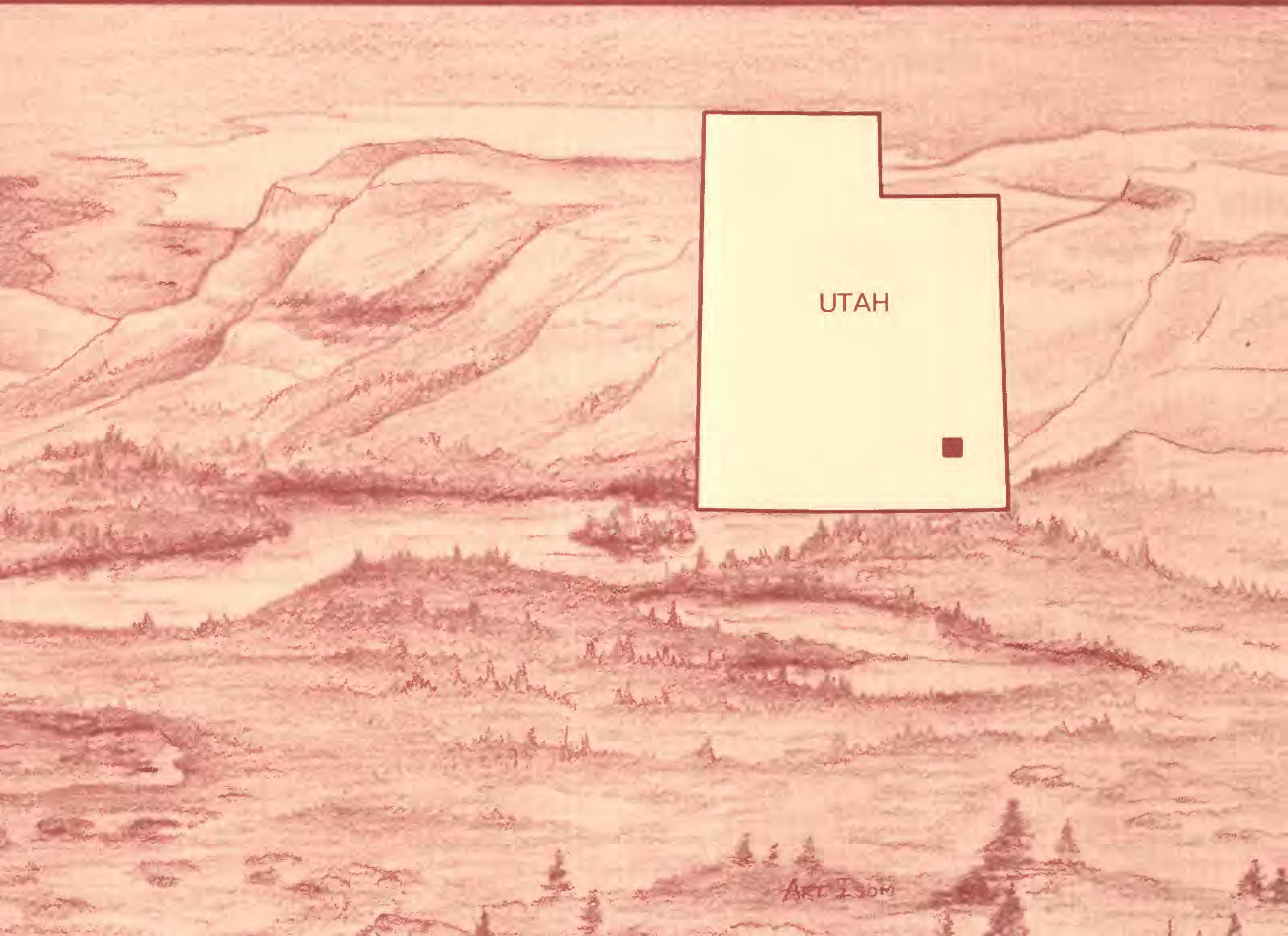
Mineral Resources of the Little Rockies Wilderness Study Area, Garfield County, Utah

U.S. GEOLOGICAL SURVEY BULLETIN 1751–A



Chapter A

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U.S. GEOLOGICAL SURVEY BULLETIN 1751

MINERAL RESOURCES OF WILDERNESS STUDY AREAS—
HENRY MOUNTAINS REGION, UTAH

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

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STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94–579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey of the Little Rockies (UT–050–247) Wilderness Study Area, Garfield County, Utah.

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Summary

The Little Rockies (UT–050–247) Wilderness Study Area comprises 38,700 acres in the Henry Mountains in Garfield County, Utah (fig. 1). Field and laboratory investigations were conducted by the USGS (U.S. Geological Survey) and the USBM (U.S. Bureau of Mines) from 1981 to 1984. These investigations indicate that a small part of the study area approximately 4 mi (miles) northeast of Mt. Ellsworth along Fourmile Canyon contains an identified subeconomic resource of uranium (fig. 2) in sandstone beds of the Shinarump Member of the Chinle Formation. The southern part of the study area has a high mineral resource potential (the likelihood of the presence of undiscovered occurrences) for uranium in sandstone beds of the Shinarump Member of the Chinle Formation, except for two small areas comprising the igneous stocks of Mt. Holmes and Mt. Ellsworth. These two areas have a low mineral resource potential for uranium. The northern part of the study area has a moderate mineral resource potential for uranium in sandstone beds of the Shinarump and Monitor Butte Members of the Chinle Formation. The entire study area has a low mineral resource potential for base (copper and lead) and precious (silver and gold) metals, nonmetals (sand, gravel, and stone), oil and gas, and geothermal energy.

The Henry Mountains consist of numerous Tertiary igneous stocks and laccoliths that were intruded into and domed the overlying sedimentary strata. (A geologic time chart is available in the appendix.) Subsequent erosion by the Colorado River and its tributaries has exposed the intrusive igneous bodies as five distinct mountains. The Little Rockies Wilderness Study Area includes the two southernmost peaks of this group, Mt. Holmes (7,930 ft (feet)) and Mt. Ellsworth (8,150 ft), and the adjacent canyon country. Mountain slopes are steep and rugged. Sedimentary rocks ranging in age from Permian to Cretaceous were eroded to form narrow and deep canyons. Trachyte Creek, which cuts across the northern part of the study area, is the only perennial stream within the area. Vegetation is sparse and precipitation is low.

Mines, prospects, and mineralized areas within 1 mi of the study area were examined; none were found within the study area. Texasgulf Minerals Exploration Co. recently drilled a uranium deposit within the Shinarump Member in the subsurface near Fourmile Canyon inside the Little Rockies Wilderness Study Area boundary. Eleven sections of land within the study area and most sections of land west of the study area have been leased for hydrocarbon exploration (fig. 3).

Stream-sediment and rock samples were collected from the Henry Mountains region for geochemical analysis as part of an investigation of several wilderness study areas. Geochemical analysis of the samples from the Little Rockies Wilderness Study Area indicates that less than half of the rock samples from the igneous stocks contain anomalous values of copper and lead, and that three of the stream-sediment samples in or near the study area contain isolated anomalous values of gold and silver. These anomalous values represent isolated mineral occurrences. The mineral resource potential is low for base (copper and lead) and precious (silver and gold) metals in the study area.

