UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Geology and mineral resource potential of the Dominguez Canyon Wilderness Study Area, Delta, Mesa, and Montrose Counties, 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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[1/]Denver, Colorado

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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 Dominguez Canyon Wilderness Study Area (WSA) carried out in June and July of 1983 by the Central Mineral Resources Branch of the U.S. Geological Survey. The study consisted of geologic mapping at a scale of 1:24,000, combined with stream-sediment, rock, and water sampling, and subsequent analysis of the samples. Further detailed mapping and sampling of the Salt Wash Member of the Morrison Formation was also conducted to investigate its uranium potential.

The Dominguez Canyon WSA (CO-030-363 and CO-70-150) covers about 75,800 acres in west-central Colorado in Delta, Mesa, and Montrose counties (fig. 1), and is located about 20 mi southeast of Grand Junction and is accessed by highways Colorado 141 and U.S. 50. The Dominguez Canyon WSA consists of several northeast-trending gently dipping plateaus dissected by Big Dominguez and Little Dominguez Creeks, which flow northeastward into the Gunnison River. The WSA lies on the northeast flank of the Uncompahgre Plateau, and is bordered by uplifts and (or) basins on all sides. Two west-northwest-trending normal faults crosscut the WSA and have offsets of at least 75 ft.

Canyon bottoms in the WSA expose Proterozoic gneisses, schists, amphibolites, hornblendites, and granites. Overlying these crystalline rocks is a sequence of nearly flat-lying sandstones, siltstones, conglomerates, mudstones, and minor limestones, ranging in age from Triassic to Cretaceous.

In Triassic time, streams flowing from the west and south and winds blowing from the northwest deposited sandstones and mudstones. In the Jurassic, deposition occurred in shallow lakes, dunefields, and (or) marginal marine areas. In Late Jurassic time a return to fully terrestrial conditions occurred, with sediments coming from the southwest. Fluviatile sediments from the south and sediments from the swampy deltaic margins of a seaway transgressing from the south deposited the Cretaceous sediments. Uplift in Laramide, Late Tertiary, and Pleistocene times outlined the present-day Uncompahgre Plateau, and helped form the topographic features in the region.

Sixty-eight streams were chosen for sampling in the WSA and at each site a panned concentrate, a fine fraction of mud and silt, and a water sample (where water was present), were collected. Panned concentrate samples were analyzed by semiquantitative emission spectrography for 66 elements and certain samples were also analyzed for Au by atomic absorption spectroscopy. The fine fraction samples were sieved to minus 100 mesh and analyzed for 45 elements using inductively coupled plasma emission spectroscopy, and were additionally analyzed for uranium using fluorimetry techniques on an acetic acid extract. Water samples were analyzed for As and Se using atomic absorption spectroscopy, for Mo by inductively coupled plasma emission spectroscopy, and U by fluorescence techniques. Rock samples were crushed and pulverized to minus 100 mesh and analyzed by semiquantitative emission spectrography for 66 elements.

Stream-sediment samples from the WSA have low contents of elements generally associated with mineralized systems. Except for Ba, no localized anomalies in any of the elements are present. The concentration of Ba in the

panned concentrate samples was uniformly high in the WSA (median 20,000 ppm) and ranged from 1,500 ppm to >100,000 ppm. The high concentration of Ba is most likely related to a barite cement in one of the underlying sedimentary formations. No anomalous concentrations of any element were observed in the analyses of the fine fraction and uranium averaged <0.2 ppm. Two samples showed anomalous concentrations of uranium (35 and 47 parts per billion (ppb) U/conductivity X 1000) in their waters. These waters were sampled adjacent to the Salt Wash Member of the Morrison Formation, which is the likely source of the uranium.

Rock samples from the WSA were also generally low in elements associated with mineralization. Samples collected at prospect pits contained from 7,000 to 30,000 ppm Cu, 0.7 to 1.5 ppm Ag, and from 15 to 500 ppm Pb.

The Dominguez Canyon WSA has no known mineral deposits and there is no evidence of past mining. This study delineated five types of mineral occurrences: coal in the Cretaceous Dakota Sandstone, Cu and amethyst in diabase and pegmatite dikes, uranium in the Salt Wash Member of the Morrison Formation, bentonite in the Brushy Basin Member of the Morrison Formation, and high barium in the stream-sediment concentrates. None of these occurrences are considered a potential 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 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 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 Dominguez Canyon WSA conducted in June and July of 1983 by the U.S. Geological Survey.

The Dominguez Canyon WSA (CO-30-363 and CO-70-150) in Delta, Mesa, and Montrose counties, Colorado, is located about 20 mi southeast of Grand Junction and comprises 75,800 acres between U.S. Highway 50 and Colorado Highway 141 (fig. 1). The Gunnison River forms the northeastern boundary of the WSA while Escalante Creek and the North Fork of Escalante Creek form the southeastern boundary. The small towns of Bridgeport and Dominguez are just northeast of the WSA, and the larger community of Delta is 10 mi to the east. The approximate longitudinal and latitudinal boundaries of the WSA are 108°35′ to 108°15′ and 38°39′ to 38°52′30″. The WSA encompasses parts of Delta, Mesa, and Montrose Counties.

A mineral resource appraisal of the Dominguez Canyon WSA by the U.S. Geological Survey in June and July of 1983 consisted of geologic mapping at a scale of 1:24,000, combined with stream-sediment, rock, and water sampling, and subsequent analysis of the samples. Further detailed mapping and study of the Salt Wash Member of the Morrison Formation was undertaken to determine its potential for uranium. Color aerial photographs were commonly used to supplement the geologic mapping and determine regional structures.

