UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Geology and mineral resource potential of the Palisade Wilderness Study Area, Mesa County, Colorado (GEM, Phase 2)

by

Dirk S. Hovorka[1], Charles G. Patterson[1], and Margo I. Toth[1]

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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 two 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 resources and was carried out by Mountain States Minerals 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 Palisade Wilderness Study Area (WSA) carried out in June and July of 1983 by personnel from the Central Mineral Resources Branch of the U.S. Geological Survey.

The Palisade WSA (CO-070-132) covers about 26,050 acres in western Colorado in Mesa County on the western edge of the Uncompahgre Plateau (fig. 1). The area is divided into two physiographic regions by a high east-west oriented cliff. The southern part of the area is lower elevation badlands terrain and includes the solitary butte named the Palisade. The northern part of the WSA is a high rolling plateau dissected by a few major creeks.

Thirty-three streams were sampled within the WSA and at each site a panned concentrate and a fines fraction were collected. At eight of the streams filtered water samples were also collected. Panned concentrate samples were analyzed by semiquantitative emission spectrography for 66 elements and fines fraction samples were sieved to a minus 100 mesh and analyzed for 45 elements using inductively coupled plasma emission spectroscopy. The fines fractions were additionally analyzed for uranium using flourimetric techniques on an acetic acid extract. Rock samples were crushed and pulverized to a minus 100 mesh and analyzed by semiquantitative emission spectrography. Water samples were acidified and analyzed for arsenic and selenium using automated hydride generation and atomic absorption spectroscopy; for molybdenum using inductively coupled plasma emmission spectroscopy; and for uranium using fluorimetry.

All the panned concentrate samples collected from the WSA are low in elements associated with mineralized systems. No localized anomalies were detected.

Four samples of the fines fraction contained uranium values greater than the detection limit of 0.2 ppb (parts per billion) and ranged from 0.2 to 2.0 ppb. No other elements were found in anomalous concentrations in the fines fraction.

Two water samples had anomalous uranium concentrations (22.3 and 52.3 ppb/conductivity X 1000) but these are the result of mobilization and concentration of low grade uranium along faults in the Salt Wash Member of the Morrison Formation, rather than a localized deposit.

Rock samples were also low in elemental indicators of mineralized systems. One abandoned mine at the top of the Palisade had anomalous uranium (20,000 ppm (parts per million)) and vanadium (15,000 ppm) in a carnotite vein and an abandoned mine in a Precambrian pegmatite had anomalous manganese (70,000 ppm), but in both locations the mineralization was of very localized extent.

Known mineral deposits in the Palisade WSA consist of uranium and vanadium in the Salt Wash Member of the Morrison Formation on the summit of the Palisade and sand and gravel along the southeastern and southwestern edges of the WSA.

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 in the National Wilderness Preservation System (NWPS). Federal mineral assessments were required to be conducted on the lands affected as part of the wilderness land review process.

In 1976, the Federal Land Policy and Management Act (FLMPA, PL 94-579), 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 in 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 exisitng 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 Palisade WSA conducted in June and July of 1983 by the U.S. Geological Survey.

The Palisade WSA includes about 26,050 acres of Mesa County in western Colorado, about 35 air mi southwest of Grand Junction and immediately north of Gateway (fig. 1). The WSA overlies, and extends onto, the western edge of the Uncompahgre Plateau. Major geographic features in the immediate vicinity include the Dolores River on the southwest and West Creek and Unaweep Canyon on the southeast. A high rolling plateau that is continuous with the highlands of the Uncompahgre Plateau lies to the north. Access into the WSA is entirely by dry weather roads originating from Colorado Highway 141 on the south and from maintained dirt roads on the west and north.

The mineral resource appraisal of the WSA by the U.S. Geological Survey involved geologic mapping at a scale of 1:24,000, aided by color aerial photographs, sampling and subsequent geochemical analysis of rocks and stream sediment concentrates, and investigation of known mines and prospects. A detailed investigation of the Salt Wash Member of the Morrison Formation for its uranium potential was also undertaken. Water samples were collected wherever there was sufficient flow for analysis for uranium.