Uranium occurs in sandstone beds of the Salt Wash Member of the Upper Jurassic Morrison Formation to the west of the study area and in sandstone beds of the Shinarump and Monitor Butte Members of the Upper Triassic Chinle Formation to the east and north of the study area, respectively. Although the Salt Wash has been eroded from the study area, the Shinarump

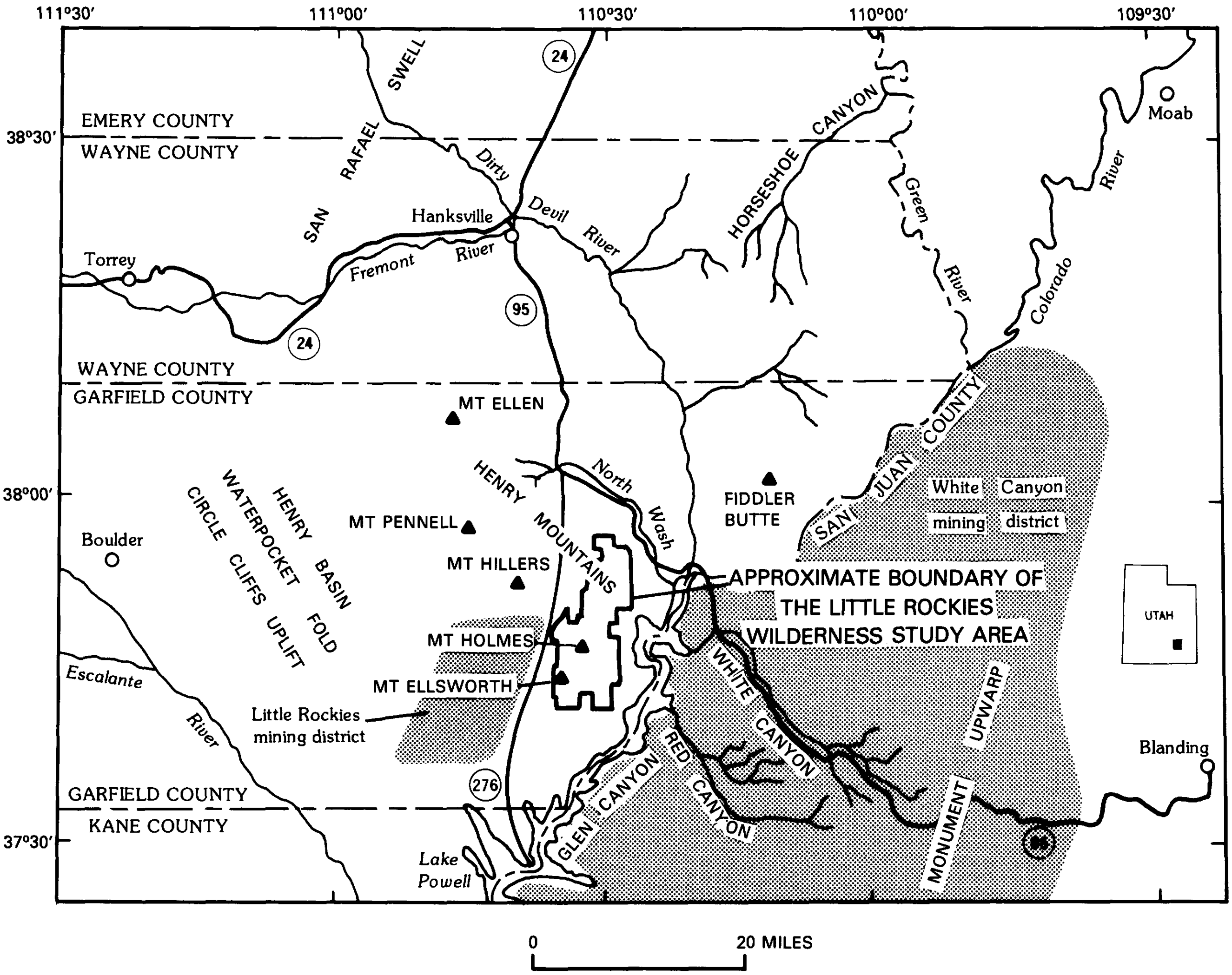


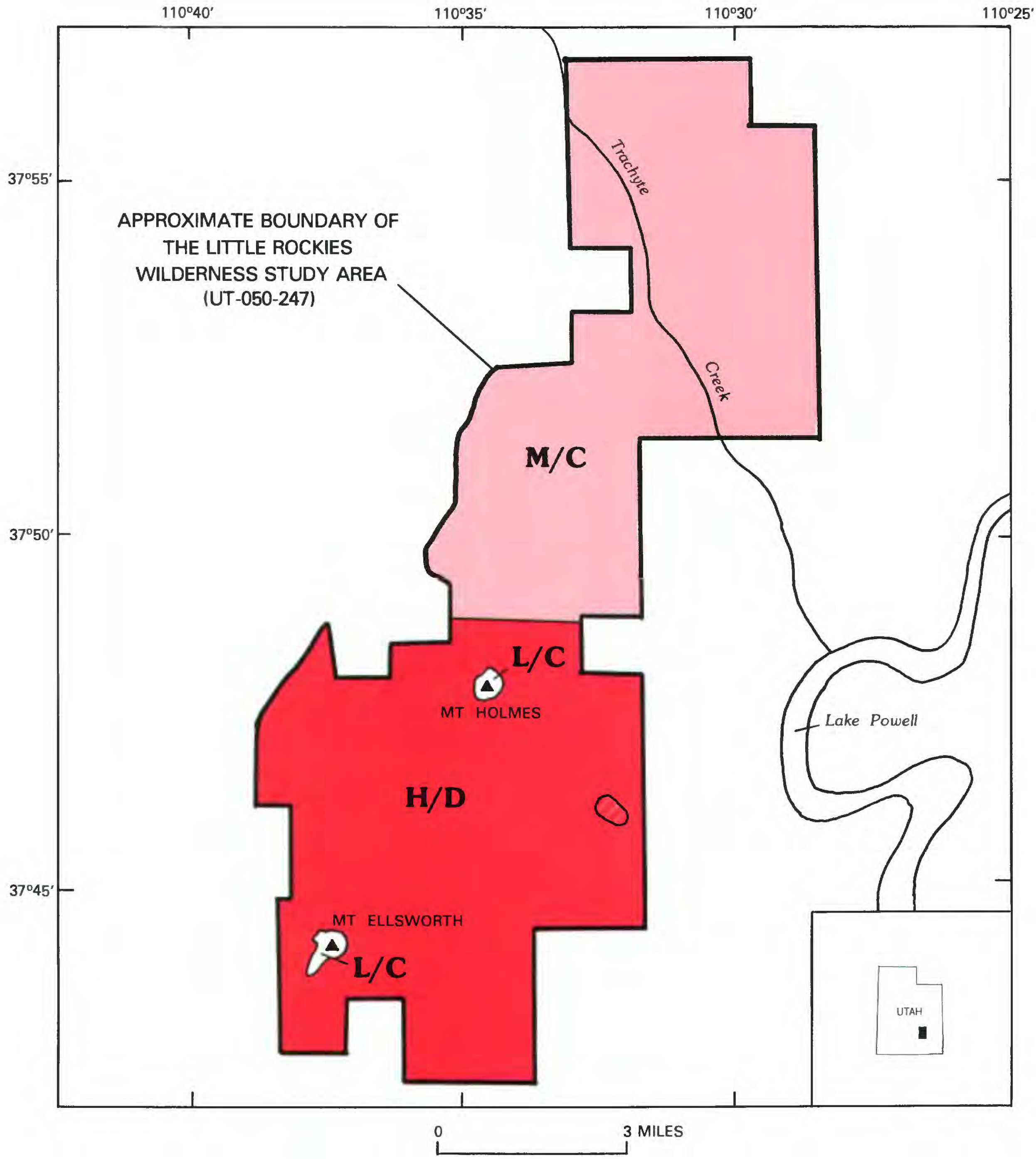
Figure 1. Index map showing location of the Little Rockies Wilderness Study Area, Garfield County, Utah.

and Monitor Butte are known to crop out in and to underlie the study area. The presence of an identified uranium resource, the projection of paleochannel trends of the Shinarump and Monitor Butte Members toward the study area, and the mapping of dolomite and mudstone related to uranium mineralization indicate that the southern part of the study area has a high mineral resource potential for uranium except where underlain by intrusive igneous rocks and that the northern part of the area has a moderate mineral resource potential for uranium. The two small areas underlain by intrusive igneous rocks have a low mineral resource potential for uranium.

