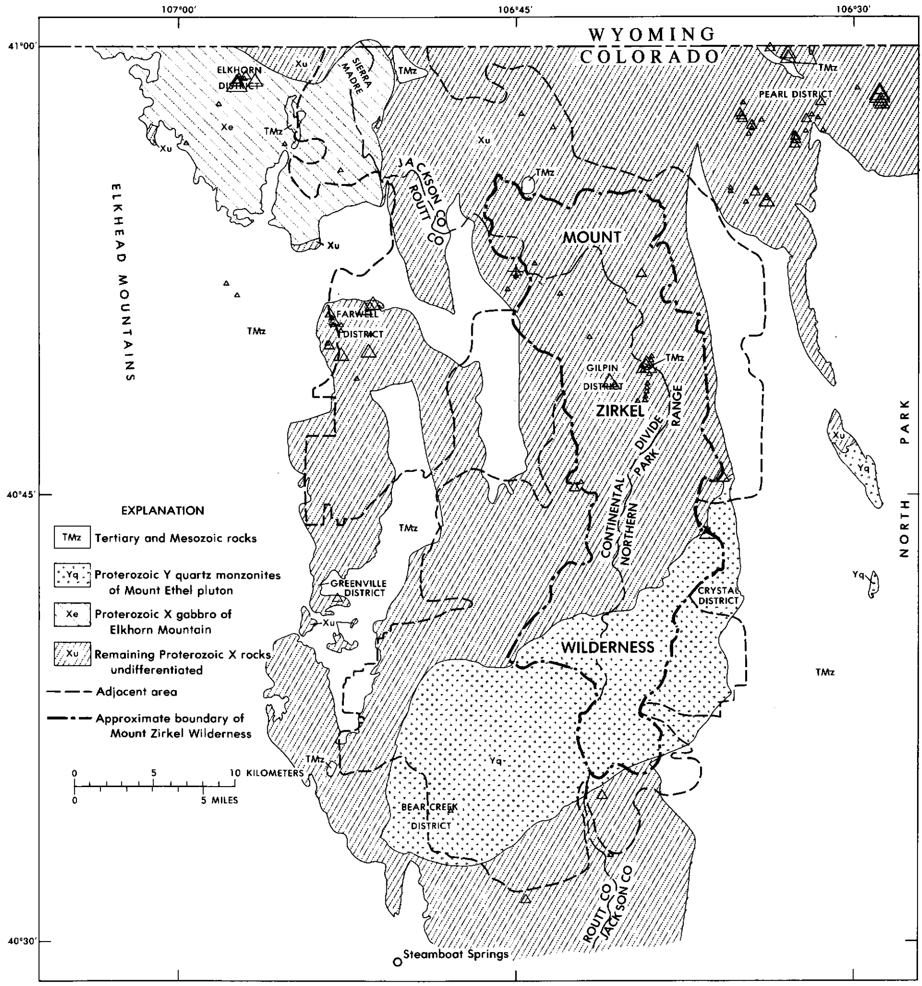


FIGURE 66.—Anomalous stream-sediment Spec Ag (spectrographic silver), Mount Zirkel area. Smallest symbol <0.5 ppm; next to smallest 0.5–0.7 ppm; next to largest 1 ppm; largest 2 ppm.

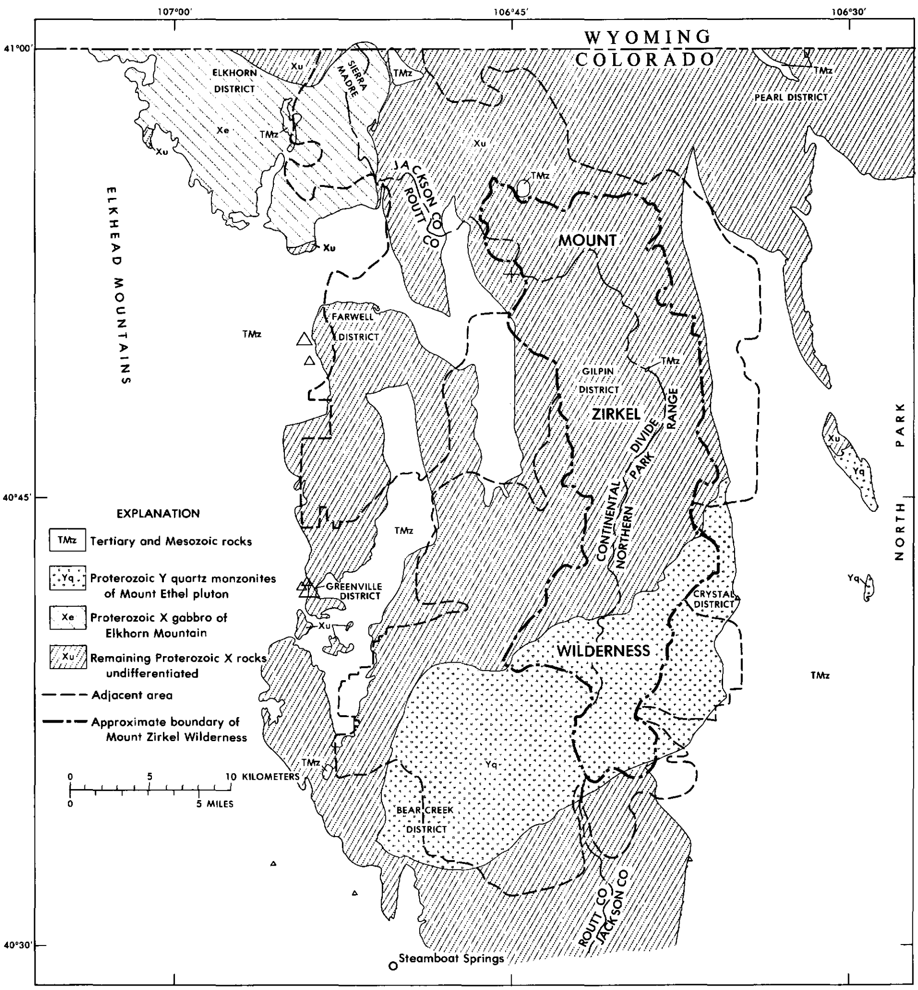


FIGURE 67.—Anomalous stream-sediment AA Ag (atomic absorption silver), Mount Zirkel area. Smallest symbol 0.4 ppm; next to smallest 0.5 ppm; next to largest 1 ppm; largest symbol 2 ppm.

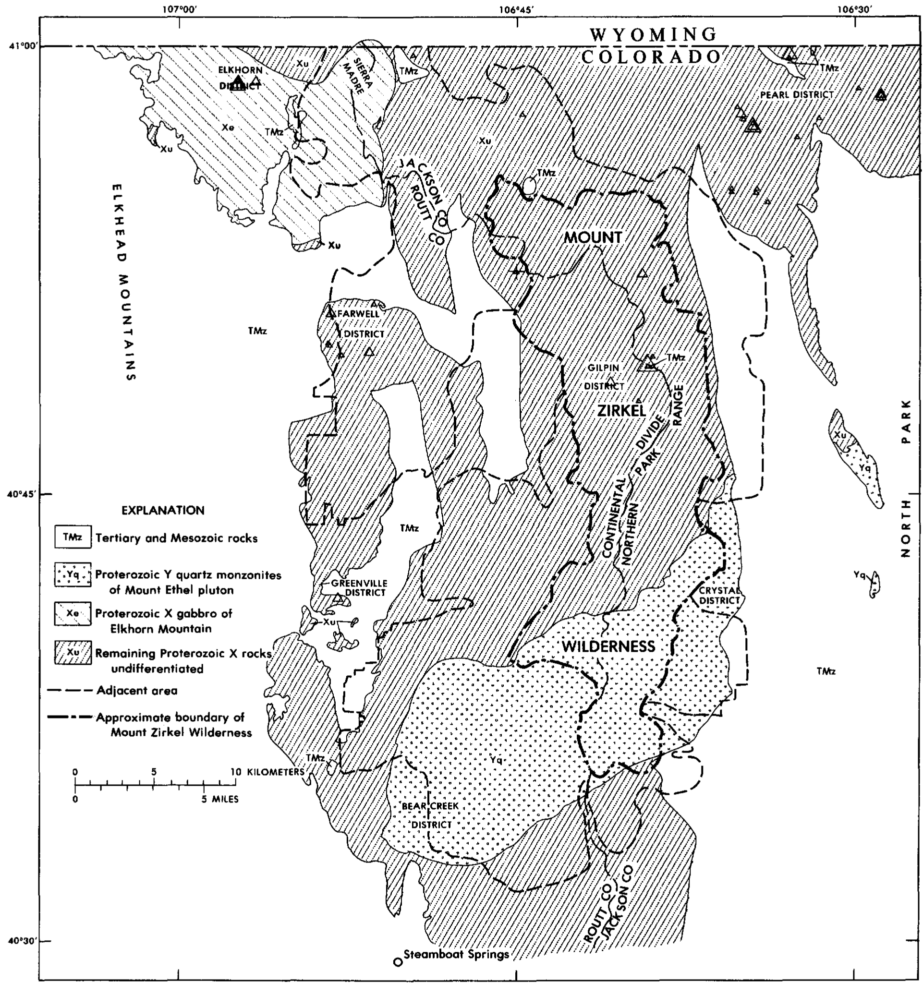


FIGURE 68.—Anomalous rock AA Au (atomic absorption gold), Mount Zirkel area. Smallest symbol 0.05–0.3 ppm; next to smallest 0.35–1.5 ppm; next to largest 3–5.5 ppm; largest 20 ppm.

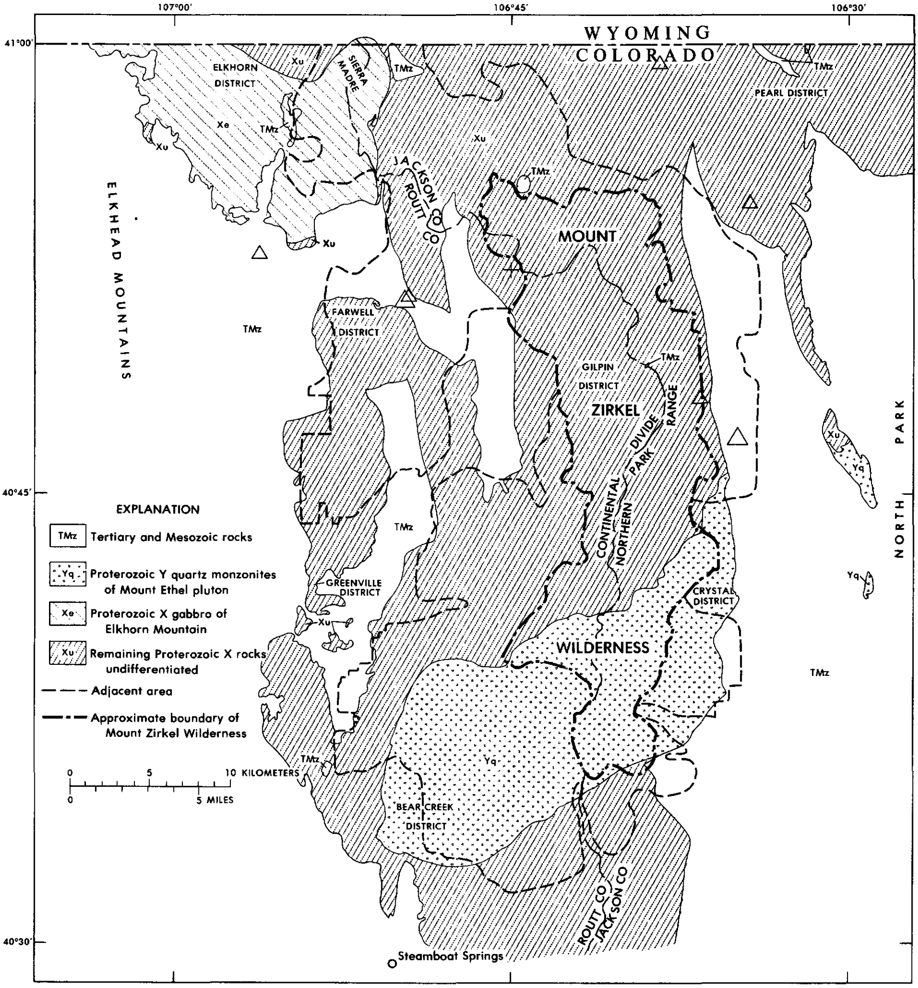


FIGURE 69.—Anomalous stream-sediment AA Au (atomic absorption gold), Mount Zirkel area. Smaller symbol 0.05–0.1 ppm; larger 0.2 ppm.

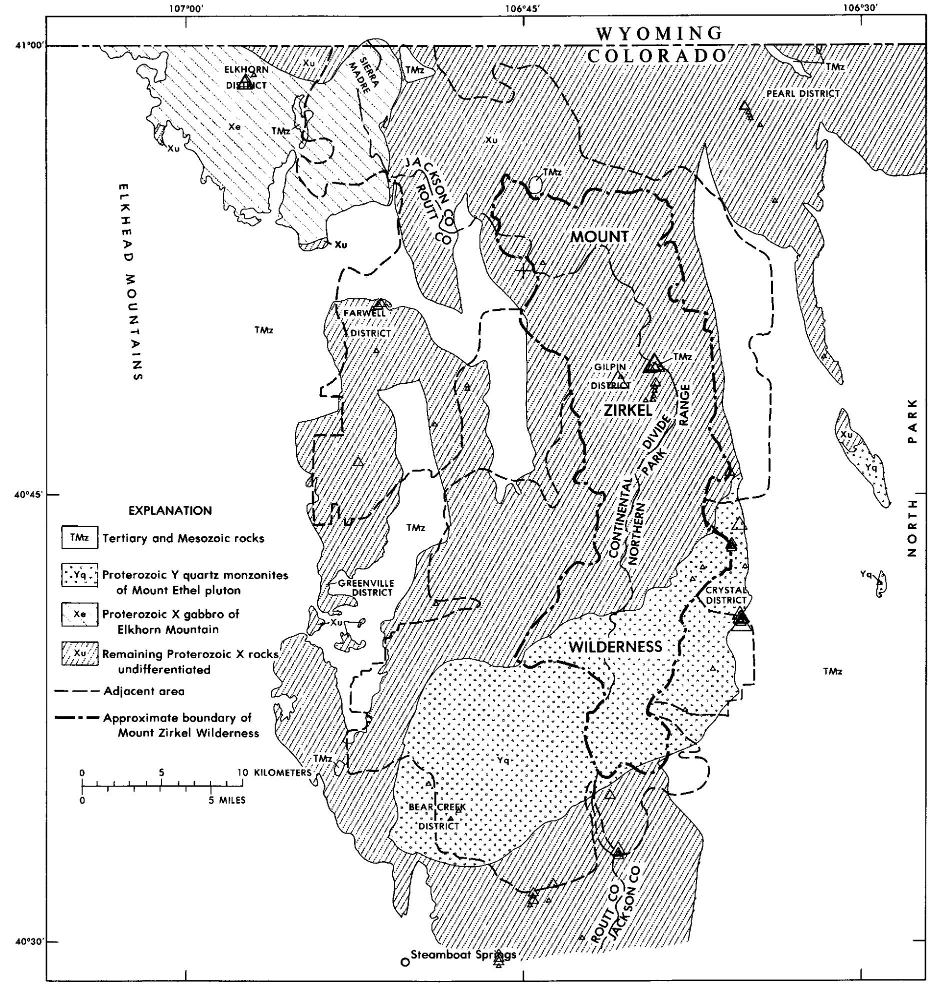


FIGURE 70.—Anomalous rock Inst Hg (instrumental mercury), Mount Zirkel area. Smallest symbol 0.04–0.24 ppm; next to smallest 0.28–0.8 ppm; next to largest 0.85–5.5 ppm; largest symbol 10–>10 ppm.

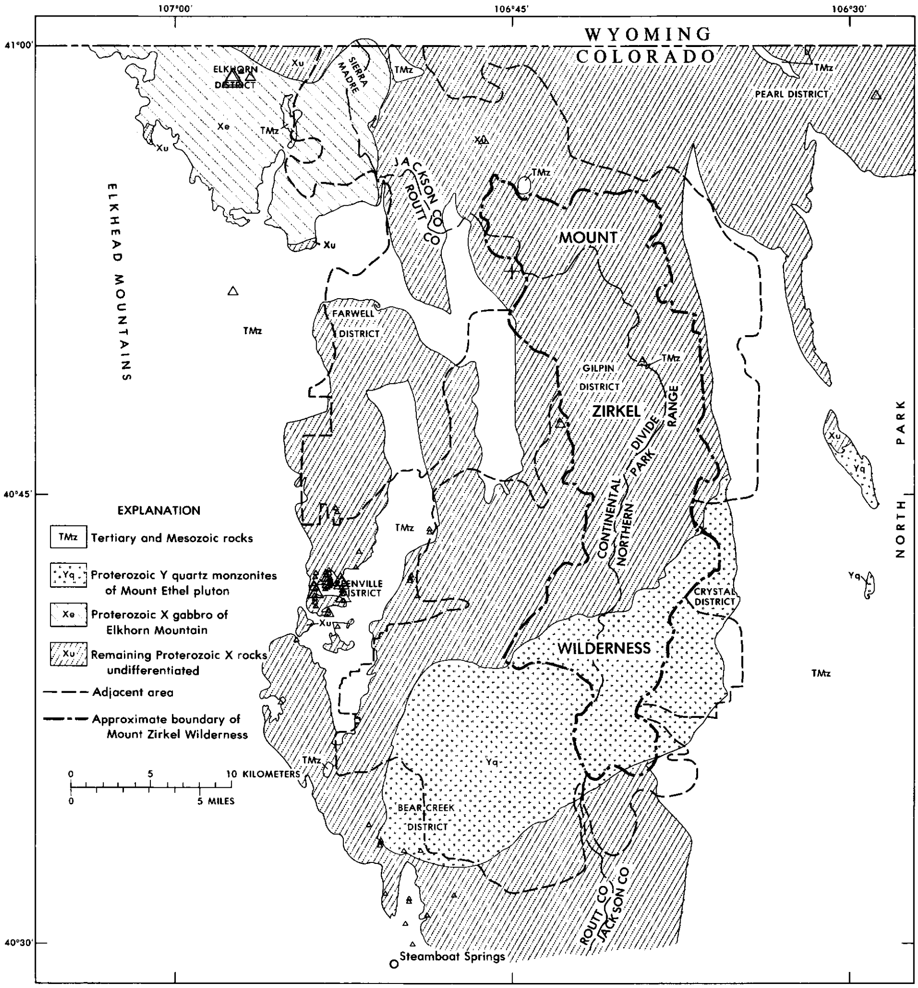


FIGURE 71.—Anomalous rock Spec Sb (spectrographic antimony), Mount Zirkel area. Smallest symbol <100 ppm; next to smallest 100–200 ppm; next to largest 300–500 ppm; largest 700–1,000 ppm.

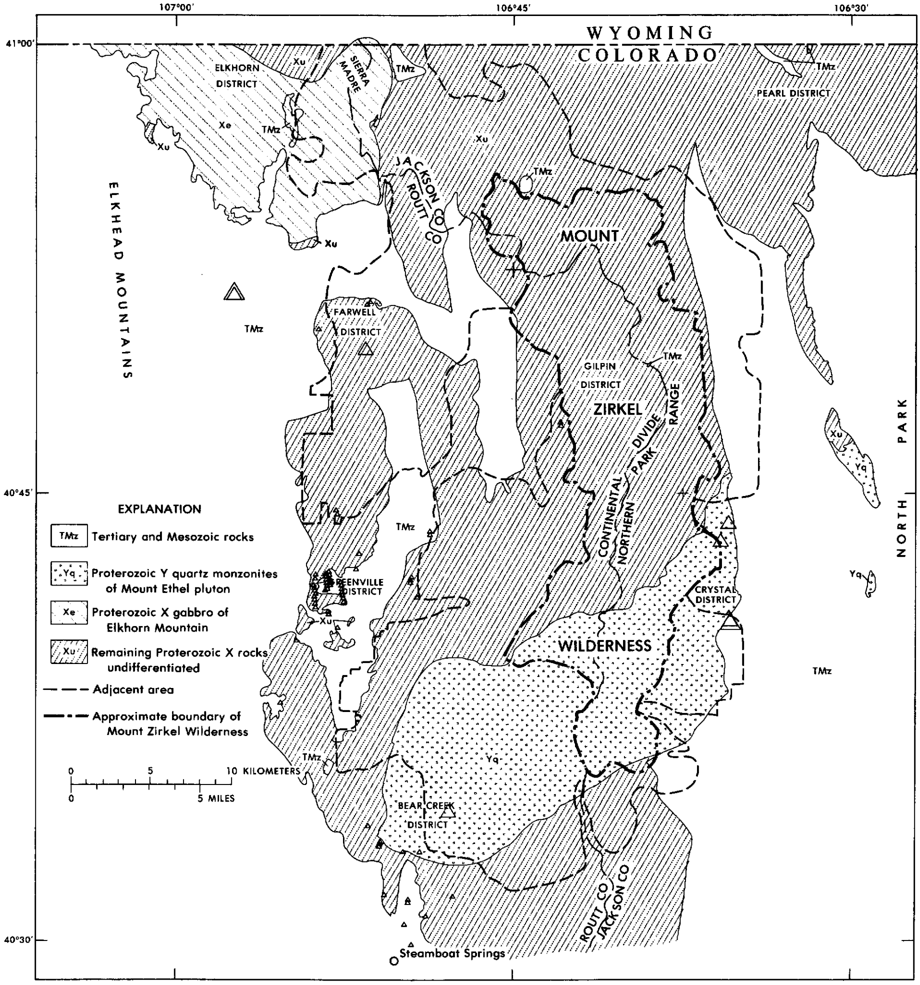


FIGURE 72.—Anomalous rock Spec As (spectrographic arsenic), Mount Zirkel area. Smallest symbol <200 ppm; intermediate 200–1,500 ppm; largest 2,000–5,000 ppm.