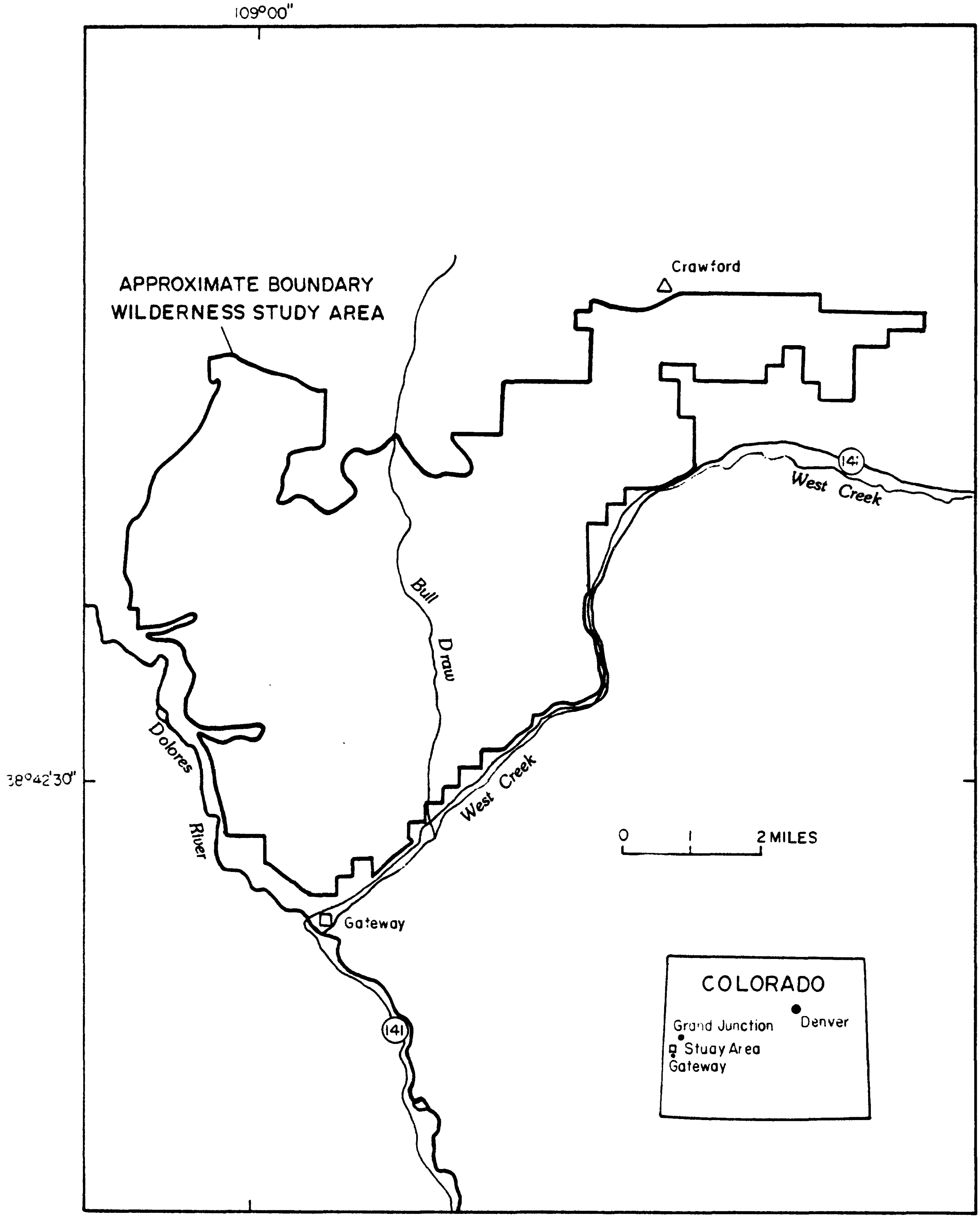

Figure 1.--Index map showing location of the Palisade Wilderness Study Area, Mesa County, Colorado.

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The rock and stream sediment analyses were done by N. M. Conklin, P. H. Briggs, and D. Brooke Hatfield under project leader James L. Seeley, Branch of Analytical Laboratories, U.S. Geological Survey, Denver, Colo. Water samples were analyzed for uranium by M. G. Kavulak under the supervision of Albert Yang, Water Resources Division, U.S. Geological Survey, Denver, Colo.

Charles G. Patterson wrote the historical geology and uranium potential sections of this report, and L. L. Jackson contributed the analytical methods section.

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GEOLOGY

Physiography

The Palisade WSA is divided ito two distinct physiograpic areas by a 100-300 ft high east-west trending cliff that traverses the entire length of the WSA. The southern and larger area consists of low badlands topography with deeply incised steep-walled arroyos. The flat plateaus and terraces between the drainages are covered with a thick layer of unconsolidated material that smooths the topography. The spectacular solitary butte named the Palisade is the most distinctive feature of this part of the WSA and it rises about 1,700 ft above the surrounding area. In the southern part of the WSA elevations range from 4,500 ft at the Dolores River to 6,600 ft at the base of the dividing cliff.

The northern part of the WSA includes the western edge of the Uncompahgre Plateau and consists of a high rolling plateau with elevations ranging from 8,200 ft to 9,400 ft. A few major creeks have cut deep steep, sided-drainages into the plateau, but most of the area is gently undulating terrain.

The climate is semi-arid, and vegetation of the lowland area is typical of dry regions. The high plateau is wetter and is characterized by large open tracts of grasses and sagebrush interspersed with stands of aspen and conifers.

Description of rock units

Precambrian crystalline rocks, extensively exposed in the eastern part of the WSA and in Unaweep Canyon, are overlain by Permian to Jurassic age sedimentary rocks in the western part of the WSA. Many of the sedimentary formations thin and wedge out eastward along the western flank of the Uncompahgre Uplift.

The Precambrian rocks exposed in the WSA consist of a variety of lithologies, including gray to purple medium-grained granite; purple, chloritized, xenomorphic granodiorite with rapakivi texture; reddish-purple fine- to medium-grained, hypidiomorphic, granular granodiorite; and gray, medium- to coarse-grained, porphyritic, hypidiomorphic granite, containing 1-3 in. carlsbad-twinned feldspars and 7-10 percent biotite clots. All these lithologies contain xenoliths of schist, amphibolite, and gneiss and are frequently cut by medium-grained to very coarse-grained pegmatites from 0.5 in. to 20 ft in thickness. The pegmatites contain milky quartz, feldspar, biotite, and rarely, garnet. The larger veins contain feldspar crystals as much as 2 ft in length. Just east of the WSA, in Unaweep Canyon, pegmatite swarms become very dense, but within the WSA they are rare.

The Permian Cutler Formation overlies the Precambrian rocks and consists of purple, green, gray, and red sandstones, arkosic sandstones, conglomerate, and fanglomerates. The rocks are generally composed of quartz, fresh feldspar, unidentified dark minerals, and pebbles derived from Precambrian rocks, in poorly sorted, rudely bedded layers, which weather into a wide variety of forms and colors. The fanglomerates are poorly sorted and contain sand, pebbles, cobbles, and boulders of predominately Precambrian origin. In localized areas and layers there is evidence of minor fluvial reworking of the material, but most of the fanglomerates are unbedded. The arkosic sandstones are moderately to well sorted and contain angular to subrounded fresh feldspar and occasional 0.5-1 in. discontinuous lenses of concentrated heavy minerals. The Cutler Formation forms a wedge between the Precambrian and Triassic rocks, and thickens rapidly to the west. In the Dolores River Canyon, 4 mi northwest of Gateway, a well pentrated more than 7,800 ft of sandstone before reaching the crystalline basement (Cater, 1955). A few miles to the northeast, within the WSA, the contact between the Cutler Formation and the Precambrian rocks is exposed; however, the formation is entirely absent in the northeastern WSA.

The Moenkopi Formation unconformably overlies the Cutler Formation and thins rapidly to the northeast until it wedges out midway across the WSA. It consists of red to purple mudstones, sandy mudstones, and silty sandstones. Its basal member often contains 1-2 in. discontinuous layers of gypsum, and locally a continuous thick layer of gypsum occurs between the Moenkopi Formation and the underlying Cutler Formation. In the area of the Palisade, the Moenkopi has been mapped separately from the Cutler Formation; in the northern part of the map area it thins rapidly and and has been mapped with the Cutler Formation because it lacks the distinct gypsum layer used to differentiate it from the Cutler.

In the WSA the Chinle Formation shows a striking relationship with the older rocks; from west to east it rests directly and unconformably on Lower Triassic Moenkopi, Permian Cutler, and Precambrian rocks. Except for local variations, the erosion surface is very flat (Cater, 1955). Within the WSA the Chinle consists of red to maroon siltstone interbedded with thin layers of fine-grained silty sandstone. In places, a basal clay-pellet conglomerate separates the Chile from the Moenkopi where it is present. The Chinle crops out as steep slopes broken with ledges of more resistant sandstone. It is about 100 ft thick in the southwest part of the area but thins rapidly to the northeast where it is very poorly exposed and in most places is buried under talus of the overlying Wingate Sandstone.