Geologic surveys of the study area (Larson and others, 1985) and studies by Molenaar and Sandberg (1983) and Molenaar and others (1983) indicate that the study area has a low mineral resource potential for oil and gas. The study area also has a low resource potential for nonmetals and geothermal energy.

INTRODUCTION

The Little Rockies (UT–050–247) Wilderness Study Area comprises 38,700 acres encompassing Mt. Ellsworth (8,150 ft) and Mt. Holmes (7,930 ft) in the Henry Mountains in Garfield County, Utah (fig. 1, pl. 1). The rugged, laccolithic Henry Mountains are draped by gravel-mantled pediment surfaces, and rise from intricately dissected, sparsely vegetated plateaus. The study area is about 75 mi south of Hanksville, Utah, and lies just west of Lake Powell. It extends northeast for about 15 mi along the east side of Utah State Highway 276. The Glen Canyon National Recreation Area borders the east side of the study area and includes Lake Powell. Access to the study area is by dirt roads from Utah State Highway 276 on the west, or by boat and foot from Lake Powell on the east.

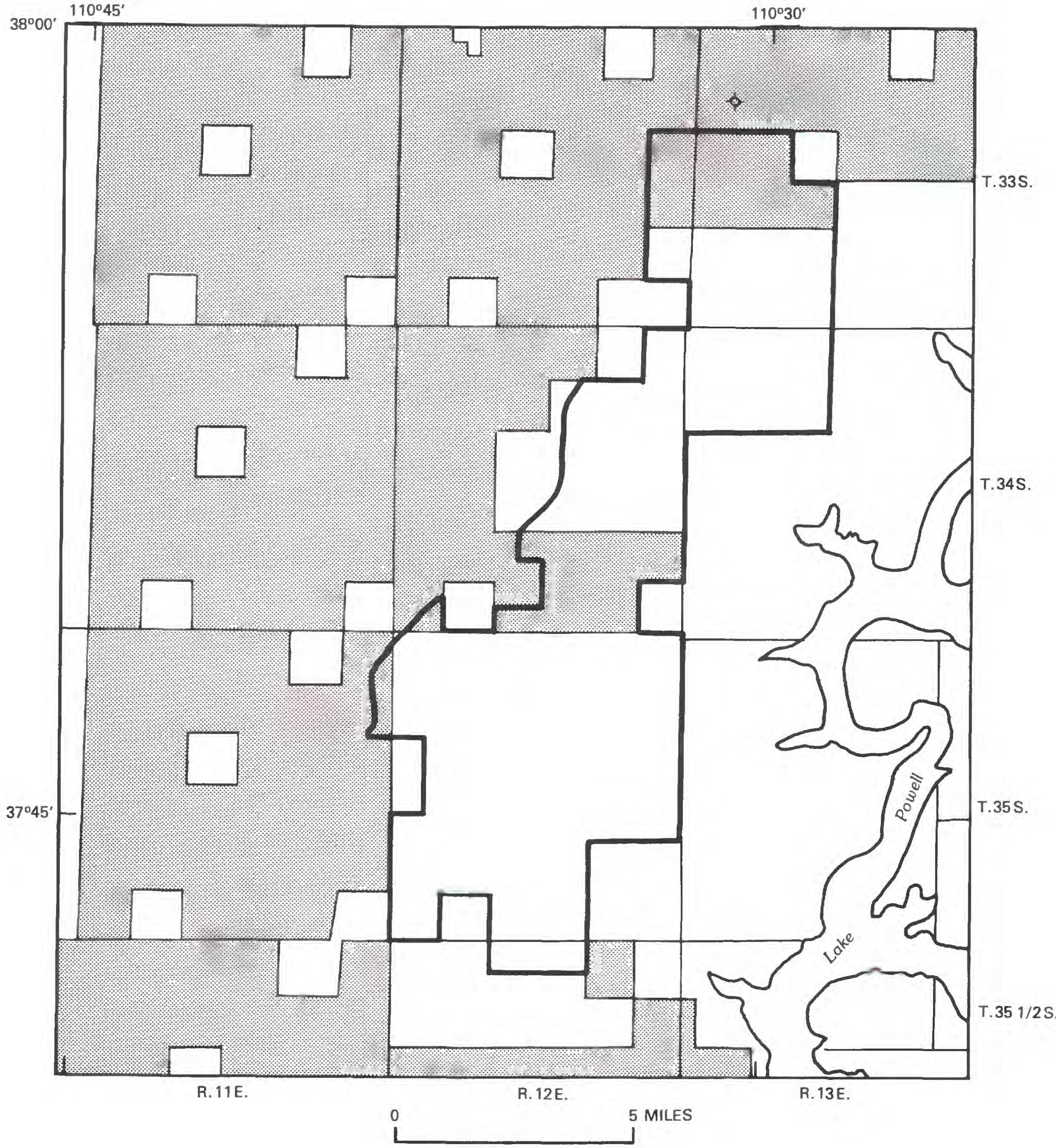


EXPLANATION

[Entire study area has low mineral resource potential for base (copper and lead) and precious (silver and gold) metals, nonmetals, oil and gas, and geothermal energy, with certainty level B]

	Area of identified uranium resource
H/D	Geologic terrane having high mineral resource potential for uranium, with certainty level D
M/C	Geologic terrane having moderate mineral resource potential for uranium, with certainty level C
L/C	Geologic terrane having low mineral resource potential for uranium, with certainty level C

Figure 2. Summary map showing mineral resource potential of the Little Rockies Wilderness Study Area, Garfield County, Utah.



EXPLANATION

Approximate boundary of the Little Rockies Wilderness Study Area

Area of oil and gas leases— As of September 1983

Oil and gas well—Dry hole

Figure 3. Map showing oil and gas leases in and near the Little Rockies Wilderness Study Area, Garfield County, Utah.

This report presents an evaluation of the mineral endowment (identified resources and mineral resource potential) of the study area and is the product of several separate studies by the USBM and the USGS. Identified resources are classified according to the system of the USBM and the USGS (1980), which is shown in the appendix. Mineral resource potential is the likelihood of occurrence of undiscovered concentrations of metals and nonmetals, of unappraised industrial rocks and minerals, and of undiscovered energy sources (coal, oil, gas, oil shale, and geothermal sources). Mineral resource potential and the level of certainty of each mineral resource assessment were classified according to the system of Goudarzi (1984; see appendix).