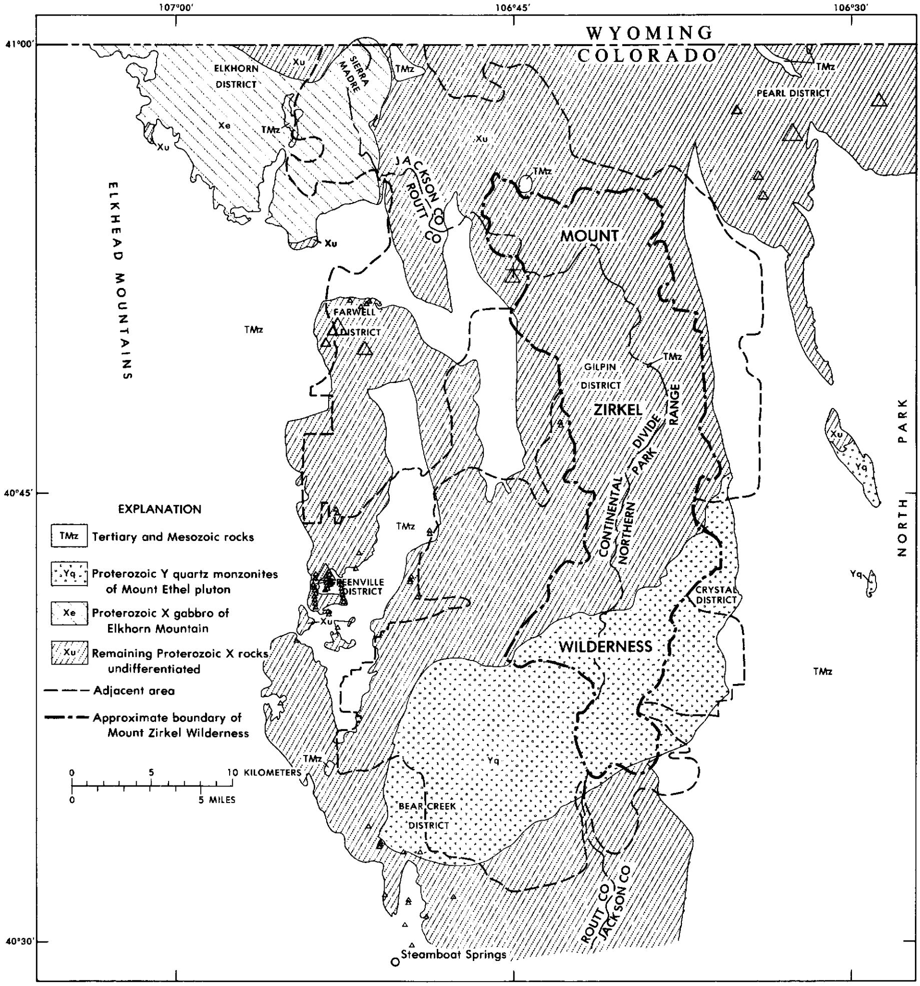


FIGURE 73.—Anomalous rock Spec W (spectrographic tungsten), Mount Zirkel area. Smallest symbol <50 ppm; next to smallest 50–100 ppm; next to largest 150–300 ppm; largest 500–1,000 ppm.

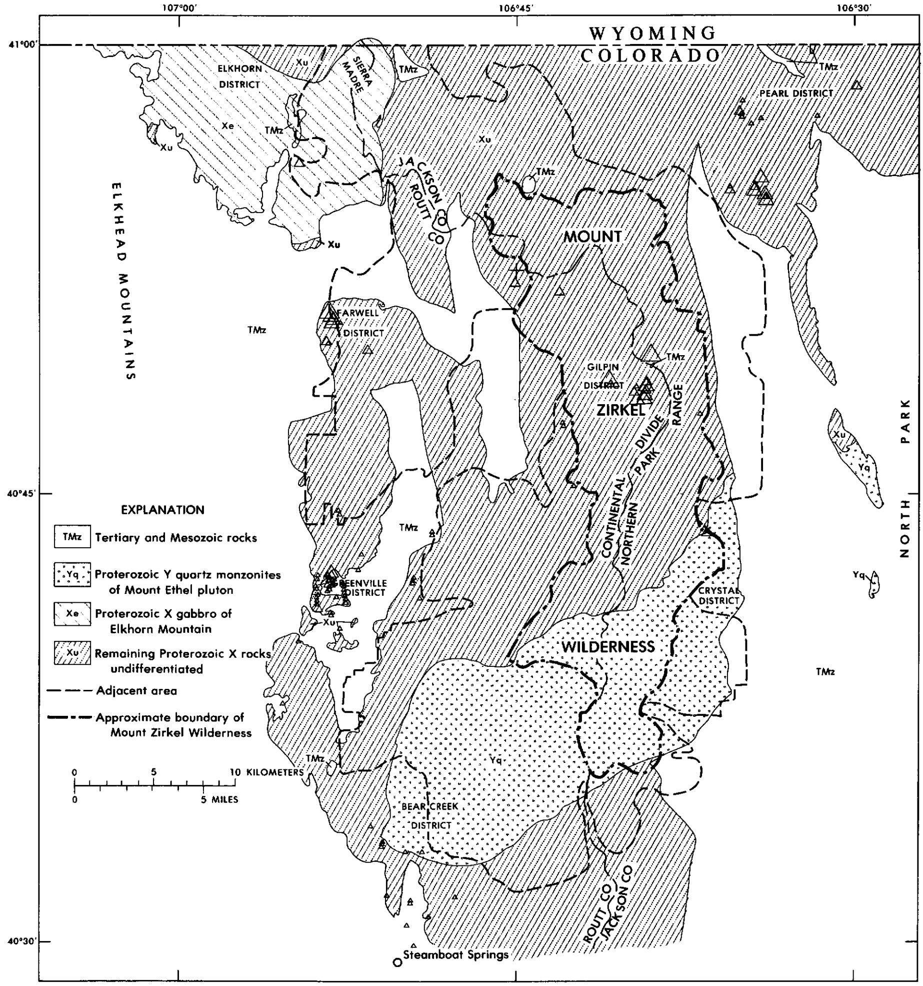


FIGURE 74.—Anomalous rock Spec Sn (spectrographic tin), Mount Zirkel area. Smallest symbol <10, 10, 15 ppm; next to smallest 20–30 ppm; next to largest 50–70 ppm; largest 100–150 ppm.

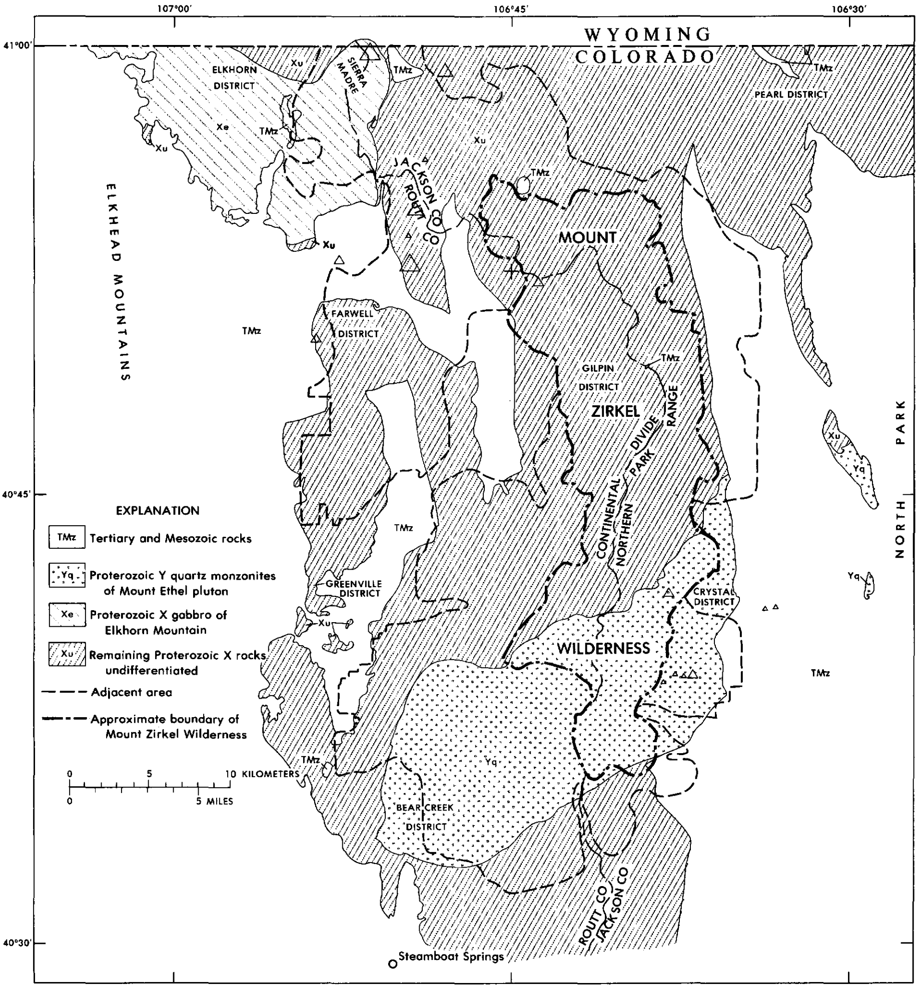


FIGURE 75.—Anomalous stream-sediment Spec Sn (spectrographic tin), Mount Zirkel area. Smallest symbol <10 ppm; next to smallest 10–15 ppm; next to largest 20–30 ppm; largest 50–70 ppm.

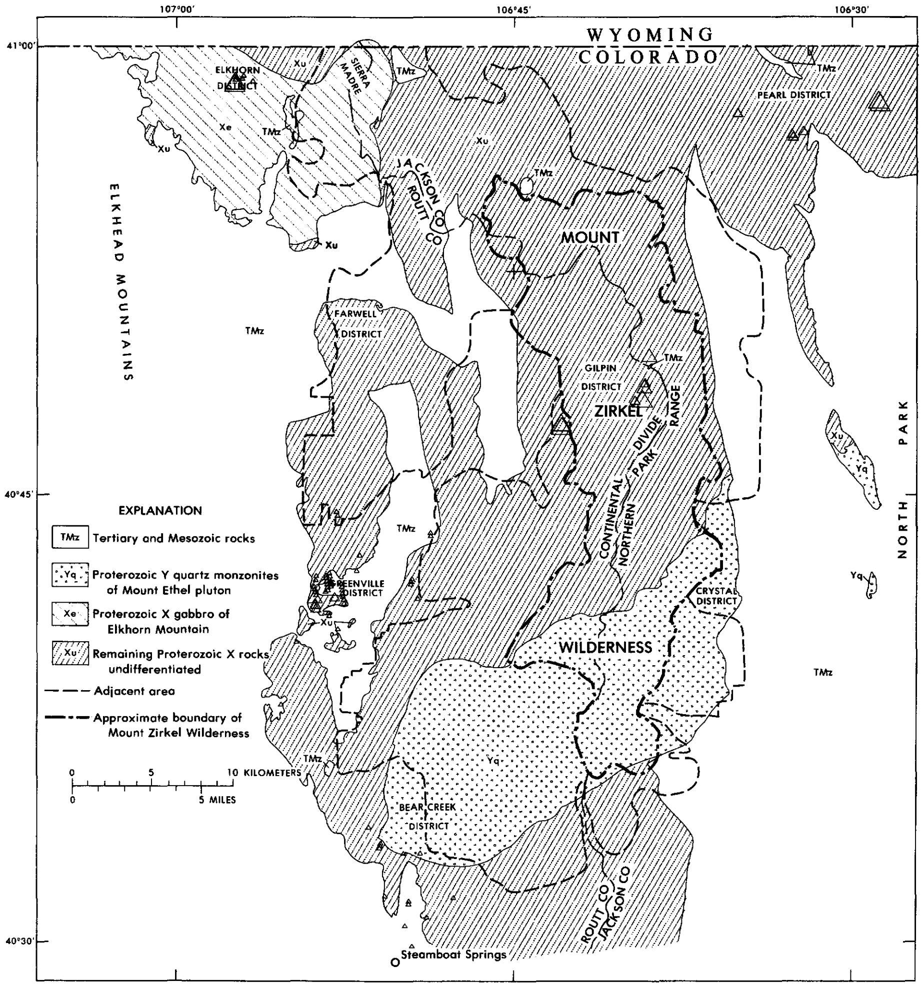


FIGURE 76.—Anomalous rock Spec Cd (spectrographic cadmium), Mount Zirkel area. Smallest symbol <20, <50, 20, 30 ppm; next to smallest 50–100 ppm; next to largest 150–300 ppm; largest 500–>500 ppm.

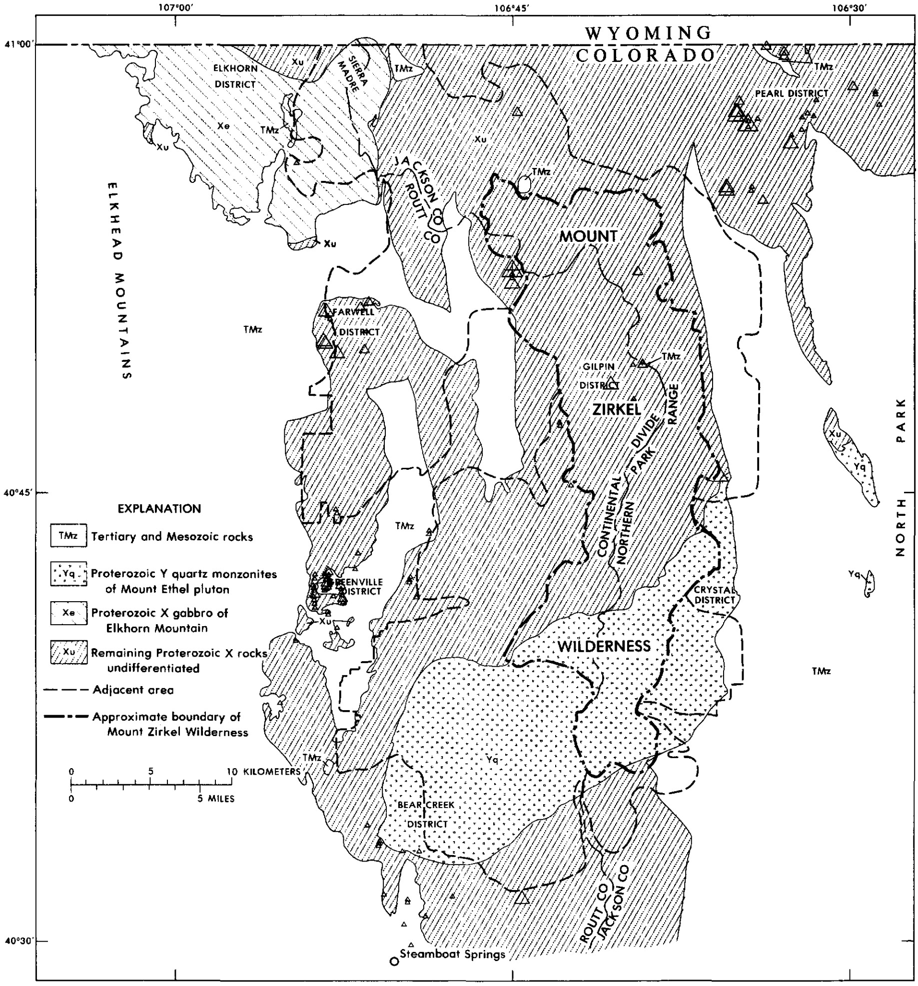


FIGURE 77.—Anomalous rock Spec Bi (spectrographic bismuth), Mount Zirkel area. Smallest symbol <10, <20, 10, 15 ppm; next to smallest 20–100 ppm; next to largest 150–700 ppm; largest 1,000–>1,000 ppm.

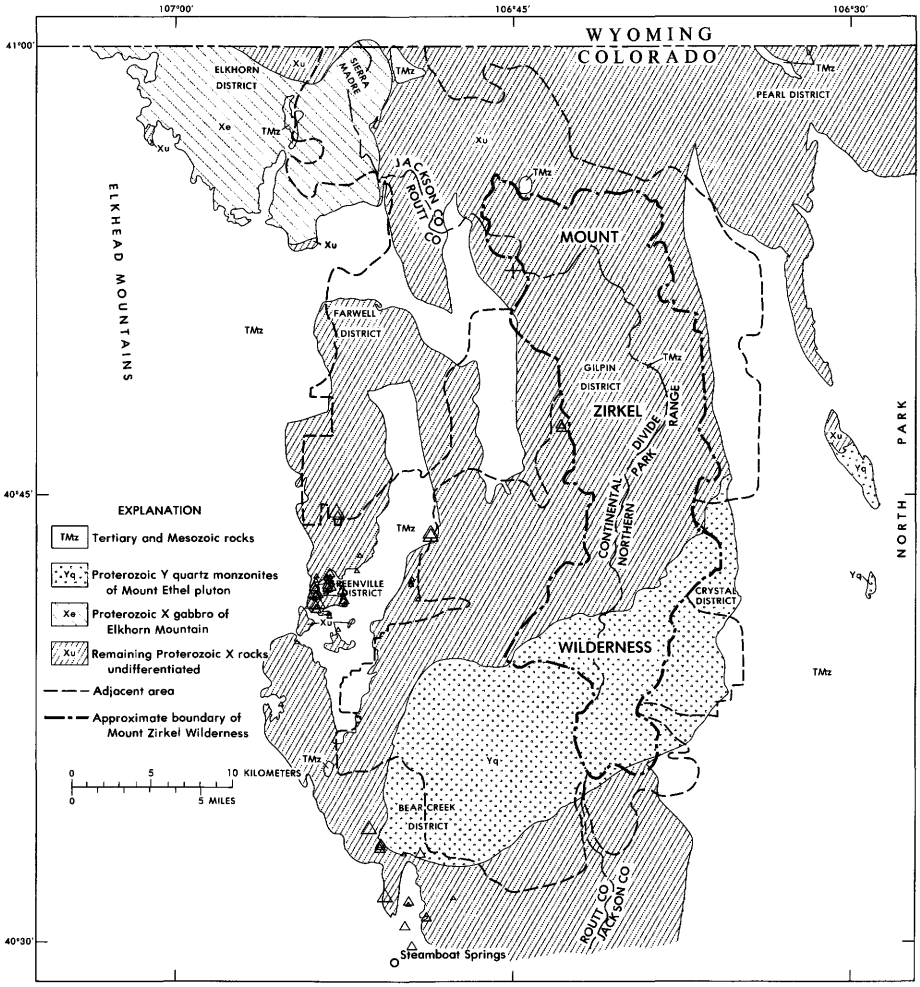


FIGURE 78.—Anomalous rock Spec Ga (spectrographic gallium), Mount Zirkel area. Smallest symbol <10, <20, 10 ppm; next to smallest 15–20 ppm; next to largest 30–50 ppm; largest 70–100 ppm.

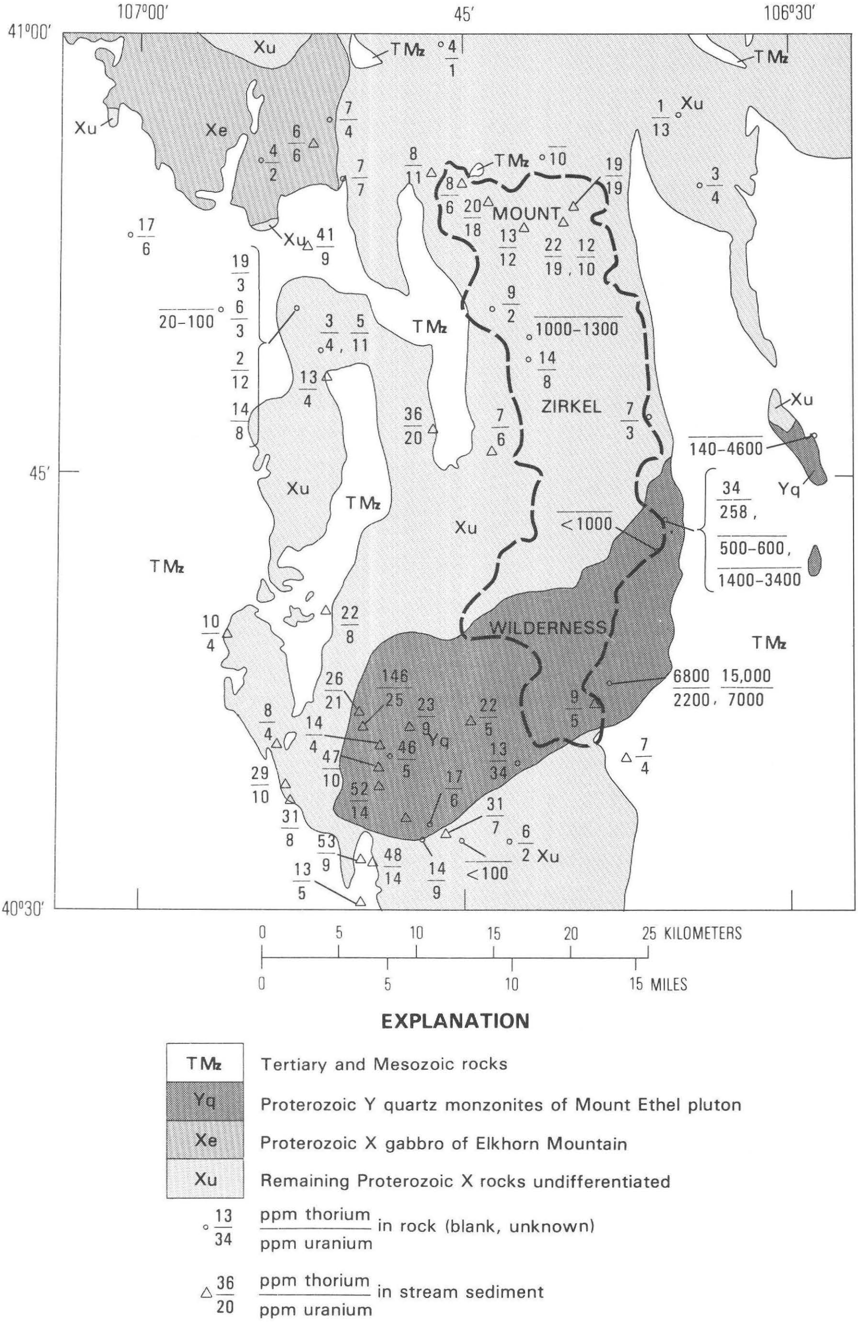


FIGURE 79.—Localities of measured thorium and uranium in rocks and mineral specimens.