Unconformably overlying the Chinle Formation is the Wingate Sandstone, a fine-grained, massive to crossbedded eolian sandstone composed of clean, well-sorted quartz sand. It normally forms spectacular cliffs that are surficially stained with red-brown to black desert varnish. However, in the northeast part of the area where it has thinned, the Wingate has weathered to steep, unstained talus slopes.

Conformably overlying the Wingate in a gradational contact is the Kayenta Formation. It consists of slabby, red, brown or gray, coarse-grained, moderately well-sorted sandstone with calcareaous cement, interbedded with minor red siltstone and shale. Discontinous thin conglomerate lenses contain subangular pebbles and cobbles of sandstone and siltstone. It is irregularly bedded and weathers to benches and ledges, which protect the Wingate Formation from erosion.

The Entrada Sandstone unconformably overlies the Kayenta Formation and consists of white to salmon pink, well sorted, fine-grained sandstone with both siliceous and calcareous cement. It is massively crossbedded and forms uniform rounded cliffs topped with steep slopes and ledges.

Unconformably overlying the Entrada Sandstone is the Summerville Formation, a yellow brown or tan, thinly-bedded, fine-grained sandstone and shale of variable thickness. It thins rapidly to the north and has been mapped with the Entrada Sandstone in the northern part of the area (Plate 1).

The Morrison Formation conformably overlies the Summerville, but in the WSA only the lower part of the Morrison is present. The lowermost part of the Morrison Formation, the Tidwell unit, has been described in the literature (Peterson, 1980) and was mapped with the Salt Wash Member in the WSA. The Salt Wash is white, gray, or buff weathering, fine- to medium-grained, trough crossbedded sandstone overlain by interbedded sandstone and gray, buff, and brown mudstone. Most of the units have a calcaeous cement. Locally, concentrations of carbonaceous material host secondary uranium minerals. The Salt Wash Member forms steep slopes, benches, and cliffs.

Quaternary units in the WSA include landslide deposits, alluvial valley and stream deposits, and large areas of fanglomerates. The fanglomerates consist of partially indurated or unconsolidated, rudely bedded or unbedded fragments, boulders, and debris that have been weathered and deposited essentially in situ.

Structure

The Palisade WSA lies on the northwest edge of the Uncompahgre Plateau, a major landform and structural feature of western Colorado. Approximately 100 mi long and 25 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, bordered by the Paradox Basin on the southwest, Douglas Arch and Piceance Creek Basin on the north and northeast, and the Gunnison Uplift and San Juan Mountains on the southeast and south (fig. 2). The Palisade WSA lies on the axis of the arch.

Geologically, it consists of Precambrian igneous and metamorphic rocks overlain by nearly flat-lying to monoclinally folded sedimentary rocks of Paleozoic and Mesozoic age. High angle faults that trend northwest are mostly along the western margin of but also within the plateau. The Ute Creek Graben (fig. 3) bounds the Precambrian exposure in the WSA and has preserved Triassic and Jurassic rocks in the northeast part of the area. The Uncompahgre Uplift is tilted to the northeast and is bounded by sharply flexed, faulted monoclines (Cater, 1966). The monoclinal fold paralleling the western edge of the uplift is not well exposed in the Gateway area because the most sharply folded sediments have been eroded away, and only the Precambrian rocks remain. A small remnant of the monocline is visible on a cross-section through the WSA (Plate 1) on a ridge with shallow northeast dips.

The structural grain of the Uncompahgre region is a result of the intersection of two wrench fault systems: the Colorado Lineament which trends northeast (Warner, 1980), and the Olympic-Wichita Lineament which trends northwest (Baars and Stevenson, 1981).

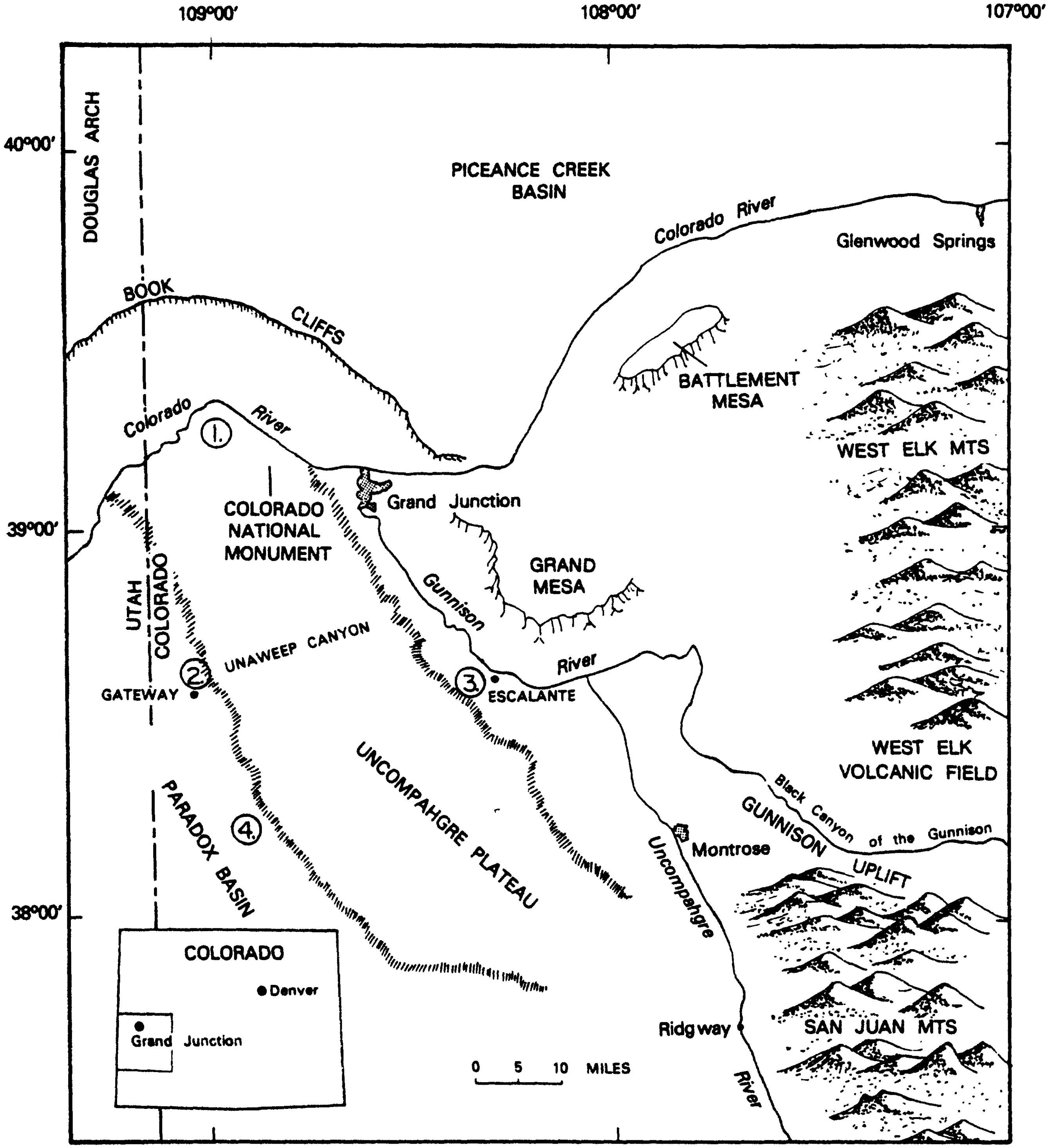


Figure 2.--Map showing location of major structural features in southwestern Colorado. Modified from Epis and Callender (1981). 1.) Black Ridge Canyon WSA; 2.) Palisade WSA; 3.) Dominguez Canyon WSA; 4.) Sewemup Mesa WSA