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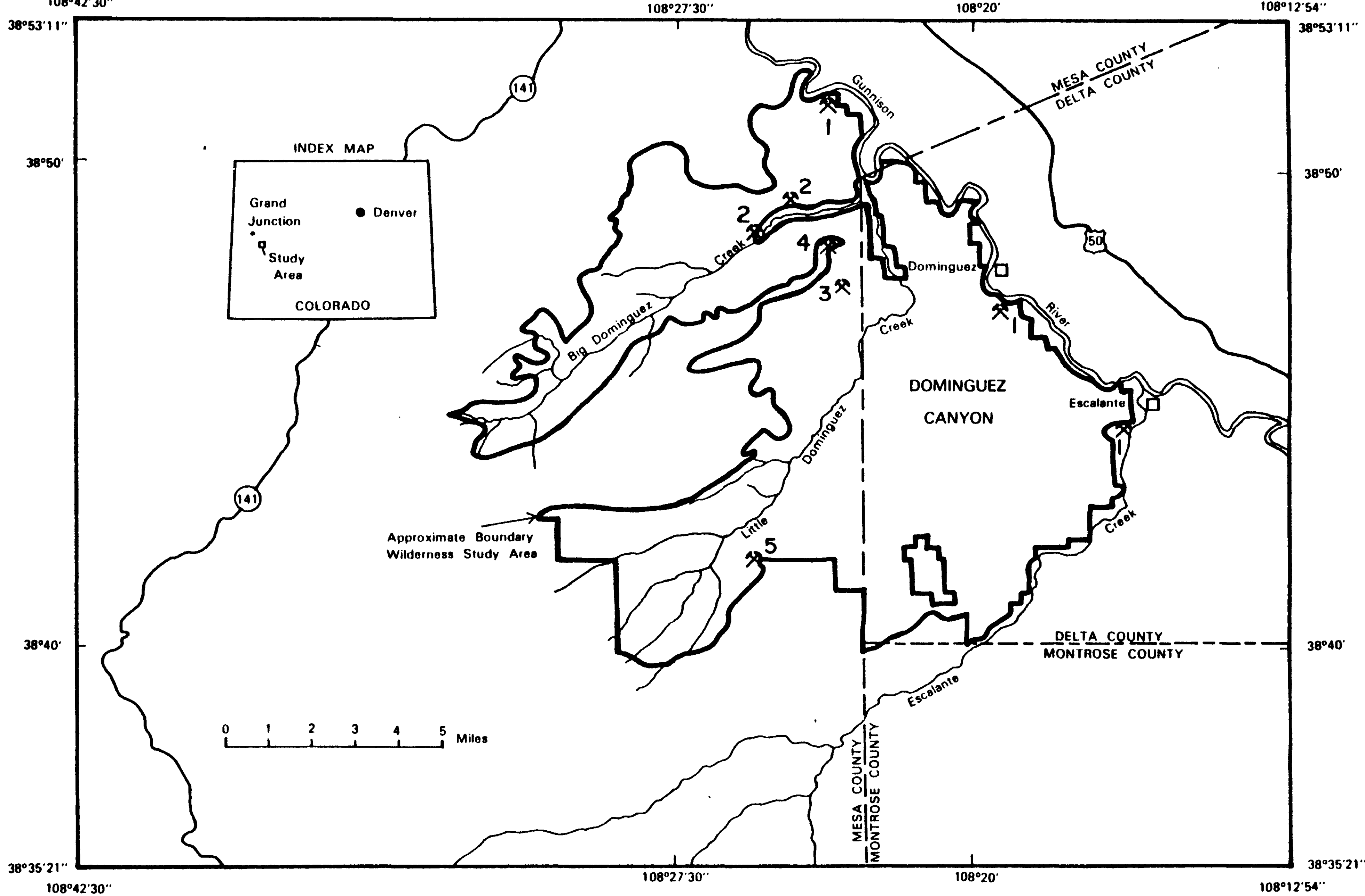

Figure 1.--Index map showing location of the Dominguez Canyon WSA, Delta, Mesa, and Montrose Counties, Colorado. Pick and hammer symbols indicate areas of prospects and (or) mineral occurrences. 1) high Ba in stream-sediment concentrates (100,000 ppm or greater); 2) Cu and amethyst in diabase and pegmatite; 3) coal in the Dakota Sandstone; 4) uranium in the Salt Wash Member of the Morrison Formation; and 5) bentonite in the Brushy Basin Member of the Morrison Formation.

senior author, Margo I. Toth, in geologic mapping (Plate 3 shows the area of responsibility for each geologist) and Linda L. Davis compiled the geologic map. Larry R. Layman, D. Brooke Hatfield, Linda Coles, and Kristine K. Wise assisted in the stream-sediment and water sampling.

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GEOLOGY

Physiography

The Dominguez Canyon WSA is a series of gently northeast-dipping plateaus dissected by deep, narrow canyons of the Big Dominquez and Little Dominguez Creeks, which drain northeastward into the Gunnison River. Vertical relief in the canyons is as much as 3,100 ft.

The climate is semiarid and the vegetation is typical of dry regions. There are various grasses, cacti, including the "jumping cholla", sage brush, juniper, mountain oak, and other small trees, and ponderosa pine. The tops of the plateaus have a dense cover of brush and scrub, except for natural grass meadows and areas that have been cleared. The walls of the canyons are cliffs with no vegetation and (or) sparsely vegetated, steep slopes. The land is utilized mainly for grazing purposes.

Description of rock units

Precambrian rocks crop out in the Dominguez Canyon WSA, but only in the deeper canyon bottoms. The following types were observed: pink and gray medium- to coarse-grained gneissic biotite schist, pink and white xenomorphic granular granite with (secondary?) foliations exemplified by biotite layers; black to dark blue, medium-grained amphibolite; gray and black, medium-grained amphibolite; pink and gray, medium-grained, biotite-hornblende granite with hypidiomorphic granular texture; pink, coarse-grained, biotite granite with hypidiomorphic granular texture; gray and pink, medium-grained mica schist with felsic xenoliths; white to gray, coarse-grained biotite granodiorite, with hypidiomorphic granular texture; pink, yellow, and gray, medium-grained gneiss with biotite showing well-defined schistosity; and a green, coarse-grained biotite hornblendite that is completely chloritized. Pegmatites are common and range from less than 1 in. to 20 ft in width and locally extend for several yards. The larger pegmatites have feldspar crystals that are as much as 2 ft long.

Diabase dikes crosscut the Precambrian granite in Big Dominguez Creek and are dark gray, indurate, fine- to medium-grained and contain accessory hornblende, biotite, and minor garnet. Foliation is slightly defined by biotite layers, and a gneissic character is developed in some of the rocks. The dikes strike to the northwest and dip at low angles to the north or south. The contact with the intruded Precambrian granite is locally very sharp, but in places the two rocks have mixed and the diabase contains xenocrysts of the granite. The age of the diabase is unknown, but Schwochow (1978) indicates that many of the diabase dikes in the Unaweep and Dominguez districts may be Cambrian, based upon correlation with other similar diabase dikes in the Dominguez district. Ogden Tweto (oral commun., 1983), however, feels that the diabase dikes in Big Dominguez Canyon are probably Precambrian in age, based upon their physical similarities to other Precambrian diabase dikes in the area.

Pegmatite dikes crosscut the diabase in a dense array in Big Dominguez Creek and range in thickness from a few inches to 20 ft, averaging 2 ft in thickness. Contacts with the diabase are sharp, and most pegmatites have chilled margins; the diabase dikes also commonly have a narrow, baked margin adjacent to the pegmatite. The age of the pegmatites is unknown, but they clearly post-date the diabase and pre-date the overlying Triassic sediments.

The pegmatite dikes are coarse-grained, light pink, and contain euhedral crystals of orthoclase and minor plagioclase, and anhedral quartz. Accessory, well-formed biotite, muscovite, and garnet comprise 3-8 percent of the dikes. Almost all of the pegmatites trend from 290 to 310 azimuth, and dip near-to-vertical. They commonly have a wide lateral extent and vary in thickness along the outcrop. Sparse copper mineralization occurs along the contacts between some of the pegmatite and diabase dikes in Big Dominguez Creek.

The Triassic Chinle Formation directly overlies the Precambrian complex and diabase and pegmatite dikes in an unconformable contact. The unit ranges from 30 to 160 ft thick, thinning to the northeast, and consists of brick-red, interlayered siltstones, shales, and fine-grained sandstones. The siltstones are commonly shaley, thinly bedded, very fissile, and are slope formers, but locally may form well-indurated columnar cliffs. The columns are of large, rounded nodules 1 to 2 ft in diameter that have shaley material between the nodules. The sandstones are well-indurated, massive, and range in thickness from 0.5 to 4 ft. The sandstones commonly form ledges.