Previous Work

G. K. Gilbert (1877) was the first geologist to examine, describe, and interpret the laccoliths in the Henry Mountains. Between 1935 and 1939, C. B. Hunt and his associates reinterpreted the geology of the Henry Mountains and later published a detailed report (Hunt and others, 1953). Doelling (1972) mapped several 7½′ quadrangles as part of a study of the Henry Mountains coalfield. Uranium has been the only mineral commodity of any importance in this region, and many investigations were conducted by, or done under contract to, the Atomic Energy Commission [Nuclear Regulatory Commission] in the 1940's and 1950's. These reports are available through the Grand Junction, Colo., Office of the Nuclear Regulatory Commission. Butler (1920) was the first to describe the mineral resources of the Henry Mountains region. Reports published on the uranium deposits of the Henry Mountains include Johnson (1959), Doelling (1967, 1975), Peterson (1977, 1980a, b), and Chenoweth (1980). Doelling (1980) also described the various metal deposits of the region.

Investigations by the U.S. Bureau of Mines

In 1983, the USBM conducted a mineral investigation to evaluate the identified mineral resources of the Little Rockies Wilderness Study Area as part of a joint effort with the USGS. Field studies by USBM personnel, during April and May 1983, included a search for mines, prospects, and mineralized areas in and within 1 mi of the study area boundary; none were found within the study area (Kreidler, 1984). The USBM collected samples and determined assay values and investigated past exploration activity in the study area. Minerals and oil and gas information was gathered from published and unpublished literature, USBM files, and oil and gas lease and mining-claim records of Garfield County and the U.S. Bureau of Land Management State Office in Salt Lake City, Utah (Kreidler, 1984). Claimants, mine operators, and minerals industry personnel having knowledge of the mining activity in the vicinity of the study area were interviewed.

USBM personnel took panned-concentrate samples from drainages within the study area. Gold and silver content were determined by fire assay, and uranium content was determined by fluorometric analysis. All samples were analyzed by semiquantitative optical emission spectrography. A complete sample data set is available for public inspection at the USBM, Intermountain Field Operations Center, Building 20, Denver Federal Center, Denver, CO, 80225.

Investigations by the U.S. Geological Survey

From 1981 to 1984, the USGS conducted field and laboratory studies to assess the potential for undiscovered mineral resources of the Little Rockies Wilderness Study Area, Garfield County, Utah. The studies consisted of geologic mapping (Larson and others, 1985); a search for mines, prospects, and mineralized areas; sedimentologic studies (Dubiel, 1983); rock and stream-sediment sampling for geochemical analysis (Detra and others, 1984); and a search of previously published studies on the geology (Peterson, 1977, 1980a) and mineral resources of the study area. Models developed for the occurrence of uranium (Peterson, 1980b; Dubiel, 1983) were applied to the evaluation of mineral resource potential for uranium in the study area.

Acknowledgments.—The development of a mineral resource potential summary of a study area is dependent upon the expertise and contributions of many people. Richard Haldane, of Plateau Resources Ltd., and W. Glenn Culver, of Texasgulf Minerals Exploration Co., provided information about their respective company's uranium operations. The USGS acknowledges the assistance of our helicopter pilots, Leonard Smith and the late Jaxon Ruby, whose skill as pilots made many of the field tasks in remote areas considerably easier. We would also like to thank all of the USGS personnel who assisted in the field on all aspects of this interdisciplinary study: Brad Esslinger, Joseph Fontaine, Darlene Francis, David Hammond, Carl Harris, Paul Milde, Denise Mruk, Chuck Patterson, Richard Reeves, Mike Rendina, David Scott, William Thoen, Ann Tirrell, Bruce van Brundt, Shawn Yasataki, and Christine Yee.

APPRAISAL OF IDENTIFIED RESOURCES

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Mining Activity

Gold, silver, and copper were mined in the Henry Mountains in the 1890's (Butler, 1920). However, within the Little Rockies Wilderness Study Area, no metal mining has taken place.

The only mineral commodity mined near the study area has been uranium, which was discovered in the region in 1912 (Butler, 1920). Many claims have been prospected and mined to the west of the study area. Uranium and minor amounts of copper were discovered in the study area in the late 1970's by Texasgulf Minerals Exploration Co., in the Fourmile Canyon area on the southeast slope of Mt. Holmes. Due to uranium market conditions and other economic factors, Texasgulf ceased operations on the deposit in 1982 and dropped its claims (W. Glenn Culver, Texasgulf Minerals Exploration Co., oral commun., 1983).

Mining Districts, Mineralized Areas, and Identified Resources

The Little Rockies Wilderness Study Area is near two uranium mining districts: the White Canyon district and the Little Rockies district (fig. 1). The White Canyon mining district is about 15 mi east of the study area, across Lake Powell in San Juan County, Utah. Uranium was discovered in this area in 1950, in paleochannels of the Shinarump Member of the Upper Triassic Chinle Formation. In the late 1970's, Texasgulf projected the paleochannel trends westward across Lake Powell into Fourmile Canyon and drilled 16 holes averaging 300 ft deep. All equipment, personnel, and water were flown in by helicopter due to the inaccessibility of the area. The program identified a subsurface deposit containing a minimum of 200,000 tons averaging 0.2 percent uranium oxide (U_3O_8), 100,000 tons of which averaged 0.5 percent copper (W. Glenn Culver, Texasgulf, oral commun., 1982). In 1982, Texasgulf dropped the project due to the depressed market for uranium and the difficulty and expense of working in an area as isolated as the Little Rockies.

USBM personnel did not examine the Texasgulf property because of its inaccessibility. However, they did sample sediments from five major stream channels that drain the study area (Kreidler, 1984). Assays of these surface samples indicate no local enrichment in uranium. This is undoubtedly due to the absence of surface exposure of the uranium-bearing units. No local enrichment of gold or silver was found in the study area.

The Little Rockies mining district is adjacent to the study area west of Utah State Highway 276; no part of the Little Rockies mining district is within the study area. Uranium deposits in the district occur in paleochannels of the Salt Wash Member of the Upper Jurassic Morrison Formation, which has been eroded from the study area. Two examples of this type of deposit are seen in Plateau Resources' Shootering Canyon mine (inactive as of April 1, 1986) and the Del Monte mine (Kreidler, 1984). The Shootering Canyon mine is 3 mi west of the study area, contains at least 6,000,000 pounds of uranium oxide (U_3O_8), and has nearly 3 mi of underground workings (Richard Haldane, senior mine geologist, Plateau Resources, oral commun., 1983). The Del Monte mine, less than 1 mi west of the study area, is much smaller and is worked intermittently by the owner.

Oil and Gas

The Little Rockies Wilderness Study Area is in the Henry Basin, a Laramide (Late Cretaceous to Eocene) structural basin in the northwestern part of the Pennsylvanian Paradox basin. The Henry Basin is one of the few Rocky Mountain basins that has not produced oil and gas (Irwin and others, 1980). Oil and gas production within the Paradox basin has been primarily from bioherms and structural traps within carbonate rocks of the Pennsylvanian Hermosa Group, although there has been minor production from Permian and Triassic rocks (Irwin and others, 1980). These formations underlie the Henry Mountains and the Little Rockies Wilderness Study Area, but remain largely untested. One well (fig. 3), located less than a mile north of the study area in sec. 8, T. 33 S., R. 13 E., was drilled to a depth of 6,625 ft to the Devonian Elbert Formation and had no oil or gas shows (Petroleum Information Corp., oil-well-log card, Denver, Colo.).