The nearly flat-lying sediments dip 3-5° southwest toward the Sagers Wash Syncline (fig. 3). Near the Cutler-Precambrian contact, the Cutler dips 8-10° southeast. This is in part caused by the steep angle of the original fanglomerate deposition off the Precambrian highland, and by later uplift and tilting. Further evidence of the proximity of the edge of the Uncompahgre Uplift is indicated by the small exposures of Precambrian rocks that show through eroded windows in the the Cutler and by the rapid wedging out of the formation northeast of the contact. Foliation in the Precambrian rock is rarely evident and always variable.

Present day landforms of the Uncompahgre region resulted from extensive erosion following uplift in Laramide, Late Tertiary, and Pleistocene times (Cater, 1955; Tweto, 1980; Hunt, 1956). Major uplift of 1,500-2,000 ft may have occurred as late as Pleistocene time (Cater, 1966).

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

Historical geology

Precambrian igneous and metamorphic rocks are exposed in the eastern part of the WSA and extend into Unaweep Canyon and also crop out in the deeper canyons of the Uncompahgre Plateau. The metamorphic complex consists of complexly folded schists and gneisses that probably originated as a thick pile of interbedded sedimentary and volcanic rocks deposited sometime between 2,000 and 1,800 m.y. ago in an oceanic environment (Carpenter and others, 1979). About 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 eastern edge of the Uncompahgre Plateau in the Black Canyon of the Gunnison area (fig. 2), partial melting of the metamorphic rocks produced the Pitts Meadow Granodiorite (Hansen, 1981). During two later phases of igneous activity the Vernal Mesa Quartz Monzonite (1,440±40 m.y.) and the Curacanti Quartz Monzonite (1420±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 varying age, but probably related to the Curecanti Quartz Monzonite, are also present.

Later events in Precambrian time were obscured by the development of an extensive regional erosional surface. Small outcrops of Precambrian age sedimentary rocks are preserved in areas near the Uncompahgre Plateau (Tweto, 1980), but none were found within the WSA.

Major tectonism began in Pennsylvanian time and produced many of the sedimentary rocks and features of the Uncompahgre Plateau region. A system of northwest-trending uplifts and complementary basins were formed in this area; the ancestral Uncompahgre highland and the Paradox Basin immediately southwest of it are one of these pairs. Hot and arid conditions led to the formation of thick sequences of evaporites and interbedded black shales in the basins, on which were deposited more normal marine limestones as the basins were invaded by less saline water. In the Paradox Basin, these deposits are the Paradox and Pinkerton Trail Members of the Hermosa Formation, but neither is exposed in the WSA. Arkosic debris and alluvial fans from the ancestral Uncompahgre highland were also being shed into these basins and formed the Cutler Formation, which overlies and interfingers with the Hermosa Formation (Campbell, 1981). The Cutler Formation pinches out just northeast of Gateway, but attains a thickness of several thousand feet 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; near Gateway however, the base of the Moenkopi is marked by a conspicuous bed of gypsum.

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

Quaternary alluvial deposits, undifferentiated

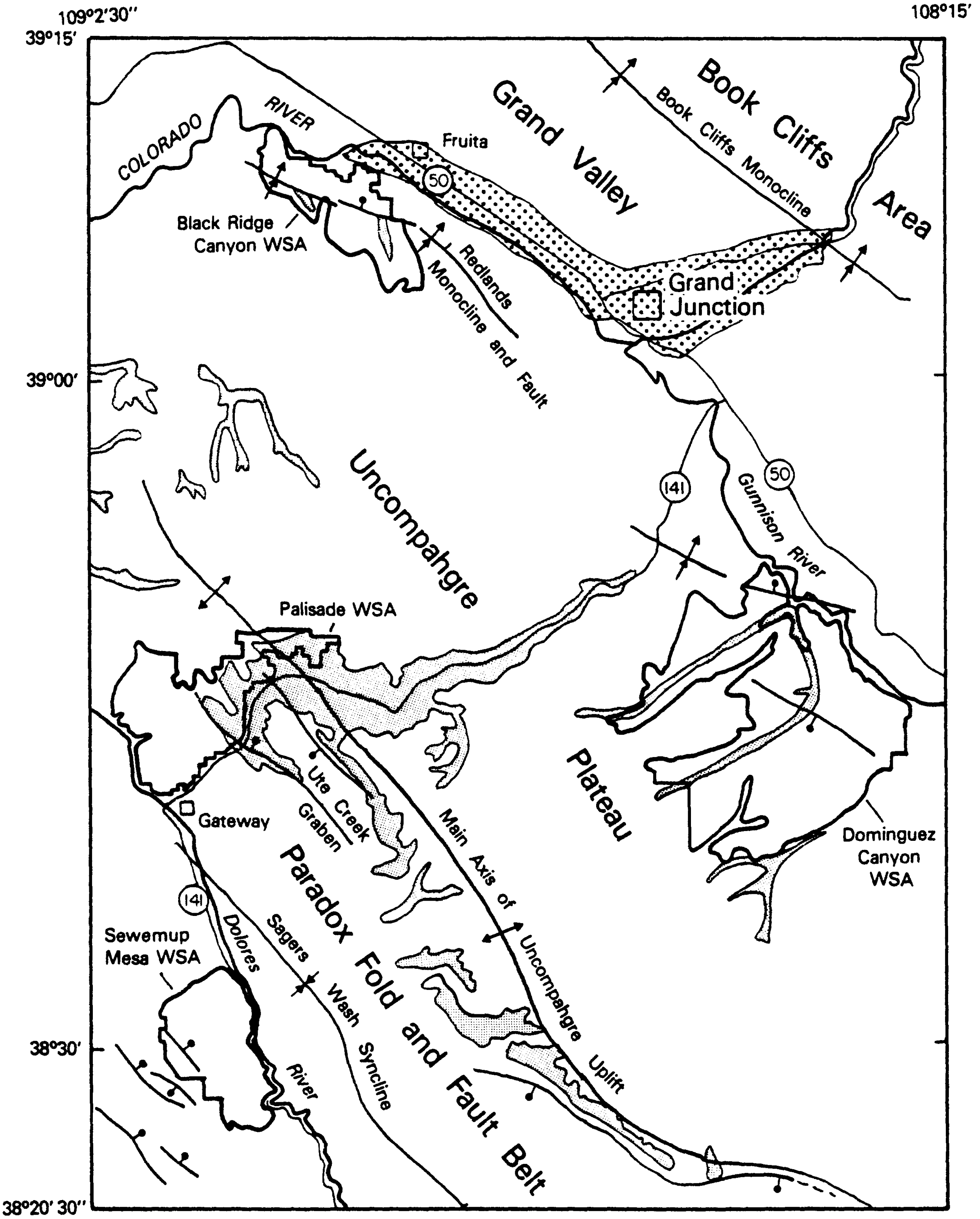
Paleozoic and Mesozoic sedimentary rocks