Twenty feet above the contact between the Precambrian rocks and the Chinle Formation in Escalante Canyon a 4 ft thick brecciated gray limestone is present, forming a discontinuous bioherm horizon. Hematitic alteration is common within the limestone and in the matrix of the breccia. Another similar bioherm horizon crops out 30 ft above the lower bioherm but is more intensely weathered, with all the matrix material removed along the top 2 ft of the layer.

The upper 5 to 20 ft of the Chinle is a cliff-forming, red, shaley sandstone containing elliptical, cobble-sized, extremely siliceous nodules. Jointing and faulting is evident and in places continues up into the overlying Wingate Sandstone. There are Cu/Fe sulfide minerals along joint planes and shear planes and in adjacent permeable layers. Much of the shale shows classic spheroidal weathering and the formation has local concentrations of desert varnish.

The Triassic Wingate Sandstone lies unconformably on the Chinle Formation and the contact is sharp in most places to locally obscure. The Wingate Sandstone has a dark, reddish-orange color on weathered surfaces but is pale orange to light buff on fresh faces; the sandstone is also locally bleached to pure white. A black desert varnish also obscures the true color in many places. The rock is a massive, fine-grained, well-sorted, quartz arenite that is poorly cemented with both silica and lime cement. It forms steep, slabby cliffs ranging from 80 to 100 ft high. In some places it forms arches and in almost all exposures it is vertically jointed. The Wingate Sandstone grades into the overlying Kayenta Formation.

The Triassic Kayenta Formation consists of red, buff, gray, and lavender, irregularly bedded, fine-to coarse-grained sandstone, siltstone, and shale with a few lenses of conglomerate. It weathers into slabs and, in many places, is coated with desert varnish. This formation was not mapped separately in the Dominguez Canyon WSA because it is discontinuous, and where it is present, it is rarely more than 5 ft thick; on the geologic map (plate 1) it is included with the Wingate.

The Jurassic Entrada Sandstone unconformably overlies the Kayenta Formation (or the Wingate Sandstone where the Kayenta is absent) and the contact is seemingly gradational in places, but usually sharp. The Entrada Sandstone is salmon pink, very fine-grained, well-sorted with occasional larger grains, and is stained with hematite. The base of the sandstone has lenses of coarse-grained, well-sorted, lithic fragments. In some localities, the sandstone is bleached to white, extremely friable, and contains calcium carbonate veinlets. In certain exposures, the Entrada Sandstone seems to have two distinct units: a lower, massive quartz arenite that has large-scale crossbedding which weathers to a curve-faced cliff with rows of potholes, and an upper, thin, muddy or earthy, horizontally layered sandstone that weathers to large rounded nodules with an easily eroded shaley mud cementing the nodules. The total thickness ranges from 70 to 120 ft.

The Jurassic Summerville Formation unconformably overlies the Entrada Sandstone in sharp contact. It consists of purple, yellow, red, green, gray, and brown, thin and evenly bedded, sandy shale and mudstone with nodular limestone and chert layers. In some exposures the rock has been leached to pistachio green. The formation usually occurs as a talus-covered slope and ranges in thickness from 20 to 45 ft thick.

The Jurassic Morrison Formation conformably overlies the Summerville, but the contact is usually obscure. In the area of the WSA, the formation is divided into three parts. The lower Tidwell unit consists of about 40 to 50 feet 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 Member on the geologic map in Plate 1.

The middle Salt Wash Member consists of white, green, gray, buff, fine-to medium-grained sandstone, weathering to rusty-red, red, and black; green, gray, red, and reddish-brown mudstone with scattered, thin limestone beds; and a white, medium-grained to fine-grained eolian sandstone at the base. The lower half of the Salt Wash Member has a distinct gray-green color. The member ranges from 285 to 425 ft thick, thickening to the west, and generally forms ledges.

The overlying upper Brushy Basin Member contains red, green, and buff variegated bentonitic shales and mudstones with interbedded red, fine-grained sandstones and conglomerate. The contact between the two members is usually obscure because of the nature of the bentonitic muds and the abundance of sandstone layers in the upper member. The Brushy Basin Member ranges from 285 to approximately 400 ft thick and generally forms gentle slopes.

The Cretaceous Burro Canyon Formation overlies the Morrison Formation and consists of white, gray, and red, fine-grained, sub-rounded to well-rounded, well-sorted, well-indurated sandstones that are locally crossbedded, and crossbedded conglomerate with interbedded green and purplish shale.

The Cretaceous Dakota Sandstone conformably overlies the Burro Canyon Formation and was mapped with the Burro Canyon Formation in the WSA. The Dakota Sandstone consists of yellow, red, and brown lenticular and slabby sandstone and conglomerate with interbedded carbonaceous shale and impure coal. The Dakota Sandstone and the Burro Canyon Formation together are at least 140 ft thick.

Structure

The Dominguez Canyon WSA lies on the northeast flank of the Uncompahgre Plateau, a major landform and structural feature of western Colorado. The Plateau is approximately 100 miles long by 25 miles wide, and 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 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 and south. Geologically, it consists of Precambrian igneous and metamorphic rocks overlain by nearly flat-lying to monoclinally folded sedimentary rocks of Paleozoic and Mesozoic Age (fig. 3). High angle faults trending west-northwest and northwest are found mostly along the western margin of but also within the Plateau. The structural grain of the Uncompahgre Plateau region is a result of the intersection of two wrench fault systems: the Colorado Lineament, trending northeast (Warner, 1980), and the Olympic-Wichita Lineament trending northwest (Baars and Stevenson, 1981).

The major structural features in the WSA are two northwest-trending high angle, normal faults that have a small (?) component of left-lateral strike-slip movement. In a few places, along distances of a few hundred yards, the faults could be interpreted as unbroken monoclines. But as faulting becomes evident again within a short distance the monoclines (?) were not indicated on the geologic map on Plate 1. It seems likely that at some point, the fault turns into a large-scale monocline as observed in other places on the Colorado Plateau.

The sediments strike northwest and are nearly flat-lying with a maximum dip of 8 degrees to the northeast. Where foliation in the Precambrian rock was evident, the rocks showed variable strikes and dips.

Present day landscapes 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 1500-2000 ft may have occurred as late as Pleistocene time (Cater, 1966).

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

Historical geology

Precambrian igneous and metamorphic rocks are exposed in the deeper canyons of Dominguez, Little Dominguez, and Escalante Canyons. 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). Around 1,750 m.y. ago, these rocks were deformed and metamorphosed to high grade, possibly by continental plate collision (Tweto, 1980; Carpenter and others, 1979). At the eastern edge of the Uncompahgre Plateau in the Black Canyon area (fig. 2) partial melting of the metamorphic rocks produced the Pitts Meadow Granodiorite (Hansen, 1981). Two later phases of igneous intrusion occurred, during which the Vernal Mesa Quartz Monzonite (1,440±40 m.y.) and the Curecanti 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).