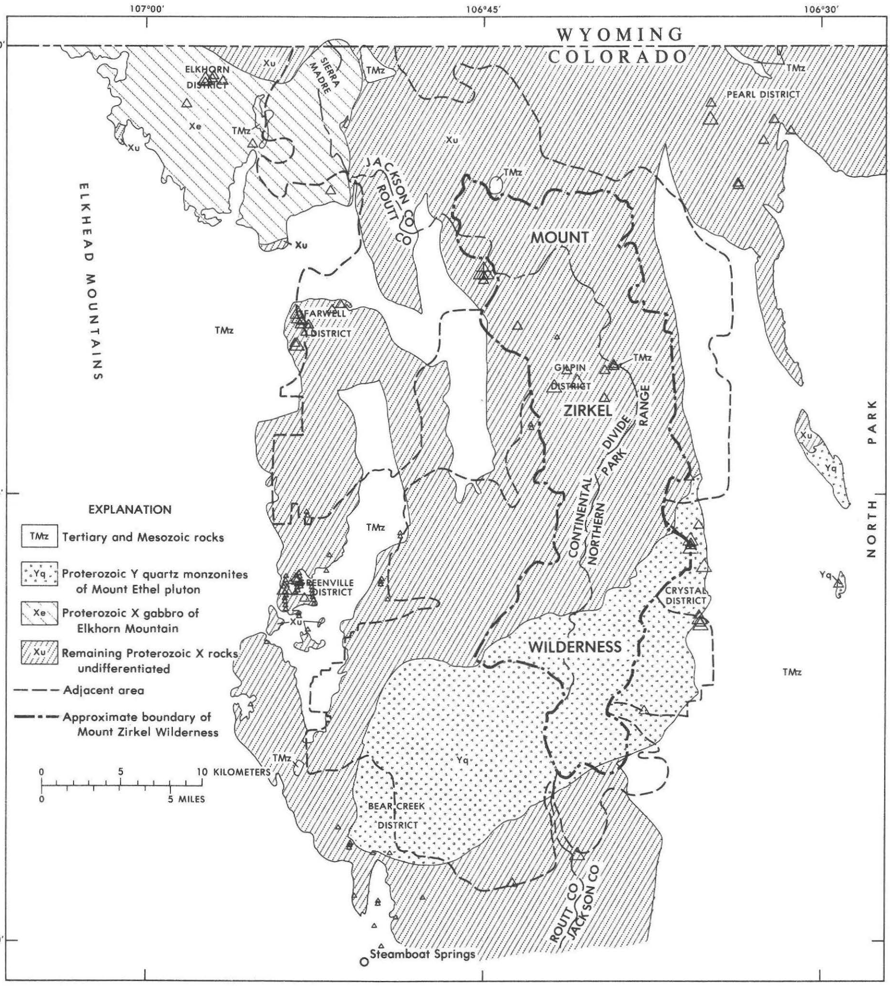


FIGURE 80.—Anomalous rock Spec Mo (spectrographic molybdenum), Mount Zirkel area. Smallest symbol <2, <5, 2, 3 ppm; next to smallest 5–30 ppm; next to largest 50–300 ppm; largest 500–1,500 ppm.

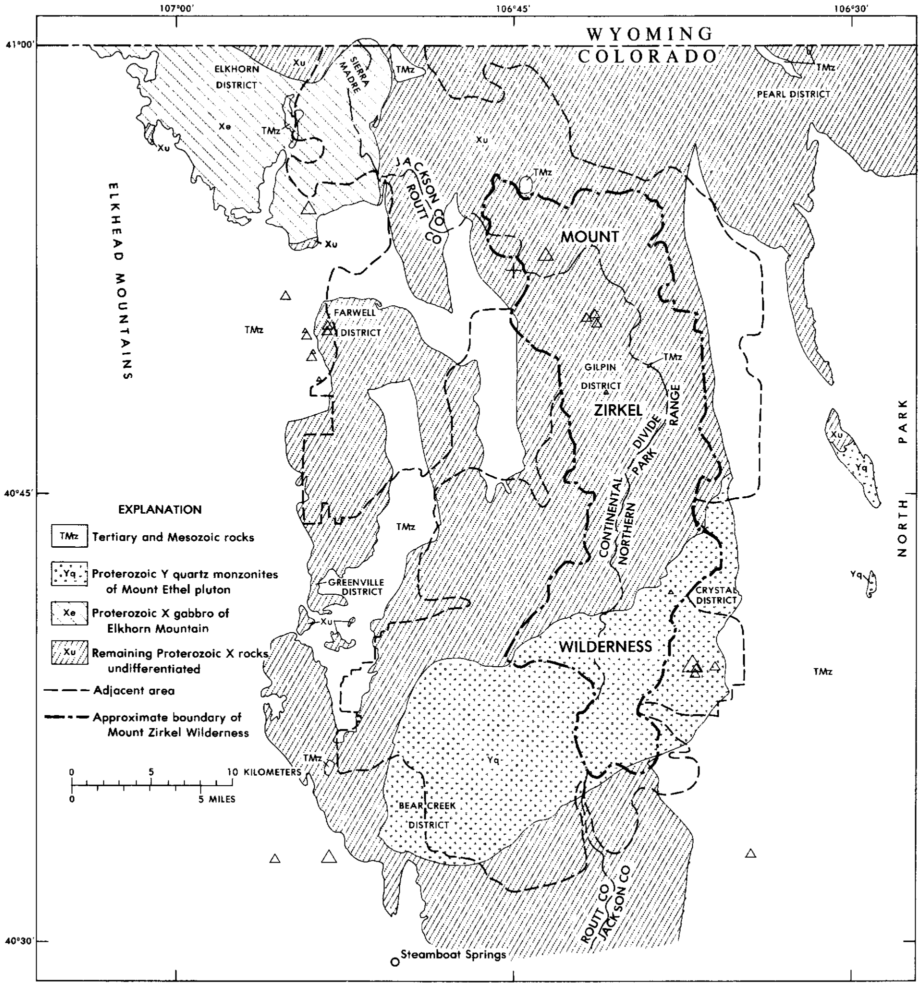


FIGURE 81.—Anomalous stream-sediment Spec Mo (spectrographic molybdenum), Mount Zirkel area. Smallest symbol <5–5 ppm; next to smallest 7–10 ppm; next to largest 15–20 ppm; largest 30–50 ppm.

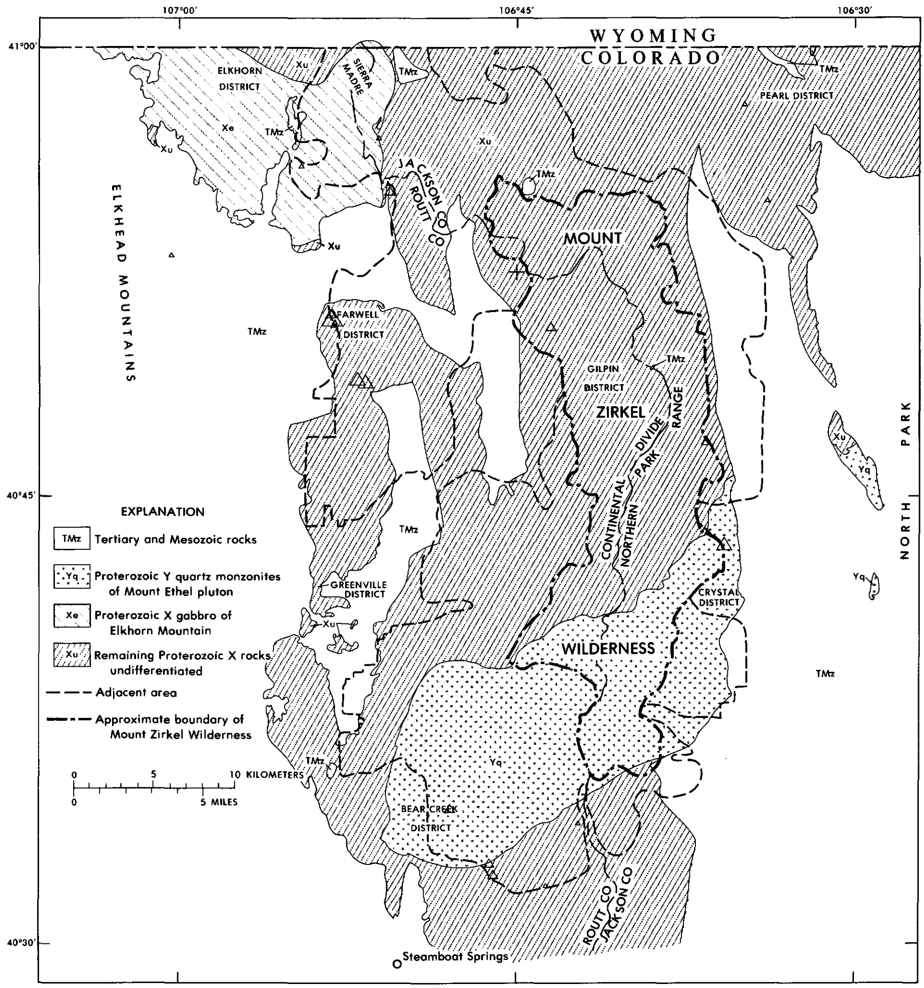


FIGURE 82.—Anomalous rock Spec Nb (spectrographic niobium), Mount Zirkel area. Smallest symbol 20 ppm; next to smallest 30 ppm; next to largest 50–70 ppm; largest 100–150 ppm.

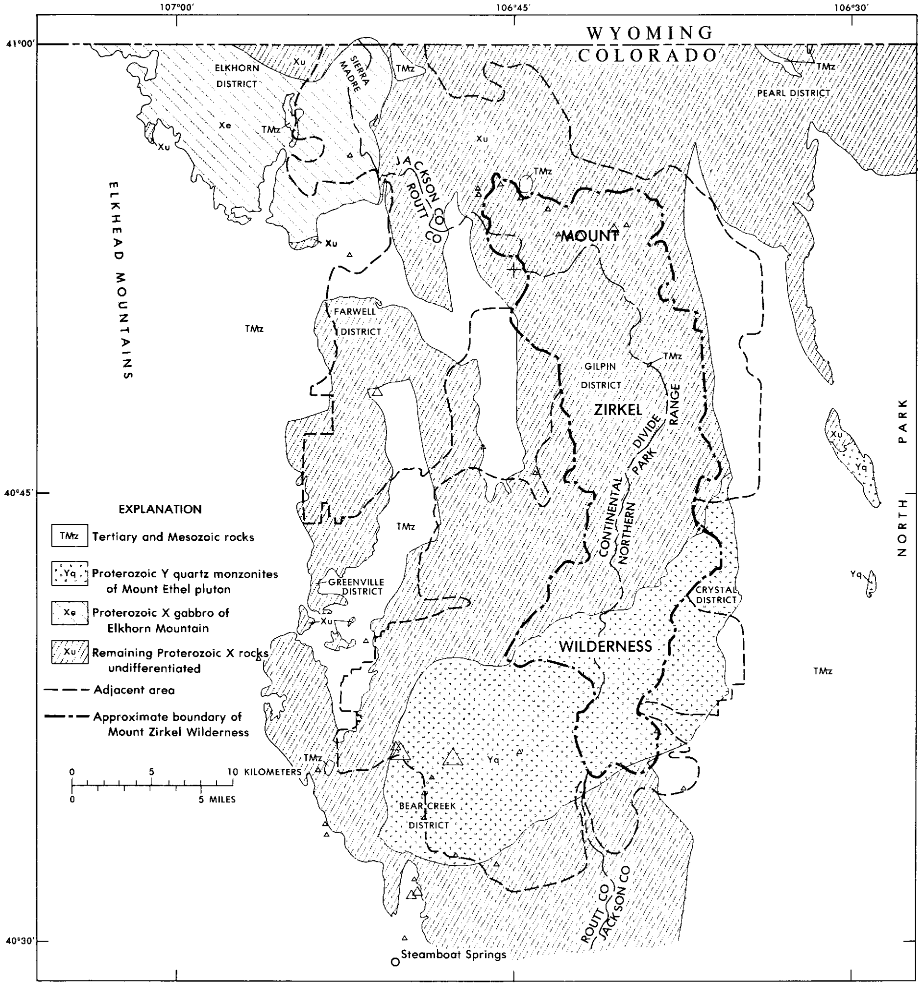


FIGURE 83.—Anomalous stream-sediment Spec Nb (spectrographic niobium), Mount Zirkel area. Smallest symbol 20 ppm; intermediate 30-50 ppm; largest 70-100 ppm.

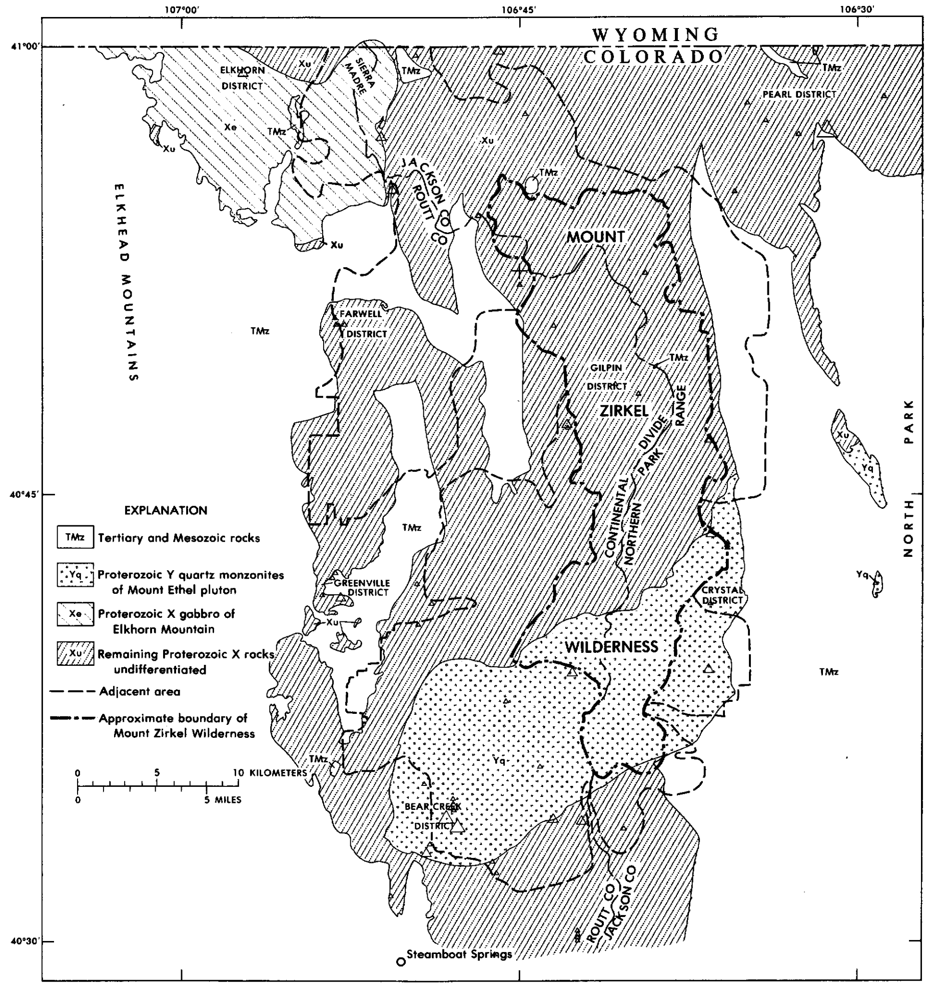


FIGURE 84.—Anomalous rock Spec La (spectrographic lanthanum), Mount Zirkel area. Smallest symbol 50–70 ppm; next to smallest 100–150 ppm; next to largest 200–300 ppm; largest 500 ppm.

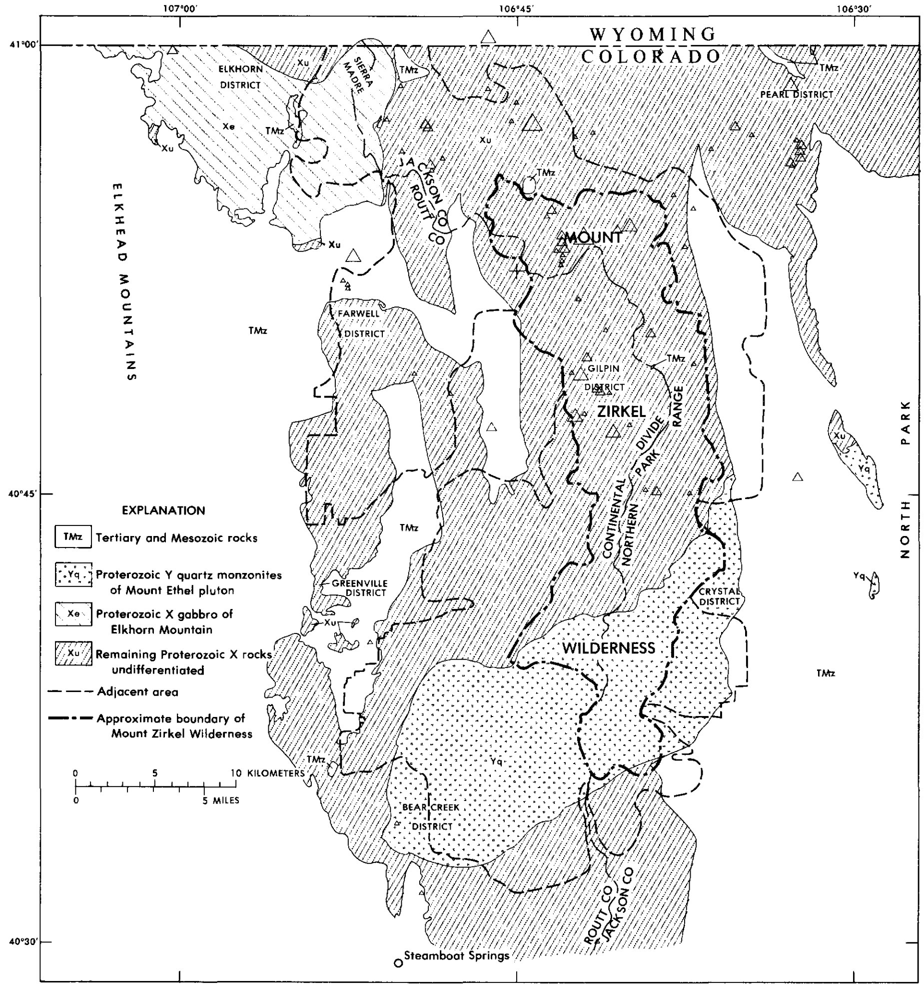


FIGURE 85.—Anomalous stream-sediment Spec La (spectrographic lanthanum), Mount Zirkel area. Smallest symbol 100 ppm; next to smallest 150 ppm; next to largest 200 ppm; largest 300 ppm.

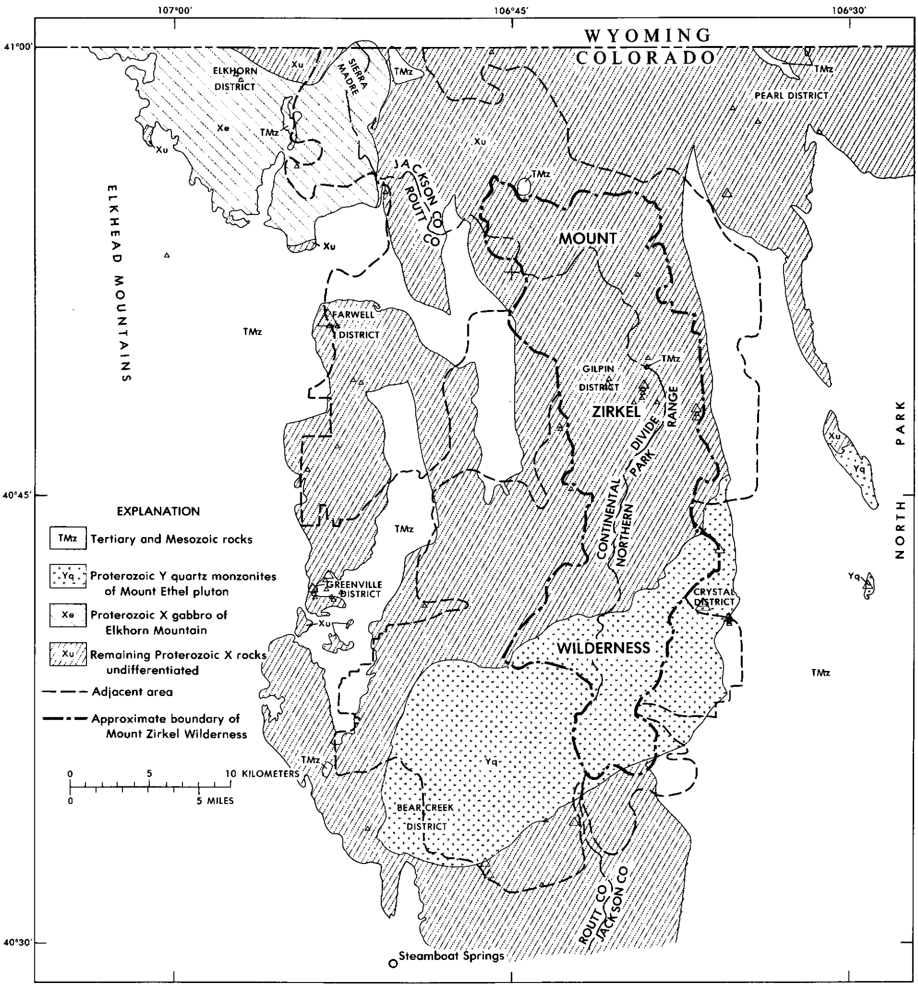


FIGURE 86.—Anomalous rock Spec Y (spectrographic yttrium), Mount Zirkel area. Smallest symbol 50–70 ppm; next to smallest 100–150 ppm; next to largest 200–300 ppm; largest 500 ppm.

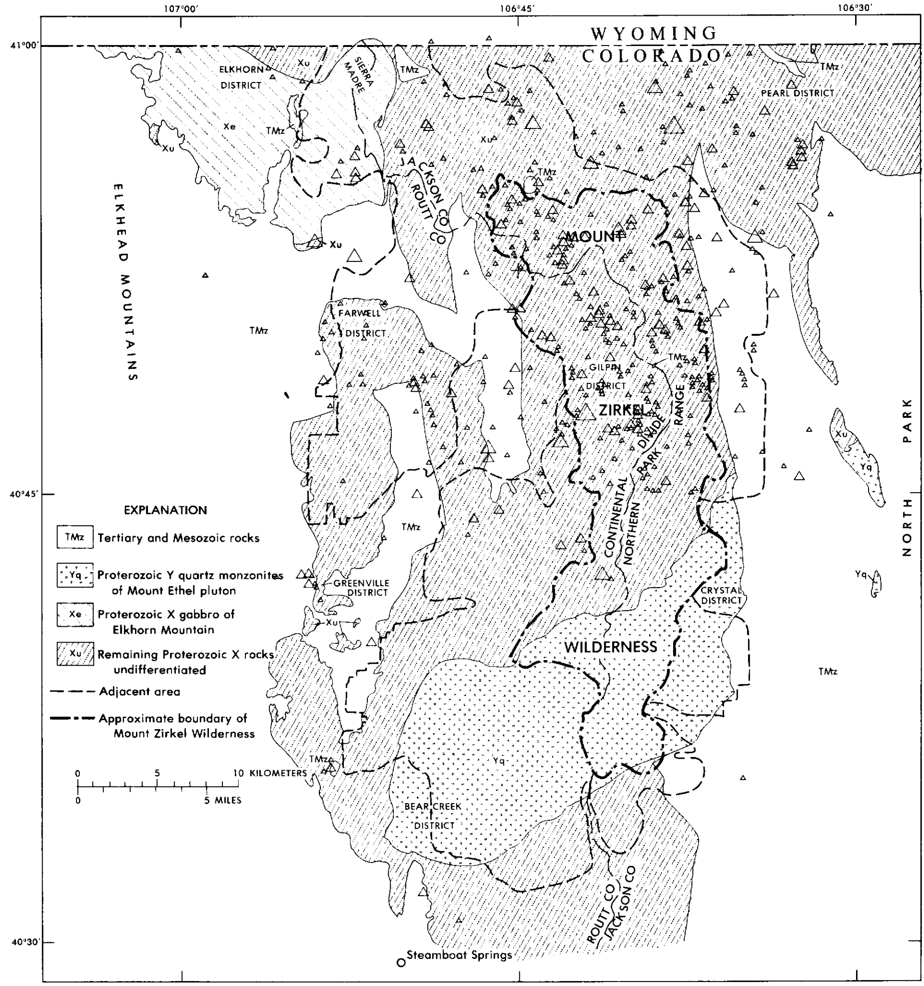


FIGURE 87.—Anomalous stream-sediment Spec Y (spectrographic yttrium), Mount Zirkel area. Smallest symbol 70 ppm; next to smallest 100–150 ppm; next to largest 200 ppm; largest symbol 300 ppm.