Eleven sections of land (fig. 3) within the study area and most sections of land west of the study area have been leased for hydrocarbon exploration (Kreidler, 1984). Due to the formation of Lake Powell and Glen Canyon National Recreation Area, there are no leases directly east of the study area.

Sand, Gravel, and Stone

Materials that could be used for construction purposes are present in the Little Rockies Wilderness Study Area. Sand and gravel are present in terrace deposits along major stream courses, and most of the Jurassic and older rocks could be sources of building stone. Development of the resources is unlikely due to lack of local markets.

ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

By Russell F. Dubiel, Calvin S. Bromfield, Stanley E. Church, William M. Kemp, Mark J. Larson, Fred Peterson, and Charles T. Pierson
U.S. Geological Survey

Geology

The Henry Mountains are on the eastern flank of the Henry Basin (fig. 1), a regional structure about 100 mi long and 50 mi wide on the west side of the Colorado Plateau. The western flank of the basin is formed by steeply eastward-dipping rocks of the Waterpocket Fold, a monocline that separates the basin from the Circle Cliffs Uplift farther west. Strata on the gently dipping east flank of the basin gradually rise eastward toward the crest of the Monument upwarp. The intrusive centers of the Henry Mountains (pl. 1) locally interrupt the gradual eastward rise of the sedimentary strata. Joints and faults of minor displacement trend northwest and northeast, and are readily apparent in some sedimentary rocks.

Sedimentary rocks of the Henry Basin range in age from Early Permian to Late Cretaceous and have a combined thickness of nearly 8,000 ft (Hunt and others, 1953; Peterson and others, 1980). These rocks were deposited in marine and continental environments and are mostly sandstone and shale, as well as minor, thin coal beds. The coal-bearing units do not occur in the study area.

The igneous intrusive centers have arched the sedimentary strata into structural domes, each several miles in diameter and having several thousand feet of structural relief. Each of the intrusive centers contains a stock of diorite porphyry that has intruded the overlying sedimentary rock, producing a shattered zone encircling the stock. Laccoliths, bysmaliths, and minor satellite bodies of diorite porphyry are clustered around most of the stocks.

The Little Rockies Wilderness Study Area includes the Mt. Ellsworth and Mt. Holmes intrusive centers (pl. 1). Each of these centers has a stock of diorite porphyry covering approximately 160 acres. The stock of the Mt. Ellsworth intrusive center has no associated laccoliths and is surrounded instead by a complex zone of dikes and sills. The sedimentary strata surrounding the Mt. Holmes intrusive center have been faulted and injected by numerous laccoliths, dikes, and satellite bodies that radiate from the stock.

Alteration and metamorphism associated with the two intrusive centers are neither pervasive nor widespread. Epidote and chlorite are locally conspicuous in the porphyries along joint surfaces and as a replacement of other minerals. Locally, iron-oxide staining is the result of the weathering of pyrite. Hunt and others (1953) noted that small amounts of pyrite occurred in association with some laccoliths. Metamorphic effects of the intrusions on the invaded sedimentary rocks generally resulted in the induration of rocks, along with some discoloration. These effects are generally within a few feet of the intrusive contacts.

The age of the igneous intrusions is in question. The youngest sedimentary rock intruded by the stocks in the Henry Mountains is Late Cretaceous. Potassium-argon ages of 44 and 48 million years have been determined for hornblende from diorite porphyry of the Bull Mountain bysmalith (Armstrong, 1969), which is northwest of the map area; these age determinations suggest an Eocene age. However, on the basis of their similarity to other intrusive complexes on the Colorado Plateau, Hunt (1980) suggested that a mid-Tertiary age for the intrusions of the Henry Mountains is more likely.

Geochemistry

A reconnaissance geochemical survey of the Little Rockies Wilderness Study Area was conducted during the summers of 1982 and 1983 to contribute to the mineral resource potential assessment. This geochemical survey was part of a larger program designed to examine the geochemistry of several wilderness study areas in the region. Stream-sediment samples, heavy-mineral-concentrate samples panned from stream sediments, and rock samples were collected for geochemical analysis. A total of 153 stream-sediment samples, 147 panned-concentrate samples, and 181 rock samples were analyzed using semiquantitative emission spectrography as described by Grimes and Marranzino (1968). Mineralogic identification of the heavy-mineral fraction of the panned-concentrate samples was also made. A sample location map and a list of the data are given in Detra and others (1984).

Analyses of igneous rock samples from stocks and laccoliths within the region indicate that virtually all of the samples that contain anomalous values of metals came from the stocks. Rarely do metal anomalies occur in the laccoliths. Analysis of sample suites collected in the Little Rockies Wilderness Study Area (24 samples) showed that less than half of the samples were anomalous in copper or lead, or both (greater than 100 parts per million copper or lead).

Isolated geochemical anomalies of gold and silver were found in stream-sediment samples collected along Trachyte Creek (Detra and others, 1984) in the northern part of the Little Rockies Wilderness Study Area and south of Mt. Ellsworth (Detra and others, 1984) outside of the study area. These anomalous samples appear to represent isolated mineral occurrences.

Mineral and Energy Resources

Evaluation of the mineral resource potential of the Little Rockies Wilderness Study Area is based on: (1) geologic investigations (pl. 1; Larson and others, 1985); (2) geochemical investigations (Detra and others, 1984); (3) development of and comparison to mineralization models (fig. 3) (Peterson, 1977, 1980b; Dubiel, 1983); and (4) previously published studies on the geology and mineral occurrences of the study area.

Metals, Other Than Uranium

Base- (copper, zinc, lead, molybdenum, and related metals) and precious- (silver and gold) metal deposits in the North American Cordillera commonly are associated with igneous plutons. The sparse metallic mineralization in the Henry Mountains and the Little Rockies Wilderness Study Area appears to be related to hydrothermal processes associated with emplacement of the intrusive stocks, and the metals are almost entirely restricted to the stocks and the complex intrusive contact or shatter zones that border them. For reasons not well understood, the igneous rocks associated with the laccolithic centers on the Colorado Plateau, including those of the Henry Mountains, generally do not contain economically important copper, lead, silver, and gold deposits.

Within the Little Rockies Wilderness Study Area, no metals mining has taken place, nor are there any known occurrences of significant nonuranium mineral deposits. Alteration associated with the two small stocks at Mt. Ellsworth and Mt. Holmes is slight, consisting of minor local development of epidote or chlorite along joint surfaces, or as minor replacement of minerals in the diorite porphyry. Metamorphism of the host sedimentary rocks is restricted chiefly to baking and discoloration. Hydrothermal processes associated with the intrusions appear to have been negligible. The Little Rockies Wilderness Study Area is considered to have a low mineral resource potential for base (copper and lead) and precious metals. This low mineral resource potential is assigned a certainty level of B, based on the known geologic and geochemical data bases and the relative uncertainty in the understanding of mineralization processes and models for this intrusive igneous terrane.

Minor occurrences of metals that are intimately associated with uranium occurrences are discussed in the following section.

Uranium

In and near the study area, uranium-vanadium deposits occur in sandstone paleochannels in the Salt Wash Member of the Upper Jurassic Morrison Formation and in the Shinarump and Monitor Butte Members of the Upper Triassic Chinle Formation. Most of the known uranium-vanadium deposits in the Salt Wash Member are in a north-trending zone known as the Henry Mountains mineral belt (Peterson, 1980a) located a few miles west of the study area. Both the Shootering Canyon mine and the Del Monte mine occur in this belt. Peterson (1980a, b) found that, in the Henry Basin, uranium-vanadium deposits in the Salt Wash Member of the Morrison Formation are directly associated with carbonaceous mudstones interbedded with the sandstones. These carbonaceous mudstones in the Salt Wash Member occur in a belt west of the study area. However, because the Salt Wash Member has been eroded from the study area there can be no occurrence of Morrison Formation uranium deposits within the study area.