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
Grand Valley
Book Cliffs Monocline
COLORADO
RIVER
Fruita
50
Black Ridge
Canyon WSA
Redlands
Monocline and Fault
Grand
Junction
Uncompahgre
141
50
Gunnison
River
Palisade WSA
Plateau
Ute Creek
Graben
Gateway
Main Axis of
Uncompahgre
Uplift
Paradox Fold and Fault Belt
141
Dolores
River
Sagers
Wash
Syncline
Sewemup
Mesa WSA
Dominguez
Canyon
WSA

Figure 3.

As the weight of overlying sediments increased, the salts of the Paradox Member were mobilized and began to flow upwards as bulges and later diapirs, piercing and invading overlying rocks and influencing sedimentation patterns of subsequent formations (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 so that Chinle sediments traverse it completely in the Palisade WSA, lying directly on the Precambrian rocks (O'Sullivan and MacLachlan, 1975; Cater, 1955). The Chinle thins rapidly eastward in the WSA and is poorly exposed.

The Wingate Sandstone, the lowest member of the Glen Canyon Group, is separated from the Chinle by a slight unconformity. Some workers (Fred Peterson, oral commun., 1983) think that the Wingate Sandstone was deposited during the Jurassic, but until further work is done it is included in the Triassic. The Wingate Sandstone is predominantly an eolian unit, characterized by large, sweeping crossbeds indicative of deposition by winds from the northwest. It is conformably overlain by fluviatile sandstones and conglomerates of the middle unit of the Glen Canyon Group, the Kayenta Formation (Triassic). Highlands to the east and southeast were source areas for the Kayenta Formation. Another eolian sandstone, the Navajo Sandstone (Triassic(?)-Jurassic) completes the Glen Canyon Group but is only found at the south edge of the Uncompahgre Plateau, in and near the Sewemup Mesa WSA.

Rocks of the Jurassic San Rafael Group overlie the Glen Canyon Group and consist of, in ascending order, the Carmel, the Entrada, the Curtis, and the Summerville Formations. In the Uncompahgre region, only the Entrada and Summerville Formations are present. The Entrada Sandstone was formed by deposition in shallow lakes and dune fields (O'Sullivan and MacLachlan, 1975; Cater, 1955). The Summerville rests conformably upon the Entrada and represents a marginal marine or lacustrine facies of a seaway lying farther to the west. This unit physically resembles and may correlate directly with the marl member of the Wanakah Formation of the Placerville, Colorado area.

An unconformity marked by chert pebbles in a sandstone bed separates the Summerville Formation from the overlying Morrison Formation. The Morrison represents a return to fully terrestrial conditions of deposition and was deposited by streams that flowed generally from the southwest. The Morrison is divisible into three parts in this region: the lower Tidwell unit, the middle Salt Wash Member, and the upper Brushy Basin Member. The Tidwell unit was deposited under lacustrine conditions and the Salt Wash Member was deposited as large alluvial fans originating 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 consists more dominantly of mudstones, many of which are bentonitic and may have been derived from a volcanic source to the west (Craig and others, 1955). The Brushy Basin Member is absent in the Palisade WSA.

The youngest rocks in the Uncompahgre region are the Cretaceous Burro Canyon Formation and the Dakota Sandstone, neither of which is present within the WSA. The Burro Canyon Formation was deposited by streams flowing from the south. The Dakota Sandstone was deposited on the swampy deltaic margins of a seaway transgressing from the south. Overlying beds of Mancos Shale and of the Mesa Verde Formation, representing the full advance and retreat of the seaway, are found north of the WSA, forming badlands and the Bookcliffs, but have been eroded away from within it.

GEOCHEMISTRY

A geochemical survey of the WSA included the sampling of stream sediments, waters, and rocks for analysis by semiquantitative emission spectrography, inductively coupled plasma spectroscopy, and fluorimetry. Sample locations are shown on a simplified geologic map (plate 2).

Sample Design

First order streams in the Palisade 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 having 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-three streams in the WSA were sampled and at least 90 percent of the area was covered by this sampling method. Where streams 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 locality: a panned concentrate sample was collected to analyze for the heavier metallic elements such as Cu, Pb, and Zn, and a fines fraction of mud and clay was collected to analyze for metals such as Mo and U that typically adhere to clays. Panned concentrate samples were obtained by collecting sediment at several different places within the active stream bed in places where heavy minerals typically accumulate. 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 3 oz; in dry streams, 15 lbs of sediment was collected for later panning. The fines fraction sample consisted of about 0.25 oz of mud, clay, and fine-grained sand collected from within the active stream channel, usually along point bars.

When water was present, approximately 250 milliliters (ml) of water was collected and filtered through a Nuclepore membrane filter of 0.4 microns pore size. The samples were acidified with Ultrex concentrated hydrochloric acid to approximately pH 2 and stored in polyethylene bottles. Conductivity, temperature, and pH were measured in the field.

Rock samples were collected at two types of localities within the WSA. The first type consisted of localities containing mineralized, altered, or otherwise anomalous rock. In these places, about 0.5 lb of thumb-size 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 only of Precambrian crystalline rock, sampled at random intervals to establish background values for the elements analysed for and to check 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 the trend of the local structure.

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.

Panned concentrates were additionally analyzed for gold using hot $HBr-Br_2$ digestion and methyl isobutyl ketone (MIBK) extraction followed by atomic absorption spectroscopy (Thompson and others, 1968). Ten grams of sample are normally used in this procedure with a resultant limit of determination of 0.1 parts per million (ppm) gold. When only smaller amounts of sample were available the limit of determination was increased proportionately.

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 are not dissolved by this digestion procedure, but most rocks and minerals are 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.