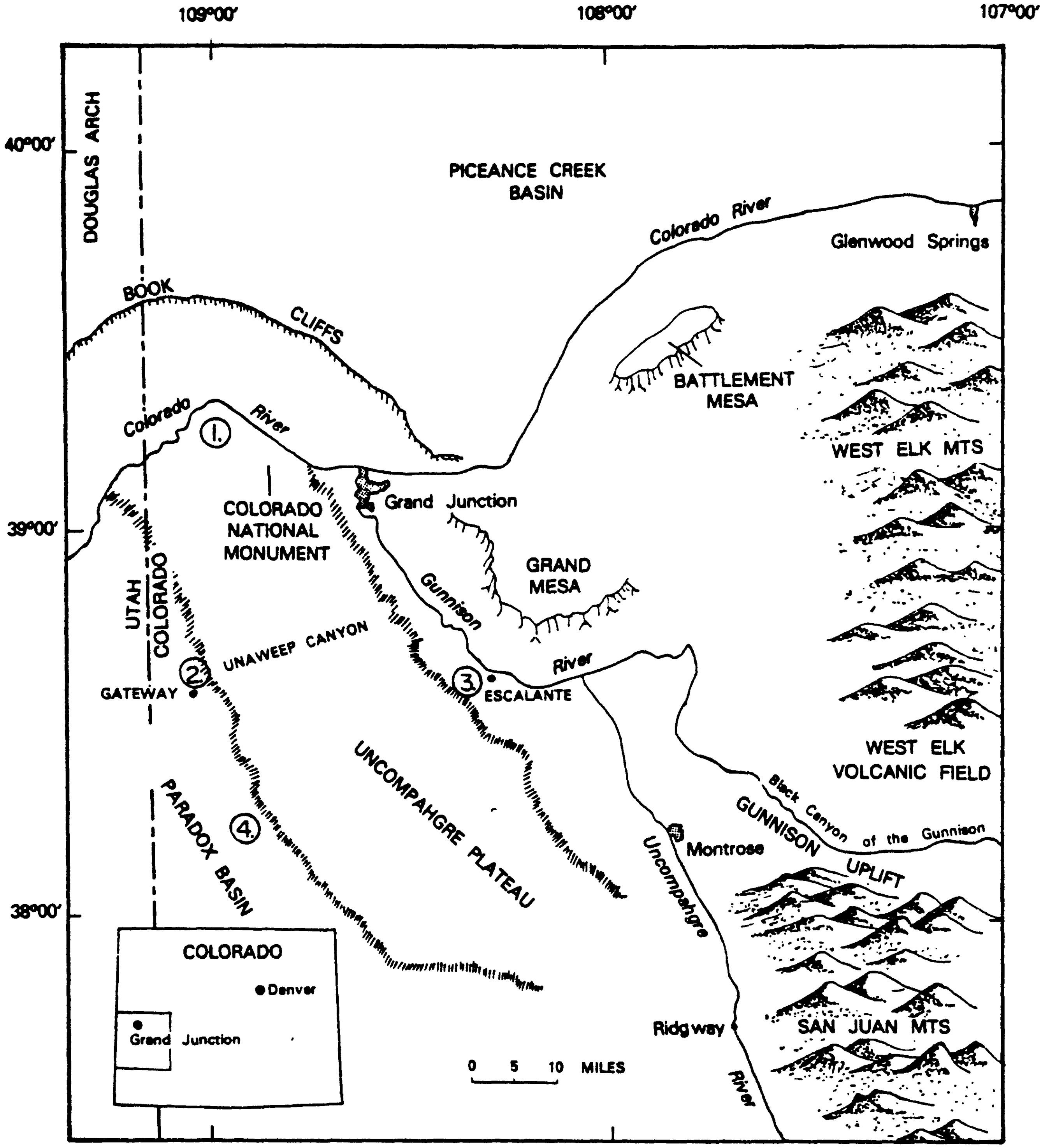

Figure 2.--Map showing location of major structural features in southwestern Colorado. Modified from Epis and Callender (1981). 1.) Black Ridge Canyon WSA; 2.) Palisade WSA; 3.) Dominguez Canyon WSA; 4.) Sewemup Mesa WSA

Figure 3.--Map showing generalized geology and location of major structural features in the region of the Dominguez 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

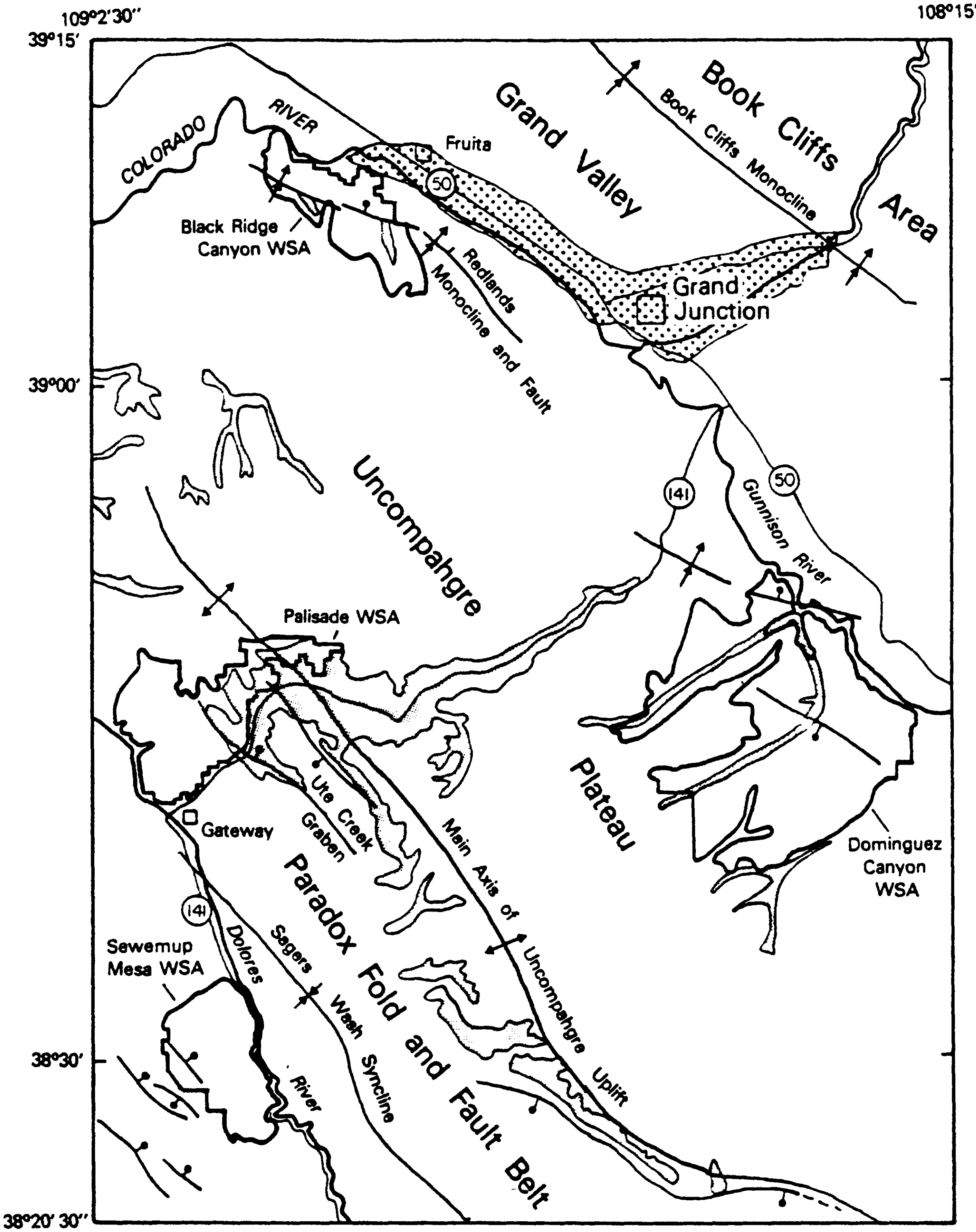
109°2'30"
108°15'
39°15'
39°00'
38°30'
38°20'30"
Book Cliffs
Area
Book Cliffs Monocline
Grand Valley
COLORADO
RIVER
Fruita
50
Black Ridge
Canyon WSA
Redlands
Monocline and Fault
Grand
Junction
Uncompahgre
141
50
Gunnison River
Palisade WSA
Plateau
Ute Creek
Graben
Gateway
Main Axis of Uncompahgre Uplift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