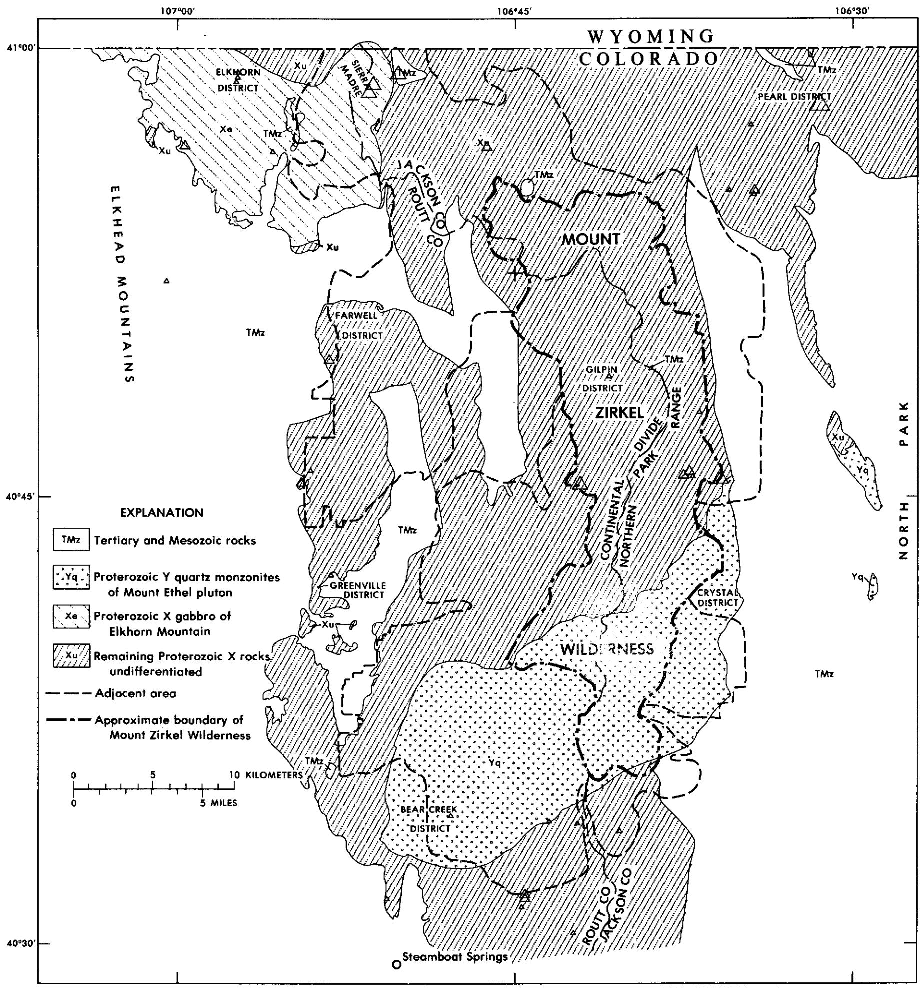


FIGURE 88.—Anomalous rock Spec Cr (spectrographic chromium), Mount Zirkel area. Smallest symbol 100–200 ppm; next to smallest 300–700 ppm; next to largest 1,000–1,500 ppm; largest symbol 2,000–3,000 ppm.

FIGURE 89.—Anomalous stream-sediment Spec Cr (spectrographic chromium), Mount Zirkel area. Smallest symbol 500 ppm; next to smallest 700 ppm; next to largest 1,000–1,500 ppm; largest 2,000–>5,000 ppm.

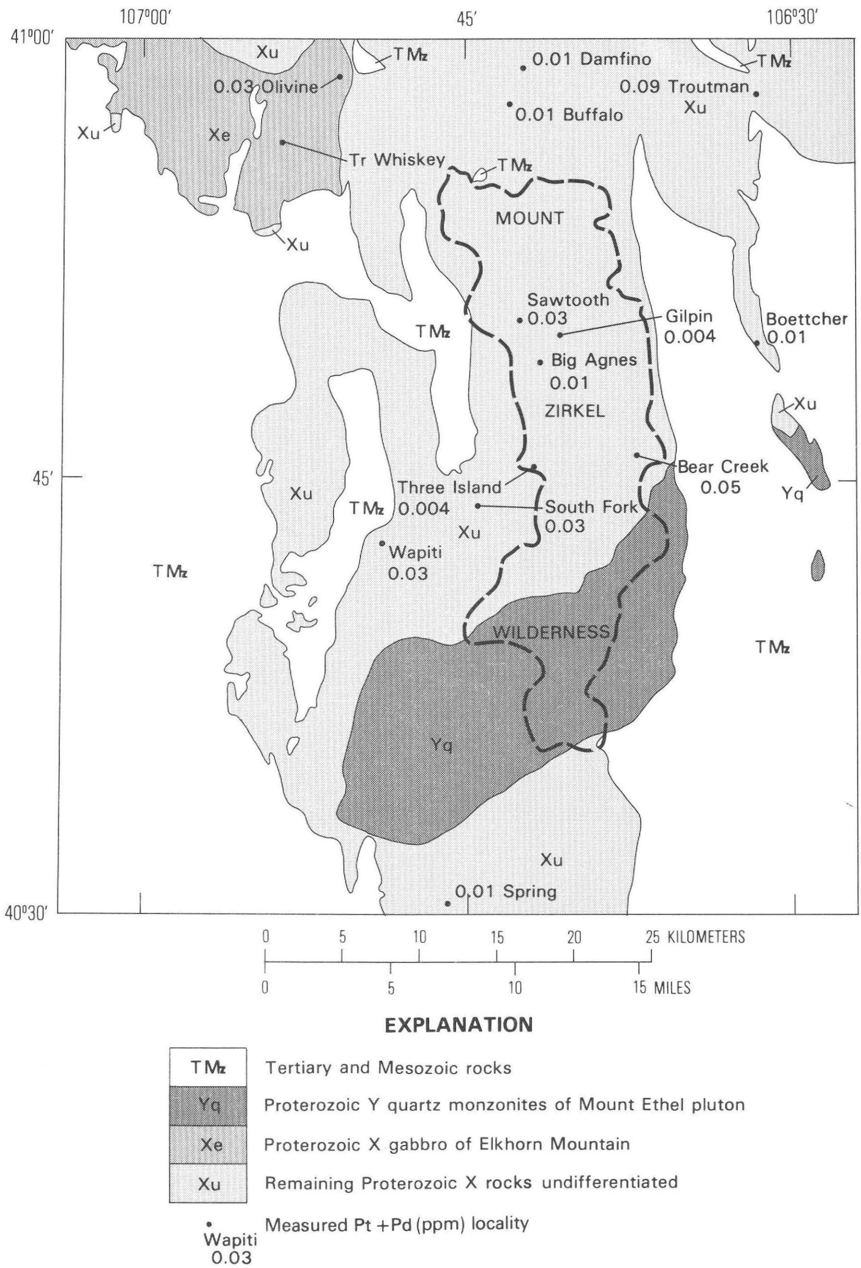


FIGURE 90.—Localities of measured platinum and palladium.

FIGURE 91.—Anomalous rock Spec Co (spectrographic cobalt), Mount Zirkel area. Smallest symbol 50-70 ppm; intermediate 100-150 ppm; largest 200 ppm.

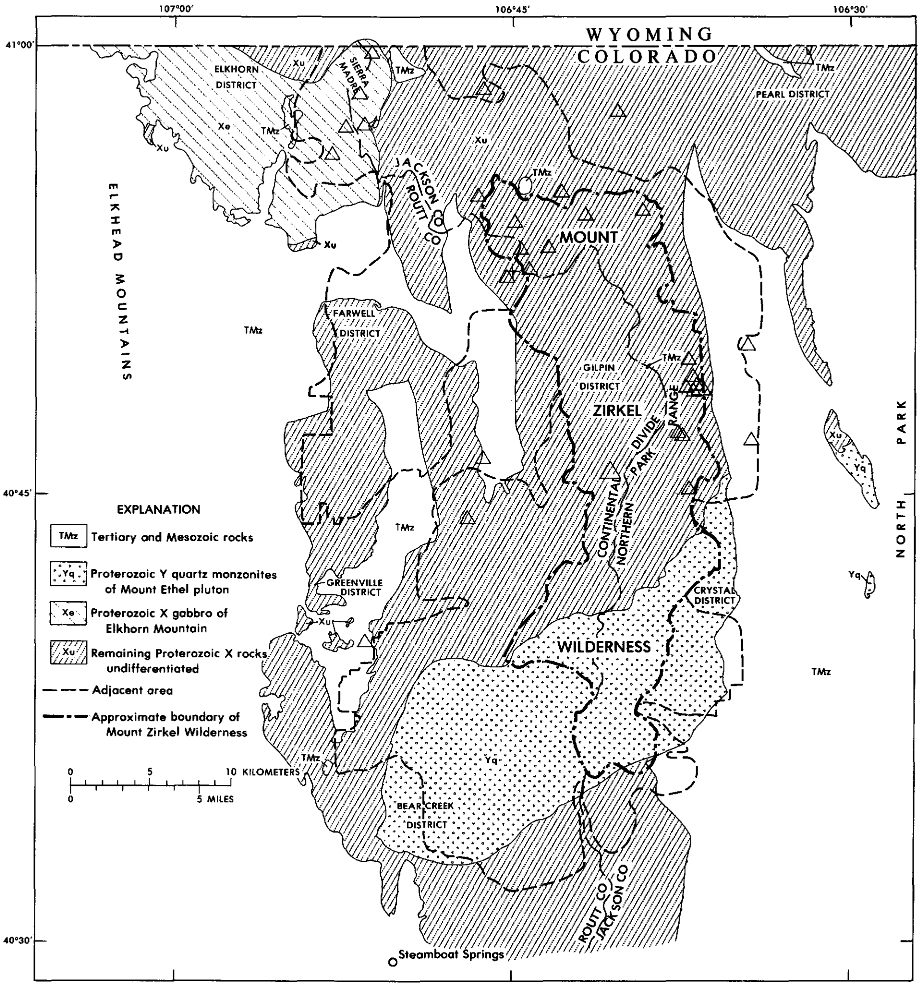


FIGURE 92.—Anomalous stream-sediment Spec Co (spectrographic cobalt), Mount Zirkel area. Smaller symbol 50 ppm; larger symbol 70 ppm.

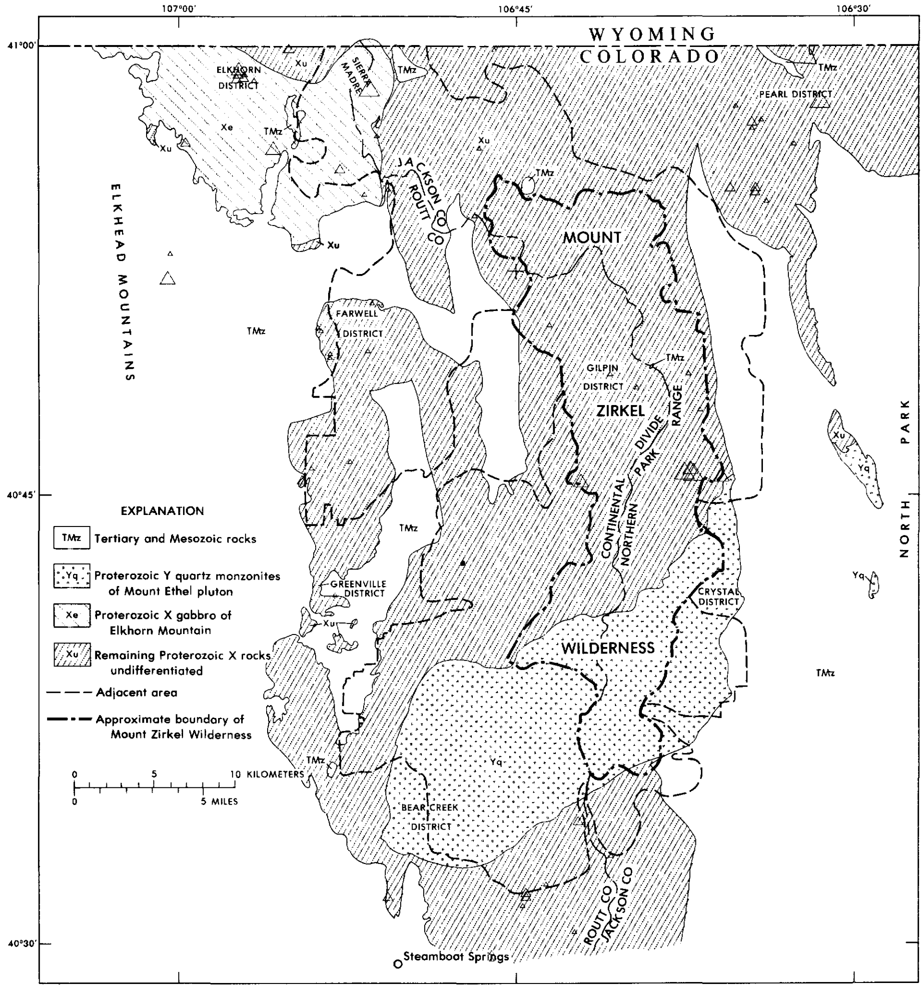


FIGURE 93.—Anomalous rock Spec Ni (spectrographic nickel), Mount Zirkel area. Smallest symbol 20–30 ppm; next to smallest 50–100 ppm; next to largest 150–300 ppm; largest symbol 500–700 ppm.

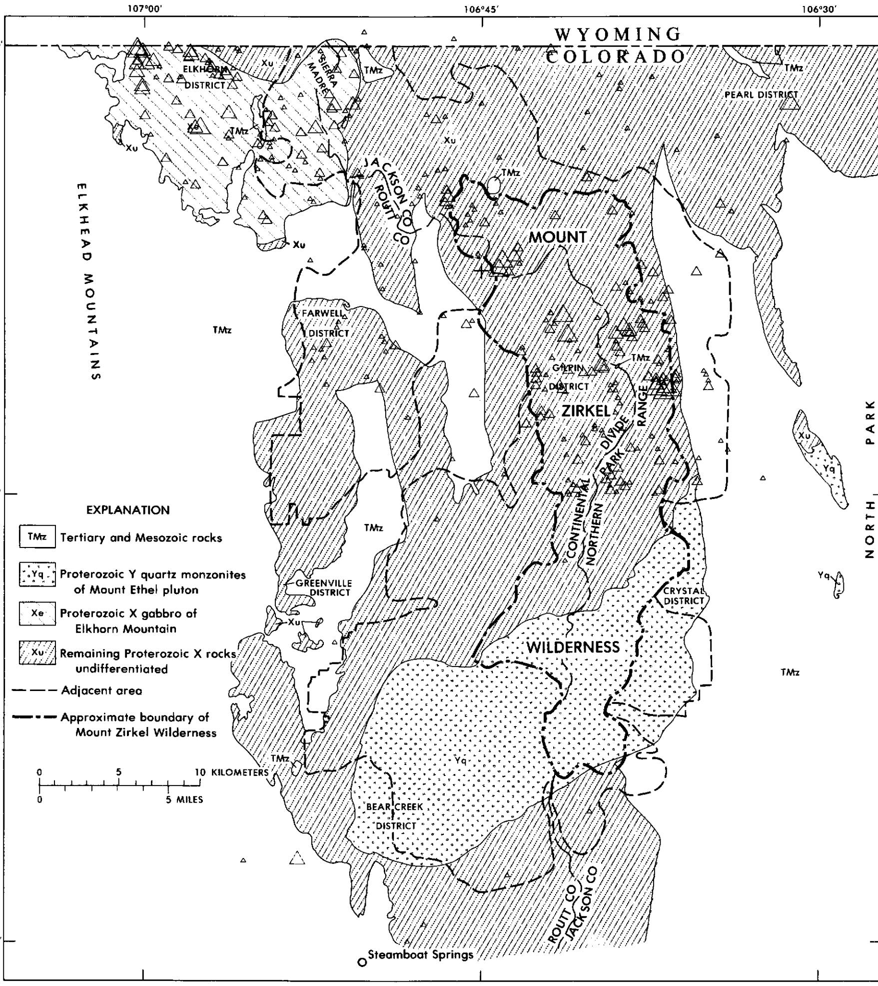


FIGURE 94.—Anomalous stream-sediment Spec Ni (spectrographic nickel), Mount Zirkel area. Smallest symbol 50 ppm; next to smallest 70 ppm; next to largest 100 ppm; largest 150–300 ppm.

FIGURE 95.—Anomalous rock Spec Ba (spectrographic barium), Mount Zirkel area. Smallest symbol 3,000 ppm; intermediate 5,000 ppm; largest >5,000 ppm.

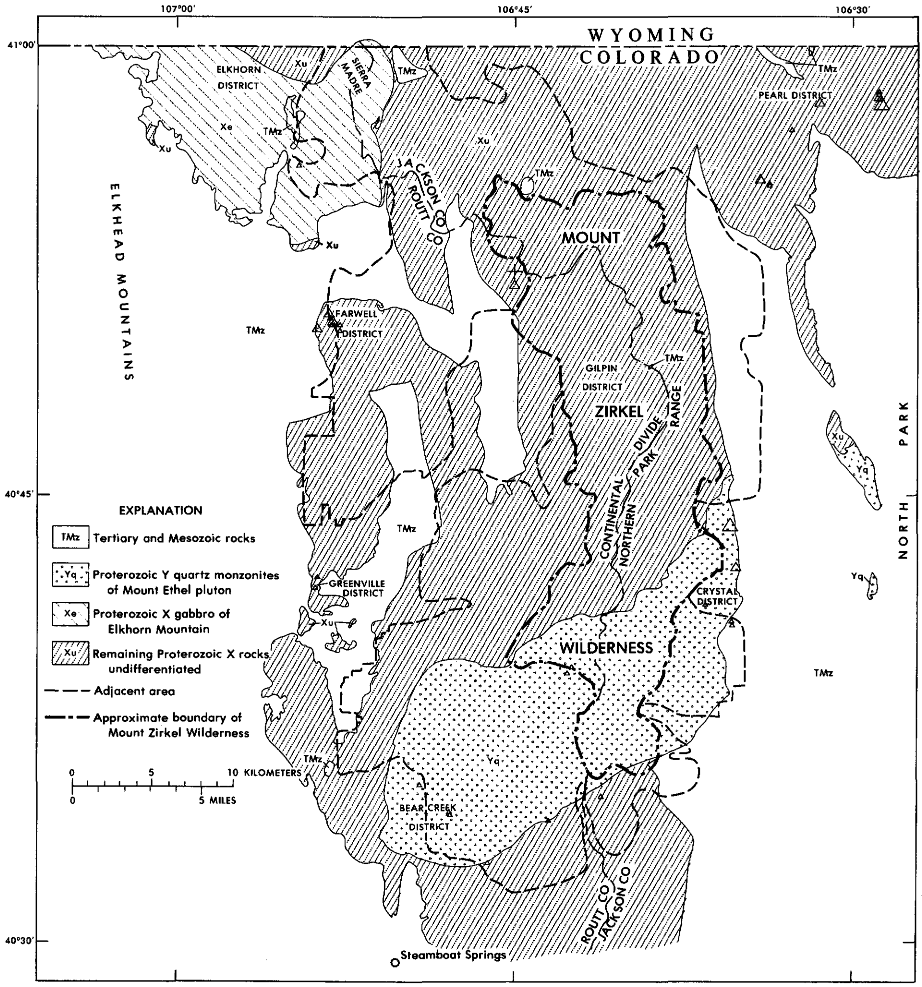


FIGURE 96.—Anomalous rock Spec Be (spectrographic beryllium), Mount Zirkel area. Smallest symbol 5-7 ppm; intermediate 10-15 ppm; largest 20-30 ppm.

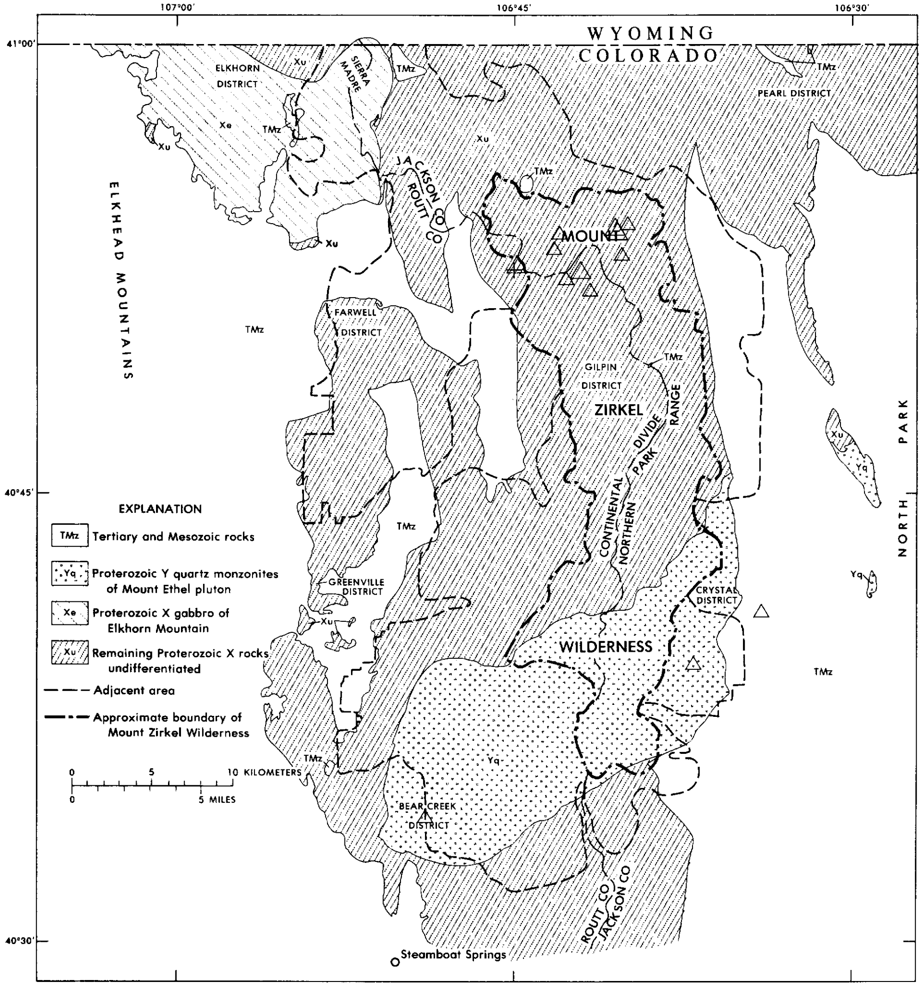


FIGURE 97.—Anomalous stream-sediment Spec Be (spectrographic beryllium), Mount Zirkel area. Smaller symbol 5 ppm; larger 7 ppm.

