UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Geology and mineral resource potential of the Black Ridge Canyon Wilderness Study Area, Mesa County, Colorado

(GEM Phase 2)

by

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature. Any use of trade names is for descriptive purposes only and does not imply endorsement by the USGS.

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EXECUTIVE SUMMARY

The U.S. Bureau of Land Management (BLM) has adopted a multi-phase procedure for the integration of geological, energy, and mineral (GEM) resources data for suitability decisions for wilderness study areas. Phase 1 included the gathering of historical GEM resource data and was carried out by Mountain States Mineral Enterprises and Wallaby Enterprises (1983). Phase 2 is designed to generate new data to support GEM resources recommendations and was contracted to the U.S. Geological Survey.

This report is the result of a Phase 2 study of the Black Ridge Canyon Wilderness Study Area (WSA) conducted in June and July of 1983 by personnel from the Central Mineral Resources Branch of the U.S. Geological Survey. The mineral resource appraisal of the WSA consisted of geologic mapping at a scale of 1:24,000, combined with stream-sediment and rock sampling, and subsequent analysis of the samples. Further detailed mapping and sampling of known mineralized prospects were also carried out, along with a detailed investigation of the Salt Wash Member of the Morrison Formation for uranium potential. Preparations were made for water sampling for uranium analyses, but none of the drainages had sufficient water for sampling during the period of study.

The Black Ridge Canyon WSA (CO-07-113) covers about 18,150 acres in western Colorado in Mesa County (fig. 1), and lies about 8 mi west of Grand Junction. The physiography of the WSA is characterized by six deeply incised canyons draining northward into the Colorado River and separated by high rolling mesas. Precambrian igneous and metamorphic rocks crop out in the canyon bottoms of the WSA and are overlain by at least 1,650 ft of sedimentary rock, ranging in age from Triassic to Cretaceous. The WSA lies on the northern edge of the Uncompahgre Plateau, and is flanked along its northern margin by a series of major normal faults and fault-related monoclines. The sedimentary rocks in the WSA strike northwest and dip very gently to the northeast, but are folded as steeply as 45° across the axes of the monoclines. Offset along the faults is as much as 300 ft.

Thirty-one streams were chosen for sampling in the WSA, and at each stream a panned concentrate and a fine fraction of mud and silt were collected at the same site. Panned concentrate samples were analyzed by semiquantitative emission spectrography for 66 elements; fine fraction samples were sieved to minus 100 mesh and analyzed for 45 elements, using inductively coupled plasma emission spectroscopy. The fine fraction was additionally analyzed for uranium using fluorimetic techniques on an acetic acid extract. Rock samples were crushed and pulverized to minus 100 mesh and analyzed by semiquantitative emission spectrography for 66 elements.

The stream-sediment samples from the WSA had low concentrations of those elements commonly associated with mineralized rocks. No localized anomalies are present; however, the concentration of Ba in the panned concentrates was uniformly high (median 10,000 parts per million (ppm)) and in a few places was as high as 70,000 ppm. Barite was positively identified in the panned concentrates by X-ray diffraction techniques, but a source was not located in the outcrop. The concentration of Zr in the panned concentrates was also very high in a few samples (20,000 ppm), but may be related to the presence of zircon in the Precambrian crystalline rocks or detrital zircon in the sediments. No anomalous concentrations of any element were detected in the analyses of the fine fraction samples except for uranium (0.4 and 0.9 ppm), two isolated samples taken close to a uranium prospect.

Rock samples from the WSA were also low in elements associated with mineralized systems. However, in two closely related localities anomalous Cu (as much as 20,000 ppm), Ag (3 ppm), and Pb (70 ppm) were present, but mineralization was only of a very localized extent.

Known mineral deposits in the WSA consist of uranium in the Salt Wash Member of the Morrison Formation at the Edna mine and some sand and gravel operations along the northern edge of the WSA (fig. 1). This study located Cu-Pb-Ag mineralization in Devils Canyon (fig. 1) at the base of the Triassic Chinle Formation in channel sands and conglomerates, and in closely related float of Precambrian aplite. None of the known mineral deposits, prospects, or mineral occurrences within the WSA presently constitutes a mineral resource.

INTRODUCTION

The Wilderness Act of 1964 (PL-577) mandated the withdrawal of major portions of the federal lands in the National Forest System for inclusion into the National Wilderness Preservation System (NWPS). Federal mineral assessments were required to be conducted on lands affected as part of the wilderness land review process.

In 1976, the Federal Land Policy and Management Act (FLPMA, PL94-579) extended the wilderness review program to the lands administered by the U.S. Bureau of Land Management (BLM). Provisions in this act require the Secretary of the Interior to cause mineral surveys to be conducted prior to his making wilderness recommendations to Congress. Natural or Primitive areas formally identified prior to November 1, 1975, were termed Instant Study Areas. Wilderness recommendations for these areas were presented to the President prior to July 1, 1980. The remainder of the BLM lands are under review by the BLM to determine which are suitable as wilderness areas for inclusion into the NWPS. The wilderness land review process is being conducted in three steps: inventory, study, and report.

The inventory of BLM lands meeting wilderness criteria was completed for the state of Colorado in November, 1980, at which time the Wilderness Study Areas were designated. The study step in the wilderness review process includes mineral resource appraisals of the Wilderness Study Areas. The BLM has adopted a multi-phase procedure for the integration of geological, energy, and mineral (GEM) resources data into the suitable/unsuitable decision process on the Wilderness Study Areas. The multi-phase approach allows termination of the mineral resource appraisal at the end of Phase 1, which consists mainly of compilation of existing information. If the data gathered in Phase 1 is not adequate, then Phase 2 would generate new GEM resources data needed to permit an assessment of the potential for GEM resources. This report is the result of a Phase 2 study of the Black Ridge Canyon WSA conducted in June and July of 1983 by the U.S. Geological Survey.

The Black Ridge Canyon WSA covers about 18,150 acres in Mesa county in west-central Colorado (fig. 1). It lies 8 mi west of Grand Junction, 2 mi southwest of Fruita, and its western border is only 8 mi from the Colorado-Utah border. The WSA is bounded by the Colorado River on the north, the Black Ridge Canyon West WSA on the west, Black Ridge on the north, and the Colorado National Monument on the west. Access to the WSA is provided by the Colorado River and by dirt roads. A four wheel drive road extends along the northern and western sides of the WSA and a well-maintained gravel road runs through private lands along the easternmost half of the southern border. No maintained trails are present in the WSA.

The U.S. Geological Survey undertook a mineral resource appraisal of the Black Ridge Canyon WSA which consisted of geologic mapping at a scale of 1:24,000, combined with stream-sediment and rock sampling, and subsequent analysis of the samples. Color aerial photographs were commonly used to supplement the geologic mapping and determine regional structures. Further detailed mapping and sampling of known mineralized prospects were also carried out, along with a detailed investigation of the Salt Wash Member of the Morrison Formation for uranium potential. Preparations were made for water sampling for uranium analysis, but none of the drainages had sufficient water for sampling during the period of study.

We would like to acknowledge Larry R. Layman, O. Brooke Hatfield, and Dirk S. Hovorka who assisted in the rock and stream-sediment sampling. Charles G. Patterson mapped the Morrison Formation and prepared the sections on

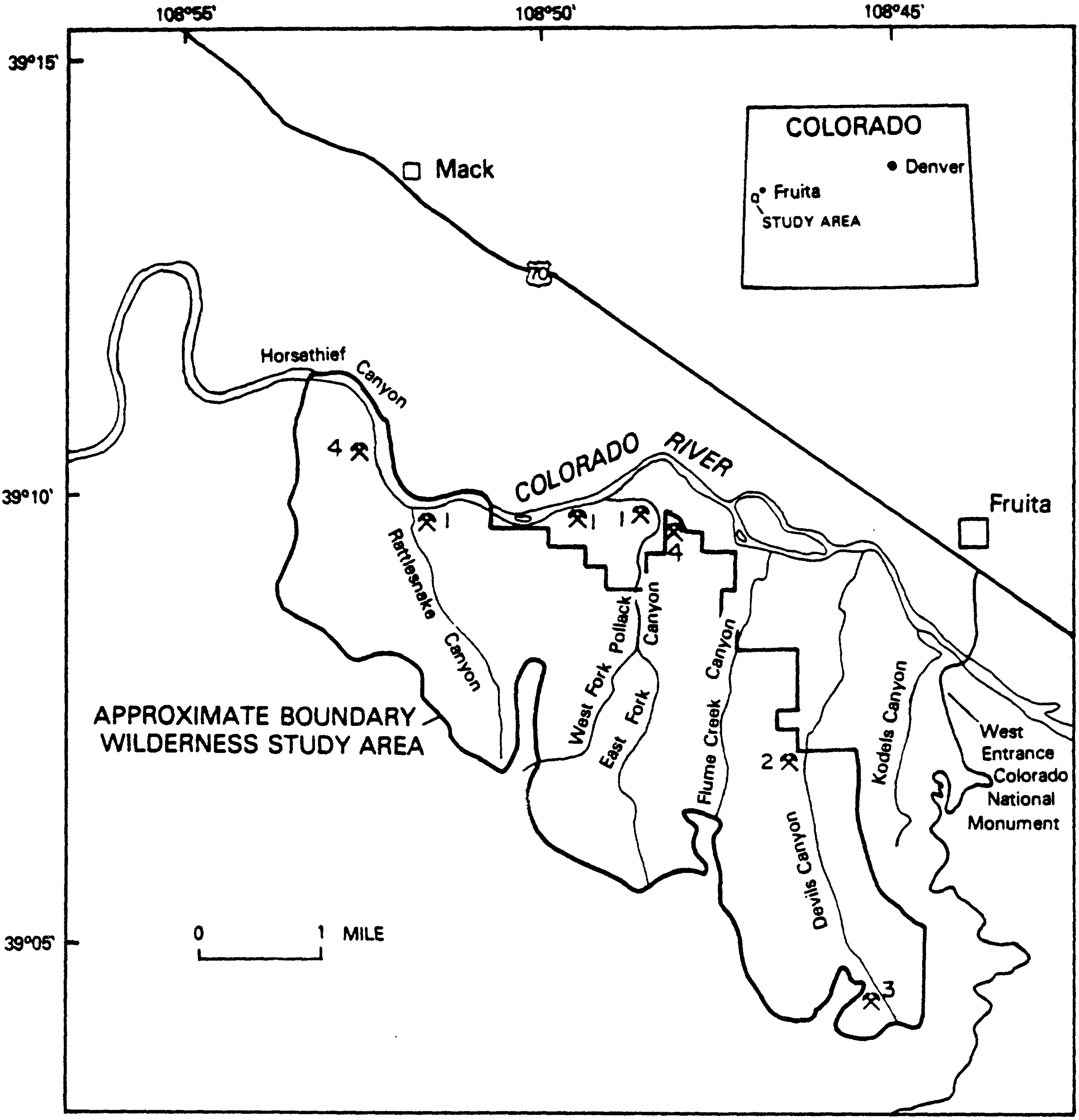

Figure 1.--Index map showing location of the Black Ridge Canyon Wilderness Study Area, Mesa County, Colorado. Pick and hammer symbols indicate areas of mineral deposits, prospects, and (or) mineral occurrences. 1) sand and gravel deposits; 2) Cu-Ag-Pb in Triassic Chinle Formation and float of Precambrian crystalline rocks; 3) Uranium in the Salt Wash Member of the Morrison Formation and 4) high Ba (70,000 ppm) in stream-sediment concentrates.

historical geology and uranium potential of the WSA. Thanks are expressed to the personnel in the U.S. Bureau of Land Management office in Grand Junction for their cooperation and help.