Figure 3.

Many pegmatites of widely varying age, but probably related to the Curecanti Quartz Monzonite, are also present.

Events later in Precambrian time were obscured by the development of an extensive regional erosional surface. A few sedimentary rocks of Precambrian age are preserved in areas near the Uncompahgre Plateau, but none were found within 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 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 produced thick sequences of evaporites with interbedded black shales in the basins, which were then overlain by 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 uplift was also being shed into these basins by alluvial fans and streams which formed the Cutler Formation. 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 Uncompahgre highland was sufficiently diminished by this time so that Chinle sediments were deposited directly on Precambrian rocks in the Dominguez Canyon WSA (O'Sullivan and MacLachlan, 1975; Cater, 1955).

The Wingate Sandstone, the lowest member of the Glen Canyon Group, is separated from the Chinle by a slight unconformity. Some workers (Fred Peterson, verbal commun., 1983) feel that the Wingate Sandstone may be Jurassic, but until further work is done it is included in Triassic time. The Wingate Sandstone is dominantly an eolian unit, characterized by large, sweeping cross- beds indicative of deposition by winds from the northwest. It is conformably overlain by fluviatile sandstones and conglomerates of the middle member of the Glen Canyon Group, the Kayenta Formation (Triassic). Highlands to the east and southeast were source areas for sediments of the Kayenta Formation. The upper member of the Glen Canyon Group, the Navajo Sandstone, is missing in the area of the 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, the Entrada and Summerville are the only formations that 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 Area.

An unconformity marked by a basal lag with chert pebbles in a sandstone bed marks the contact between the Summerville Formation and overlying Morrison Formation. The Morrison represents a return to fully terrestrial conditions of deposition. Streams flowing generally from the southwest and associated lakes and swamps supplied these sediments. The Morrison is divisible into three parts in the Dominguez Canyon WSA, 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 by 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 youngest rocks in the Uncompahgre region are the Cretaceous Burro Canyon Formation and the Dakota Sandstone. The Burro Canyon Formation was deposited by streams flowing from the south. The Dakota Sandstone, here mostly incomplete due to erosion, was deposited on the swampy deltaic margins of a seaway transgressing from the south. Overlying beds of the Mancos Shale and of the Mesa Verde Formation represent the full advance and retreat of the seaway; they are found near the Dominguez Canyon WSA forming Bookcliffs and badlands, but have been eroded away from within it.

GEOCHEMISTRY

The geochemical survey conducted as part of this study included sampling stream sediments, waters, and rocks for chemical analysis by semiquantitative emission spectrography, inductively coupled plasma, atomic absorption, and fluorimetry. Sample localities are shown on plate 2.

Sample Design

First order streams in the Dominguez 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 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. Sixty-eight 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. Some of the drainages in the Dominguez Canyon WSA consist of one long central 3rd or 4th order drainage, fed by many 1st order streams of <1 sq mi drainage basin area. In these instances, the main drainage was sampled in several different places at a spacing of 1 to 2 mi, and the small, side drainages were also sampled.

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, 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 from 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 (.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 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 of the water were measured in the field.

Rock samples were collected at two types of localities within the WSA. The first were any localities containing mineralized or altered rock or areas with characteristics indicative of related mineralized rock. In these localities about 0.5 lb of thumb-size rock chips were collected from the outcrop; when mineralized rock was present, the sample was collected along the vein or mineralized layer. The second type of locality consisted only of Precambrian crystalline rocks, sampled at random intervals to establish background values of the various elements and to look for any trends or values that indicate presence of mineralized rock. 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. The sample was collected perpendicular to foliation where evident.

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 ppm gold. When 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 were 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 fine 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 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 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 the method used for panned concentrates as discussed above.

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	--

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 microgram/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 micrograms/liter.

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

The various analyses were done by N. M. Conklin and D. B. Hatfield under project leader J. L. Seeley, Branch of Analytical Laboratories U. S. Geological Survey, Denver, Colo. Albert Yang of the Water Resources Division did the uranium analysis of the waters.

Results of geochemical survey

The panned concentrate samples from the Dominguez Canyon WSA were analyzed for 66 elements, but only showed detectable amounts of B, Ba, Co, Cr, Cu, Ni, Nb, Pb, Sc, Sr, V, Y, and Zr, and mainly in low concentrations near the detection limits. The analytical data for each of these elements were composited into histograms to look for anomalous concentrations. Except for Ba and possibly Zr, none of the elements were present in any clearly anomalous concentration, and were in general characterized by a very wide range of concentrations, possibly reflecting the high variability in the lithologies of the source rocks.

The concentration of Ba in the panned concentrates ranged from 1,500 ppm to >100,000 ppm, and had a median value of 20,000 ppm (fig. 4 and Plate 2). Two samples along the east and northeast side of the WSA (DLC004C and DLD008C) contained 100,000 ppm Ba, and were collected where the streams cut through outcrop of Wingate Sandstone and Morrison Formation, respectively. A third sample from the northeast side of the WSA (DAL005C) contained >100,000 ppm Ba and was collected where the stream cut through outcrop of Wingate Sandstone. A. M. Leibold positively identified barite in the panned concentrates by visual examination and by X-ray diffraction.

Because the streams drained heterolithologic source areas, it is not possible to identify the source of the Ba anomalies. However, as the samples were collected above outcrops of the Chinle Formation, the source must also be above the Chinle. The barite could be contained in barite cement, barite nodules, or barite veinlets, but field examination is necessary to establish the source. Fred Peterson (oral commun., 1983) indicates that the Salt Wash Member of the Morrison locally contains Ba cement, so the Member may be a possible source of the Ba.