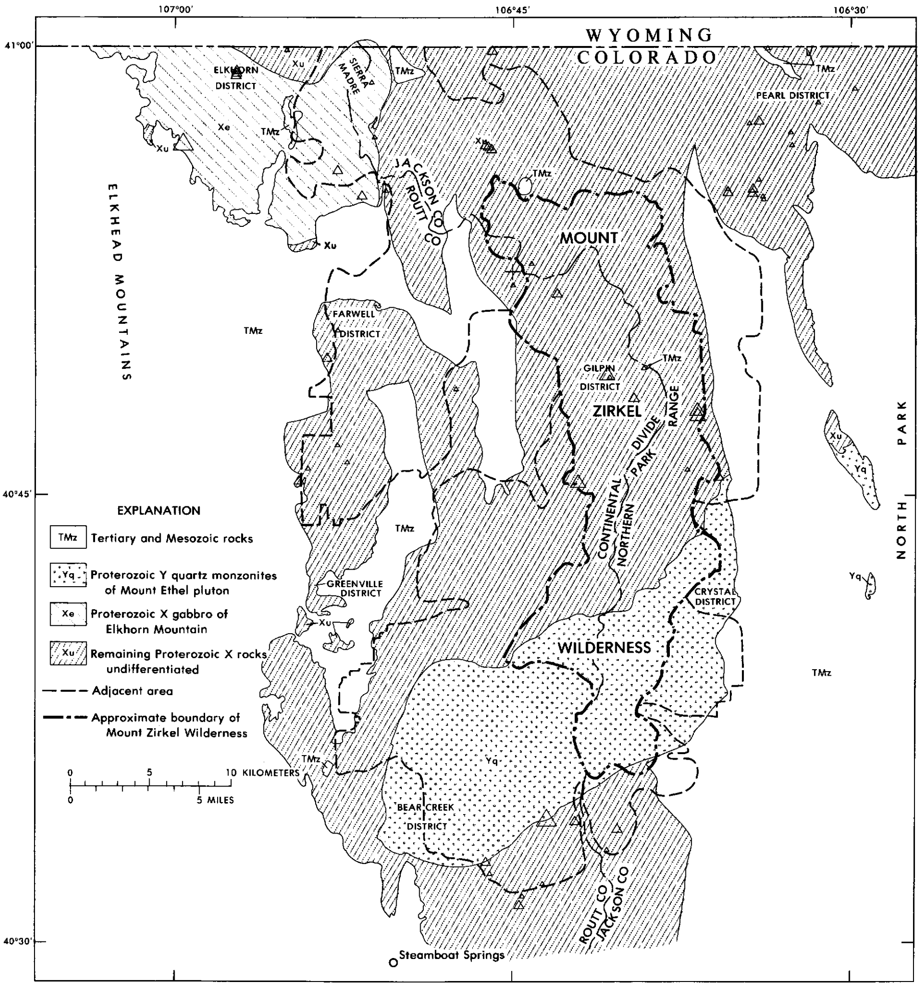


FIGURE 98.—Anomalous rock Spec Sc (spectrographic scandium), Mount Zirkel area. Smallest symbol 20 ppm; next to smallest 30 ppm; next to largest 50 ppm; largest 70–100 ppm.

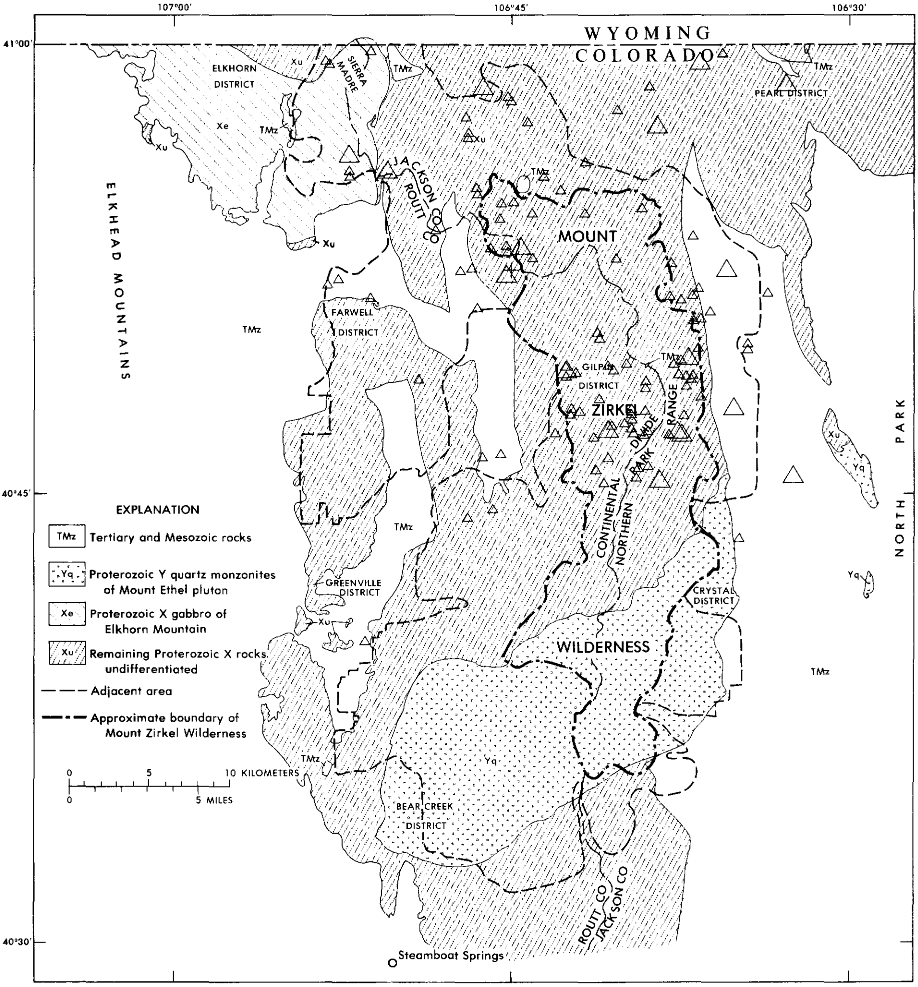


FIGURE 99.—Anomalous stream-sediment Spec Sc (spectrographic scandium), Mount Zirkel area. Smaller symbol 50 ppm; larger 70 ppm.

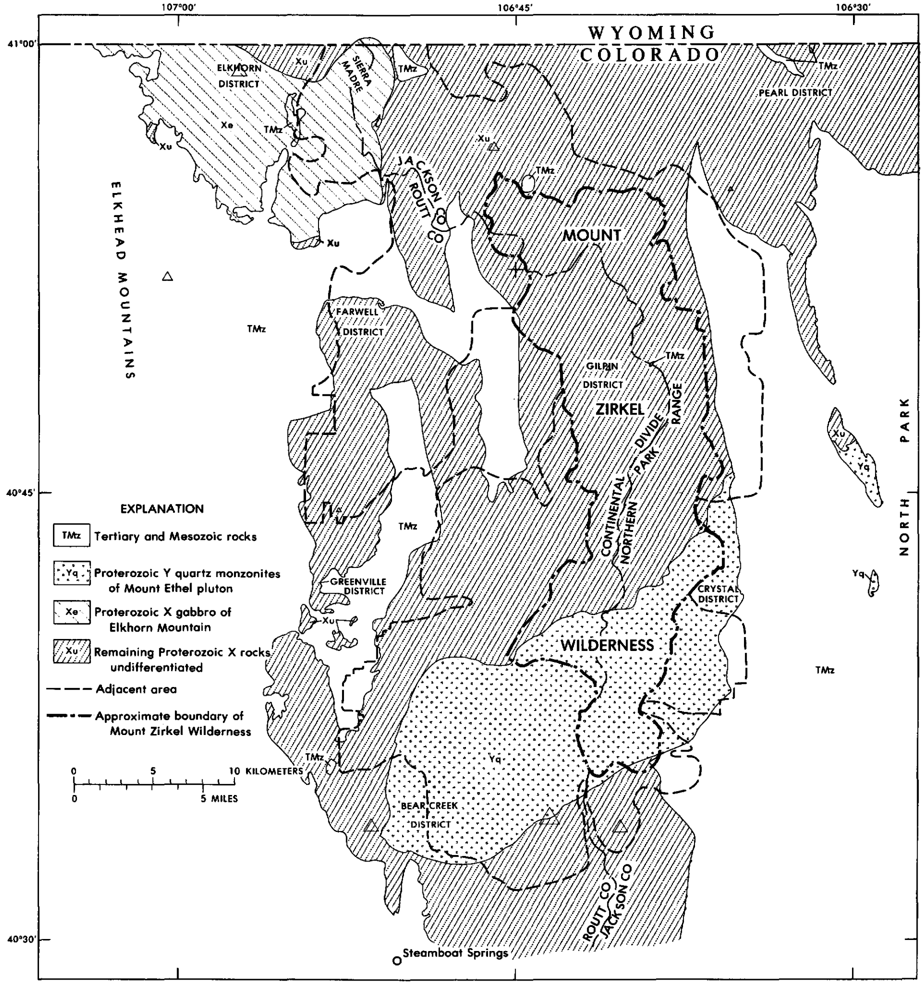


FIGURE 100.—Anomalous rock Spec Sr (spectrographic strontium), Mount Zirkel area. Smallest symbol 1,000 ppm; next to smallest 1,500 ppm; next to largest 2,000 ppm; largest >5,000 ppm.

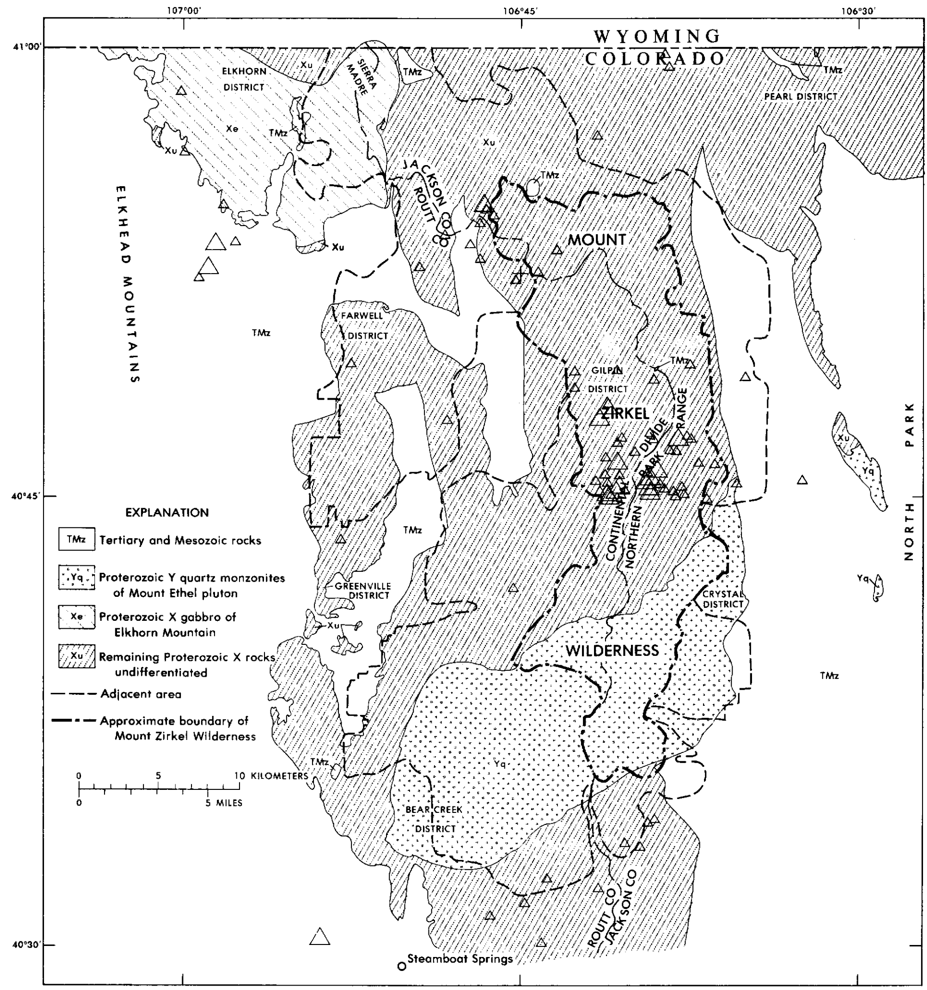


FIGURE 101.—Anomalous stream-sediment Spec Sr (spectrographic strontium), Mount Zirkel area. Smaller symbol 500 ppm; larger 700 ppm.

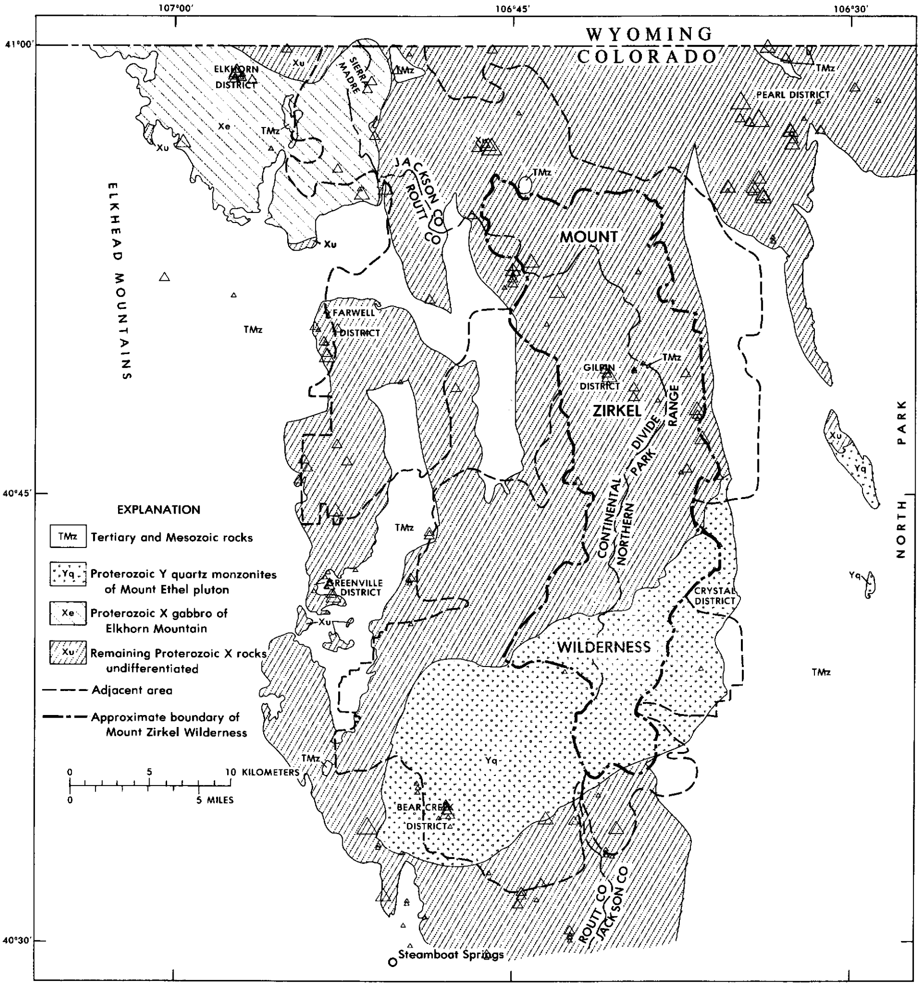


FIGURE 102.—Anomalous rock Spec V (spectrographic vanadium), Mount Zirkel area. Smallest symbol 30–70 ppm; next to smallest 100–150 ppm; next to largest 200–300 ppm; largest 500–700 ppm.

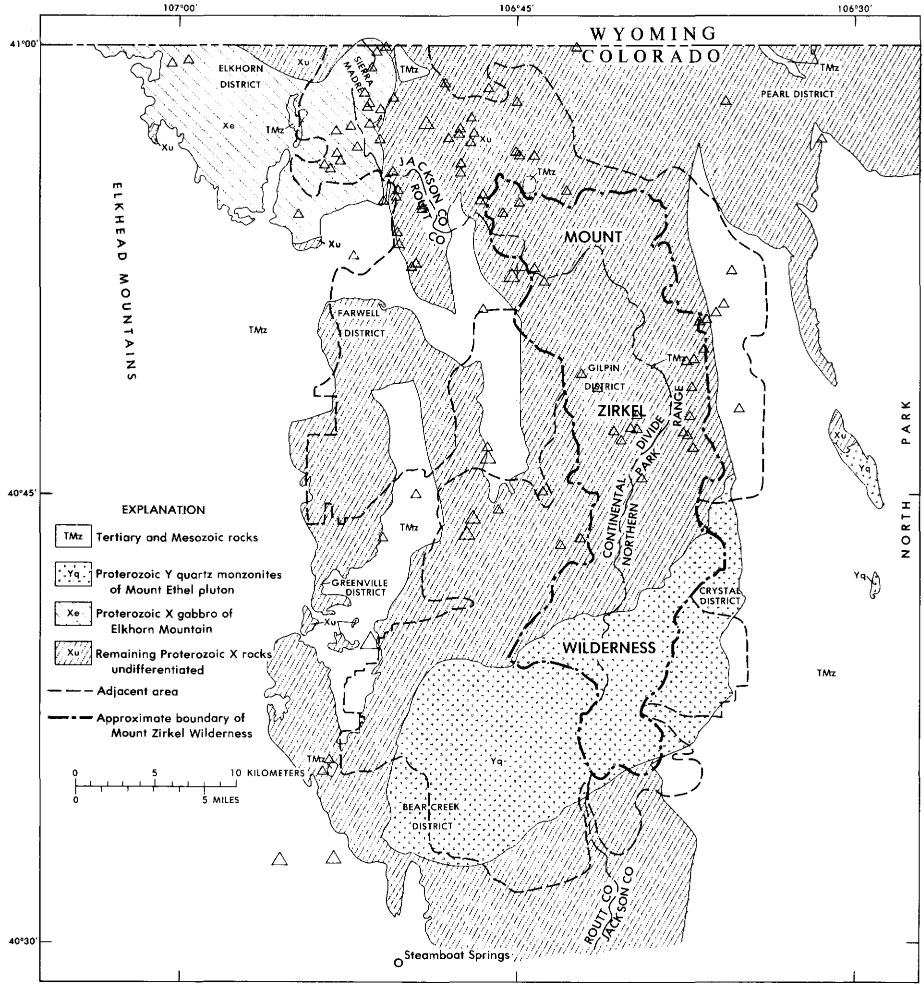


FIGURE 103.—Anomalous stream-sediment Spec V (spectrographic vanadium), Mount Zirkel area. Smallest symbol 300 ppm; intermediate 500 ppm; largest 700 ppm.

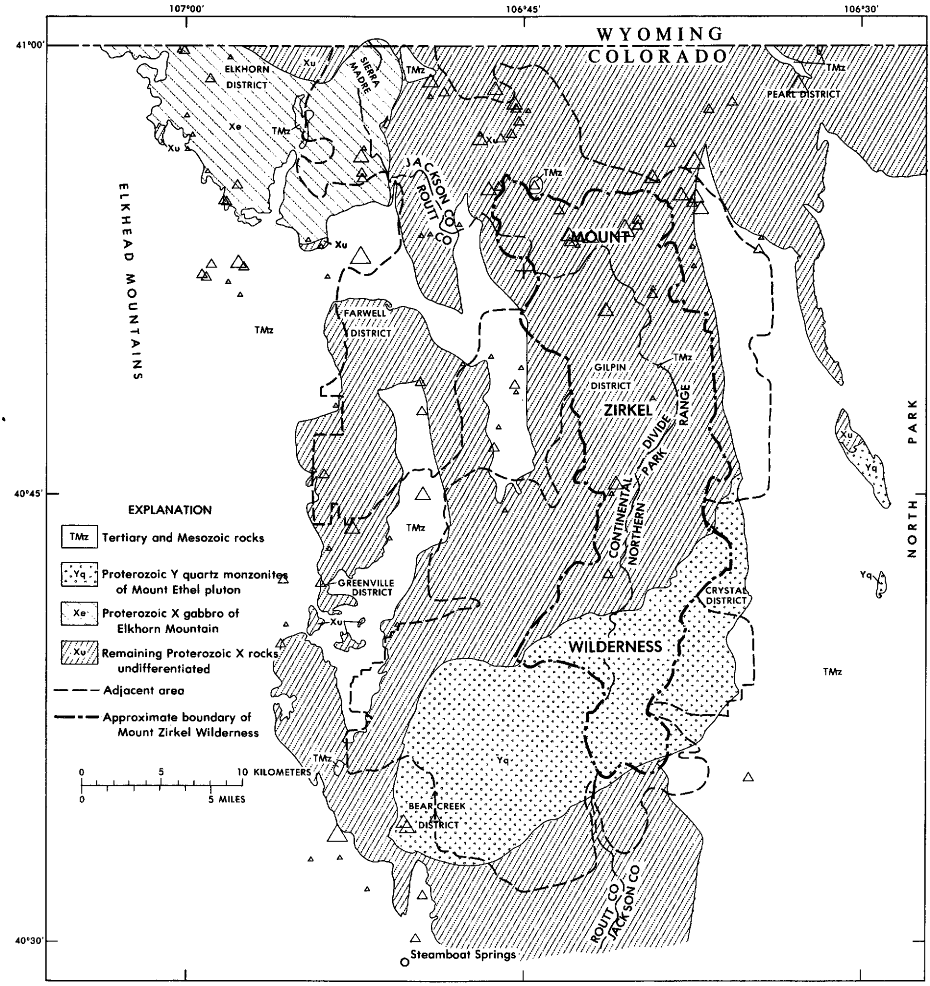


FIGURE 104.—Anomalous stream-sediment Spec Zr (spectrographic zirconium), Mount Zirkel area. Smallest symbol 500 ppm; next to smallest 700 ppm; next to largest 1,000 ppm; largest >1,000 ppm.