GEOLOGY

Physiography

The Black Ridge Canyon WSA contains a series of six deeply incised canyons separated by high, rolling mesas. These major canyon systems drain northward into the Colorado River and reach depths of 700 ft below their intervening plateaus. Each canyon is characterized by a central, deep, canyon with numerous small, short canyons draining into the main canyon. The width of the main canyons ranges from open canyons about 0.5 mi wide, to narrow, very steep chasms. In the lower parts of the canyons, steep gorges are commonly developed in Precambrian crystalline rocks and form cliffs, which in places exceed 100 ft.

The canyons all have some combination of arches, windows, natural bridges, overhangs, balanced rocks, and spires developed in sandstones of the Entrada and Wingate Formations. Rattlesnake Canyon is well known for at least 13 natural arches, second only to Arches National Monument in Utah.

Description of rock units

Precambrian crystalline rocks crop out in the canyon bottoms of the Black Ridge Canyon WSA and are overlain by at least 1,650 ft of subhorizontal sedimentary rock ranging in age from Triassic to Cretaceous. Thicknesses and descriptions of the different rock units are presented in the stratigraphic column accompanying the geologic map (Plate 1).

The Precambrian rocks consist of a complex sequence of highly variable igneous and metamorphic rock types that are moderately to strongly deformed; the age relationships between the varying units were not observed in the field. In the eastern part of the WSA the following lithologies were observed: purple xenomorphic granular hornblende-biotite granodiorite; gray to purple trachytic granite gneiss containing feldspar phenocrysts as much as 3 in. long; and dark gray, vertically foliated spotted mica schist with hornblende porphyroblasts 1 to 2 in. across. In contrast to the eastern part of the WSA, the western part consists dominantly of igneous rock. In the west the canyons are underlain by slightly foliated to gneissic, pink, equigranular, medium-grained garnet biotite granodiorite with smoky gray quartz. All the igneous and metamorphic units are crosscut by varying amounts of pegmatites, averaging 6 in. to 2 ft in thickness. The pegmatites contain feldspar, rose quartz, and variable amounts of biotite and hornblende, and show some spectacular examples of zoning, having feldspar margins and hornblende interiors. The pegmatites both crosscut and parallel the foliation in the structured rocks and have in places been deformed with the host rock. Aplite dikes are also present in a minor occurrence.

In most places, the top surface of the Precambrian rock is heavily grussified and altered to clay over a vertical distance of 1 to 4 ft, and is commonly slightly green to blue in color. This weathering surface may represent the paleosoil developed in Paleozoic time before deposition of the overlying sedimentary rock.

The Triassic Chinle Formation unconformably overlies the Precambrian rocks and consists of brownish-red to brick red sandy siltstone with 0.5 to 4 ft thick interbedded layers of brick red, well sorted, subrounded, fine-grained sandstone. At a few places in Devils Canyon, the Chinle Formation contains a medium- to coarse-grained conglomeratic sandstone at its base. The sandstone contains subangular pieces of quartz, chert, and jasper, comprising 30-40 percent of the total rock, and has some copper mineralization in one locality. The formation generally weathers into a steep slope with small steps defined by the sandstone interlayers. Petrified wood fragments and root casts are common in the Chinle in the lower portions of Devils Canyon and were occasionally found in place in the outcrop.

The contact between the Chinle Formation and overlying Triassic Wingate Sandstone is fairly sharp and unconformable. The Wingate consists of pinkish-buff, fine-grained, well sorted, well rounded, massively crossbedded, calcareous-cemented sandstone. The sandstone forms steep to vertical cliffs, making access into the top of most of the canyons in the WSA very difficult. Vertical jointing and desert varnish in the sandstone are also common.

The Wingate Sandstone grades upward into the Triassic Kayenta Formation, which consists of purple to reddish brown, coarse-grained, subangluar, moderately sorted sandstone with calcareous cement. Thin conglomerate lenses are common and contain subangular pebble to small cobble clasts consisting predominantly of sandstone and some siltstone. The sandstone of the formation weathers into thin slabs and is crossbedded with occasional massive beds 3 to 4 ft thick. The sandstones are generally harder and more resistant than those of the underlying Wingate, and serve as a protective capping to the Wingate.

The Jurassic Entrada Sandstone unconformably overlies the Kayenta Formation and consists of salmon red, fine-grained, subrounded sandstone with both siliceous and calcareous cement, and contains a few percent dark opaque minerals. This formation is massively crossbedded and contains some graded beds. The lower portion of the formation forms massive, fairly uniformly rounded cliffs, and the upper portion forms a series of slopes and steps. The arches in Rattlesnake Canyon are developed in this formation.

The Entrada Sandstone is unconformably overlain by and in sharp contact with the Jurassic Summerville Formation, which is highly variable in thickness (5 to 20 ft) and consists of yellow brown, thinly-bedded, fine-grained sandstone and shale. Because of the narrow and variable thickness, the formation was mapped with the Entrada Sandstone on the geologic map (Plate 1).

The Jurassic Morrison Formation conformably overlies the Summerville and consists of three parts in the Black Ridge Canyon WSA. The lower Tidwell unit consists of about 45 ft of flat-bedded, fine-grained sandstone, mudstone, and a few nodular limestones. It is overlain by the Salt Wash Member, and because of the thinness of the Tidwell, it was mapped together with the Salt Wash on the geologic map on Plate 1.

The Salt Wash Member consists of a basal trough crossbedded sandstone overlain by interlayered sandstone and mudstone. A few thin limestone beds are present near the base of the member. The sandstone is light yellowish-gray to grayish green or light reddish, mostly calcareous, and contains a few thin lenses of granule conglomerate or clay rip-up conglomerate. The beds of sandstone are lenticular at the top of the member to laterally continuous at the base and have low angle trough to planar cross-stratification. The mudstones are light to dark gray, purple, or red brown, and are massive, laminated, or interbedded with thin sandstone or siltstone. Rare concentrations of carbonaceous debris host small grade uranium deposits. The member as a whole forms steep slopes, benches, and cliffs.

The Salt Wash Member grades upward into the Brushy Basin Member, a light to dark gray, pale green, red-brown, and purple bentonitic mudstone. A few thin sandstone and multicolored chert-granule to pebble conglomerate lenses are also present and contain rare silicified plant and vertebrate remains. The Brushy Basin Member forms gentle, rounded slopes in contrast to the underlying Salt Wash Member.

The Morrison Formation grades upward into the Cretaceous Burro Canyon Formation, which crops out only in the southern and westernmost parts of the WSA. It consists of white to gray, thickly bedded to massive sandstone, with interbedded greenish siltstone and shale. The Burro Canyon is conformably overlain by Cretaceous Dakota Sandstone, consisting of yellowish-brown, buff to gray sandstone with interbedded gray to black organic shale and thin coal beds. A white, coarse-grained, basal conglomerate is locally present at the base of the Dakota. The contact between the two formations is often quite difficult to locate and they were not separated on the geologic map (Plate 1).

Structure

The Black Ridge Canyon WSA lies on or adjacent to the northern edge of the Uncompahgre Plateau, a major landform and structural feature of western Colorado. Approximately 100 mi long by 25 to 30 mi wide, it trends northwest-southeast from Grand Junction and Colorado National Monument to near Ridgway and the San Juan Mountains (fig. 2). Structurally, it is a large arch with a steeper southwest limb and a gentler northeast limb, flanked by the Paradox Basin to the southwest, Douglas Arch and Piceance Creek Basin to the north and northeast, and the Gunnison uplift and San Juan Volcanic Field to the southeast and south (fig. 2). It consists of Precambrian igneous and metamorphic rocks overlain by flat-lying to monoclinally folded sedimentary rocks of Paleozoic and Mesozoic age (fig. 3). The block is tilted to the northeast and bounded by sharply flexed, faulted monoclines (Cater, 1965).

Much of the structural grain of the Uncompahgre region was formed by the intersection of two Precambrian wrench fault systems. The Colorado lineament, trending northeast (Warner, 1980), and the Wichta-Olympic lineament, trending northwest (Baars and Stevenson, 1981) probably formed as systems of shear zones, related to regional stress fields during the Precambrian generated by plate interactions (Warner, 1980; Baars and Stevenson, 1981). Tectonic movements and resultant patterns of sedimentation in the area of the Uncompahgre Plateau have been influenced greatly by subsequent reactivation of the Precambrian fault systems. More recently-formed high-angle faults trending west-northwest are found mostly along the western margin of but also within the plateau (fig. 3).

The sedimentary rocks in the Black Ridge Canyon WSA strike to the northwest and dip 3-5° NE, and are deformed by a system of faults and fault-related monoclines trending about N65W. These major structural features bound the northern border of the WSA and are, from west to east, the Rattlesnake Canyon monocline and associated fault-monocline, the Flume Creek Fault, and the Devils Canyon Monocline (Plate 1).