The Upper Triassic Chinle Formation does crop out and is present in the subsurface. Uranium deposits that contain minor copper and vanadium are known in the Chinle to the east in the White Canyon area, where they are restricted to fluvial sandstone and conglomerate beds of the Shinarump Member, and to the north where they occur in fluvial sandstones of the Monitor Butte Member. Sedimentologic analysis (Dubiel, 1983) indicates that the fluvial depositional systems of the Shinarump Member trend west in the area of White Canyon (fig. 4) and that they probably underlie the southern part of the Little Rockies Wilderness Study Area (fig. 4), where Texasgulf drilled a moderate-size uranium-copper deposit. The sedimentology study (Dubiel, 1983) also indicates that the fluvial depositional systems of the Monitor Butte Member trend north in the area of North Wash, but there remains some uncertainty as to whether or not they underlie the study area. Studies of the intrusive igneous rocks of the Henry Mountains (Hunt, 1980), geologic mapping (Larson and others, 1985), and sedimentologic investigations (Dubiel, 1983) indicate that the fluvial rocks of the Chinle Formation probably do not underlie the intrusive igneous stocks of Mt. Holmes and Mt. Ellsworth.

Detailed mineralogic and geochemical studies by Northrup (1982) of uranium ore deposits in Jurassic rocks of the Henry Basin suggest that authigenic dolomite occurs in fluvial sandstone beds that contain ore deposits. In a comparative study, rock samples from the lower part of the Chinle Formation, including the Shinarump and Monitor Butte Members, were collected for dolomite analysis where the Chinle crops out in the White Canyon and adjacent areas. X-ray diffraction studies indicate that the areas of greatest concentration of authigenic dolomite coincide with the areas of the Shinarump and Monitor Butte paleochannel systems (fig. 4), thus supporting the concept that the Shinarump and Monitor Butte fluvial systems may have some potential for containing uranium deposits.

Dubiel (1983) showed that carbonaceous mudstones, similar to those reported to be related to Morrison Formation uranium deposits (Peterson, 1977), are abundant in the lower part of the Chinle in the same areas

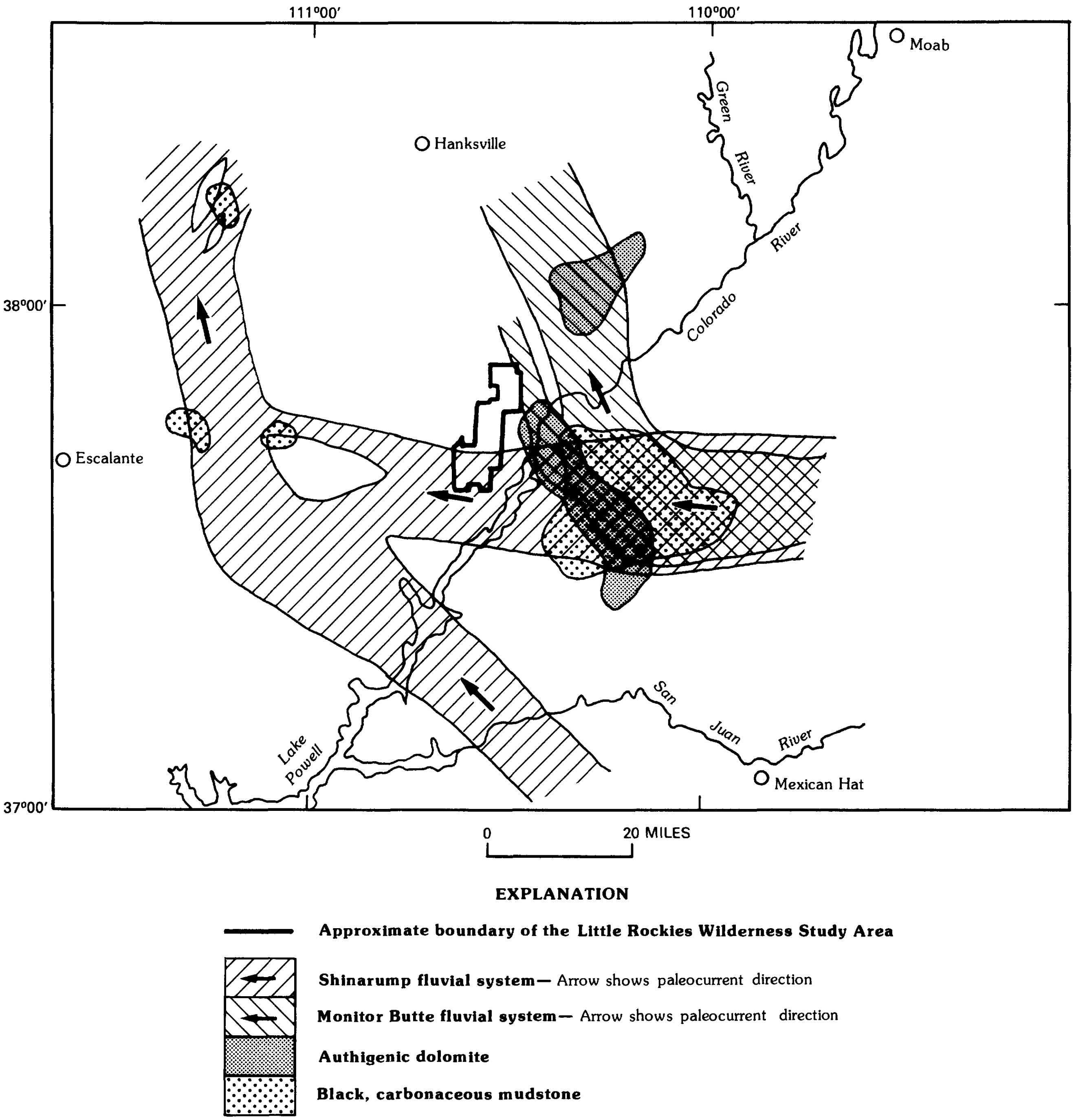


Figure 4. Map showing distribution of Shinarump and Monitor Butte fluvial systems, authigenic dolomite, and black carbonaceous mudstone used to evaluate uranium potential in the Little Rockies Wilderness Study Area and vicinity. (Modified from Dubiel and others, 1985.)