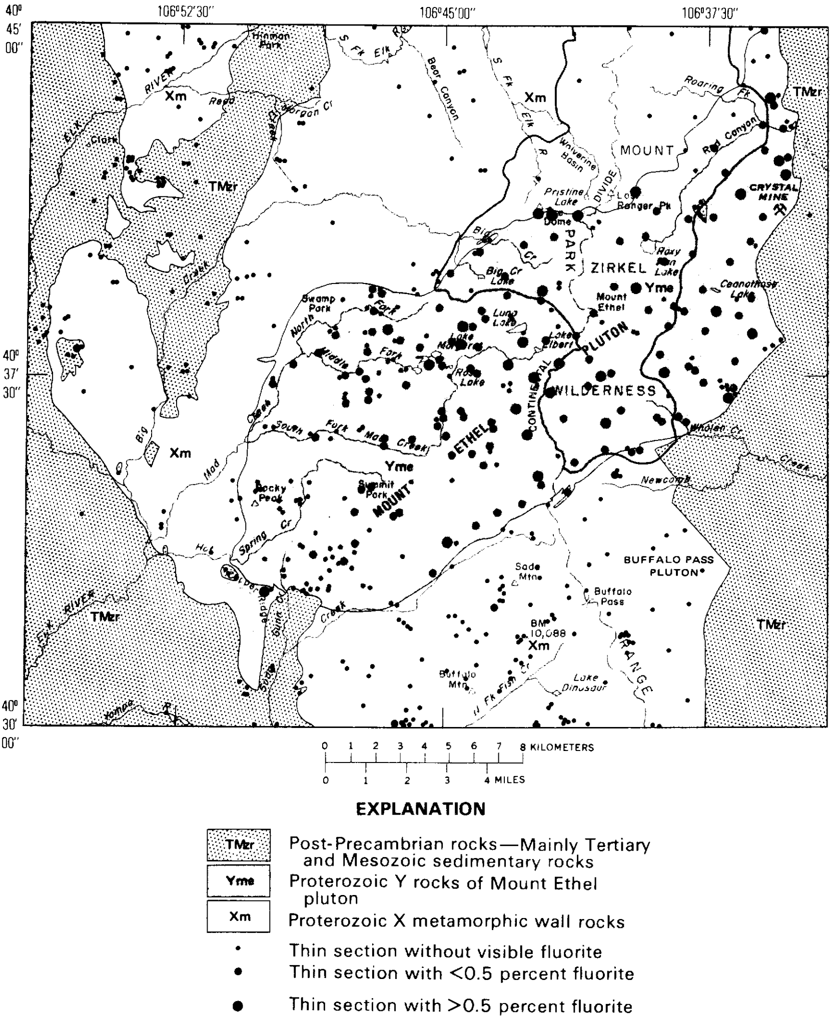


FIGURE 105.—Association of interstitial fluorite with rocks of the Mount Ethel pluton.

Geophysical Appraisal

By JEFFREY J. DANIELS, U.S. GEOLOGICAL SURVEY

MINERAL RESOURCES OF THE MOUNT ZIRKEL WILDERNESS AND NORTHERN PARK RANGE VICINITY, JACKSON AND ROUTT COUNTIES, COLORADO

U.S. GEOLOGICAL SURVEY BULLETIN 1554-D

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GEOPHYSICAL APPRAISAL

By JEFFREY J. DANIELS, U.S. GEOLOGICAL SURVEY[8]

INTRODUCTORY NOTE

Aeromagnetic surveys were made in the Mount Zirkel region by the U.S. Geological Survey in 1965 (U.S. Geological Survey, 1970) and 1972 (U.S. Geological Survey, 1981) as a part of the North Park aeromagnetic survey. The 1965 and 1972 surveys were flown at altitudes of 13,000 and 12,000 ft, respectively, above sea level. The base datum for the 1965 survey was 52,725 gammas. The 1972 survey was adjusted to this datum by adding 1,140 gammas to all map values. Results of these surveys are presented as a total-intensity magnetic map (pl. 1). The values on the map are the total magnetic intensities minus 52,725 gammas. Corrected values range from 3,100 gammas in the southern part of the adjacent area to 3,900 gammas in the northwestern part. Additionally, an induced polarization survey is available for the Hahns Peak area (Young and Segerstrom, 1973, p. 12).

MAGNETIC PROPERTIES

Table 12 shows magnetic susceptibility values for selected samples from pertinent rock units within the wilderness. The localities of these samples are indicated on plate 1. Because most of the samples were not oriented, the direction and intensity of remanent magnetization

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TABLE 12.—*Magnetic susceptibility values for selected rocks in the Mount Zirkel region*

[μCGS, micro-centimeter-gram-second units; to convert to current SI unit, multiply μCGS value by 4 π]

Rock group	Sample No.	Susceptibility (CGS units)
1.8 b.y. gabbros and mafic intrusives	1018	2,330
	1411	421
	1501-A	2,407
	1685	2,990
	1765	926
	1781	2,847
	1927	156
	1985	2,500
1.7 b.y. quartz monzonites	554	1,858
	555	1,703
	984	127
	985	141
	1066	40
	1067	199
	1068	51
	1290	14
	1525	133
	1676	9.12
	1827	204
1.4 b.y. quartz monzonites	437	3,839
	522	48
	524	4,271
	1023	834
	1097	512
Pelitic schists	1006	21.5
	1077	29.9
	1080	8,592
	1657	19.8
Other Precambrian metasedimentary and metavolcanic rocks	975	6,119
	987	56.7
	988-A	34.0
	989	10.7
	1014	5.39
	1029	5.92
	1065	6.69
	1148	54.5
	1285	678
	1298	624
	1388	25.4
	1643	80.3
	1849	18.2
	1854	38.9
	1970	55.2
Browns Park Formation	1243	165
	1244	213
	1707	88
	1708	8.69
	1782	57.2
	1919	142
	1961	8.08
	1979	19.1
	1980	12.5
	1983	8.98
Tertiary intrusives	19	1,620
	22	605
	226	4,160
	1691	2,381
	1693	2,058
	1808	44.9
	1813	2,035
	1819	70.8
	1896	2,120
	1958	13.3

could not be determined. The Precambrian mafic and ultramafic intrusive rocks have the highest magnetic susceptibilities as a group, but individual measured highs were from chloritized pelitic schist (No. 1080) and a gedrite gneiss (No. 975), both volumetrically minor. With the further exception of two hornblende gneisses (Nos. 1285, 1298), the rest of the Precambrian metasediments and metavolcanics gave low susceptibilities. The two highest measurements of the 1.7-b.y. quartz monzonites (Nos. 554, 555) are from Buffalo Mountain south of the Mount Ethel pluton. Similarly, the two highest susceptibility measurements on the 1.4-b.y. quartz monzonites (Nos. 437, 524) are near each other east of Swamp Park and on the flanks of anomaly M1 (pl. 1). Four Tertiary intrusives containing olivine (Nos. 226, 1691, 1693, 1896) averaged 2,680 susceptibility units, and six of more intermediate or silicic composition (Nos. 19, 22, 1808, 1813, 1819, 1958) averaged 732 susceptibility units. Four unaltered Browns Park sediments averaged 144 susceptibility units, whereas six red-oxidized Browns Park sediments (Nos. 1708, 1961, 1979, 1980, 1983) averaged 24 units.

INTERPRETATION OF AEROMAGNETIC DATA

The magnetic map generally reflects the surface and subsurface geology of this region, with topography having very little influence on the magnetic anomalies. Positive anomalies, related to intrusives, dominate the magnetic character of the area. Prominent evidence for faulting is in the northern part of the map area (about long 106°50′ W.). Northerly magnetic trends in this region may be caused either by faulting (for example, east of Silver City basin and west of Black Mountain) or by the large intrusive indicated by anomaly M4 (pl. 1). The prominent magnetic lineament that extends S. 60° W. from the northeast corner of the mapped area is apparently controlled by a zone of 1.7-b.y. quartz monzonite intrusives.

Anomaly M4 has a magnetic intensity of 600–700 gammas. This anomaly is almost certainly caused by the highly magnetic gabbro of Elkhorn Mountain. The northeastern extension of anomaly M4 accurately mirrors the northeastern extension of the gabbro of Elkhorn Mountain. Having anomaly M4 centered on the western exposed part of the gabbro batholith suggests that the gabbro body extends west and southwest under Tertiary cover by an amount roughly equal to its exposed mass. Gabbro inclusions in the City Mountain Tertiary intrusive 4.7 km (2.9 mi) southwest of the beginning of cover support this conclusion. Likewise, with this area exhibiting the largest quantity of red-altered Browns Park sediments, the contribution of the Tertiary cover to anomaly M4 must be minimal. No relation is apparent between this anomaly and topography. The gabbro of Elkhorn Mountain apparently also accounts for a gravity high on the Bouguer gravity map of Colorado (Behrendt and Bajwa, 1974).

Anomalies M1 and M2 are of special interest owing to their position in relation to the Mount Ethel pluton. Model studies indicate that the main source of these anomalies is at depth. A cross section (*A*–*A*′) of the anomaly and a three-dimensional model are shown on figure 106. Talwani's three-dimensional magnetics modeling program was used to generate the model. The estimated depths of M1 and M2, determined by Thalens Depth Rule (De Ridder, 1972), are 0.73 km (2,400 ft) and 0.91 km (3,000 ft) below the surface, which are considerably less than the depths determined from the model studies. However, as De Ridder pointed out, depths determined from "rules-of-thumb" are only approximate values. The model assumes a susceptibility contrast of

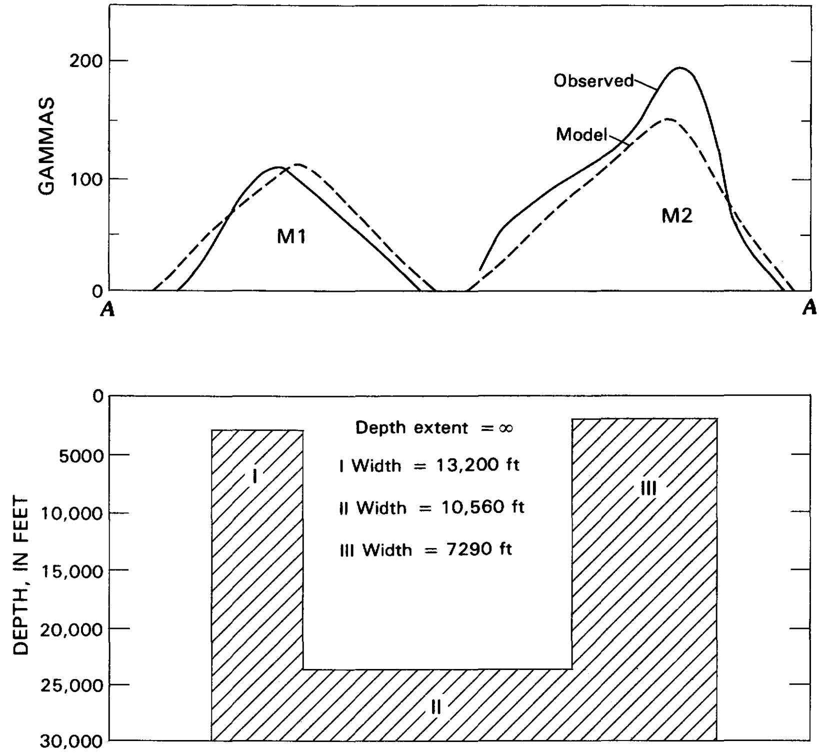
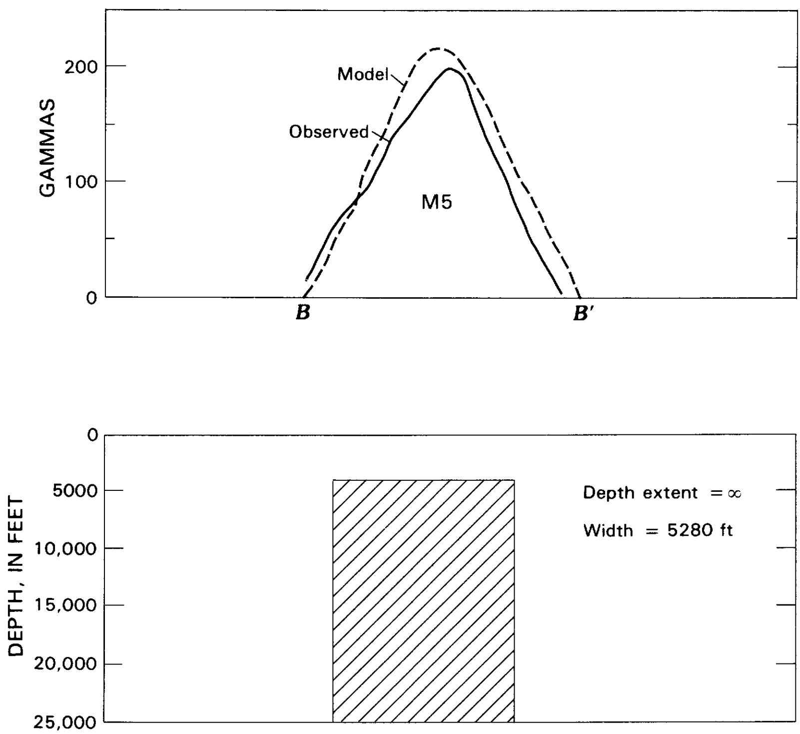


FIGURE 106 (above and facing page).—Cross sections of three-dimensional prismatic models for anomalies M1 and M2 (profile *A-A'*) and M5 (profile *B-B'*). Susceptibility contrast equals 2,000 μCGS units; to convert to current standard SI unit, multiply μCGS value by 4 π. I-III are like artificial rock masses having assigned susceptibility. Horizontal distances not drawn to scale.

2,000 μCGS units[9] between the "body" and the surrounding rock. A lower contrast would yield a shallower depth. The quartz monzonite porphyry (sample 437) or more mafic granodioritic rocks, like sample 551 (Snyder, 1978, table 5), are likely candidates (in terms of geology and volume) to have caused the 2,000 μCGS contrast. Quartz monzonite porphyry forms a highly irregular carapace around the north and west sides of the Mount Ethel pluton and could account not only for anomaly M1 but also for M3 and several anomalies between. Anomaly M3 also lies on the edge of the Mount Ethel pluton and has a Thalen-depth estimate of less than 1.16 km (3,800 ft) below the surface. The sources of anomalies M1, M2, and M3 all extend to depths

[9] μCGS units were the standard units when this report was prepared. To convert μCGS units to the current, SI unit, multiply μCGS value by 4 π.



of several kilometers. Anomaly M2 is also within the quartz monzonite porphyry carapace, but it happens to coincide with the surface exposure of a 1.6-km-long (1-mi-long) inclusion of a more mafic plutonic phase of dark granodiorite.

A cross section (*B–B′*) and the model generated for anomaly M5 are also shown on figure 106. The depth of this source as indicated by this model is 1.5 km (5,000 ft) below the surface. The susceptibility contrast assumed for this anomaly is also 2,000 μCGS units. The anomaly is centered on Big Agnes Mountain where felsic gneisses, pelitic schists, and granites are complexly interlayered and interfolded and many smaller intrusive bodies of pegmatite and ultramafic rock also occur. The anomaly is consistent with an ultramafic intrusive source at depth but could also be explained by a subsurface Tertiary intrusive.

From a minerals exploration point of view, anomalies M1 through M5 are all of interest. A pluton–country rock contrast associated with magnetic highs is a potentially mineralized area. Also, the faults east of anomaly M4 could give rise to mineralization. All of these are near the margin of the adjacent area, except M5, which is squarely in the center of the Mount Zirkel Wilderness.

SUMMARY EVALUATION OF MINERAL RESOURCE POTENTIAL

By GEORGE L. SNYDER, U.S. GEOLOGICAL SURVEY

There is a good possibility of a substantial mineral resource underlying part of the Mount Zirkel Wilderness and adjacent area. Water is ubiquitous, abundantly utilized, and renewable—the only renewable mineral resource. Fluorite is the main nonrenewable *surface* resource that is presently mineable, largely in the Crystal district overlapping the wilderness boundary and on Delaney Butte. Other possible *subsurface* mineral resources are less certain but could be much more valuable. (In the following discussion a *surface* resource is defined as one exposed in bedrock at the ground surface or buried beneath a thin layer of soil or rock, whereas a *subsurface* resource is defined as that enclosed in bedrock as much as several miles deep but capable of being utilized by man from surface workings, if it can be found.)

Potential *surface* mineral resources, shown on figure 109*A*, are based on observations in surface outcrops or prospect pits or on geochemical anomalies in surface rocks or stream sediments. Many are described in greater detail in the preceding sections on mine appraisal and geochemical appraisal, in tables 5, 6, and 8, and on figures 52–104. Geochemical maxima are highlighted on figures 107 and 108. Most areas are small and scattered, mainly near the fringes of the wilderness or adjacent area, but some, for example the Gilpin district (figs. 3, 14, 36), are squarely in the center of the most scenic part of the wilderness. The high fluorite potential and active geothermal areas are based on field observations, whereas the moderate base- and precious-metal potential, low uranium-thorium potential, and low platinum-chromium potential are based on geochemical anomalies.

Potential *subsurface* mineral resources, shown on figure 109*B*, are untested but could be substantial; they are based partly on figure 109*A* and partly on both a detailed knowledge of local geology and a broad knowledge of distant but geologically similar producing mineral provinces. There is a moderate to high subsurface fluorite potential anywhere within the steep-sided 1.4-b.y. Mount Ethel pluton (fig. 105), where the common interstitial fluorite (Snyder, 1978) could have been easily concentrated along joint sets, fault planes, or fault breccia zones that penetrated these rocks. Three belts of high copper–lead–zinc–silver–gold potential are shown on figure 109*B*, controlled by the bedrock geochemical anomalies and mines of figure 109*A* and the northeastward grain of both the mapped geologic units and some geophysical lineaments. (Some stream-sediment geochemistry suggests that the southern two belts may merge with each other.) Ores in the northern two of these three belts would all be within 3.2 km (2 mi) of the contact of a 1.7-b.y. granite body, which might have served as the concentrating engine for the ore elements; most ores in the southern belt seem to have been controlled by calc-silicate or marble beds as favorable replacement horizons. The judgment that there is high potential for a deeply buried base- and precious-metal sulfide deposit within these geochemically favorable belts is based on the

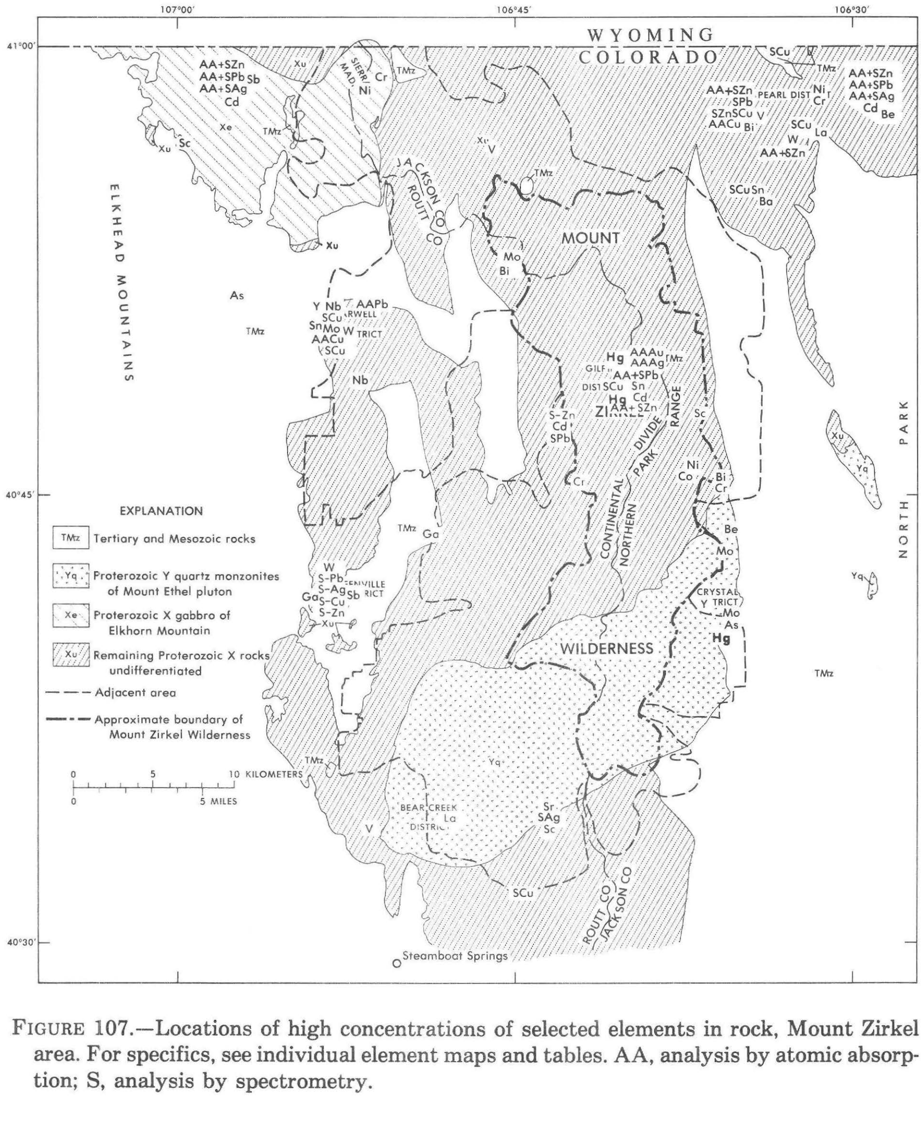


FIGURE 107.—Locations of high concentrations of selected elements in rock, Mount Zirkel area. For specifics, see individual element maps and tables. AA, analysis by atomic absorption; S, analysis by spectrometry.