Triassic and Jurassic sedimentary rocks are sharply folded 45° to the north across the axis of the Rattlesnake Canyon Monocline. Just south of the monocline, the rocks are more gently folded across the axis of another monocline (unnamed), which also shows fault displacement of at least 75 ft, transposing Precambrian crystalline rocks next to Triassic sedimentary rocks of the Chinle Formation in both Bull and Rattlesnake Canyons. The sedimentary rocks dip 45° north along the eastern part of the monocline-fault where

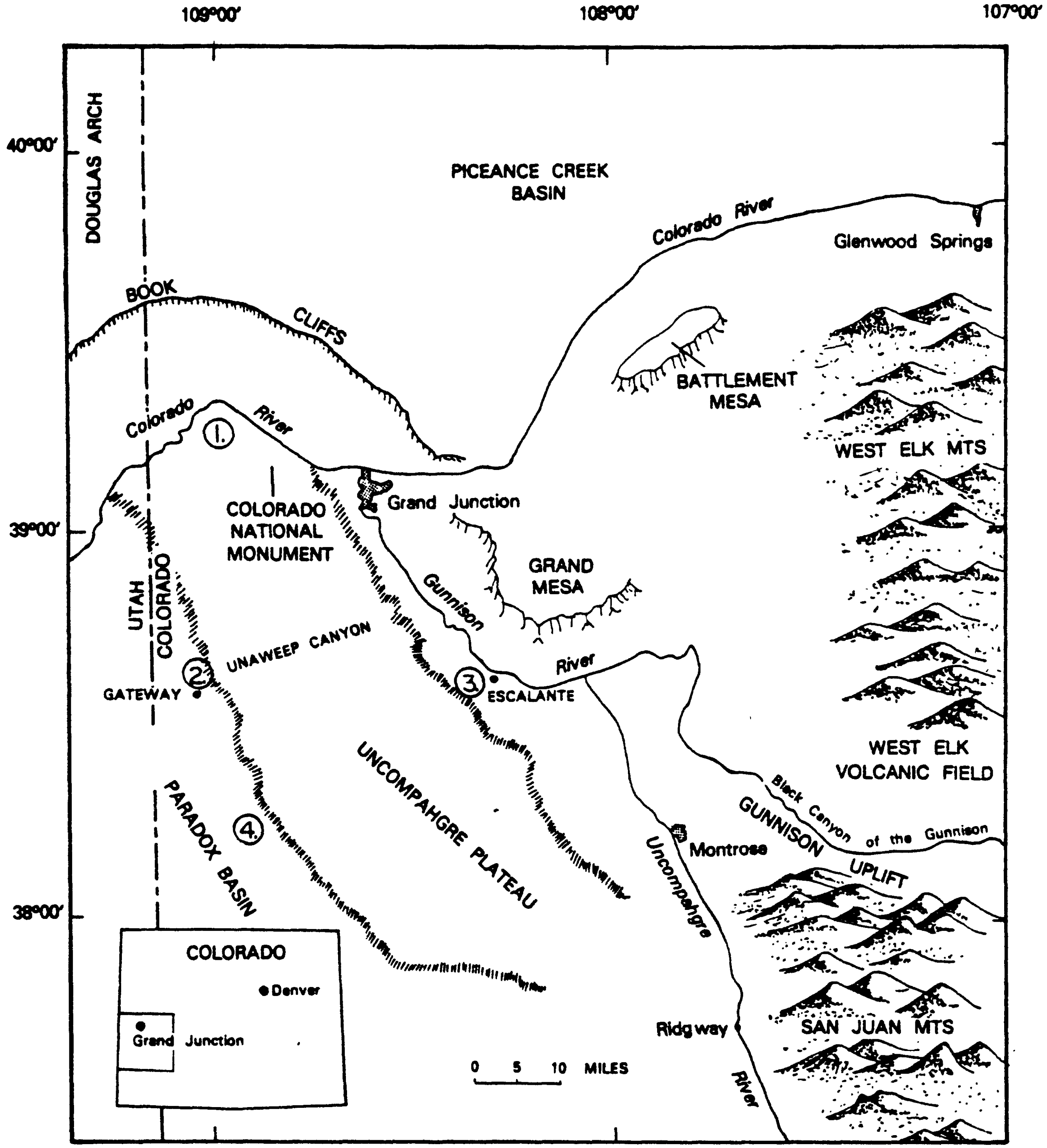

Figure 2.--Map showing location of major structural features in southwestern Colorado. Modified from Epis and Callender (1981). 1.) Black Ridge Canyon WSA; 2.) Palisade WSA; 3.) Dominguez Canyon WSA; 4.) Sewemup Mesa WSA

Figure 3.--Map showing generalized geology and location of major structural features in the region of Black Ridge Canyon Wilderness Study Area, Mesa County, Colorado. Geology modified from Tweto (1979).

Quaternary alluvial deposits, undifferentiated

Paleozoic and Mesozoic sedimentary rocks

Precambrian crystalline rocks

Monocline, showing trend of axis and direction of dip

Normal fault, ball and bar on downthrown side

Approximate Wilderness Study Area outline

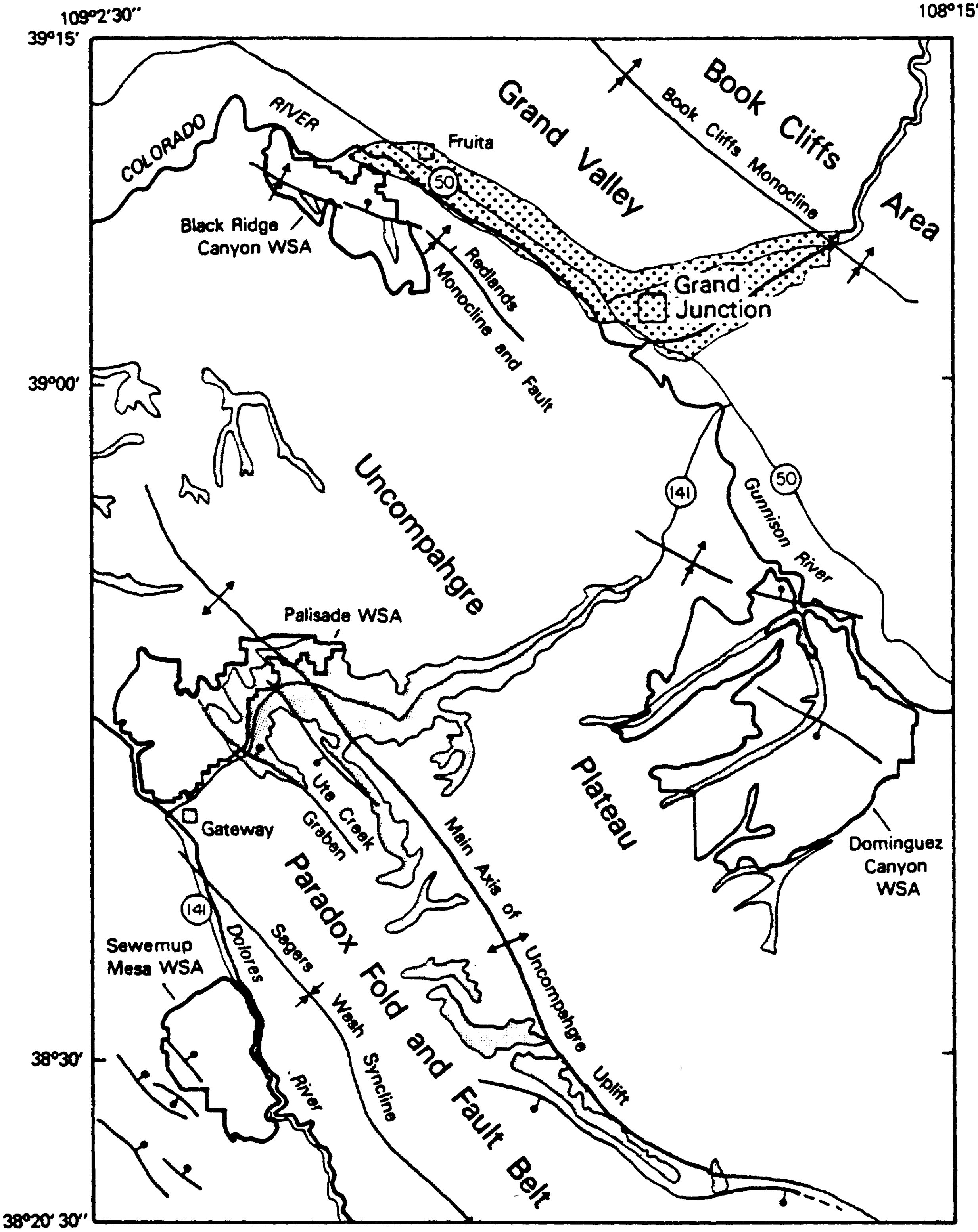
109°2'30"
108°15'
39°15'
39°00'
38°30'
38°20' 30"
Book Cliffs Area
Book Cliffs Monocline
Grand Valley
COLORADO RIVER
Fruita
50
Black Ridge Canyon WSA
Redlands Monocline and Fault
Grand Junction
Uncompahgre
Plateau
141
50
Gunnison River
Palisade WSA
Ute Creek Graben
Gateway
Main Axis of Uncompahgre Uplift
Dominguez Canyon WSA
Paradox Fold and Fault Belt
141
Sewemup Mesa WSA
Dolores River
Sagers Wash Syncline

Figure 3.

it merges with the Rattlesnake Canyon Monocline, but the dip of the beds decreases to the west to about 17° north.

The Rattlesnake Canyon Monocline and associated fault-monocline merge in Rattlesnake Canyon and extend southeastward to Pollock Canyon. Along this stretch, the sedimentary units are both folded across the axis of a monocline to a dip of about 35° north, and are also faulted along a normal fault that dips 75° to the north. In Pollock Canyon only minor folding is present, and the major structural influence is faulting along the Flume Creek Fault, resulting in a displacement of 300 ft. A small, southern splay of the Flume Creek Fault shows displacement of about 75 ft, faulting Precambrian rocks against Triassic Chinle Formation. The Flume Creek fault continues southeastward and extends outside of the WSA as a part of the Redlands Fault system (fig. 3) (Lohman, 1965).

At the northeast boundary of the WSA, the Flume Creek Fault splays to form the Devils Canyon Monocline; a short normal fault 70° to the Flume Creek Fault joins the two. The monocline dips gently northward and dies out after a short distance to the southeast.

About 1 mi north of the Flume Creek Fault system, the sedimentary units are folded about 21° N across the axis of the Flume Creek Monocline. The monocline is fairly symmetrical and strikes N. 45 W. and its eastward extension is unknown.

The metamorphic rocks in the Black Ridge Canyon WSA are moderately to strongly foliated and strike consistently to the northwest, with variable but steep dips from 65° to 85° to the north and south. The igneous rocks in Rattlesnake Canyon have a primary flow foliation and also strike northwest, but dip at much shallower angles. The northwest strike of the igneous and metamorphic rocks parallels the structural grain of the Wichta-Olympic Precambrian lineament.

Present day landscapes of the Uncompahgre Plateau region have resulted from extensive erosion following uplift in Laramide, Late Tertiary, and Pleistocene times (Cater, 1966; Tweto, 1980; Lohman, 1965; Hunt, 1956). Major uplift of 1,500-2,000 ft may have occurred as late as Pleistocene time (Cater, 1966). This uplift defined and outlined the present-day Uncompahgre Plateau.

No evidence for glaciation has been found in the Uncompahgre Plateau.