that contain the fluvial systems and the dolomite concentrations (fig. 4). All of these factors, combined with the knowledge that Texasgulf discovered a subsurface uranium deposit near Fourmile Canyon, indicate that the southern part of the Little Rockies Wilderness Study Area underlain by the Shinarump fluvial system has a high mineral resource potential for uranium (fig. 2, pl. 1). Copper, vanadium, and other metals such as cobalt and nickel may be associated with this area of uranium potential because these metals are known to occur in uranium deposits in the Shinarump Member in other places on the Colorado Plateau (Shoemaker and others, 1959), although the present data do not indicate their presence. Because of the nature of emplacement of the intrusive igneous stocks of Mt. Holmes and Mt. Ellsworth (Hunt, 1980; Larson and others, 1985), the fluvial rocks of the Chinle Formation probably do not underlie the igneous stocks. These studies and the fact that the geochemical survey (Detra and others, 1984) reported no uranium anomalies from igneous rock samples indicate that the two small areas comprising Mt. Holmes and Mt. Ellsworth have a low mineral resource potential for uranium (fig. 2, pl. 1). Because of the uncertain presence of subsurface Shinarump and Monitor Butte Member fluvial systems in the northern part of the Little Rockies Wilderness Study Area, the mineral resource potential for uranium in this area is moderate. The area of high mineral resource potential for uranium is assigned a certainty level of D (fig. 2, pl. 1), based on the geologic mapping, the sedimentologic studies, the development of mineralization models that include paleochannel, carbonaceous mudstone, and dolomite occurrences, and the knowledge that Texasgulf drilled a uranium deposit in the area. The area of moderate mineral resource potential for uranium is assigned a certainty level of C (fig. 2, pl. 1), based on the known occurrences of uranium deposits in adjacent areas, the occurrence of similar host rocks within the study area, and the more uncertain projection of trends favorable for the formation of uranium deposits into the study area based on models developed for this study. The area of low mineral resource potential for uranium is assigned a certainty level of C (fig. 2, pl. 1), based on the geologic mapping, the sedimentologic studies, and the current understanding of the nature of emplacement of the intrusive igneous rocks in the study area.

Sand, Gravel, and Stone

The Little Rockies Wilderness Study Area is considered to have a low mineral resource potential for sand, gravel, and stone in alluvial deposits greater than 5 ft thick; the certainty level is B, based on geologic mapping.

Oil and Gas

Oil and gas have been produced from Pennsylvanian, Permian, and Triassic rocks in basins adjacent to the Henry Basin, and these same strata are known to occur in the subsurface of the Henry Basin, but they remain largely untested. Factors detrimental to oil and gas accumulation in the study area are the extensive dissection of the region by the Colorado River and its tributaries, which would have lowered reservoir pressures (Irwin and others, 1980), and the emplacement of the Henry Mountain intrusive bodies, which have uplifted, deformed, and heated the adjacent rocks (Molenaar and Sandberg, 1983). Thus, the Little Rockies Wilderness Study Area has been assessed as having a low mineral resource potential for oil and gas, based on data from this study and from studies by Molenaar and others (1983) and Molenaar and Sandberg (1983). A certainty level of B is assigned, based on the regional geology and occurrence of possible hydrocarbon-bearing units within the study area coupled with a lack of knowledge on the exact subsurface distribution of these rocks and their hydrocarbon content.

Geothermal Energy

There is no evidence such as heated waters or associated mineral deposits to suggest any occurrence of geothermal water. The Little Rockies Wilderness Study Area is considered to have a low resource potential for geothermal energy. A certainty level of B is assigned, based on the lack of geologic evidence for geothermal waters in the study area

REFERENCES CITED

Armstrong, R. L., 1969, K–Ar dating of laccolithic centers of the Colorado Plateau and vicinity: Geological Society of America Bulletin, v. 80, p. 2081–2086.

Butler, B. S., 1920, Henry Mountains region, *in* The ore deposits of Utah: U.S. Geological Survey Professional Paper 111, p. 622–632.

Chenoweth, W. L., 1980, Uranium-vanadium deposits of the Henry Mountains, Utah, *in* Picard, M. D., ed., Henry Mountains symposium: Utah Geological Association Publication 8, p. 299–304.

Detra, D. E., Erickson, M. S., Kemp, W. M., 3rd, and Willson, W. R., 1984, Analytical results for stream sediments and panned concentrates from stream sediments, collected from the Mt. Pennell, Mt. Hillers, and Little Rockies Wilderness Study Areas, Garfield County, Utah: U.S. Geological Survey Open-File Report 84–575, 37 p.

Doelling, H. H., 1967, Uranium deposits of Garfield County, Utah: Utah Geological and Mineral Survey Special Studies 22, 113 p.

———1972, Henry Mountains coal field, *in* Doelling, H. H., and Graham, R. L., eds., Eastern and northern Utah coal fields: Utah Geological and Mineral Survey, Monograph Series, No. 2, p. 97–190.

———1975, Geology and mineral resources of Garfield County: Utah Geological and Mineral Survey Bulletin 107, 175 p.

———1980, Mineral deposits of the Henry Mountains, *in* Picard, M. D., ed., Henry Mountains symposium: Utah Geological Association Publication 8, p. 287–296.

Dubiel, R. F., 1983, Sedimentology of the lower part of the Upper Triassic Chinle Formation and its relationship to uranium deposits, White Canyon area, southeastern Utah: U.S. Geological Survey Open-File Report 83–459, 48 p.

Dubiel, R. F., Larson, M. J., Peterson, Fred, Willson, W. R., and Schreiner, R. A., 1985, Mineral resource potential map of the Dirty Devil, French Spring–Happy Canyon, and Horseshoe Canyon Wilderness Study Areas, Wayne and Garfield Counties, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF–1754–A, scale 1:50,000.

Gilbert, G. K., 1877, Geology of the Henry Mountains: U.S. Geographical and Geological Survey of the Rocky Mountain Region, 160 p.

Goudarzi, G. H., comp., 1984, Guide to preparation of mineral survey reports on public lands: U.S. Geological Survey Open-File Report 84–787, 42 p.

Grimes, D. J., and Marranzino, A. P., 1968, Direct-current arc and alternating-current spark emission spectrographic methods for the semiquantitative analysis of geologic materials: U.S. Geological Survey Circular 591, 6 p.

Hunt, C. B., 1980, Structural and igneous geology of the Henry Mountains, Utah, *in* Picard, M. D., ed., Henry Mountains symposium: Utah Geological Association Publication 8, p. 15–106.

Hunt, C. B., Averitt, Paul, and Miller, R. L., 1953, Geology and geography of the Henry Mountains region, Utah: U.S. Geological Survey Professional Paper 228, 234 p.

Irwin, C. D., Clark, W. R., and Peabody, W. W., 1980, Petroleum geology of the Henry Mountains basin, *in* Picard, M. D., ed., Henry Mountains symposium: Utah Geological Association Publication 8, p. 353–366.

Johnson, H. S., Jr., 1959, Uranium resources in the Green River and Henry Mountains districts, Utah—A regional synthesis: U.S. Geological Survey Bulletin 1087–C, 104 p.

Kreidler, T. J., 1984, Mineral investigations of the Little Rockies Wilderness Study Area, Garfield County, Utah: U.S. Bureau of Mines Open File Report MLA 19–84, 11 p.

Larson, M. J., Bromfield, C. S., Dubiel, R. F., Patterson, C. G., and Peterson, Fred, 1985, Geologic map of the Little Rockies Wilderness Study Area and the Mt. Hillers and Mt. Pennell study areas, Garfield County, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF–1776–B, scale 1:50,000.

Molenaar, C. M., and Sandberg, C. A., 1983, Petroleum potential of wilderness lands in Utah, *in* Miller, B. M., ed., Petroleum potential of wilderness lands in the Western United States: U.S. Geological Survey Circular 902, p. K1–K14.

Molenaar, C. M., Sandberg, C. A., and Powers, R. B., 1983, Petroleum potential of wilderness lands, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I–1545, scale 1:1,000,000.

Northrup, H. R., 1982, Origin of the tabular-type vanadium-uranium deposits in the Henry structural basin, Utah: Golden, Colo., Colorado School of Mines, Ph. D. thesis T–2614, 340 p.