Uranium in the fines fraction of the stream sediments was determined using a Scintrex pulsed laser fluorimeter on an acetic acid extract. Five grams of sample were digested with 15 micrograms/liter of 50 percent acetic acid and 5 micrograms/liter of 30 percent hydrogen peroxide (Rose and Keith, 1976). The extract solution was filtered, taken to dryness, treated with concentrated nitric acid, and again taken to dryness. The residue was re-dissolved in hydrochloric acid and this solution was diluted 100-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 less than 100 mesh (0.0059 in.) and were analyzed by semiquantitative emission spectrography similar to that on the panned concentrates discussed above.

The water samples were analyzed for As, Se, Mo, and U. Arsenic and selenium were determined on 25 ml of water using automated hydride generation and atomic absorption spectroscopy (Crock and Lichte, 1982). The samples were digested using potassium persulfate and hydrochloric acid (Nygaard and Lowry, 1982). The limit of determination is 1 milligram/liter for both arsenic and selenium. The precision of the method is approximately 5 percent relative standard deviation.

The water samples were analyzed for molybdenum by taking 50 ml of sample to dryness, diluting to 2 ml with 10 percent HCl, and analyzing the resulting solution by ICP methods. Estimated precision is 5 percent relative standard deviation and the determination limit is 10 milligrams/liter.

Uranium in the water samples was determined by fusing the dried residue from 7 ml of water with a fluoride-carbonate flux and measuring the uranium fluorescence in a fusion disc (Thatcher and Janzer, 1977). The detection limit and the relative standard deviation of the method are approximately 0.4 milligrams/liter and 15 percent, respectively.

Results of geochemical survey

The panned concentrate samples from the Palisade WSA were analyzed for 66 elements, but only concentrations of B, Ba, Co, Cr, Cu, Ni, Nb, Pb, Sc, Sr, V, Y, and Zr were detected, and in most cases the concentration of the elements

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	--

was very low and near the detection limit (table 1). The analytical data for each element was composited into histograms to look for anomalous concentrations. Except for one sample, none of the elements were present in any clearly anomalous concentrations, and in general, all were characterized by a small range of low concentrations.

Sample PDH033 contained 15,000 ppm zirconium (median for all samples was 1,000 ppm). It is possible that the source is zircon in the Precambrian rocks, but no other samples of Precambrian rocks showed a similar anomaly. Very little detritus from sedimentary rocks was present in the area of this sample.

Panned-concentrate samples from drainages with substantial amounts of Precambrian outcrop were also anlayzed for gold but no gold was detected in any of the samples (detection limit 0.1 ppm).

The fines fraction of the stream sediments were analyzed for 45 elements. Four samples contained concentrations of uranium greater than the detection limit, 0.2 parts per billion (ppb). Sample PDH012 contained 0.2 ppb; PDH020 contained 0.3 ppb; PDH017 and PDH022 contained 0.6 ppb; and sample PDH018 contained 2.0 ppb uranium. All of these samples are from drainages that include exposures of the Salt Wash Member of the Morrison Formation. No other samples contained anomalous values of any element.

Water samples from the Palisade WSA were analyzed for U, Mo, As, and Se, and, except for two samples, showed no anomalous concentations of any of these elements. PDH016W and PDH017W contained 22.3 and 52.3 ppb/conductivity X 1,000 uranium, respectively; these are the result of mobilization and concentration of low grade uranium along faults in the Salt Wash Member of the Morrison Formation, rather than a localized deposit.

The rock samples from the WSA are low in elements associated with mineralized systems. Of the 66 elements looked for in the rocks only Ba, Be, Co, Cr, Cu, La, Mn, Pb, Sc, Sr, U, V, Y, and Zr were present, and most of these were in low concentrations near the detection limit for each element. Two samples from mines yielded the only anomalous values in the WSA. A carnotite vein (sample PDH 057A) from the Winfield claim at the top of the Palisade contained 20,000 ppm U and 15,000 ppm V, values repectively 7 and 10 times the background concentrations of U and V in the host sandstone. Sample PDH042D was taken from an abandoned mine in a thick garnetiferous pegmatite near Fish Creek and contained 70,000 ppm Mn.

Uranium potential

General statement

The Palisade WSA lies on the northwestern flank of the Colorado Plateau just north of the Gateway mining district. Historically, the adjacent Uravan mineral belt (fig. 4) has supplied more than 12 percent of the uranium mined in this country (Chenoweth, 1978). The deposits are principally found in the Salt Wash Member of the Jurassic Morrison Formation and a voluminous literature exists on these deposits and the stratigraphy of the Morrison Formation. Good summaries of the uranium production and history of 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 (1980). General descriptions of the Morrison Formation are given by Craig and others (1955) and Mullens and Freeman (1957). More detailed disscussions of the Morrison Formation, especially the Salt Wash Member, are given by Tyler and Ethridge (1983), Huffman and others (1980), and Peterson (1980).