Historical geology

Precambrian igneous and metamorphic rocks are exposed in several of the deeper canyons of the Uncompahgre Plateau, notably Unaweep, Dominguez, and Escalante Canyons (fig. 3), and in drainages within and adjacent to Colorado National Monument. These rocks may have originated as a thick pile of interbedded sedimentary and volcanic rocks deposited sometime between 2000 and 1,800 m.y. ago in an oceanic environment (Carpenter and others, 1979). Around 1,750 m.y. ago, these rocks were deformed and metamorphosed to high grade, possibly by plate collisions (Tweto, 1980; Carpenter and others, 1979). At the northern edge of the Uncompahgre Plateau in the Black Canyon area (fig. 3), partial melting of the metamorphic rocks in the later stages of metamorphism produced the Pitts Meadow Granodiorite (Hansen, 1981). Two later phases of igneous intrusion also occurred in the same area, during which the Vernal Mesa Quartz Monzonite (1,480±40 m.y.) and the Curecanti Quartz Monzonite (1,420±15 m.y.) were emplaced. The causes for this igneous activity are obscure but may be related to plate interactions at that time (Carpenter and others, 1979). Many pegmatites of widely ranging age, but probably related to the Curecanti Quartz Monzonite, are also present (Hansen, 1981).

During early Paleozoic time a geosyncline developed to the west in Utah. Shallow-water shelf sedimentation in marginal seas produced thin, flat-bedded limestones and sandstones in Colorado. These may be seen in Glenwood Canyon, but are not present anywhere near the WSA.

Major tectonism began in Pennsylvanian time, and produced many of the major sedimentary rocks and features of the Uncompahgre Plateau region. A system of northwest-trending uplifts and complementary basins, including the ancestral Uncompahgre highland and the Paradox Basin immediately southwest of it, were formed in this area. Hot and arid conditions led to deposition of thick sequences of evaporites with interbedded black shales in the basins, which were followed by deposition of more normal marine limestones as the basins deepened. In the Paradox Basin, these deposits are the Paradox and Pinkerton Trail Members of the Hermosa Formation. Arkosic debris from the ancestral Uncompahgre highland was also being shed into these basins by alluvial fans and streams. These deposits are known as the Culter Formation, and overlie and interfinger with the Hermosa Group (Campbell, 1981). The Cutler Formation pinches out northeast of Gateway, but attains a thickness of more than 14,000 ft just a few miles to the southwest (Campbell, 1981; Cater, 1955). An unconformity separates Permian beds of the upper Cutler from the overlying Triassic Moenkopi Formation. In places, this contact is difficult to determine without close examination; however, near Gateway, the base of the Moenkopi is marked by a conspicuous bed of gypsum. During the following Triassic time a seaway transgressed across western Utah. Tidal flats marginal to this sea lapped over the Cutler sediments, but were stopped by the still present ancestral Uncompahgre highland. Resultant sediments were brick red to chocolate, thin and even bedded siltstones, sandstones, rare evaporites and thin conglomerates, many showing distinctive and spectacular ripple marks and mud cracks (O'Sullivan and MacLachlan, 1975).

As the weight of overlying sediments increased, the salts of the Paradox Member of the Hermosa Formation were mobilized and began to flow upwards as bulges and later diapirs, piercing and invading overlying rocks, and influencing sedimentation patterns of subsequent formations. This is shown in the Moenkopi and some overlying formations by the thickening and thinning unrelated to other tectonic elements (Szabo and Wengerd, 1975). Diapirs of salt also rafted blocks of the Hermosa Formation sediments upward, to be exposed in the center of the so-called salt anticlines, or upheaval-dome type structures (Cater, 1955; Baars and Stevenson, 1981; Mattox, 1975).

Later in Triassic time, new highland sources to the west and south developed. Streams flowing from these sources across the Uncompahgre region and farther into Utah deposited sediments of the Chinle Formation. The ancestral highland was sufficiently diminished that Chinle sediments traverse it completely in the vicinity of the WSA, lying directly on the Precambrian (O'Sullivan and MacLachlan, 1975; Cater, 1955). The base is generally marked by a chert-pebble conglomerate, but the Chinle is difficult to separate from the underlying Moenkopi wherever it is present.

Separated from the Chinle by a minor unconformity is the Wingate Sandstone, the lowest member of the Glen Canyon Group. Some workers (Fred Peterson, oral commun., 1983) feel that the Wingate is Jurassic in age, but until further work is done it is included in Triassic time. The Wingate is a dominantly eolian unit, characterized by large sweeping crossbeds indicative of deposition by wind. Wind directions were from the northwest, as they were for most of the other eolian sand bodies of the Colorado Plateau. The Wingate is conformably overlain by weathered fluvatile sandstones and conglomerates of the middle member of the Glen Canyon Group, the Triassic Kayenta Formation. Highlands to the east and southeast were source areas for the Kayenta. The upper member of the Glen Canyon Group, the Navajo Sandstone (Triassic(?) or Jurassic), is another eolian sandstone unit and contains in places thin lacustrine limestones. The Navajo Sandstone is not present in the northern part of the Colorado Plateau or near the Black Ridge Canyon WSA and is found only in and near Sewemup Mesa WSA on the southwest edge of the Plateau.

Rocks of the Jurassic San Rafael Group overlie the Glen Canyon Group. These are, in ascending order, the Carmel Formation, Entrada Formation, Curtis Formation and Summerville Formation. In the Uncompahgre region, the Entrada and Summerville are the only formations that are present. Where the Navajo is absent, the Entrada lies directly upon the Kayenta. Formed by deposition in shallow lakes and dune fields, the Entrada consists of alternating flat-bedded and crossbedded layers. The Summerville Formation rests conformably upon the Entrada and represents marginal marine or lacustrine facies of a seaway lying farther to the west. This formation physically resembles and may correlate directly with the marl member of the Wanakah Formation of the Placerville area.

An unconformity marked by a basal lag with chert pebbles in a sandstone bed separates the Summerville and overlying Morrison Formation. The Morrison represents a return to fully terrestrial conditions of deposition. Streams that flowed generally from the southwest and associated lakes and swamps supplied these sediments. In some places, abundant dinosaur bones and woody material, as well as various kinds of agate, may be found in these rocks. The Morrison is divisible in three readily identifiable parts, in ascending order: the Tidwell unit, the Salt Wash Member, and the Brushy Basin Member. The Tidwell represents deposition under lacustine conditions (Fred Peterson, oral commun., 1983). The Salt Wash Member is a series of interconnecting sandstone lenses with interbedded claystone and limestone deposited by a large alluvial fan system that originated in south central Utah. Some eolian sandstone bodies at the base of the Salt Wash may correlate with the Bluff Sandstone of Utah. The overlying Brushy Basin Member is more dominantly mudstone, some of which is bentonitic and may have been derived from a volcanic source to the west (Craig and others, 1955). A few sandstone and conglomerate lenses, as well as thin limestones indicative of temporary lakes, are also found in the Brushy Basin Member.

The youngest rocks in the Uncompahgre region are the Cretaceous Burro Canyon and Dakota Formations. Rocks of the Burro Canyon were deposited by streams flowing from the south, and rocks of the Dakota Formation, mostly remnants left by erosion, were deposited on the swampy deltaic margins of a seaway transgressing from the south. Overlying beds of the Mancos Shale and the Mesa Verde Formation represent the full advance and retreat of the seaway; they are found nearby forming Bookcliffs and badlands, but they have been eroded completely from the Black Ridge Canyon WSA.

GEOCHEMISTRY

A geochemical survey of the WSA included the sampling of stream sediments and rocks for analysis by semiquantitative emission spectrography, inductively coupled plasma spectroscopy, and fluorimetry. Sample localities are shown on plate 2.

Sample design

First order streams in the Black Ridge Canyon WSA were defined as the smallest unbranched tributaries depicted on U.S. Geological Survey 1:24,000 scale topographic maps; second order streams were defined as streams having two or more first order tributaries and no higher order tributaries; and third order streams were defined as streams having two or more second order tributaries and no higher order tributaries. Stream sediment sampling sites in the WSA were chosen by identifying all first order streams that have drainage basins of 2 to 3 sq mi. If the drainage area outlined by the first order stream was substantially smaller, then the second or third order drainages were sampled instead. Thirty-one stream sites in the WSA were sampled and at least 90 percent of the area was covered by this sampling method. Where a stream drained outside of the WSA, the stream was sampled as close as possible to the WSA boundary.

Two types of stream sediments were collected at each sampling site. A panned concentrate sample was collected to analyze for the heavier metallic elements such as Cu, Pb, and Zn, whereas a fine fraction of mud and clay was collected to analyze for metals such as Mo and U which typically adhere to clays. Panned concentrate samples were obtained by collecting sediment at several different places within the active stream bed where heavy minerals would be concentrated. The sediment was screened through a stainless steel screen at the site to less than 10 mesh (0.039 in.). Where water was available, the samples were panned to a concentrate of about 0.15 to 0.35 oz; in dry streams 15 lbs of sediment was collected for later panning. The fine fraction samples consisted of about 0.25 oz of mud, clay, and fine-grained sand collected from within the active stream channel, generally along point bars.

Rock samples were collected at two types of localities within the WSA. The first type consisted of all localities containing mineralized, altered, or otherwise anomalous rock. In these cases, about 0.5 lb of thumb-sized rock chips were collected from the outcrop; where mineralized rock was present, the sample was collected along the vein or mineralized layer. The second type of sample consisted of only Precambrian crystalline rocks, sampled at random intervals to establish background values of the various elements and to look for any mineralization. About 0.5 lb of monolithologic, unweathered, thumb-sized rock chips were collected by sampling along the outcrop for distances of 15 to 20 ft. Where foliation was evident, the sample was collected perpendicular to its trend.

Analytical methods

Ten milligrams of the panned concentrate samples were analyzed semiquantitatively for 66 elements by optical emission spectrography (Myers and others, 1961). The results for each element are reported as mid-points of geometric brackets within each order of magnitude (i.e. 0.7, 0.5, 0.3, 0.2, 0.15, 0.1). The precision of the results is approximately one standard deviation per bracket. Table 1 lists the elements looked for and their determination limits.

The fine fraction of the stream sediment samples were sieved to minus 100 mesh (0.0059 in.) and analyzed for 45 elements using inductively coupled plasma atomic emission spectroscopy (ICP) (Taggart and others, 1981). Two hundred milligrams of sample were dissolved by sequential acid digestion using HF, HNO_3, and $HClO_4$, and taken to dryness. The residue was dissolved with 1 ml of aqua regia and diluted to 10 ml. Resistate minerals such as zircon were not dissolved by this digestion procedure, but most rocks and minerals were thoroughly digested. The elements looked for by ICP analysis and their determination limits are given in Table 1. The precision of the method is approximately 5 percent relative standard deviation.