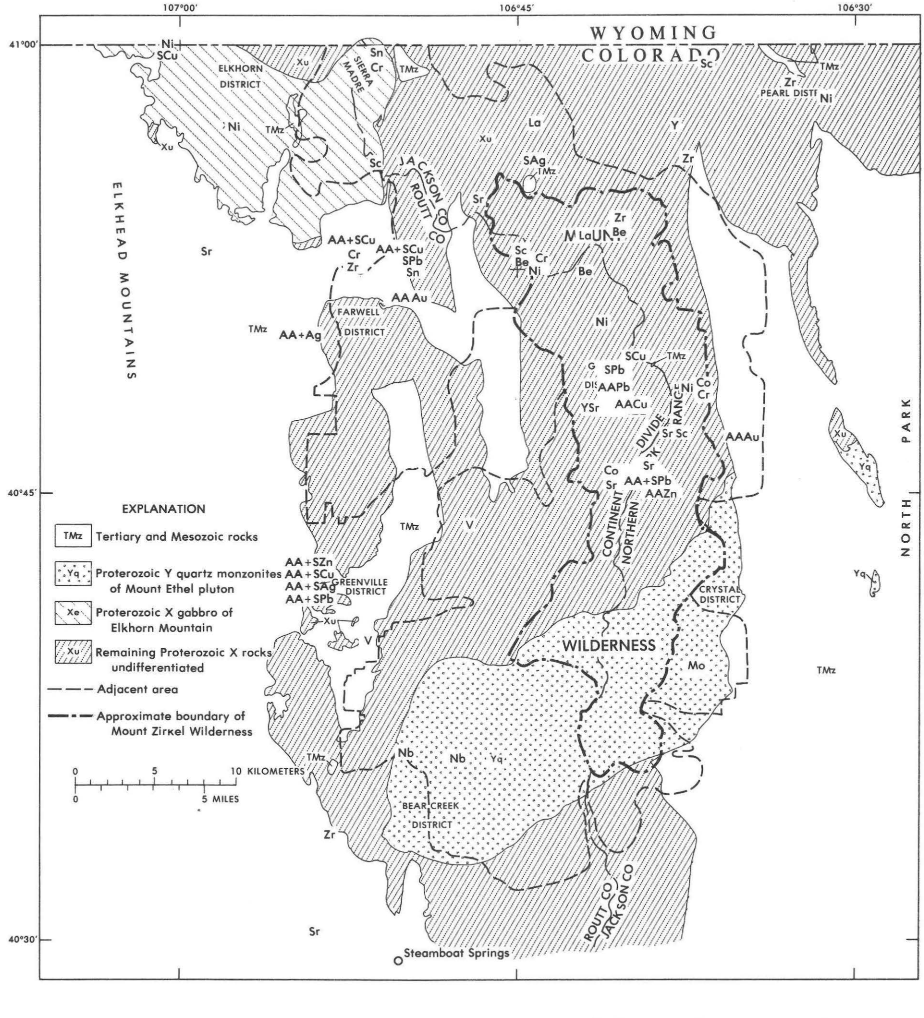


FIGURE 108.—Locations of high concentrations of selected elements in stream sediment, Mount Zirkel area. For specifics, see individual element maps and tables. AA, analysis by atomic absorption; S, analysis by spectrometry.

knowledge that many such massive sulfide deposits occur throughout the world in marine metasediments and metavolcanics of this (1.8 b.y.) age; for example, Mount Isa and Broken Hill, Australia; the Kidd Creek mine at Timmins, Ontario; McArthur River, Canada; Outukumpu, Finland; the United Verde mine at Jerome, Ariz., and the recent Exxon and Bear Creek finds in Wisconsin. Two areas of low platinum-chromium potential are indicated on figure 109*B*. One, based on the largest peridotite intrusive on the ridge between Lone Pine

Creek and Bear Creek, is here extended north to include the high cobalt and chromium stream-sediment anomalies measured on streams issuing from beneath rock glaciers between Ute Lake and Twin Lake. The other, essentially the area of the gabbro of Elkhorn Mountain, is included for completeness. Funnel-shaped layered gabbro bodies this size throughout the world are known to have a potential for magmatically segregated platinum–chromium ores. Here, there is no geological or geochemical indication of such magmatically segregated gabbroic layering, so the potential for a buried resource is judged to be low. Three low-potential uranium-thorium areas are indicated near the boundaries of the wilderness or adjacent area on figure 109*B*, and another is included within the molybdenum-potential area near the Crystal district. All of these are based on uranium, thorium, beryllium, niobium, or lanthanum geochemical anomalies. Though the potential is low, a large low-grade Rössing-type deposit beneath the indicated areas might be economically leachable. A linear belt of low molybdenum potential is shown from the Gilpin district through the Crystal district to east of Steamboat Springs. Based mainly on anomalous instrumental mercury, this belt nevertheless includes some anomalous molybdenum, the fluorite veins of the Crystal district and some uranium and thorium maxima; the northern part of the belt also includes aeromagnetic anomalies M3 and M5, which have no ready explanation in the surface geology and could be revealing the tops of deeply buried Tertiary intrusive pipes. Such a geochemical suite characterizes molybdenum-bearing carapaces near the tops of Tertiary porphyry vertical cylindrical intrusives in the Western United States—for example, the Climax and Henderson deposits in Colorado. Although no Tertiary intrusives occur at the surface in this part of the Park Range, such rocks are present both southeast and northwest of this geochemical belt. It may be pertinent to note that neither of the recently discovered valuable molybdenum deposits at Mount Emmons, Crested Butte, Colo., or Pine Grove, Utah, were exposed at the surface or had much of a geochemical anomaly. Although the potential for a similar Park Range deposit is judged to be low, the implications of such a deposit beneath the wilderness would be profound. A moderate geothermal potential is indicated in a north-south zone enclosing Steamboat Springs, but this is outside of the adjacent area. There is no potential for coal at all, and only low potential for oil and gas, largely in undrilled thrust-faulted Precambrian areas overlying apparently dry Mesozoic anticlines near the western boundary of the adjacent area. Other commodities or elements of possible economic interest are known to be present but in concentrations far smaller than would justify mining.

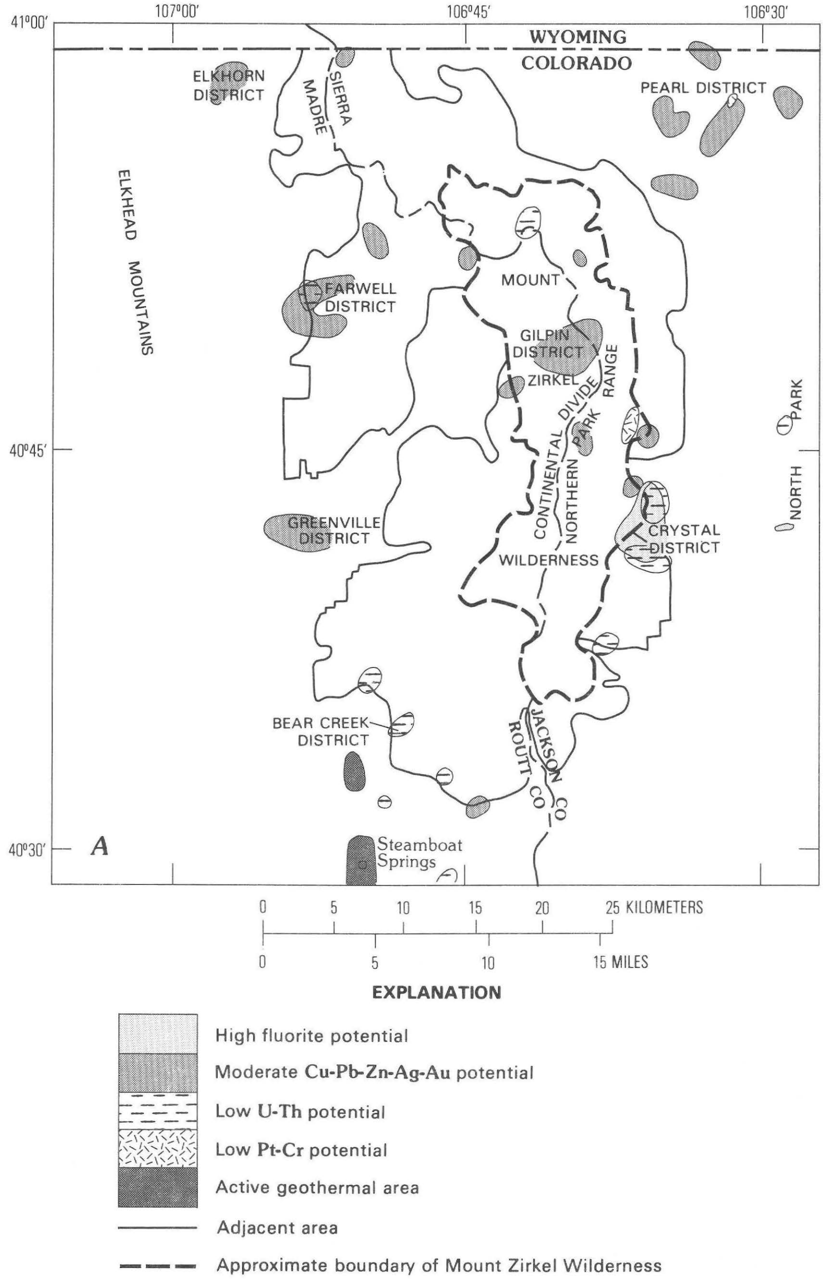
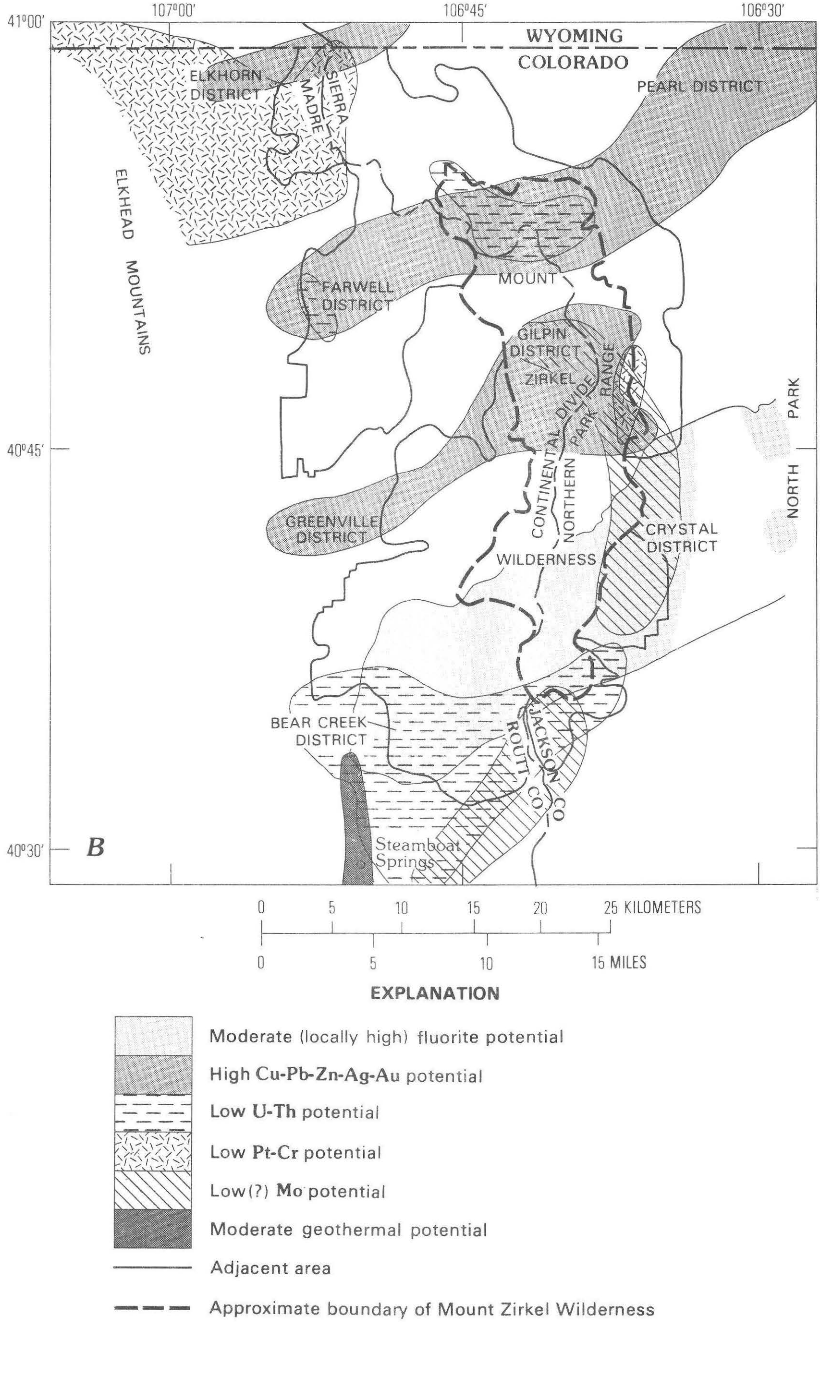


FIGURE 109 (above and facing page).—Map of Mount Zirkel Wilderness and adjacent area, showing areas of *A*, surface, and *B*, subsurface mineral resource potential. (Entire area has high water-resource potential.)


107°00'
106°45'
106°30'
41°00'
40°45'
40°30'
WYOMING
COLORADO
PEARL DISTRICT
ELKHORN DISTRICT
SIERRA MADRE
ELKHEAD MOUNTAINS
FARWELL DISTRICT
MOUNT
GILPIN DISTRICT
ZIRKEL
CONTINENTAL DIVIDE
RANGE
PARK
NORTHERN
NORTH PARK
GREENVILLE DISTRICT
CRYSTAL DISTRICT
WILDERNESS
BEAR CREEK DISTRICT
ROUTT CO
JACKSON CO
Steamboat Springs
B
0 5 10 15 20 25 KILOMETERS
0 5 10 15 MILES
EXPLANATION
Moderate (locally high) fluorite potential
High Cu-Pb-Zn-Ag-Au potential
Low U-Th potential
Low Pt-Cr potential
Low(?) Mo potential
Moderate geothermal potential
Adjacent area
Approximate boundary of Mount Zirkel Wilderness

Except for water, no large high-grade economically interesting mineral deposits are present anywhere at the surface in the study area. However, subeconomic surface deposits outlined by this report could guide others in more detailed searches for valuable subsurface resources, a step encouraged by the Congress of the United States in the Mining and Minerals Policy Act of 1970 (Osborn, 1974, p. 16, 17).

REFERENCES CITED

Abbott, J. T., 1972, Rb-Sr study of isotopic redistribution in a Precambrian mylonite-bearing shear zone, northern Front Range, Colorado: Geological Society of America Bulletin, v. 83, no. 2, p. 487–493.

Adams, J. W., 1964, Pegmatite minerals, *in* Mineral and water resources of Colorado: Washington, U.S. Government Printing Office, p. 169–173.

Amstutz, G. C., 1964, Introduction *to* Developments in sedimentology, volume 2 *of* Sedimentology and ore genesis: Amsterdam, Netherlands, Elsevier, p. 1–7.

Anderson, C. A., and Creasey, S. C., 1958, Geology and ore deposits of the Jerome area, Yavapai County, Arizona: U.S. Geological Survey Professional Paper 308, 185 p.

Anderson, C. A., and Nash, J. T., 1972, Geology of the massive sulfide deposits at Jerome, Arizona—A reinterpretation: Economic Geology, v. 67, p. 845–863.

Antweiler, J. C., 1966, Isotopic evidence of Precambrian episodes of mineralization in Colorado: Geological Society of America Abstracts for 1965, Special Paper 87, p. 270, 271.

Antweiler, J. C., Doe, B. R., and Delevaux, M. H., 1972, Lead isotope and other evidence on the bedrock source of placer gold at Hahns Peak, Colorado: Economic Geology, v. 67, p. 302–314.

Atwood, W. W., Jr., 1937, Records of Pleistocene glaciers in the Medicine Bow and Park Ranges [Wyoming and Colorado]: Journal of Geology, v. 45, no. 2, p. 113–140.

Ball, M. W., and Stebinger, Eugene, 1910, Eastern part of the Little Snake River coal field, Wyoming: U.S. Geological Survey Bulletin 381, p. 186–213.

Barclay, C. S. V., 1968, Geology of the Gore Canyon–Kremmling area, Grand County, Colorado: U.S. Geological Survey Open-File Report.

Barnwell, W. W., 1955, The geology of the south Hahns Peak district: Laramie, Wyo., University of Wyoming M.A. thesis, 91 p.

Bass, N. W., Eby, J. B., and Campbell, M. R., 1955, Geology and mineral fuels of parts of Routt and Moffat Counties, Colorado: U.S. Geological Survey Bulletin 1027–D, 250 p.

Beekly, A. L., 1915, Geology and coal resources of North Park, Colorado: U.S. Geological Survey Bulletin 596, 121 p.

Behrendt, J. C., and Bajwa, L. Y., 1974, Bouguer gravity map of Colorado: U.S. Geological Survey Geophysical Investigations Map GP–895.

Behrendt, J. C., and Popenoe, Peter, 1969, Basement structure contour map of North Park–Middle Park basin, Colorado: American Association of Petroleum Geologists Bulletin, v. 53, no. 3, p. 678–682.

Behrendt, J. C., Popenoe, Peter, and Mattick, R. E., 1969, A geophysical study of North Park and the surrounding ranges, Colorado: Geological Society of America Bulletin, v. 80, p. 1523–1528.

Bernard, A. J., 1973, A review of processes leading to the formation of mineral deposits in sediments, *in* Amstutz, G. C., and Bernard, A. J., eds., Ores in sediments: International Union of Geological Sciences, ser. A, no. 3, p. 16.

Beroni, E. P., and Derzay, R. C., 1955, The uranium deposits of the Fish Creek district, Colorado, *in* Guidebook to the geology of northwest Colorado: Intermountain Association of Petroleum Geologists and Rocky Mountain Association of Geologists, p. 123.

Beroni, E. P., and McKeown, F. A., 1952, Reconnaissance for uraniferous rocks in northwestern Colorado, southwestern Wyoming, and northeastern Utah: U.S. Geological Survey Trace Elements Investigations Report 308-A, 41 p.

Blackstone, D. L., Jr., 1977, Independence Mountain thrust fault, North Park basin, Colorado: Laramie, Wyo., University of Wyoming Contributions to Geology, v. 16, no. 1, 15 p.

Boyle, R. W., 1970, The source of metals and gangue elements in hydrothermal deposits, *in* Pouba, Zdeněk, and Štemprok, Miroslav, eds., Problems of hydrothermal ore deposition: International Union of Geological Sciences, ser. A, no. 2, p. 3–6.

Brady, B. T., 1975, Map showing fluorspar deposits in Colorado: U.S. Geological Survey Mineral Investigations Resources Map MR-70, 10 p.

Brobst, D. A., and Pratt, W. P., 1973a, Summary of United States mineral resources: U.S. Geological Survey Circular 682, 19 p.

Brobst, D. A., and Pratt, W. P., eds., 1973b, United States mineral resources: U.S. Geological Survey Professional Paper 820, 722 p.

Buckner, D. L., 1977, Ribbon forest development and maintenance in the central Rocky Mountains of Colorado: Boulder, Colo., University of Colorado Ph. D. thesis, 239 p.

Buffler, R. T., 1967, The Browns Park Formation and its relationship to late Tertiary geologic history of the Elkhead region, northwestern Colorado-south central Wyoming: Berkeley, Calif., University of California Ph. D. thesis; available Ann Arbor, Mich., University Microfilms, Inc., 215 p.

Christensen, A. L., 1942, Igneous geology of the Elkhead Mountains, Colorado: Berkeley, Calif., University of California Ph. D. thesis, 180 p.

Clark, S. P., Jr., Peterman, Z. E., and Heier, K. S., 1966, Abundances of uranium, thorium and potassium, *in* Handbook of physical constants: Geological Society of America Memoir 97, p. 521–541.

Colton, R. G., Holligan, J. A., Patterson, P. E., and Anderson, L. W., 1975, Preliminary map of landslide deposits, Craig 1°× 2° quadrangle, Colorado: U.S. Geological Survey Mineral Investigations Field Studies Map MF-700.

Crawford, R. D., Wilson, K. M., and Perini, V. C., Jr., 1920, Some anticlines of western Colorado: Colorado Geological Survey Bulletin 23, 61 p.

de la Montagne, John, 1955, Cenozoic history of the Saratoga valley area, Wyoming and Colorado: Laramie, Wyo., University of Wyoming Ph. D. thesis, 140 p.

De Nault, K. J., 1967, Geology and distribution of copper, lead, and zinc in streams and soil—Broadway mine area, Carbon County, Wyoming: Laramie, Wyo., University of Wyoming M.S. thesis, 38 p.

DeRidder, Edward, 1972, The relative accuracy of some magnetic depth determination techniques: Golden, Colo., Colorado School of Mines M.S. thesis T-1488, 78 p.

Divis, A. F., 1975, The geology and geochemistry of the Sierra Madre Mountains, Wyoming: San Diego, Calif., University of California Ph. D. thesis.

______1976, Geology and geochemistry of Sierra Madre Range, Wyoming: Quarterly of the Colorado School of Mines, v. 71, no. 3, 127 p.

______1977, Isotope studies on a Precambrian geochronologic boundary, Sierra Madre Mountains, Wyoming: Geological Society of America Bulletin, v. 88, p. 96–100.

Doe, B. R., 1978, The application of lead isotopes to mineral prospect evaluation of Cretaceous-Tertiary magmatothermal ore deposits in the Western United States [abs.]: Association of Exploration Geochemists, Seventh International Geochemists Exploration Symposium, Program, p. 35–37.

Ebbett, B. E., 1970, Geologic maps of the Singer Peak, Encampment, Red Mountain, and Bridger Peak quadrangles: Laramie, Wyo., Geological Survey of Wyoming open-file maps.

Eckel, E. B., 1961, Minerals of Colorado—A 100-year record: U.S. Geological Survey Bulletin 1114, 399 p.

Fenneman, N. M., and Gale, H. S., 1906, The Yampa coal field, Routt County, Colorado: U.S. Geological Survey Bulletin 297, 96 p.

Fenton, M. D., 1965, The geology of parts of Mad Creek, Clark, Floyd Peak quadrangles, Routt County, Colorado: Laramie, Wyo., University of Wyoming M.S. thesis, 39 p.

Ferris, C. S., Jr., 1964, Petrology and structure of the Precambrian rocks southeast of Encampment, Wyoming: Laramie, Wyo., University of Wyoming Ph. D. thesis.

Gabelman, J. W., 1976, Strata-binding mineralization processes, *in* Wolf, K. H., ed., Handbook of strata-bound and strataform ore deposits, volume 4, Tectonics and metamorphism: Amsterdam, Netherlands, Elsevier, p. 31–73.

Gale, H. S., 1906, Hahns Peak gold field: U.S. Geological Survey Bulletin 285, p. 28–34.

______1909, Coal fields of northwestern Colorado and northeastern Utah: U.S. Geological Survey Bulletin 341, p. 283-315.

______1910, Coal fields of northwestern Colorado and northeastern Utah: U.S. Geological Survey Bulletin 415, 265 p.

George, R. D., and Crawford, R. D., 1909, Hahns Peak region, Routt County, Colorado: Colorado Geological Survey 1st Report, p. 189-229.

Godwin, L. H., Haigler, L. B., Rioux, R. L., White, D. E., Muffler, L. J. P., and Wayland, R. G., 1971, Classification of public lands valuable for geothermal steam and associated geothermal resources: U.S. Geological Survey Circular 647, 18 p.

Goldschmidt, V. M., 1954, Geochemistry: London, Oxford University Press, 730 p.

Graff, Paul, 1973, The areal geology of the West Fork Lake quadrangle, northern Colorado: De Kalb, Ill., Northern Illinois University M.S. thesis, 59 p.

______1978, Geology of the lower part of the Early Proterozoic Snowy Range Supergroup, Sierra Madre, Wyoming, with chapters on Proterozoic regional tectonics and uraniferous quartz-pebble conglomerates: Laramie, Wyo., University of Wyoming Ph. D. thesis, 85 p.

Grim, P. J., 1977, [Map of] Geothermal energy resources of the Western United States: National Geophysical and Solar-Terrestrial Data Center, National Oceanic and Atmospheric Administration.

Grout, F. F., Worcester, P. G., and Henderson, Junius, 1913, Reconnaissance of the geology of the Rabbit Ears region, Routt, Grand and Jackson Counties, Colorado: Colorado Geological Survey Bulletin 5, pt. 1, 57 p.