Two samples from the WSA contained 20,000 ppm Zr in the panned concentrates. A source for the high Zr is not clear, but may be zircon in the Precambrian rocks.

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

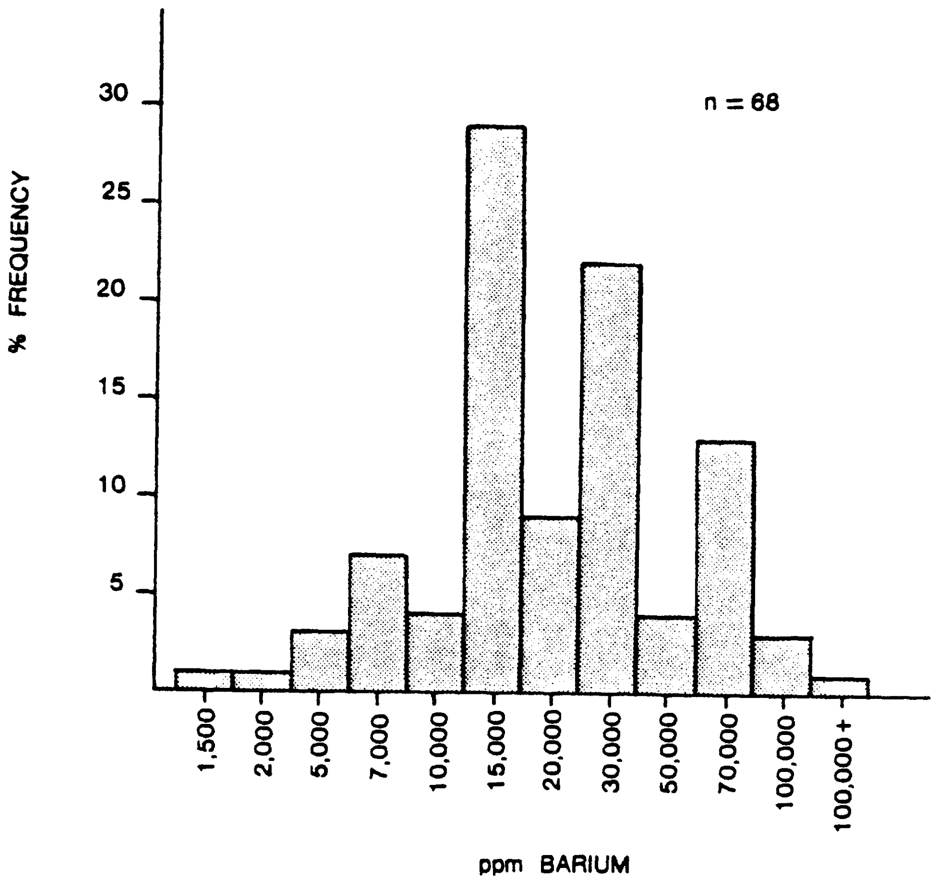

Figure 4--Histogram showing distribution of barium in stream-sediment concentrates. n= total number of samples

The fine fraction of the stream sediments were analyzed for 45 elements and showed no anomalous concentrations of any of the elements. Very few of the samples contained concentrations of elements above the detection limits. Uranium values ranged from <0.2 to 0.5 ppm, with 68 percent of all values being <0.2 ppm.

Water samples from the Dominguez Canyon WSA were analyzed for U, Mo, As, and Se, and except for two samples, showed no anomalous concentrations of any of these elements. Samples DLD018 and DLD019 contained 48 and 34 ppb uranium/conductivity X 1000, respectively. These waters were sampled adjacent to the Salt Wash Member of the Morrison Formation, which was a likely source for the uranium.

The rock samples from the WSA are low in elements associated with mineralization. Of the 66 elements looked for in the rocks only Ba, Be, Co, Cr, Cu, La, Pb, Sc, Sr, V, Y, and Zr were present, and most of these were in low concentrations near the detection limit for each element . Mineralized prospects in the WSA contained from 7,000 to 30,000 ppm Cu, 0.7 to 1.5 ppm Ag, 15 to 500 ppm Pb, and 5 to 15 ppm Mo.

URANIUM POTENTIAL IN THE DOMINGUEZ CANYON WSA

General statement

The Dominguez Canyon WSA lies on the northeastern flank of the Colorado Plateau. Historically, adjacent areas on the plateau have supplied over 12 percent of the uranium mined in this country (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 the stratigraphy of the Morrison Formation. Good summaries of the history of uranium exploration and production on the Plateau are given by Chenoweth (1978) and good descriptions of deposits of the Salt Wash type 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 disscussions of the Morrison Formation, especially the Salt Wash, 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 Dominguez Canyon WSA had been conducted. 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 Salt Wash-type deposits in the WSA.

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, occassional 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 the Upper Jurassic units. The 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. In most places, one or more similar sandstone layers occur higher in the Tidwell, but the chert granule layer is found 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.

In the Dominguez Canyon WSA, several bodies of sandstone derived from eolian sand lie at the top of the Tidwell. These bodies have variable thicknesses to as much as 60 ft, and may persist laterally for several miles along outcrop. They are composed of white, fine-grained quartz sandstone containing sparse black sand-sized chert grains and are friable with massive to large-scale crossbeds. They weather to make distinctive columnar shapes along vertical joints. These sandstones may correlate directly with the Bluff Sandstone in eastern Utah and the Junction Creek Sandstone of southwestern Colorado, and represent a small dune field that was migrating eastward across the expanse of the dried-up Tidwell Lake.

The base of the Salt Wash Member is marked by the lowest appearance of true fluvial channel sandstones. 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, 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 occassionally organic debris. Flat to massive bedding in these sandstones is, however, still most common, especially as compared to more proximal facies in the Uravan mineral belt to the south. 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 in thickness. The Salt Wash is considered to have been deposited by streams traversing an alluvial fan system originating in south-cental Utah or western Arizona.

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

Uranium deposits of the Salt Wash Member

Regionally, the Dominguez Canyon WSA is in uranium country. The major deposits of the Uravan mineral belt (fig. 5) lie just to the south, 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 which is transverse to the flow directions within the Salt Wash. Individual ore bodies are of the tabular or so called "roll" type (but of no relation to the Wyoming basin-type roll front) (Chenoweth, 1978). 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) who indicate that major ore bodies follow paleochannels within the Salt Wash upper rim. Deposits in the lower rim 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

Guides for uranium exploration in the Salt Wash consist of suites of large- and small-scale features known or supposed to be favorable for mineralization. These guides are tabulated and duscussed 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 indentification 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; and identification of local sedimentary basins transverse to the Salt Wash flow directions which might form ponds in which humate bodies and (or) brines may have formed.