Table 1.--Approximate lower limits of detection for semiquantitative 6-step emission spectroscopy and inductively coupled plasma atomic emission spectroscopy. (-- indicates not presently determinable.)

Element	6-Step	ICP	Element	6-Step	ICP
	%			%	
Al	0.01	0.05	Na	0.05	0.1
Ca	0.002	0.05	P	0.2	0.01
Fe	0.001	0.05	Si	0.002	--
K	0.7	0.1	Ti	0.0002	0.01
Mg	0.002	0.05			
	parts per million			parts per million	
Ag	0.5	2	Nd	70	4
As	1000	10	Ni	3	2
Au	20	8	Os	50	--
B	20	--	Pb	10	4
Ba	2	1	Pd	2	--
Be	1.5	1	Pr	100	10
Bi	10	10	Pt	50	--
Cd	50	2	Re	50	--
Ce	200	4	Rh	2	--
Co	3	1	Ru	10	--
Cr	1	1	Sb	150	--
Cu	1	1	Sc	5	2
Dy	50	4	Sm	100	50
Er	50	4	Sn	10	4
Eu	100	2	Sr	5	2
Ga	5	4	Ta	500	--
Gd	50	10	Tb	300	20
Ge	10	--	Te	2000	--
Hf	100	--	Th	200	4
Ho	20	4	Tl	50	--
In	10	--	Tm	20	--
Ir	50	--	U	500	100
La	30	2	V	7	1
Li	100	2	W	100	--
Lu	30	--	Y	10	2
Mn	1	4	Yb	1	1
Mo	3	2	Zn	300	2
Nb	10	4	Zr	10	--

Uranium in the fine fraction of the stream sediments was determined by use of a Scintrex pulsed laser fluorimeter on an acetic acid extract. Five grams of sample were digested with 15 milliliters (ml) of 50 percent acetic acid and 5 ml of 30 percent hydrogen peroxide (Rose and Keith, 1976). After filtration the extract solution was taken to near dryness, refluxed with concentrated HNO_3, taken to dryness, and the residue was dissolved in 5 ml of 10 percent HCl. This solution was diluted 1000-fold and analyzed with the fluorimeter. The determination limit is 0.2 ppm, and the estimated relative standard deviation is 15 percent.

Rock samples were crushed and pulverized to a minus 100 mesh (0.0059 in.) and were analyzed by semiquantitative emission spectrography similar to the panned concentrates discussed above.

The various analyses were done by N. M. Conklin, P. H. Briggs, M. J. Malcolm, and D. B. Hatfield under project leader J. L. Seeley, Branch of Analytical Laboratories, U.S. Geological Survey, Denver, Colo.

Results of geochemical survey

The panned concentrate samples from the WSA were analyzed for 66 elements, but only showed detectable concentrations of nine elements, including B, Ba, Cr, Cu, Ni, Pb, Sr, Y, and Zr. The analytical data for each of these elements were composited into histograms (such as fig. 4) and chemically anomalous samples were defined as the higher population wherever a well-defined separation was present in the data. Because only 31 streams were sampled, no statistical analyses were used. None of the elements showed any clearly anomalous concentrations and were in general characterized by a very wide range in concentrations, possibly reflecting the high variability in the lithologies of the source rock. With the exception of Ba and Zr, the elements were also only present in very low concentrations, commonly quite close to their actual detection limits.

The concentration of Ba in the panned concentrates ranged from 1,500 parts per million (ppm) to very high concentrations of 70,000 ppm (fig. 4a and Plate 2). The highest Ba anomalies were not restricted to any single geographic area. Because the streams drained heterolithologic source areas, it is not possible to identify the source of the high concentrations. Barite was positively identified in the panned concentrates by X-ray diffraction methods (A. M. Leibold, oral commun., 1983) and is most likely the source of the high Ba.

The concentration of Zr in the panned concentrates ranged from 70 ppm to as much as 20,000 ppm (fig. 4b). The highest value of Zr was associated with a stream that drained an area consisting solely of sedimentary rock. The source for the Zr is unknown, but might be detrital zircon grains in the sands. Samples containing 15,000 ppm Zr were from streams that drained basins with various amounts of outcrop of Precambrian crystalline rock, which may be a likely source for the Zr.

The fine fraction of the stream sediments were analyzed for 45 elements by ICP and showed no anomalous concentrations of any elements; detection limits for the elements are given in table 1. However, the fine fraction analyzed by fluorimetry showed some detectable concentrations of uranium. Most of the samples contained <0.2 ppm uranium, but BMT004 and BMT005 contained 0.9 and 0.4 ppm uranium, respectively. Both of these samples are in close proximity to the Edna uranium mine, where the Salt Wash Member of the Morrison Formation is a likely source for the uranium. The Edna mine is discussed in detail in the section on mineral deposits.

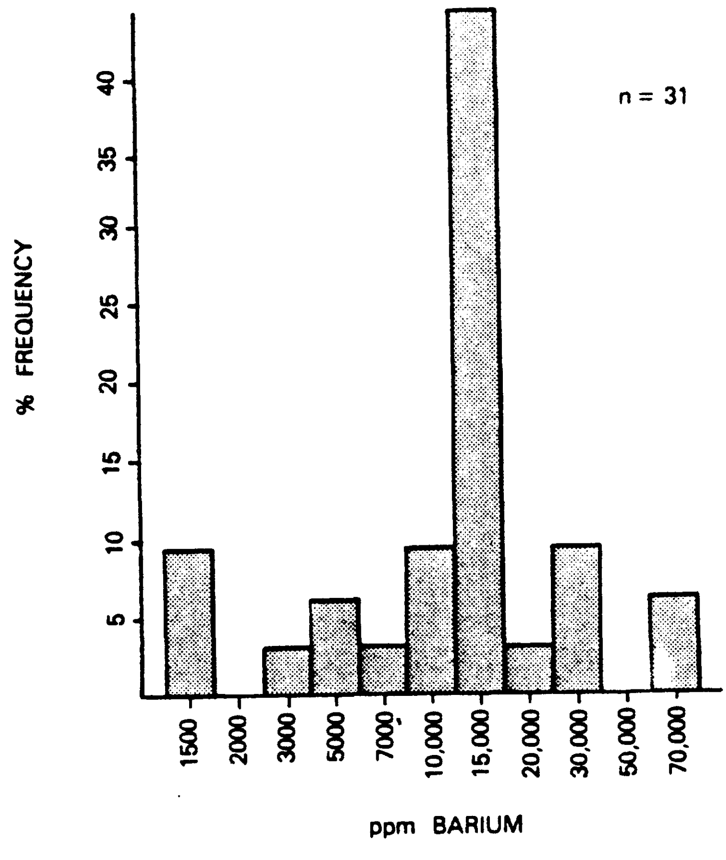

Figure 4a.--Histogram showing distribution of Ba in panned concentrates from the Black Ridge Canyon Wilderness Study Area, Mesa County, Colorado. n= total number of samples.

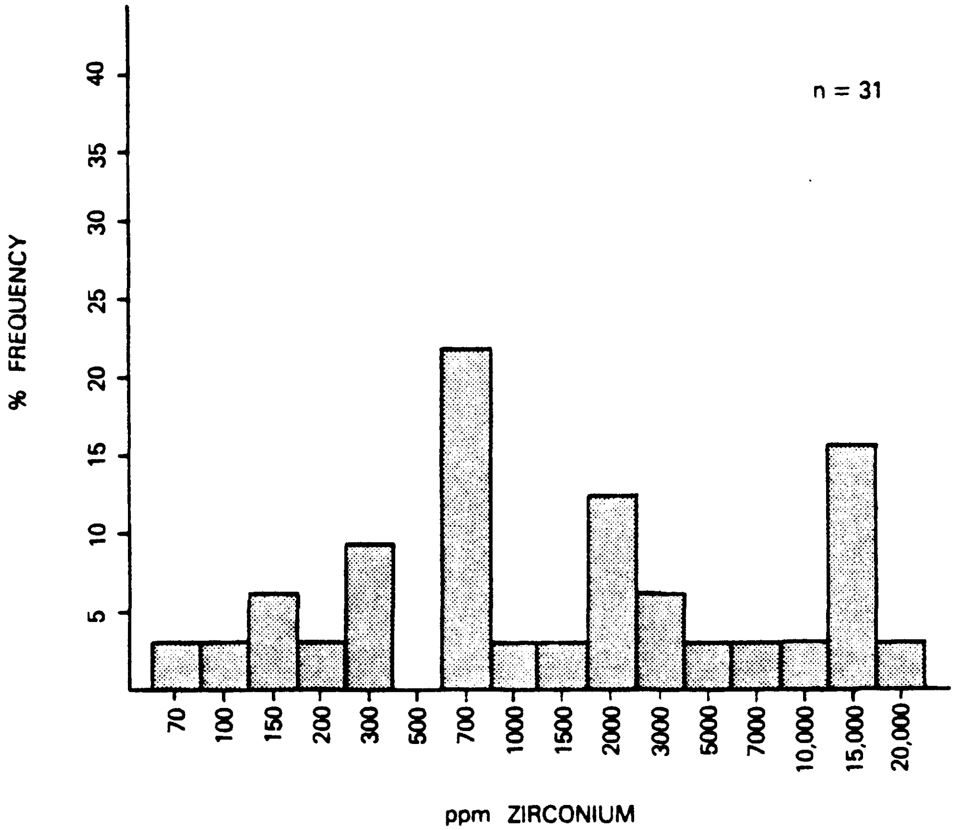

Figure 4b.--Histogram showing distribution of Zr in panned concentrates from the Black Ridge Canyon Wilderness Study Area, Mesa County, Colorado. n= total number of samples.

The rock samples from the Black Ridge Canyon WSA are also low in elements associated with mineralized systems. The only geochemical anomalies were restricted to two mineralized localities. Near the mouth of Devils Canyon, malachite and (or) chrysocolla mineralization was observed both in sedimentary and Precambrian igneous rocks. Sample BMT009A, a mineralized sandstone at the base of the Chinle Formation, contained 2 ppm Ag, 500 ppm Cu, and no anomalous Pb. Sample BMT009B, a seemingly unmineralized sandstone at the same locality, contained 500 ppm Cu and no detectable Ag or Pb. Sample BMT007, an aplite dike in Precambrian gneiss, contained 3 ppm Ag, 20,000 ppm Cu, and 70 ppm Pb. Rock samples from the Edna uranium mine at the head of Devils Canyon contained 3 and 15 ppm Ag, 20 and 50 ppm Cu, <3 and 150 ppm Mo, 150 and 300 ppm Pb, 700 ppm U, and 1500 and 3000 ppm V.

Other than the mineralized aplite dike, none of the other Precambrian rocks showed anomalous concentration of any elements.