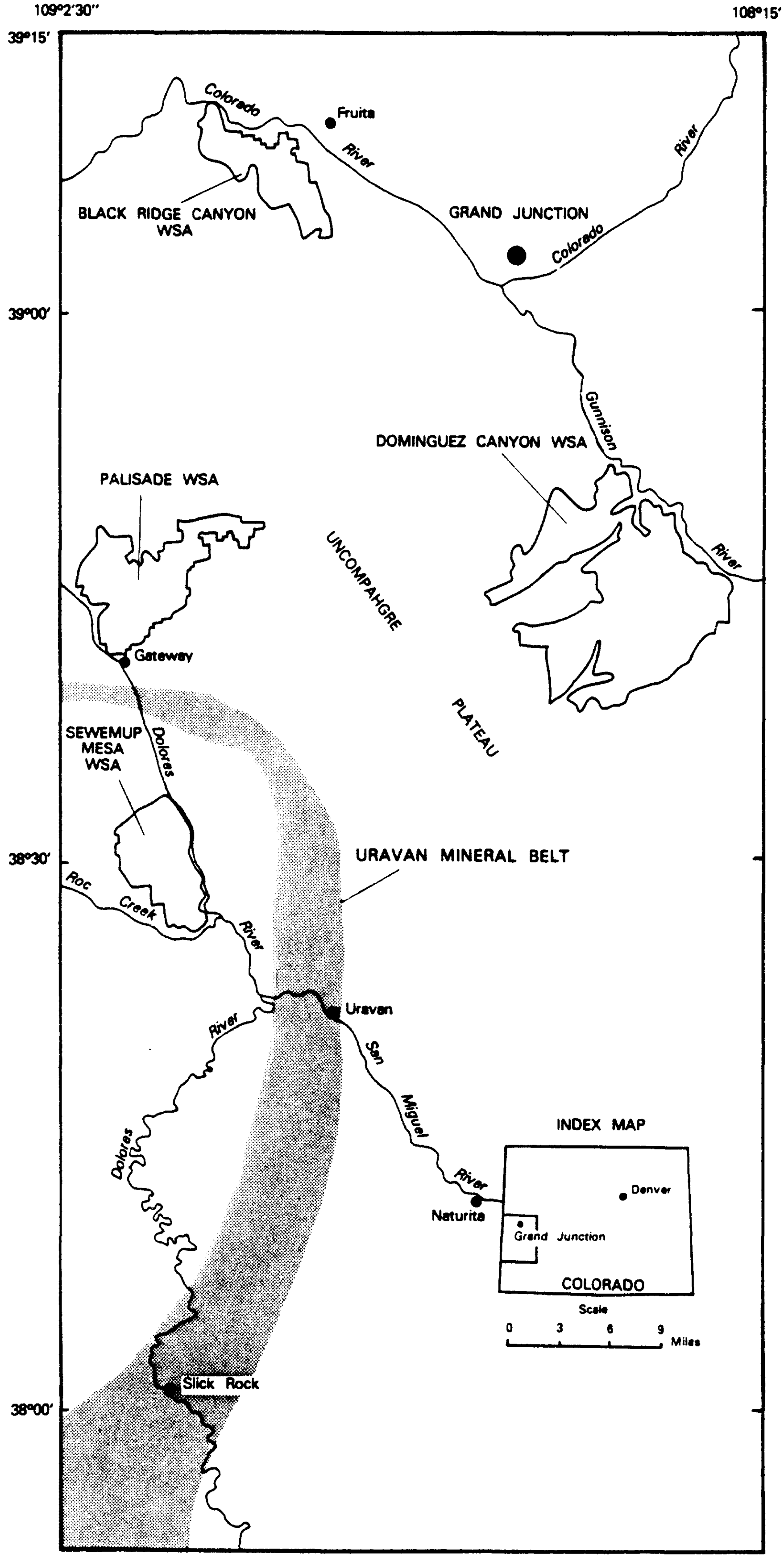


Figure 4.--Map showing location of the Uravan mineral belt (modified from Schwochow, 1978).

The Palisade WSA has only minor exposures of Salt Wash Member and extreme difficulties in access to outcrop usually prevented detailed examination. Dense pinyon-oak-juniper forest prevented foot and helicopter access, and jeep roads in the area have deteriorated to the point of impassability.

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 conglomerate, sandstone, siltstone, mudstone, and limestone deposited by northeastward to eastward flowing streams. 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 Brushy Basin Member is not present in the WSA.

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". 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. 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 present 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 averges 45 ft in thickness and contains no known uranium mineralization.

The base of the Salt Wash Member is marked by the lowest appearance of true fluvial channel fills. 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 in the upper portion ("upper rim"). The sandstones are light gray green to reddish or limonite speckled, fine grained, with rare medium- to coarse-grained 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, which occasionally 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 averaged 150 to 200 ft in thickness in the WSA.

The upper rim of the Salt Wash displays a somewhat higher energy regime. Sandstone, mainly cemented by calcite with local zones or patches of dolomite and (or) barite, dominates this portion, with more cut-and-fill structures, more trough crossbedding, a few more chert pebble and clay rip-up conglomerates, and occasionally organic debris. In these sandstones flat bedding and massive unbedded layers are more common, especially as compared to more proximal facies in the Uravan mineral 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 Member is considered to have been deposited by streams traversing an alluvial fan system extending from south-cental Utah or western Arizona to western Colorado.

Uranium deposits of the Salt Wash Member

Regionally, the Palisade WSA is in uranium country. The major deposits of the Uravan mineral belt lie just to the south (fig. 4). The known deposit within the WSA is of the "Uravan type" and potential ore deposits within the WSA would probably be similar in nature. The Uravan mineral belt is composed of a number of districts arranged in a roughly arcuate pattern transverse to the flow direction within the Salt Wash Member. Individual ore bodies are of the tabular or so-called "roll front" type (not related to the Wyoming basin roll front type) (Chenoweth, 1978). In the Uravan mineral belt 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 Fischer and Hilpert (1952) and Chenoweth (1978), who indicate that 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 low energy, distal-fan 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 Member consist of suites of large- and small-scale features known or supposed to be favorable for mineralization. These are tabulated and duscussed in McKay (1955), Campbell and others (1980), Huffman and others (980), Thamm and others (1981), and Northrop (1982). Large-scale guides include major sandstone "thicks" or depositional axes, because large-scale 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 blue-green mudstone; and identification of local sedimentary basins, transverse to the Salt Wash flow directions, which might have had ponds in which humate-generating favorable gray mudstones and (or) brines may have formed.

Small-scale guides, as discussed by the previously cited works, include the presence of altered blue-green mudstone which often underlies uranium deposits, or gray, carbonaceous, bentonitic mudstones ("favorable gray mudstones") adjacent to or above deposits; layers of carbonaceous or woody "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. Visual examination of oucrops and scintillometer surveys were done on all favorable appearing rock units. The presence of a dolomite layer adjacent to and overlying ore horizons in the Henry Basin has been documented by Northrop (1982). The position of the 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 the Palisade WSA lies adjacent to the extensive Uravan mineral belt, which exhibits a rather abrupt cut-off in grade towards the WSA, and has undoubtedly been rather heavily prospected by individuals and companies.

Uranium Potential in the Palisade WSA

Although lack of exposures of the Salt Wash Member and difficulty of access indicate that the Palisade WSA must be considered imperfectly evaluated for the presence of uranium deposits, the availible data does provide a basis for evaluation with moderate levels of confidence of the resource potential. The WSA location outside the principal mineral belt, limited occurrence of the Salt Wash Member within the WSA, unfavorable facies and lack of carbonaceous material in the Salt Wash Member, lack of results from visual and scintillometer surveys, and general small size and low grade of observed deposits, indicate low potential for economic levels of uranium mineralization in the Salt Wash Member in the Palisade WSA.

ENERGY AND MINERAL DEPOSITS

Known mineral deposits

The Winfield claims located atop the Palisade butte (sec. 36, T. 15 S., R. 104 W.) were examined with the aid of helicopter support. These workings are inaccessible by vehicle and very difficult to reach by foot so the ore was sling loaded out by helicopter (unpub. BLM report, 1980). The layer of the Salt Wash Member capping the butte consists only of the lower portion of the member. Very steep outcrops prevented intensive examination, but reconnaissance work showed the lower portion to be more sandy, displaying structures more characteristic of higher energy deposition than are seen in the Dominguez Canyon and Black Ridge Canyon WSAs (fig. 3). Facies changes occur rather abruptly over the space of a few miles between the Palisade WSA and the Dominguez Canyon WSA. This has been documented by Shawe (1962) and may be, in part, responsible for the sparse mineralization found in Dominguez Canyon and Black Ridge WSAs.