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 woody "trash" in channel-fill deposits; favorable sedimentary structures such as abundant cut-and-fill structures displaying rough 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 diffractometer studies were done on samples from

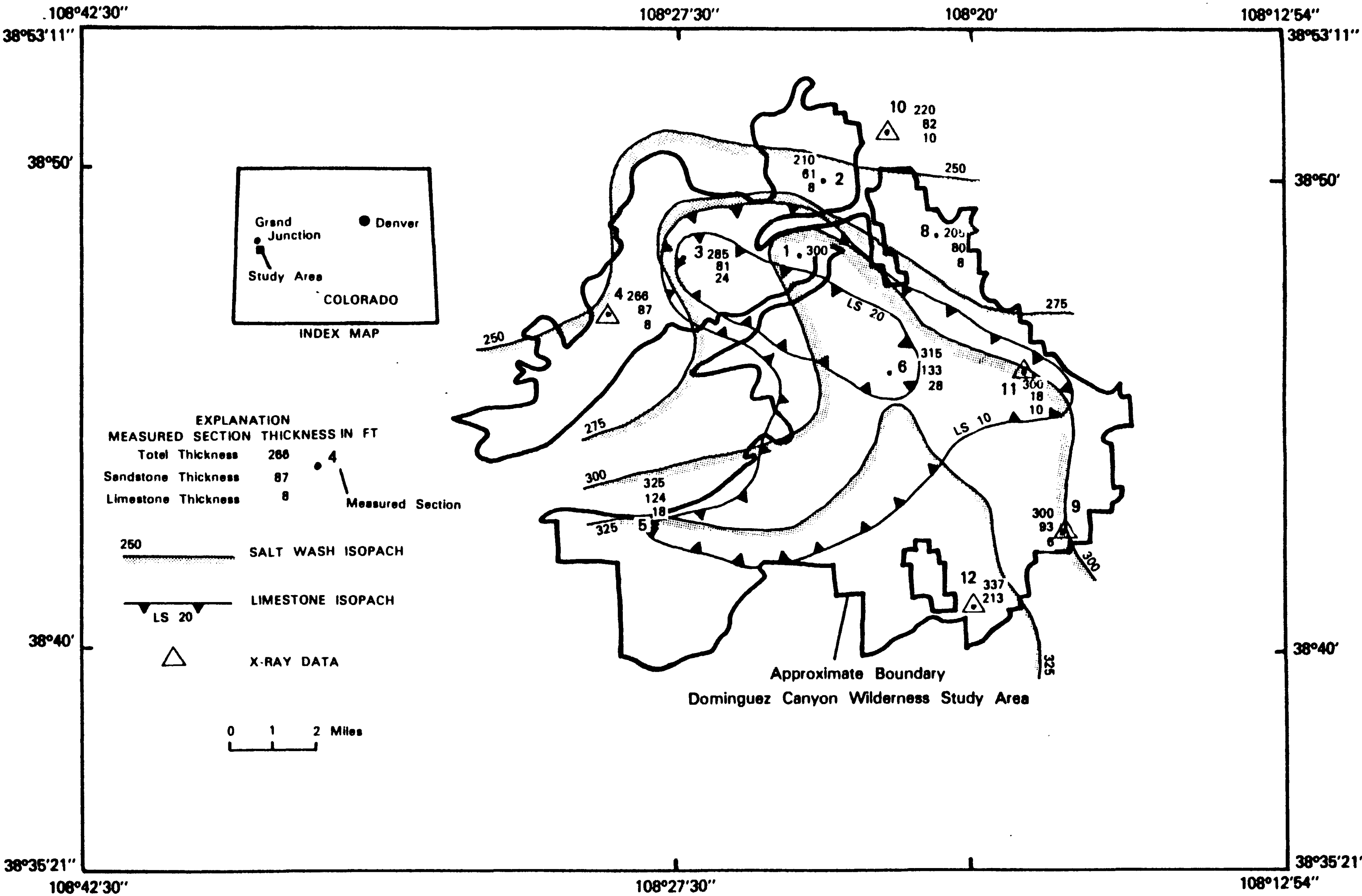

Figure 5.--Index map of the Dominguez Canyon Wilderness Study Area showing location of measured sections and isopachous contours of the Salt Wash Member and limestone thicknesses within the Salt Wash.

each locality to locate samples with anomalous dolomite. 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 the dolomite horizon 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 Dominguez 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 independent individuals and companies. Interviews with local residents and geologists (Jack Musser, and W. L. Chenoweth, oral commun., 1983) confirm that during the 1950's, prospecting was conducted on an intense level in the area, with no major or minor discoveries being made. The latest activities have included drilling operations in the late 1970's, but the operators could not be located to discuss their findings.

Methods of Study

In the Dominguez Canyon WSA, numerous stratigraphic sections were measured 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 (fig. 6) to establish patterns of deposition within the Salt Wash. In this way, favorable thick sandstone "depo-axes" may be located, as well as lakes or synclinal troughs thought to be favorable settings for production of humate bodies and (or) localizing a meteoric water-brine interface. The downstream side of the trough is considered most favorable for humate production (Peterson, 1980). Also noted were any areas containing carbonaceous material, and general oxidized or reduced character of the sandstone units.

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 dolomite horizon of cement had a potentially large lateral and vertical extent in the rocks (3 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 was 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 an X-ray diffractometer. Scans were from 24 to 37 degrees for main peak; peak heights were visually compared and ratios taken. Dolomite cement in excess of calcite cement was considered anomalous, but any presence of dolomite was noted.

Uranium potential of the Dominguez Canyon WSA

Isopach data for the Dominguez Canyon WSA reveal a trend shown first by Craig and others (1955) and by Mullens and Freeman (1957). Total thickness and limestone thickness outline a trough or synclinal feature oriented approximately transverse to flow directions in the Salt Wash Member. This may be due to deflection of Salt Wash drainages by a remnant of the ancestral Uncompahgre highland. Ordinarily these are considered to be favorable guides to uranium mineralization, as they create appropriate conditions for humate generation and for a brine-meteoric water interface. Fred Peterson (oral commun., 1983) feels that the downstream edge of the cross-trending trough is the most favorable location for humates generated by favorable gray mudstones. Several small adits on Star Mesa (near section 1, fig. 6) are located in