URANIUM POTENTIAL

General statement

The Black Ridge Canyon WSA lies on the northern flank of the Colorado Plateau. Historically, adjacent areas on the plateau have supplied more than 12 percent of the uranium mined in the United States (Chenoweth, 1978). The uranium deposits are principally found in the Salt Wash Member of the Jurassic Morrison Formation and a voluminous literature exists on these deposits and on the stratigraphy of the Morrison Formation. Good summaries of the uranium production and history on the Plateau are given by Chenoweth (1978) and good descriptions of the Salt Wash-type deposits and of exploration techniques for such deposits are given in Thamm and others (1981). General descriptions of the Morrison Formation are given by Craig and others (1955) and Mullens and Freeman (1957). More detailed discussions of the Morrison Formation, especially the Salt Wash Member, are given by Tyler and Ethridge (1983), Huffman and others (1980), and Peterson (1980).

Prior to this report, no specific study of the Salt Wash Member in the Black Ridge Canyon WSA had been performed. Because of the limitations of time, this report must be considered preliminary, but will serve as a basis for evaluation of the uranium potential in the WSA in Salt Wash-type deposits.

General description of the Morrison Formation

The Morrison Formation is widespread throughout the Colorado Plateau and Four Corners region and consists of fluvial and lacustrine conglomerates, sandstones, siltstones, mudstones, and limestones deposited by northeastward to eastward flowing streams. In the WSA the Morrison is divisible into three recognizable parts. These are, in ascending order, the Tidwell unit, the Salt Wash Member, and the Brushy Basin Member.

The Tidwell unit was recognized by Peterson (1980) as consisting of light gray laminated to thin-bedded fine-grained sandstone, and interbedded greenish-gray and reddish-brown shale and mudstone. The unit locally contains layers of gray nodular limestone which may contain discontinuous seams of red "welded chert". In the WSA, the Tidwell is characterized further by flat-bedded, thin basal sandstones 6 to 10 ft thick, which display long-crested ripples, occasional mudcracks, and rare casts of salt crystals. A thin, discontinuous conglomerate of mainly black chert pebbles at the base of the lowermost unit may mark the J-5 unconformity which separates the San Rafael Group from Upper Jurassic units. This basal sandstone is widespread and continuous, forming a visible marker between the Morrison and the underlying marginal marine Summerville Formation (Jurassic) which forms covered slopes. Generally, one or more similar sandstone layers will be found higher in the Tidwell, but the chert granule layer occurs only in the lowermost unit. The Tidwell represents lacustrine conditions just prior to Salt Wash time. It averages 45 ft in thickness and contains no uranium mineralization.

The base of the Salt Wash Member is marked by the lowest appearance of true fluvial channels. These form either isolated lenticular bodies encased in mudstone in the lower portion ("lower rim") of the Salt Wash, or more continuous layers formed by laterally interfingering lenticular bodies as in the upper portions ("upper rim"). The sandstones are light gray green to reddish or limonite speckled, fine-grained, with rare medium to coarse sand or granule conglomerates and clay rip-up conglomerates at the base of cut-and-fill sequences. They are mainly calcareous with isolated patches or zones of dolomite or barite cement. In the lower rim, the sandstones are mainly flat bedded to small to medium low-angle trough crossbedded, indicative of low energy fluvial or lacustrine deposition. The sandstones are encased in mudstones which are dominantly reduced, and in thin dark gray, fossiliferous limestones, some of which smell fetid along freshly broken surfaces. These characteristics seem to indicate a more distal, lacustrine, low energy environment for the lower rim portions. The lower rim averages 150 to 200 ft in thickness in the WSA.

The upper rim of the Salt Wash displays a somewhat higher energy regime. Sandstone dominates this portion, with more cut-and- fill structures, more trough crossbedding, a few more chert pebble and clay rip-up conglomerates, and sparse organic debris. Flat to massive bedding in these sandstones, however, is more common than in the more proximal facies in the Uravan belt. The upper rim sandstones generally form a steep, tiered cliff or slope composed of two or more laterally continuous layers interbedded with reddish mudstones, which form small slopes or breaks. The upper rim ranges from 40 to 100 ft thick. The Salt Wash is thought to have been deposited by streams traversing an alluvial fan system that extended from south-cental Utah or western Arizona to this region.

Overlying the Salt Wash Member is the Brushy Basin Member. Dominantly composed of bentonitic mudstones and claystones, it forms rubble-covered rounded slopes above the Salt Wash. Scattered throughout the Brushy Basin are channel deposits, displaying trough crossbedding and a characterisitc red and green chert-granule conglomerate. For this report, the top of the Salt Wash was taken as the uppermost continuous rim sand. Other workers (Fred Peterson, oral commun., 1983) would tentatively set the boundary at the top of the first channel fill immediately above the upper rim, regardless of lithology. Thickness of the the Brushy Basin Member was not often directly measured in this study, but it appears on the basis of other workers' field mapping to average 300 ft.

Uranium deposits of the Salt Wash Member

Regionally, the Black Ridge Canyon WSA is in uranium country. The major deposits of the Uravan mineral belt lie to the south (fig. 5), and ore deposits within the WSA would presumably be of this type. The Uravan mineral belt is composed of a number of districts and these are arranged in a roughly arcuate pattern that is transverse to the flow directions within the Salt Wash. Individual ore bodies are of the tabular or so called "roll" type (Chenoweth, 1978) (which is not related to the Wyoming basin-type roll front

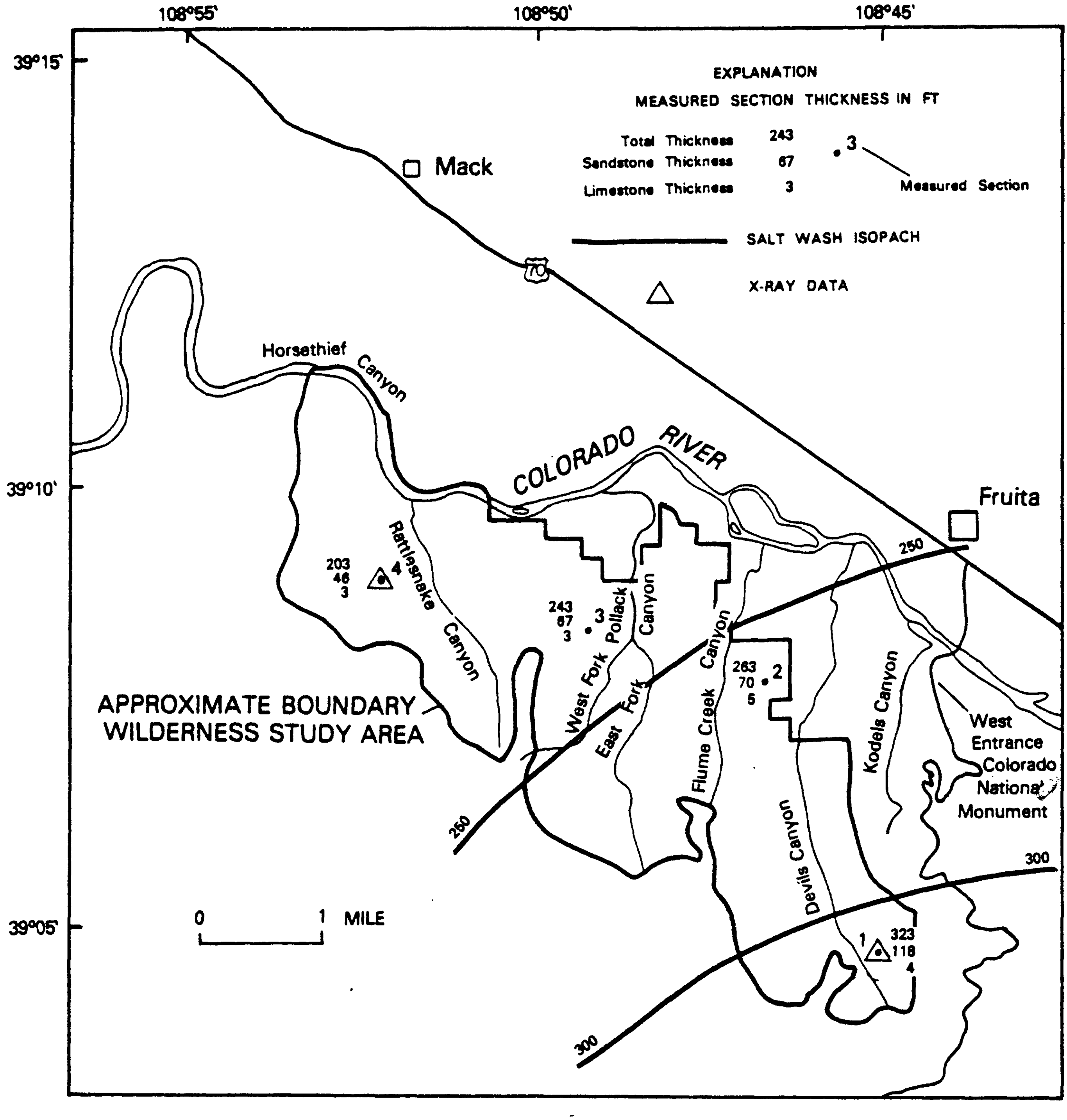

Figure 5.--Index map of the Black Ridge Canyon Wilderness Study Area, Mesa County, Colorado, showing location of measured sections and isopachous contours in the Salt Wash Member of the Morrison Formation.

type). The ore bodies either "float" within sandstone layers or terminate against impermeable mudstone (Northrop, 1982; Huffman and others, 1980; Shawe, 1956). Ore consists of oxidized uranium vanadates such as yellow carnotite, or dark unoxidized "primary" ore consisting of silicates and oxides of uranium and vanadium.

The location and orientation of the Uravan belt has been discussed by various authors (Fischer and Hilpert, 1952; Chenoweth, 1978). Major ore bodies follow paleochannels within the Salt Wash upper rim; lower rim deposits are known, but the lower rim is less explored than the upper. Several authors feel that the placement of the Uravan mineral belt is approximately at a redox/facies-change boundary within the Salt Wash, where oxidized and unoxidized rocks interfinger, and bedding structures change from higher energy mid-fan to distal-fan low energy structures (Shawe, 1962; Thamm and others, 1981). Peterson (1980) indicates that areas of facies change may be suitable for deposition of favorable gray mudstones, which produced a humate substance that caused precipitation of uranium.