Examination of the three adits at the Winfield claims showed sparse discontinuous mineralization localized about a thin carbonaceous layer near the base of a channel sandstone in the lower rim of the Salt Wash Member. A visual and scintillometer survey revealed few areas of remaining radioactive mineralization. Because of the low grade of the remaining ore, limited total amount of ore possible in the eroded fragment of Salt Wash atop the butte, and limited access, this deposit is considered to have low potential.

The Phase 1 GEM report (Mountains States Mineral Enterprises and Wallaby Enterprises, 1983) reported another uranium mine in the area of the Palisade (sec. 10, T. 15 S., R. 103 W.) but no evidence of this mine could be found.

The Jerry Lewis claim in Bull Draw just outside the WSA (sec. 1, T. 15 S., R. 104 W.) consists of one timbered adit approximately 35 ft long. The Salt Wash Member at this location is light gray, fine-grained, trough crossbedded to massive, with a thin basal conglomerate and clay clasts. Traces of carnotite were seen along joint surfaces, as blebs in interstitial holes in the sandstone, and in several seeps on the adit wall. A 1 ft zone gave scintillometer counts approximately 40 times background. Dark layers along trough crossbeds and along thin carbonaceous layers below channels may contain primary unoxidized uranium minerals but showed little radioactivity. The deposit appeared to be worked out. The access road had slumped extensively and would require major reworking to make it passable.

A mine in a 35 to 45 ft thick pegmatite below the falls in Fish Creek in the eastern part of the area (sec. 31, T. 14 S., R. 102 W.) consists of a 10 ft deep trench leading to two adits perpendicular to the trend of the pegmatite (N05E). One adit is very small and has collapsed, and the other is about 40 ft long and 15 ft in diameter. None of the workings follow any noted structural trends. Large (1-2 in.) clots of garnet are the source of the anomalous Mn (70,000 ppm) detected in one sample from this pegmatite. No other anomalies were observed in the field or in the analyzed samples.

Two sand and gravel operations are located near West Creek outside the WSA boundary. Though no production figures are availible, both deposits appear to be limited in size.

Known prospects, mineral occurrences, and mineralized areas

In the northwest corner of the WSA, a fault system that trends N75W intersects the Salt Wash Member. Considerable botanical indication of uranium was present below the Salt Wash outcrop where it was intersected by the fault system. No uranium mineralization was observed along a 1 mi traverse of outcrop, although some carbonaceous layers were seen. Evidently, groundwater migrating along the fault surfaces mobilized sufficient selenium and uranium to provide suitable conditions for growth of prince's plume and vetch.

The anomalous levels of uranium found in water farther downstream from this fault system are probably caused by uranium-rich waters emerging from the fault system as springs and seeps to feed surface drainages.

Mining claims and leases

As of June 1982, there were no patented claims within the WSA (Mountain States Mineral Enterprises and Wallaby Enterprises, 1983). The Phase 1 GEM report located 90 unpatented claims in the WSA or on the WSA boundary of which 60 were estimated to be within the WSA. The majority of these lie in sections 1, 2, 3, 11, 12, 22, 27, and 34, T. 15 S., R. 104 W., and section 34, T. 14 S., R. 104 W. There are no known oil and gas leases within the WSA.

Mineral resource types

Two mineral resource types are present in the Palisade WSA: uranium and vanadium in the Salt Wash Member of the Morrison Formation, described earlier, and sand and gravel deposits along the southern boundary of the WSA, related to Quaternary terrace and alluvial deposits of the Dolores River and West Creek.

Mineral economics

Mineral economics are affected by a variety of factors, including access, transportation of ore, grade and volume of ore, recovery, extraction methods, areas within the Palisade WSA have poor economic potential because of their poor access, the low grade of the deposits, and the extremely localized nature of the deposits.

Land classification

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

No evidence for precious metals mineralization within the WSA was found so the area is considered to have low potential for base and precious metals in both the Precambrian and the sedimentary rocks.

The geology of the area and lack of suitable source formations indicate low potential for oil, gas, and coal deposits within the WSA.

Mineralization in the Salt Wash Member capping the Palisade has low potential for uranium and vanadium because of the extremely localized nature of the mineralization, difficulty of access, and previous removal of the ore. No evidence for mineralization was found at other claim sites within the Salt Wash Member so these are also considered to have low potential.

Sand and gravel deposits along the southern edge of the WSA are accessible and have been previously mined. The small size and poorly sorted nature of these deposits indicate a low to moderate potential.

Dimension stone is available in the Entrada and Wingate Formations but is not considered to be a likely resource because of the ready availibilty in areas with better access.

RECOMMENDATIONS FOR FURTHER WORK

Because of the the limited time framework, this study of the Palisade WSA concentrated on geologic mapping, stream-sediment, rock, and water sampling; examination of mines and mineral occurrences; and appraisal of the Salt Wash Member of the Morrison Formation for uranium potential. Although much of the Salt Wash Member present in the area could not be examined in detail, it should be noted that, where a geochemical signature was observed in the water or stream sediments, no mineralization could be identified in the souce rocks. Only known and worked deposits indicated any anomalous element concentrations in the stream-sediment, rock, or water samples. More detailed mapping of the Salt Wash Member, particularly where it is intersected by faults, might prove helpful, but the lack of any anomalous values in the chemistry of the stream sediments downstream from these areas reduces the probability that any significant deposit would be located.

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 Palisade Wilderness Study Area

Resource	Classification	Comments
METALS		
Precious (Au, Ag)	2C	Precious metals associated with the Precambrian
	2C	Precious metals associated with sedimentary rocks
Base (Cu, Pb, Zn)	2C	Mineralization associated with the Precambrian
	2C	Mineralization associated with sedimentary rocks
URANIUM-THORIUM	2D	Potential for uranium in the Salt Wash
URANIUM-THORIUM	2C	Potential for uranium in other sedimentary rocks of the WSA
NONMETALLIC		
Ba	2B	
OIL AND GAS	1D	Potential in Precambrian rocks
OIL AND GAS	2D	Lack of stratigraphic section favorable for oil and gas occurrences
COAL	1D	Classification for Precambrian rocks
COAL	1D	WSA lacks coal-bearing units
GEOTHERMAL	1D	No evidence for heat-producing bodies
NA/K	2D	
BULK COMMODITIES		
Sand and gravel	3C	Sand and gravel deposits along the southern boundary of the area
Dimension stone	3C	Entrada, Wingate, and Chinle Formations may contain favorable units for dimension stone

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