Peterson, Fred, 1977, Uranium deposits related to depositional environments in the Morrison Formation (Upper Jurassic), Henry Mountains mineral belt of southern Utah, *in* Campbell, J. A., ed., Short papers of the U.S. Geological Survey uranium-thorium symposium, 1977: U.S. Geological Survey Circular 753, p. 45–47.

———1980a, Sedimentology of the uranium-bearing Salt Wash Member and Tidwell Unit of the Morrison Formation in the Henry and Kaiparowits Basins, Utah, *in* Picard, M. D., ed., Henry Mountains symposium: Utah Geological Association Publication 8, p. 305–322.

———1980b, Sedimentology as a strategy in uranium exploration—Concepts gained from an analysis of a uranium-bearing depositional sequence in the Morrison Formation of south-central Utah, *in* Turner-Peterson, C. T., ed., Uranium in sedimentary rocks—application of the facies concept to exploration: Rocky Mountain Section, Society of Economic Paleontologists and Mineralogists, short course notes, p. 65–126.

Peterson, Fred, Ryder, R. T., and Law, B. E., 1980, Stratigraphy, sedimentology, and regional relationships of the Cretaceous System in the Henry Mountains region, *in* Picard, M. D., ed., Henry Mountains symposium: Utah Geological Association Publication 8, p. 151–170.

Shoemaker, E. M., Miesch, A. T., Newman, W. L., and Riley, L. B., 1959, Elemental composition of the sandstone-type deposits, *in* Garrels, R. M., and Larsen, E. S., 3rd, comps., Geochemistry and mineralogy of the Colorado Plateau uranium ores: U.S. Geological Survey Professional Paper 320, p. 25–54.

U.S. Bureau of Mines and U.S. Geological Survey, 1980, Principles of a resource/reserve classification for minerals: U.S. Geological Survey Circular 831, 5 p.

APPENDIX

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

Definitions of Mineral Resource Potential

LOW mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics define a geologic environment in which the existence of resources is unlikely. This broad category embraces areas with dispersed but insignificantly mineralized rock as well as areas with few or no indications of having been mineralized.

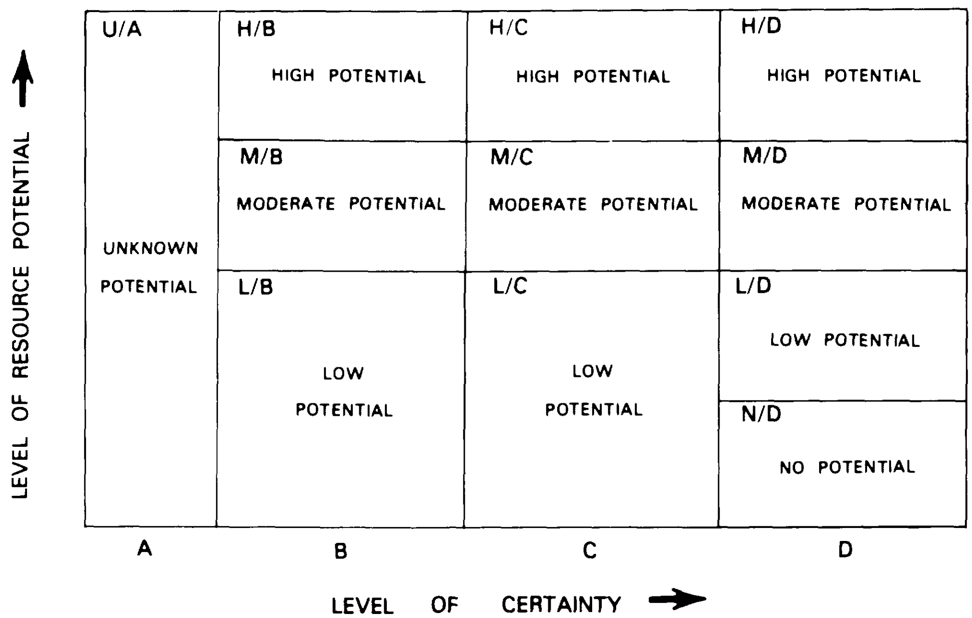
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application of mineral-deposit models indicates favorable ground for the specified type(s) of deposits.

HIGH mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a high degree of likelihood for resource accumulation, where data support mineral-deposit models indicating presence of resources, and where evidence indicates that mineral concentration has taken place. Assignment of high resource potential to an area requires some positive knowledge that mineral-forming processes have been active in at least part of the area.

UNKNOWN mineral resource potential is assigned to areas where information is inadequate to assign low, moderate, or high levels of resource potential.

NO mineral resource potential is a category reserved for a specific type of resource in a well-defined area.

Levels of Certainty



A. Available information is not adequate for determination of the level of mineral resource potential.
B. Available information suggests the level of mineral resource potential.
C. Available information gives a good indication of the level of mineral resource potential.
D. Available information clearly defines the level of mineral resource potential.

Abstracted with minor modifications from:

Taylor, R. B., and Steven, T. A., 1983, Definition of mineral resource potential: Economic Geology, v. 78, no. 6, p. 1268–1270.

Taylor, R. B., Stoneman, R. J., and Marsh, S. P., 1984, An assessment of the mineral resource potential of the San Isabel National Forest, south-central Colorado: U.S. Geological Survey Bulletin 1638, p. 40–42.

Goudarzi, G. H., compiler, 1984, Guide to preparation of mineral survey reports on public lands: U.S. Geological Survey Open-File Report 84–0787, p. 7, 8.

RESOURCE / RESERVE CLASSIFICATION

	IDENTIFIED RESOURCES			UNDISCOVERED RESOURCES	
	Demonstrated		Inferred	Probability Range (or)	
	Measured	Indicated		Hypothetical	Speculative
ECONOMIC	Reserves		Inferred Reserves		
MARGINALLY ECONOMIC	Marginal Reserves		Inferred Marginal Reserves		
SUB-ECONOMIC	Demonstrated Subeconomic Resources		Inferred Subeconomic Resources		

Major elements of mineral resource classification, excluding reserve base and inferred reserve base. Modified from U. S. Bureau of Mines and U. S. Geological Survey, 1980, Principles of a resource/reserve classification for minerals: U. S. Geological Survey Circular 831, p. 5.

GEOLOGIC TIME CHART

Terms and boundary ages used by the U.S. Geological Survey, 1986

EON	ERA	PERIOD		EPOCH	BOUNDARY AGE IN MILLION YEARS
Phanerozoic	Cenozoic	Quaternary		Holocene	0.010
				Pleistocene	1.7
		Tertiary	Neogene Subperiod	Pliocene	5
				Miocene	24
			Paleogene Subperiod	Oligocene	38
				Eocene	55
				Paleocene	66
	Mesozoic	Cretaceous		Late	96
				Early	138
		Jurassic		Late Middle Early	205
		Triassic		Late Middle Early	~ 240
	Paleozoic	Permian		Late Early	290
		Carboniferous Periods	Pennsylvanian	Late Middle Early	~ 330
			Mississippian	Late Early	360
		Devonian		Late Middle Early	410
		Silurian		Late Middle Early	435
		Ordovician		Late Middle Early	500
		Cambrian		Late Middle Early	~ 570[1]
Proterozoic	Late Proterozoic				900
	Middle Proterozoic				1600
	Early Proterozoic				2500
Archean	Late Archean				3000
	Middle Archean				3400
	Early Archean				3800?
pre-Archean[2]					4550

[1] Rocks older than 570 m.y. also called Precambrian, a time term without specific rank

[2] Informal time term without specific rank.

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