Grutt, E. W., Jr., and Whalen, J. F., 1955, Uranium in northern Colorado and southern Wyoming, *in* Guidebook to the geology of northwest Colorado: Intermountain Association of Petroleum Geologists and Rocky Mountain Association of Geologists, p. 126–129.

Hail, W. J., Jr., 1965, Geology of northwestern North Park, Colorado: U.S. Geological Survey Bulletin 1118, 133 p.

______1968, Geology of southwestern North Park and vicinity, Colorado: U.S. Geological Survey Bulletin 1257, 119 p.

Hedge, C. E., Houston, R. L., Tweto, Ogden, Reid, R. R., Harrison, J. E., and Peterman, Zell, 1977, The Precambrian of the Rocky Mountain region: Geological Society of America Abstracts with Programs, v. 9, no. 7, p. 1010.

Hewett, G. C., 1889, The northwestern Colorado coal region: American Institute of Mining Engineers Transactions, v. 17, p. 375-380.

Hill, J. J., 1969, Petrology and structure of the Precambrian rocks of the Park Range of north-central Colorado: Eugene, Oreg., University of Oregon M.S. thesis, 75 p.

Hills, F. A., Gast, P. W., Houston, R. S., and Swainbank, I. G., 1968, Precambrian geochronology of the Medicine Bow Mountains, southeastern Wyoming: Geological Society of America Bulletin, v. 79, p. 1757-1784.

Hills, F. A., and Houston, R. S., 1979, Early Proterozoic tectonics of the Central Rocky Mountains, North America: Laramie, Wyo., University of Wyoming Contributions to Geology, v. 17, no. 2, p. 89-109.

Hills, R. C., 1893, Coal fields of Colorado: U.S. Geological Survey Mineral Resources of the United States, 1892, p. 319-365.

Houston, R. S., and others, 1968, A regional study of rocks of Precambrian age in that part of the Medicine Bow Mountains lying in southeastern Wyoming—with a chapter on the relationship between Precambrian and Laramide structure: Wyoming Geological Survey Memoir 1, p. 1-167.

Houston, R. S., and Ebbett, B. E., 1977, Geologic map of the Sierra Madre and western Medicine Bow Mountains, southeastern Wyoming: U.S. Geological Survey Map MF-827.

Houston, R. S., Karlstrom, K. E. [incorrectly listed as Karl E. Strom on cover], and Graff, P. J., 1979, Progress report on the study of radioactive quartz-pebble conglomerate of the Medicine Bow Mountains and Sierra Madre, southeastern Wyoming [incorrectly listed as southeastern Montana on cover]: U.S. Geological Survey Open-File Report 79-1131, 43 p.

Houston, R. S., Schuster, J. E., and Ebbett, B. E., 1975, Preliminary report on the distribution of copper and platinum group metals in mafic igneous rocks of the Sierra Madre, Wyoming: U.S. Geological Survey Open-File Report 75-85, 129 p.

Huang, Chi-I, 1970, Cataclastic rocks in the Little Beaver Creek area, Carbon County, Wyoming: Laramie, Wyo., University of Wyoming M.S. thesis, 63 p.

Hunter, J. M., 1955, Geology of the north Hahns Peak area, Routt County, Colorado: Laramie, Wyo., University of Wyoming M.A. thesis, 77 p.

Izett, G. A., 1975, Late Cenozoic sedimentation and deformation in northern Colorado and adjoining areas, *in* Cenozoic history of the Southern Rocky Mountains: Geological Society of America Memoir 144, p. 179-209.

Izett, G. A., and Barclay, C. S. V., 1973, Geologic map of the Kremmling quadrangle, Grand County, Colorado: U.S. Geological Survey Geologic Quadrangle Map GQ-1115.

Izett, G. A., Cobban, W. A., and Gill, J. R., 1971, The Pierre Shale near Kremmling, Colorado, and its correlation to the east and the west: U.S. Geological Survey Professional Paper 684-A, p. A1-A19.

Izett, G. A., Denson, N. M., and Obradovich, J. D., 1970, K-Ar age of the lower part of the Browns Park Formation, northwestern Colorado: U.S. Geological Survey Professional Paper 700-C, p. C150-C152.

Jensen, M. L., and Bateman, A. M., 1979, Economic mineral deposits, 3d edition: New York, John Wiley, 593 p.

Johnson, R. B., Jr., 1979, Structural and stratigraphic controls on Precambrian Pb-Zn-Cu type mineralization at the Greenville mine, Clark, Colorado: Geological Society of America Abstracts with Programs, v. 11, no. 6, p. 275.

King, Clarence, 1878, Report of the geological exploration of the fortieth parallel, v. I, Systematic geology: U.S. Army Professional Papers of the Engineer Department, No. 18, 803 p.

Kucera, R. E., 1962, Geology of the Yampa district, northwest Colorado: Boulder, Colo., University of Colorado Ph. D. thesis, 675 p.

Lackey, L. L., 1965, Petrography of metavolcanic and igneous rocks of Precambrian age in the Huston Park area, Sierra Madre, Wyoming: Laramie, Wyo., University of Wyoming M.A. thesis, 78 p.

Lamarre, A. L., and Hodder, R. W., 1978, Distribution and genesis of fluorite deposits in the Western United States and their significance to metallogeny: Geology, v. 6, no. 4, p. 236–238.

Larson, E. E., Ozima, Minoru, and Bradley, W. C., 1975, Late Cenozoic basic volcanism in northwestern Colorado and its implications concerning tectonism and the origin of the Colorado River system, *in* Cenozoic history of the Southern Rocky Mountains: Geological Society of America Memoir 144, p. 155–178.

Larson, T. G., 1955, Stratigraphy of the Steamboat Springs area, Colorado, *in* Intermountain Association of Petroleum Geologists (and Rocky Mountain Association of Geologists) Guidebook, 6th Annual Field Conference, 1955: p. 10, 11.

Lovering, T. S., 1963, Epigenetic, diplogenetic, syngenetic, and lithogene deposits: Economic Geology, v. 58, p. 315–331.

Madden, D. H., 1977a, Exploratory drilling in the Coalmont coal field, Jackson County, Colorado: U.S. Geological Survey Open-File Report 77-887, 138 p.

_____1977b, Exploratory drilling in the McCallum coal field, Jackson County, Colorado: U.S. Geological Survey Open-File Report 77–788, 80 p.

Madole, R. F., 1982, Surficial geologic map of the Craig ½°×1° quadrangle, Moffat and Routt Counties, Colorado: U.S. Geological Survey Miscellaneous Investigations Series Map I-1346.

Malan, R. C., 1957, Geology of uranium occurrences in North and Middle Parks, Colorado: Guidebook to the geology of North and Middle Parks Basin, Colorado; Rocky Mountain Association of Geologists, p. 126–136.

McCallum, M. E., 1968, Cenozoic history of the East-Central Medicine Bow Mountains, Wyoming: Mountain Geologist, v. 5, no. 2, p. 69–81.

McConnell, M. D., 1960, The geology of the Clark–Hinman Park area, Routt County, Colorado: Laramie, Wyo., University of Wyoming M.A. thesis, 71 p.

McDowell, F. W., 1966, Potassium-argon dating of Cordilleran intrusives: New York, Columbia University Ph. D. thesis, p. 6, 221.

Merry, R. D., 1963, Precambrian geology, shear zones and associated mineral deposits of the Hog Park area, Carbon County, Wyoming: Laramie, Wyo., University of Wyoming M.S. thesis, 73 p.

Millard, H. T., 1976, Determination of uranium and thorium in U.S.G.S. standard rocks by the delayed neutron technique, *in* Flanagan, F. J., ed., Descriptions and analyses of eight new U.S.G.S. rock standards: U.S. Geological Survey Professional Paper 840, p. 61–65.

Miller, W. R., 1971, Geology of the Indian Rocks area, Carbon County, Wyoming, with particular reference to the evolution of mafic dikes: Laramie, Wyo., University of Wyoming M.S. thesis, 40 p.

Morse, J. G., and Curtin, M. S., 1977, CERI Colorado energy resources handbook, volume 3, Uranium: Golden, Colo., Colorado School of Mines, 68 p.

Murphy, R. W., 1958, Geology of the Slavonia–Diamond Park area, Routt County, Colorado: Laramie, Wyo., University of Wyoming M.A. thesis, 54 p.

Oriel, S. S., 1954, Tectonic map of Colorado, *in* The oil and gas fields of Colorado: Denver, Colo., Rocky Mountain Association of Geologists, pl. 1.

Osborn, E. F., 1974, Our mineral resource problem and what we can do about it (Edward H. Draus memorial lecture, Ann Arbor, Mich., University of Michigan, September 12, 1974): Carnegie Institution of Washington Geophysical Laboratory Paper 1652, 17 p.

Osterwald, F. W., and Dean, B. G., 1958, Preliminary tectonic map of northern Colorado and northeastern Utah showing the distribution of uranium deposits: U.S. Geological Survey Mineral Investigations Field Studies Map MF–130.

_____1961, Relation of uranium deposits to tectonic pattern of the central Cordilleran foreland: U.S. Geological Survey Bulletin 1087–I, p. 337–390.

Park, G. M., 1977, Oil potential of Mesozoic sediments beneath the Independence Mountain thrust fault, North Park, Colorado, *in* Exploration frontiers of the Central and Southern Rockies: Rocky Mountain Association of Geologists, 1977 Symposium, p. 61-66.

Parsons, H. F., and Liddell, C. A., 1903, Coal and mineral resources of Routt County: Colorado School of Mines Bulletin 1, no. 4, p. 47-59.

Peterman, Z. E., and Hedge, C. E., 1967, Precambrian history of the Front Range and adjacent areas, Colorado, *in* Geochronology of Precambrian stratified rocks: Geochronology Commission, I.U.G.S., Canada Geological Survey, and Department of Geology, Alberta University, p. 77-78.

Peterman, Z. E., Hedge, C. E., and Braddock, W. A., 1968, Age of Precambrian events in the northeastern Front Range, Colorado: Journal of Geophysical Research, v. 73, no. 6, p. 2227-2296.

Popenoe, Peter, Brinkworth, G. L., Worl, R. G., and Behrendt, J. C., 1970, Geophysical lineations in north-central Colorado and their possible relationship to Tertiary plutonic activity: Geological Society of America Abstracts, v. 2, no. 5, p. 343.

Price, Don, and Arnow, Ted, 1974, Summary appraisals of the Nation's ground-water resources—Upper Colorado region: U.S. Geological Survey Professional Paper 813-C, 40 p.

Read, T. T., 1903, Nodular-bearing schists near Pearl, Colorado: Journal of Geology, v. 11, p. 493-497.

Renner, J. L., White, D. E., and Williams, D. L., 1975, Hydrothermal convection systems, *in* Assessment of geothermal resources of the United States, 1975: U.S. Geological Survey Circular 726, p. 5-57.

Ridge, J. D., 1976, Origin, development, and changes in concepts of syngenetic ore deposits as seen by North American geologists, *in* Wolf, K. H., ed., Handbook of strata-bound and stratiform ore deposits, volume 1, Classifications and historical studies: Amsterdam, Netherlands, Elsevier, p. 183-297.

Ridgely, N. H., 1971, Precambrian rocks in the Blackhall Mountain area, Carbon County, Wyoming: Laramie, Wyo., University of Wyoming M.S. thesis, 50 p.

Ritzma, H. R., 1949, Geology along the southwest flank of the Sierra Madre, Carbon County, Wyoming: Laramie, Wyo., University of Wyoming M.A. thesis, 77 p.

Rollins, J. F., 1952, Stratigraphy and structure of the Sheep Mountain area, in North Park, Jackson County, Colorado: Lincoln, Nebr., University of Nebraska M.S. thesis, 106 p.

Ryan, Starley, 1976, Pearl—A forgotten mountain jewel: Denver Post Empire Magazine, September 26, 1976, p. 12-15.

Sangster, D. F., and Scott, S. D., 1976, Precambrian, strata-bound, massive Cu-Zn-Pb sulfide ores of North America, *in* Wolf, K. H., ed., Handbook of strata-bound and stratiform ore deposits, volume 6, Cu, Zn, Pb and Ag deposits: Amsterdam, Netherlands, Elsevier, p. 129-222.

Scott, R. W., 1961, Geology of Rabbit Ears Pass area, Jackson and Grand Counties, Colorado: Laramie, Wyo., University of Wyoming M.A. thesis, 73 p.

Segerstrom, Kenneth, and Kirby, S. H., 1969, Tuffaceous epiclastic breccia and sandstone near Hahns Peak, Colorado, and their genetic implications, *in* Geological Survey research 1969: U.S. Geological Survey Professional Paper 650-B, p. B19-B22.

Segerstrom, Kenneth, and Young, E. J., 1972, General geology of the Hahns Peak and Farwell Mountain quadrangles, Routt County, Colorado: U.S. Geological Survey Bulletin 1349, 63 p. [1973].

Shawe, D. R., 1976, Geology and resources of fluorine in the United States: U.S. Geological Survey Professional Paper 933, 99 p.

Shawe, D. R., 1979, Comment and reply *on* Distribution and genesis of fluorite deposits in the Western United States and their significance to metallogeny: Geology, v. 7, no. 3, p. 115-116.

Sheridan, D. M., and Raymond, W. H., 1977, Preliminary data on some Precambrian deposits of zinc-copper-lead sulfides and zinc spinel (gahnite) in Colorado: U.S. Geological Survey Open-File Report 77-607, 27 p.

Short, B. L., 1958, A geologic and petrographic study of the Ferris-Haggarty mining area, Carbon County, Wyoming: Laramie, Wyo., University of Wyoming M.A. thesis, 138 p.

Smith, J. B., 1974, The mineral industry of Colorado, *in* U.S. Bureau of Mines Minerals Yearbook, 1974, volume 2: p. 143-163.

Snyder, G. L., 1977a, Geologic map of the northernmost Park Range and southernmost Sierra Madre, Jackson and Routt Counties, Colorado: U.S. Geological Survey Open-File Report 77-188.

______1977b, Geologic map of the central part of the northern Park Range, Jackson and Routt Counties, Colorado: U.S. Geological Survey Open-File Report 77-187.

______1977c, Geologic map of the northernmost Gore Range and southernmost northern Park Range, Grand, Jackson, and Routt Counties, Colorado: U.S. Geological Survey Open-File Report 77-189.

______1978, Intrusive rocks northeast of Steamboat Springs, northern Park Range, Colorado, *with a section on* Geochronology by C. E. Hedge: U.S. Geological Survey Professional Paper 1041, 42 p.

______1980a, Geologic map of the northernmost Park Range and southernmost Sierra Madre, Jackson and Routt Counties, Colorado: U.S. Geological Survey Miscellaneous Investigations Series Map I-1113.

______1980b, Geologic map of the central part of the northern Park Range, Jackson and Routt Counties, Colorado: U.S. Geological Survey Miscellaneous Investigations Series Map I-1112.

______1980c, Geologic map of the northernmost Gore Range and southernmost northern Park Range, Grand, Jackson, and Routt Counties, Colorado: U.S. Geological Survey Miscellaneous Investigations Series Map I-1114.

Snyder, G.L., Brandt, E.L., and Smith, V.C., 1987, Precambrian petrochemistry of the northern Park Range, Colorado, and its implications for studies of crustal derivation: U.S. Geological Survey Professional Paper 1343, 116 p.

Snyder, G. L., Hopkins, R. T., Jr., Domenico, J. A., Frisken, J. G., and Mitchell, J., 1981, Analyses of rock and stream sediment samples from the Mount Zirkel Wilderness and northern Park Range vicinity, Jackson and Routt Counties, Colorado: U.S. Geological Survey Open-File Report 81-186, 85 p.

Solomon, M., 1976, "Volcanic" massive sulphide deposits and their host rocks—A review and an explanation, *in* Wolf, K. H., ed., Handbook of strata-bound and stratiform ore deposits, volume 6, Regional studies and specific deposits: Amsterdam, Netherlands, Elsevier, p. 21-77.

Spencer, A. C., 1903a, Mineral resources of the Encampment copper region, Wyoming: U.S. Geological Survey Bulletin 213, p. 158-162.

______1903b, Reconnaissance examination of the copper deposits at Pearl, Colorado: U.S. Geological Survey Bulletin 213, p. 163-169.

______1904, The copper deposits of the Encampment district, Wyoming: U.S. Geological Survey Professional Paper 25, 107 p.

Stanton, R. L., 1972, Ore petrology: New York, McGraw-Hill, 713 p.

Steven, T. A., 1954, Geology of the Northgate fluorspar district, Colorado: U.S. Geological Survey Mineral Investigations Field Studies Map MF-13.

Steven, T. A., 1956, Cenozoic geomorphic history of the Medicine Bow Mountains near the Northgate fluorspar district, Colorado: Colorado Scientific Society Proceedings, v. 17, no. 2, p. 35-55.

______1957, Metamorphism and the origin of granitic rocks, Northgate district, Colorado: U.S. Geological Survey Professional Paper 274-M, p. 335-377.

______1960, Geology and fluorspar deposits, Northgate district, Colorado: U.S. Geological Survey Bulletin 1082-F, p. 323-422.

Sullivan, C. J., 1958, The origin of massive sulphide ores, *in* Gill, J. E., Symposium on the genesis of massive sulphide deposits: Canadian Mining and Metallurgical Bulletin 570, p. 613-619.

Taylor, R. B., Theobald, P. K., and Izett, G. A., 1968, Mid-Tertiary volcanism in the central Front Range, Colorado, *in* Cenozoic volcanism in the southern Rocky Mountains: Colorado School of Mines Quarterly, v. 63, no. 3, p. 39-50.

Theobald, P. K., Jr., and Thompson, C. E., 1968, Platinum and associated elements at the New Rambler mine and vicinity, Albany and Carbon Counties, Wyoming: U.S. Geological Survey Circular 607, 14 p.

Todd, D. K., 1970, The water encyclopedia: Port Washington, N.Y., Water Information Center, Inc., 559 p.

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

Tweto, Ogden, 1960, Scheelite in the Precambrian gneisses of Colorado: Economic Geology, v. 55, p. 1406-1428.

______1968, Geologic setting and interrelationships of mineral deposits in the mountain province of Colorado and south-central Wyoming, *in* part 5 *of* Ore deposits of the United States, 1933-1967: Colorado Rockies, p. 551-588.

______1975a, Laramide (late Cretaceous-early Tertiary) orogeny in the Southern Rocky Mountains, *in* Cenozoic history of the Southern Rocky Mountains: Geological Society of America Memoir 144, p. 1-44.

______1975b, Preliminary geologic map of the Craig 1° × 2° quadrangle, northwestern Colorado: U.S. Geological Survey Mineral Investigations Field Studies Map MF-666.

______1976a, Geologic map of the Craig 1° × 2° quadrangle, northwestern Colorado: U.S. Geological Survey Miscellaneous Investigations Map I-972.

______1976b, Preliminary geologic map of Colorado: U.S. Geological Survey Miscellaneous Field Studies Map MF-788.

______1977a, Tectonic history of west-central Colorado, *in* Exploration frontiers of the Central and Southern Rockies: Rocky Mountain Association of Geologists, 1977 Symposium, p. 11-22.

______1977b, Nomenclature of Precambrian rocks of Colorado: U.S. Geological Survey Bulletin 1422-D, 22 p.

______1977c, Tectonic map of the Rio Grande rift system in Colorado: U.S. Geological Survey Open-File Report 77-750.

Tweto, Ogden, Bryant, Bruce, and Williams, F. E., 1970, Mineral resources of the Gore Range-Eagles Nest Primitive Area and vicinity, Summit and Eagle Counties, Colorado: U.S. Geological Survey Bulletin 1319-C, 127 p.

Tweto, Odgen, and Sims, P. K., 1963, Precambrian ancestry of the Colorado mineral belt: Geological Society of America Bulletin, v. 74, p. 991-1014.

U.S. Geological Survey, 1970, Aeromagnetic survey of North Park and vicinity, north-central Colorado: U.S. Geological Survey Open-File Report, 1 sheet, scale 1:125,000.

______1975, Mineral resource perspectives, 1975: U.S. Geological Survey Professional Paper 940, 24 p.

U.S. Geological Survey, 1978, Aeromagnetic survey of North Park and vicinity, Colorado: U.S. Geological Survey Open-File Report 78-112, 1 sheet, scale 1:125,000.

U.S. Geological Survey and Colorado Geological Survey, 1977, Energy resources map of Colorado.

Van Alstine, R. E., 1964, Fluorspar, *in* Mineral and water resources of Colorado: Washington, U.S. Government Printing Office, p. 160–165.

_____1976, Continental rifts and lineaments associated with major fluorspar districts: Economic Geology, v. 71, no. 6, p. 977-987.

Vanderwilt, J. W, 1947, Mineral resources of Colorado: Colorado Mineral Resources Board, 547 p.

Wakefield, L. W., 1952, Geology of the Boetcher [sic] Ridge–Sheep Mountain–Delanos Butte area, North Park, Colorado: Boulder, Colo., University of Colorado M.S. thesis, 74 p.

Wallace, S. R., Muncaster, N. K., Jonson, D. C., MacKensie, W. B., Bookstrom, A. A., and Surface, V. E., 1968, Multiple intrusion and mineralization at Climax, Colorado, *in* Ridge, J. D., ed., Ore deposits in the United States 1933-1967: New York, American Institute of Mining, Metallurgical and Petroleum Engineers, p. 605-640.

Walters, R. F., 1953, Geology of the Independence Mountain area, North Park, Colorado: Laramie, Wyo., University of Wyoming M.A. thesis, 64 p.

Walton, D. S., 1963, The geology of Slater Park, Routt County, Colorado, and the stratigraphy of the Lewis Shale, northern Routt County, Colorado: Golden, Colo., Colorado School of Mines M.S. thesis, 164 p.

Warner, L. A., 1978, The Colorado Lineament—A middle Precambrian wrench fault system: Geological Society of America Bulletin, v. 89, p. 161–171.

Wellborn, R. E., 1977, Structural style in relation to oil and gas exploration in North Park–Middle Park basin, Colorado, *in* Exploration frontiers of the Central and Southern Rockies: Rocky Mountain Association of Geologists, 1977 Symposium, p. 41–60.

Welsh, J. E., 1951, Geology of the Sheep Mountain–Delaney Butte area, North Park, Colorado: Laramie, Wyo., University of Wyoming M.A. thesis, 51 p.

Wied, O. J., 1960, Geology of the Encampment area, Carbon County, Wyoming: Laramie, Wyo., University of Wyoming M.S. thesis, 52 p.

Wood, H. B., 1974, Fluorspar and cryolite, *in* U.S. Bureau of Mines Minerals Yearbook, 1974, volume 1: p. 565–587.

Woodmansee, W. W., 1974, Uranium, *in* U.S. Bureau of Mines Minerals Yearbook, 1974, volume 1: p. 1327–1349.

Young, E. J., and Segerstrom, Kenneth, 1973, A disseminated silver–lead–zinc sulfide occurrence at Hahns Peak, Routt County, Colorado: U.S. Geological Survey Bulletin 1367, 33 p.

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