Guides for Uranium Exploration in the Salt Wash Member

Guides for uranium exploration in the Salt Wash consist of suites of large- and small-scale features known or thought to be favorable for mineralization. These are tabulated and discussed in McKay (1955), Campbell and others (1980), Huffman and others (1980), Thamm and others (1981), and Northrop (1982). Large-scale guides, some discussed previously, include identification of major sandstone "thicks" or depositional axes because large-scale uranium deposits seem to be associated with zones of high transmissivity and individual sandstone layers greater than 40 ft thick; identification of regional or local redox boundaries between oxidized and reduced facies; zones of highly altered blueish-green mudstone; and identification of local sedimentary basins transverse to the Salt Wash flow directions which might have form ponds in which humate-generating favorable gray mudstones and (or) brines may have formed. Downstream from the troughs is considered the most favorable for the formation of favorable gray mudstones (Peterson, 1980).

Small-scale guides, as discussed by the previously cited works, include visual survey of outcrops to detect the presence of altered blue-green mudstone below uranium deposits, or gray carbonaceous, bentonitic mudstones ("favorable gray mudstones") adjacent to or above deposits; layers of carbonaceous or wood "trash" in channel-fill deposits; favorable sedimentary structures such as abundant cut-and-fill structures displaying trough crossbedding adjacent to impermeable channel-fill mudstones and siltstones; and the presence of botanical indicators such as the selenium-bearing vetches or prince's plume. Scintillometer surveys were done on all favorable appearing rock units. X-ray diffraction studies were done on samples from each locality to look for the presence of unusual amounts of dolomite at a particular horizon within the Salt Wash. The presence of a dolomite layer adjacent to,and overlying ore horizons in the Henry Basin has been demonstrated by Northrop (1982). The position of a dolomite horizon of fine-grained dolomite cement represents a solution interface between meteoric uranium-bearing waters and reducing brines trapped against impermeable layers below. A synclinal setting is considered favorable for localizing the solution interface.

It must also be noted that, although simple consideration of the location of an area is not a truly valid exploration guide, the Black Ridge Canyon WSA lies adjacent to the extensive Uravan mineral belt (fig. 5), which exhibits a rather abrupt cut-off in grade towards the WSA, and has undoubtedly been rather heavily prospected by individuals and companies. Interviews with local residents and geologists (Jack Musser, and W. L. Chenoweth, personal commun., 1983) confirm that although prospecting was conducted on an intense level in the area in the 1950's, no major or minor uranium deposits were discovered. The most recent activities have included drilling operations in the late 1970's, but the operators could not be located to discuss their findings.

Methods of Study

Four stratigraphic sections were measured (fig. 6) in the Black Ridge Canyon WSA, and as much ground as possible was seen and examined. From each section, total thickness, thickness of sandstone and limestone layers, and percent sandstone were calculated and plotted to establish patterns of deposition within the Salt Wash. In this way, favorable thick sandstone depoaxes may be located, as well as Jurassic lake sites or synclinal troughs thought to be favorable settings for production of humate bodies and (or) localizing a meteoric water-brine interface. Also noted the general oxidized or reduced character of the sandstone units and any areas containing carbonaceous material.

The sections chosen for X-ray analysis for dolomite horizons were located after several discussions with H. R. Northrop of the Isotope Branch of the U.S. Geological Survey, who developed and utilized the technique. Northrop indicated that the horizon of dolomite cement had a potentially large lateral and vertical extent in the rocks (3.0 to 3.5 mi radius, 30 yd vertical extent) away from ore zones. A sampling interval of 25 ft was selected, and a few pounds of sample were collected along a 5 ft trench. This was considered adequate to detect a dolomite-rich horizon, if not the actual peak value. Samples were ground and split, slurry mounted, and X-rayed on a X-ray diffractometer. Scans were from 24 to 37° for main peaks; peak heights were visually compared and ratios recorded. Dolomite cement in excess of calcite cement was considered anomalous, but any presence of dolomite was noted.

Uranium potential of the Black Ridge Canyon WSA

Figure 6 shows thickness and isopach data of the Salt Wash Member for the Black Ridge Canyon WSA based upon four stratigraphic sections, and indicates that the Salt Wash thins to the north or north-northeast. Reference to adjacent measured sections in the Colorado National Monument (Lohman, 1965) allowed orientation of the contours. No obvious depositional or synclinal axes were indicated by total thickness or thickness of limestone. Percent sandstone values are also well below 50 percent. The Edna mine, a small uranium prospect described below is located near stratigraphic section locality 1. A dolomite anomaly is associated with this section at the approximate stratigraphic location of the ore deposit. Section 4, at Rattlesnake Canyon, also showed a dolomite anomaly, but was stratigraphically 75 ft lower in the section. This may simply represent the paleohydrologic gradient during Salt Wash time, or more subtle geochemical conditions that the data did not clarify. A thin, discontinuous seam of favorable gray mudstone was found immediately adjacent to the mineralized zone at the Edna mine and carbonaceous material was also present in the mine. H. R. Northrop (personal commun., 1983) states that mineralization is most likely to occur at the intersection of the dolomite precipation zone at the fluid interface with either carbonaceous debris or favorable gray mudstones. No evidence of

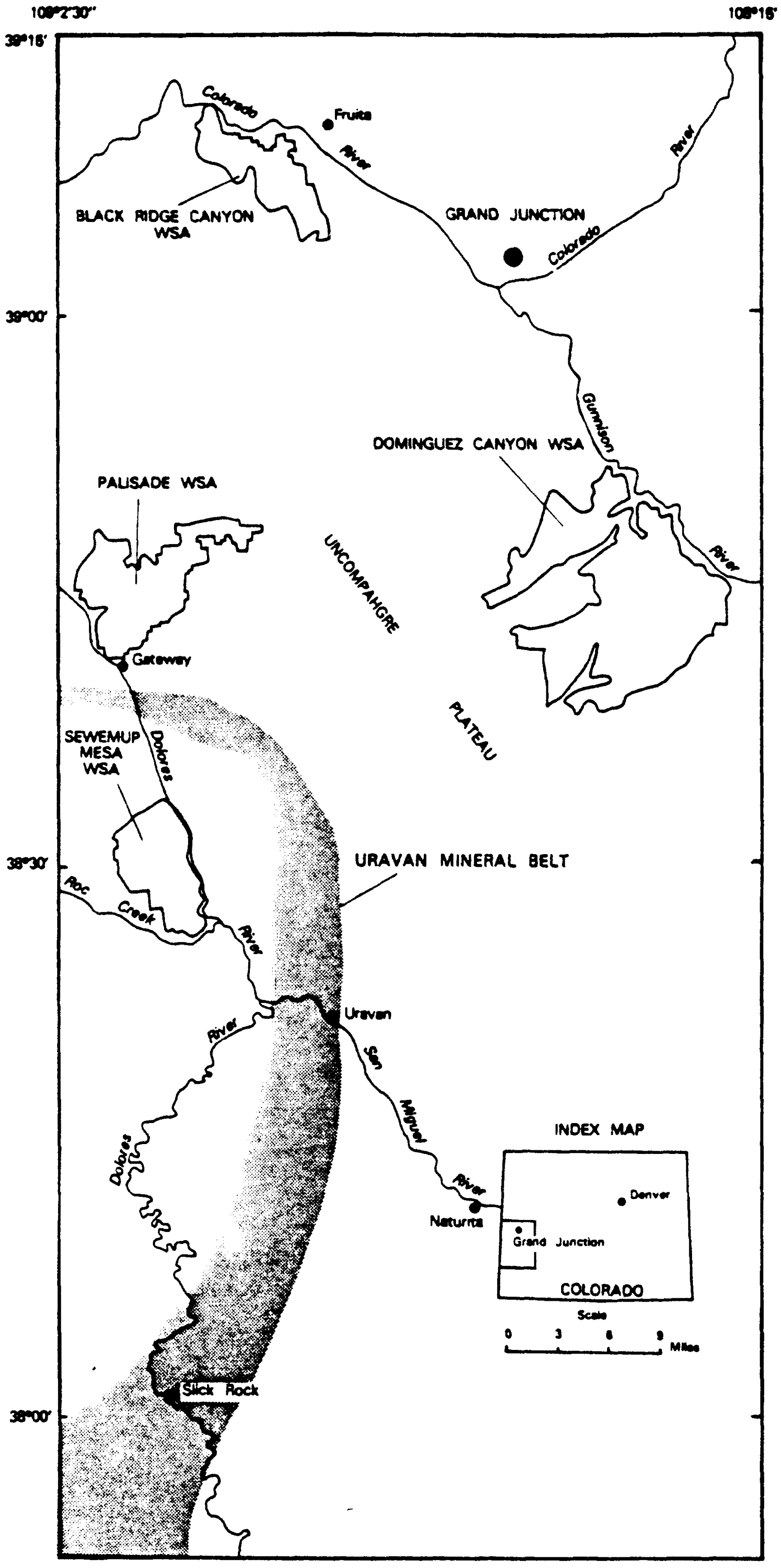

Figure 6.--Map showing location of the Uravan mineral belt (modified from Schwochow, 1978).

carbonaceous debris or favorable gray mudstone layers was observed in sections 2, 3, and 4. Unfavorable conditions for accumulation and preservation of carbonaceous material are suggested by the generally flat to massive bedding displayed by most lower and some upper sandstones in the WSA. Fred Peterson (personal commun., 1983) feels that these beds may be more dominantly lacustrine than fluvial, and that woody debris is absent from the area. Humate generated by favorable gray mudstones may also act to preserve carbonaceous debris, but this was only found at the Edna mine. The stratigrahic lowering of the dolomite anomaly horizon below the zone containing carbonaceous material further decreases chances of mineralization to the northwest in the remainder of the district.

In summary, the potential for medium- to large-scale uranium deposits in the Black Ridge WSA must be considered low. Unfavorable facies in the Salt Wash, lack of appreciable carbonaceous debris, non-intersection of the dolomite anomaly zone with any potentially carbonaceous layer, and lack of uranium mineralization noted from extensive visual and scintillometer surveys by individuals and U.S. Geological Survey personnel, all imply low potential for uranium mineralization in the Salt Wash Member.

ENERGY AND MINERAL DEPOSITS

Known mineral deposits

The known mineral deposits in the Black Ridge Canyon WSA can be placed into two main groups: uranium deposits and sand and gravel deposits.

The Edna uranium mine workings are located near the head of Devils Canyon (sec. 26, T. 11 S., R. 102 W.) in a basal sandstone channel unit of the Salt Wash Member of the Morrison Formation. The channel unit is approximately 75 ft by 20 ft thick, gently lenticular, and composed of several smaller trough crossbedded cut and fill units. The mineralized layer was localized along the base of a channel-fill sequence, which contained much carbonaceous material, including fossil logs of unknown length, averaging 8 in. in diameter. A thin, discontinuous layer of favorable gray mudstone was found adjacent to the workings. Traces of carnotite were present on joint surfaces, and some dark minerals, probably vanadium-micas or primary oxide or silicate uranium minerals were sparingly distributed along bedding planes within small troughs near the carbonaceous layer. Concentrations of uranium ore minerals gave radiation levels of nearly 30 times background, but covered less than one sq ft in area. The deposit was mined by a 75 ft adit with two rooms at the end. A small ore-loading platform is present. There was no evidence of mineralization rich enough to warrant further mining, although maintenance work had been done on the road leading to the deposit.

There are several sand and gravel operations outside the northern edge of the Black Ridge Canyon WSA along the Colorado River, but only one occurs within the WSA (sec. 16, T. 1 N., R. 102 W.) (Schwochow, 1978). Production figures from these deposits are unavailable.

Known prospects, mineralized areas, and mineral occurrences

Base and precious metals were found in the lower parts of Devils Canyon (sec. 36, T. 1 N., R. 102 W.) in two contrasting sedimentary and igneous mineralized areas. Sedimentary Cu was localized in a paleochannel at the base of the Triassic Chinle Formation, adjacent to the underlying Precambrian rock. The lithology of the channel deposit consists mainly of white to red quartzose conglomerate to medium-grained sandstone, with scattered fragments of red jasper and silicified wood, and with a siliceous cement. Individual cut-and-fill structures of approximately 6 to 10 ft by 1 to 2 ft coalesced to make an overall deposit of nearly 100 by 10 ft at the outcrop. Current directions, as measured from several trough crossbeds, were generally to the northwest. A continuation of the channel was searched for on the opposite canyon wall, but was not found.

The deposit had been worked by a horizontal adit in the deepest scour of the conglomerate and the adit was approximately 50 ft in length by 6 ft in height and width. A survey of the tunnel showed red to white mottled sandstone, conglomerate, and in places similarly mottled Precambrian gneiss and schist. The adit bottomed and ended against nonmineralized Precambrian rock. Possible slickensides were observed at the end of the tunnel, however, no other evidence of faulting was observed. Traces of ore remaining in the wall rock consisted of banded malachite and (or) chrysocolla and limonite-cemented grains surrounding a bleached core, as well as isolated flecks of malachite and (or) chrysocolla in scattered zones. In no place was sufficient ore remaining to constitute a resource.

About 0.1 mi south from the workings, disseminated Cu, Pb, and Ag mineralization was found in float of aplite dike rock in Precambrian rock. The mineralized rock was extremely localized and was only found in scattered float in an area of about 20 ft by 20 ft. The rock was bleached white (saussuritized?) and contained 3-5 percent accessory muscovite and chlorite, with some minor hematitic alteration along joint surfaces and around a few isolated grains.

Mining claims and leases

Information on mining claims and leases within the Black Ridge Canyon WSA was obtained from the Phase 1 GEM reports on the WSA by Mountain States Mineral Enterprises and Wallaby Enterprises (1983). As indicated in that report, as of June 14, 1982, there were no patented mining claims or leases in the Black Ridge Canyon WSA. There are 32 unpatented mining claims that consist of 17 lode claims (secs. 14, 24, 25, and 26, T. 11 S., R. 102 W.) and 15 placer claims located along the northern boundary of the WSA. There are no oil and gas leases within the WSA.

Mineral resource types

Four mineral resource types are present within the Black Ridge Canyon WSA: base and precious metals in the lower part of Devils Canyon in float of Precambrian rock and at the base of the Chinle Formation, possible Ba in the sedimentary rocks, uranium in the upper part of Devils Canyon in the Morrison formation, and sand and gravel deposits along the northern boundary of the WSA.

Cu-Pb-Ag mineralization occurs in one locale in float of a Precambrian aplite, but without better exposure it is not possible to determine the origin of the mineralization.

Because the Chinle was deposited on the surface of the Precambrian rocks, Cu-Pb-Ag was probably leached from the underlying Precambrian and deposited in channel systems in the Chinle. This mineralization is extremely localized in the Black Ridge Canyon WSA and occurs only near mineralization in the Precambrian.

Uranium mineralization in the Salt Wash Member of the Morrison Formation occurs in stream channels at redox/facies-change boundaries where oxidized and unoxidized rocks interfinger and bedding structures change from higher energy mid-fan to distal-fan low energy structures (Shawe, 1962; Thamm and others, 1981). Uranium deposits in the Black Ridge Canyon WSA are discussed earlier in this report.

High Ba in the stream-sediment concentrates is related to discrete barite grains present in the stream sediment. No source for the Ba was located in the field, but the source may be authigenic barite crystals, or possibly barite nodules in the sedimentary rock underlying the drainage basins. Stewart and others (1972) indicate that authigenic barite commonly occurs in the Chinle Formation, and Fred Peterson (oral commun., 1983) indicates that the Morrison Formation also commonly has a barite cement.

The sand and gravel resources within the WSA occur within terrace deposits of the Colorado River.

Mineral economics

As indicated previously, the only mineral resource types found in and near the Black Ridge Canyon WSA are precious and base metals in the Precambrian rocks and in the Triassic Chinle Formation, barite in the sedimentary rocks, uranium in the Salt Wash Member of the Morrison Formation, and sand and gravel deposits. Access, transportation, grade, recovery, volume, extraction methods, and market value effect the economics of mining the various deposits. All of the deposits, known prospects, and mineralized areas within the WSA have low economic potential because of the poor access, the low grade of the deposits, and the extremely localized nature of the mineralization.

Land classification

Land classification decisions were made on the basis of field investigations, geochemical study, and historical research. The classification scheme used by the Bureau of Land Management is given in table 2, and the land classification decisions are presented in table 3.

Ag, Cu, and Pb mineralization in the lower parts of Devils Canyon in Precambrian and sedimentary rock has low potential because of the extremely localized nature of the mineralization, and because most of the mineralized rock has already been removed.

Until the source for the high Ba in the stream-sediment concentrates has been located, the resource potential for barite cannot be accurately determined. The potential for Ba is therefore presently considered to be low, but future work may change this classification.

The access to the Edna uranium mine at the head of Devils Canyon is good, but mineralization is not rich enough to warrant further mining. Most of the ore has already been removed. As discussed earlier in this report the potential for uranium in the Salt Wash Member is low. Resource potential for uranium in the WSA is therefore low.

Sand and gravel deposits along the northern edge of the WSA are easily accesssible and have been mined in the past. Very little information was obtainable concerning the size of these deposits, but because of their accessibility, resource potential is low to moderate.

Dimension stone is readily available in the Entrada, Wingate, and Chinle Formations in the mouths of most of the canyons in the WSA. However, since

Table 2.--Favorability/Resource Potential Classification for BLM Mineral Resource Reports

Level of Favorability	Level of Certainty
Resource potential cannot be classified	
0. Favorability unknown; information on the likelihood of presence of mineral resources is inadequate for classification; equates with **UNKNOWN** potential.	A. The available data are not sufficient for determination of the degree of favorability for the occurrence of mineral resources.
Resource potential can be classified	
1. The nature of the geologic environment, and, the geologic processes that have acted in the area, indicate no favorability for the presence of mineral resources; equated with NO resource potential.	B. The available data are adequate to give an indication of the degree of favorability, but lack key evidence that would help define geologic environments or activity of resource-forming processes.
2. The nature of the geologic environment, and, the geologic processes that have acted in the area, indicate low favorability for the presence of mineral resources; the data define a geologic environment permissive for the presence of mineral resources but there is no evidence of the action of processes of resource accumulation; equates with **LOW** resource potential.	C. The available data provide a good indication of the degree of favorability, but are minimal in terms of definition of degree of activity of possible resource-forming processes, and nature of geologic environment.
3. The nature of the geologic environment, and, the geologic processes that have acted in the area, indicate moderate favorability for the presence of mineral resources; the data define a geologic environment favorable for the presence of mineral resources; evidence is present of the action of processes likely to form resources; equates with **MODERATE** resource potential.	D. The available data define the geologic environment and the degree of activity of possible resource-forming processes with considerable certainty; key evidence to interpretation of the presence or absence of appropriate ore deposit types is available.
4. The nature of the geologic environment, and, the geologic processes that have acted in the area, indicate high favorability for the presence of mineral resources; the data define a geologic environment highly favorable for the presence of mineral resources, and strongly support the interpretation that resources are probably present; evidence is compelling for the activity of processes likely to form resources; equates with HIGH resource potential.	
Reserves have been discovered	
5. Reserves have been discovered	E. The available information is adequate to identify reserves, and to specify to varying degrees of certainty, the quantity and grade of valuable materials in a well-defined area.

Table 3.--Land classification for the Black Ridge Canyon WSA

Resource	Classification	Comments
METALS		
Precious (Au, Ag)	2C	Ag mineralization associated with aplite dike in Precambrian rocks
	2C	Ag mineralization associated with Triassic Chinle red beds
Base (Cu, Pb, Zn)	2C	Cu-Pb mineralization associated with aplite dike in Precambrian rocks
	2C	Cu mineralization associated with Triassic Chinle red beds
URANIUM-THORIUM	2D	Potential for uranium in the Salt Wash Member of the Morrison Formation
URANIUM-THORIUM	2C	Potential for uranium in other sedimentary rocks in the WSA
NONMETALLIC		
Ba	2B	Regionally high Ba in stream-sediment concentrates; barite identified in sediment samples
OIL AND GAS	1D	Classification for Precambrian rocks
OIL AND GAS	2D	Lack of stratigraphic section favorable for oil and gas occurrence
COAL	1D	Classification for the Precambrian rocks
COAL	2C	WSA lacks coal-bearing units
GEOTHERMAL	2B	WSA lacks evidence of heat-providing bodies
NA/K	2B	
BULK COMMODITIES		
Sand and Gravel	3D	Sand and gravel deposits occur along the northern edge of the WSA
Dimension stone	2B	Entrada, Wingate, and Chinle Formations may contain favorable units for dimension stone

these lithologies are abundant in the vicinity of the WSA where they have good road access, the deposits in the WSA are not considered to be a likely resource.

RECOMMENDATIONS FOR FURTHER WORK

The stream-sediment and rock sampling program isolated a few anomalies in the Black Ridge Canyon WSA that should be further studied by more extensive field examinations. A source for the high Ba in the stream-sediment concentrate samples should be looked for in the field, including barite nodules, barite cement, and (or) barite veins possibly indicative of an igneous body at depth. More detailed field mapping, combined with thin section analyses of the various formations in the areas of highest Ba anomalies might delineate the source of the Ba.

Further mapping should be carried out along the base of the Chinle Formation in the channel conglomerate to look for any additional Cu mineralization. Because the stream system trends northwest-southeast, the other canyons in the WSA should be studied along strike of the channel system.

Although mapping located only very localized mineralization in the Precambrian rocks, further detailed mapping of the Precambrian units might locate additional mineralized rocks. It should be noted, however, that if any mineralized areas exist, they are not large enough to have a chemical expression in the analyses of the stream-sediment samples.

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