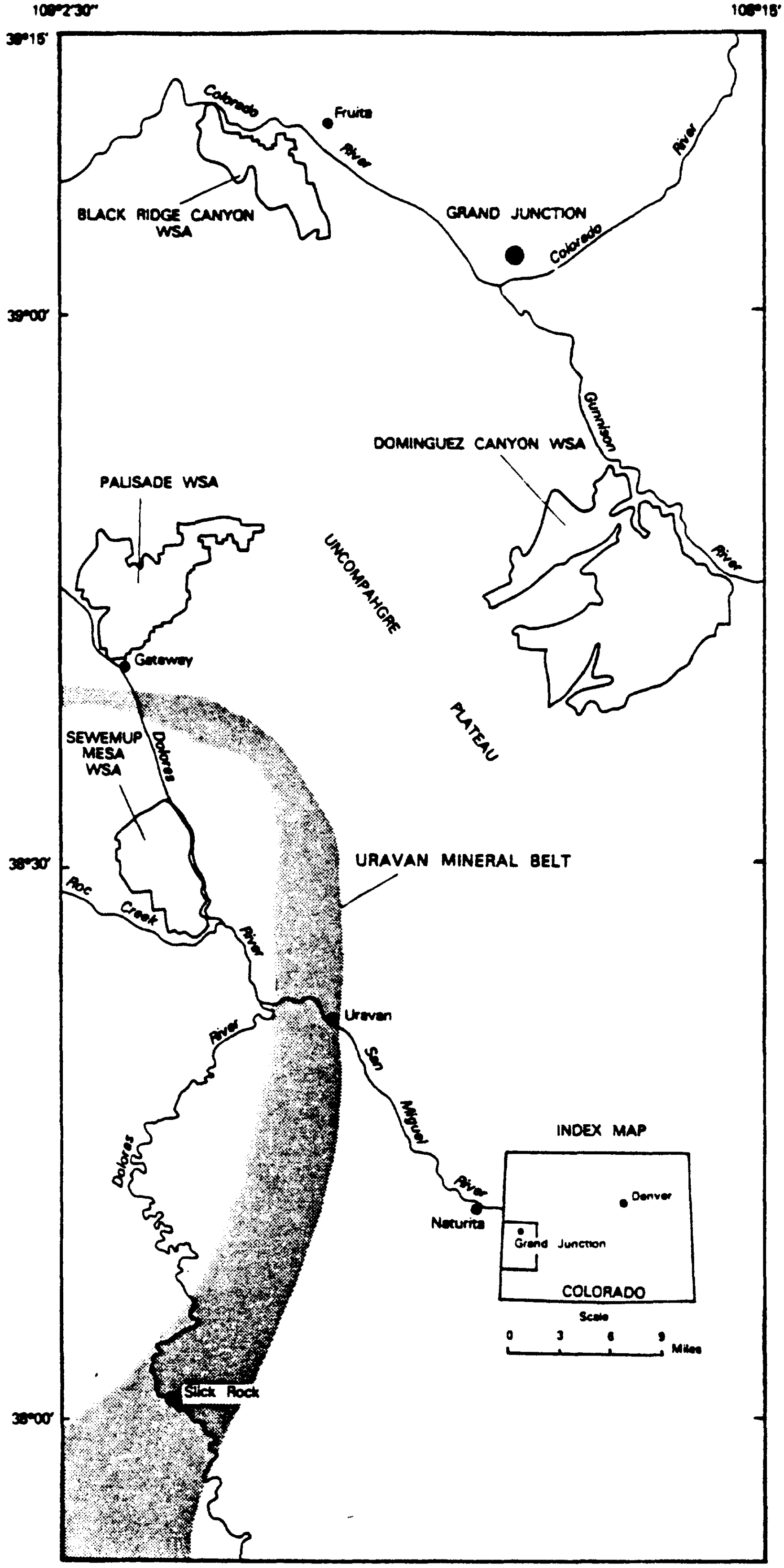

Figure 6.--Map showing location of the Uravan mineral belt (modified from Schwochow, 1978).

approximately the correct position. A dolomite anomaly that is highly persistent throughout the Dominguez Canyon WSA at approximately 75 ft below the top of the uppermost rim sand coincides with the level of sparse carbonaceous material found near the base of the upper rim. Intersections of carbonaceous material with dolomite anomalies are considered favorable indications of mineralization (Northrop, 1982). That the mineralization occurs on the downstream side of the trough gives confidence in the techniques. Two factors, however, argue against large deposits. First, erosion by the Gunnison River may have removed the most favorable ground; and second, the extreme scarcity of carbonaceous debris in favorable gray mudstones in the upper or lower rims of the Salt Wash diminished opportunities for uranium-bearing solutions to precipitate the uranium.

Anomalous uranium values were detected in water samples collected for this study and by the NURE investigation (Campbell and others, 1980). Field mapping revealed these to be associated with a northwest-trending fault system. Because the Salt Wash is known to contain widespread but extremely low-grade amounts of uranium, it is deemed likely that the anomaly is due to leaching and secondary concentration of uranium along the fault, and does not indicate the presence of an ore body.

The potential for a uranium resource in Dominguez Canyon WSA is considered minimal. In summary, this is because of extremely sparse carbonaceous material and lack of favorable gray mudstones, location outside of a known mineral belt, and location in a zone of unfavorable facies for this type of mineralization. The lack of reported claims during the uranium boom of the 1950's, 1960's, and 1970's also suggest that the uranium potential is low.

ENERGY AND MINERAL DEPOSITS

Known mineral deposits

There are no known mineral deposits in the Dominguez Canyon WSA.

Known prospects, mineral occurrences, and mineralized areas

Known prospects, mineral occurrences, and mineralized areas are of limited extent in the WSA and only five such areas were located in this study. A small coal prospect occurs at Star Mesa in the Cretaceous Dakota Sandstone (Mountain States Mineral Enterprises and Wallaby Enterprises, 1983), copper and amethyst are present in diabase and pegmatite dikes in Big Dominguez Creek, bentonite occurs in the Brushy Basin Member of the Morrison Formation, uranium prospects are present in the Salt Wash Member of the Morrison Formaiton, and high Ba occurs in the stream-sediment concentrate samples.

Copper prospects are present in two areas in Big Dominguez Creek about 1.5 and 3 mi upstream from the confluence with Little Dominguez Creek. The first area of mineralization (sec. 26, R. 99 W., T. 14 S.) contains a shaft, trench, and a small prospect pit. The shaft is 4 ft by 4 ft by 80 ft deep and is braced with wood and a metal frame for the upper 5 ft. The shaft was constructed into a 200 ft-thick, mineralized diabase dike, although pegmatite may be present at depth in the shaft. Mineralized diabase and pegmatite float is present on the surface over an area of about 40 ft by 40 ft and consists of disseminated malachite, azurite, and minor chalcopyrite, and amethyst.

About 20 ft northwest of the shaft, a 2.5 ft wide by 12 ft long by 8 ft deep trench was excavated along the contact between a pegmatite and diabase dike. Disseminated azurite, malachite, chalcopyrite, and amethyst are concentrated along the contact in the diabase dike. No mineralization is present within the pegmatite or on the other side of the pegmatite along the diabase/pegmatite contact. Vugs and comb structures are common in the mineralized rock. The pegmatite was traced in the diabase to where it was covered by overlying Triassic sedimentary rocks and no other mineralization was observed.

A prospect pit exposed a 2 ft wide pegmatite in Precambrian granite about 250 ft northeast of the shaft. The pit is 6 ft deep and funnel shaped, 3 ft wide by 6 ft long at the bottom, and 9 ft wide by 12 ft long at the top. No mineralization is present.

The second area of copper mineralization occurs 1.5 mi to the northeast (sec. 24, R. 99 W., T. 14 S.) in a 0.5 mi wide body of diabase that intrudes Precambrian granite. The westernmost prospect (DMT004) consists of a pit 5 ft wide by 6 ft long by 18 ft deep, and was dug along the contact of diabase and a crosscutting pegmatite. No mineralization was observed. A few hundred feet to the east, another pit was also dug along a pegmatite/diabase contact (DMT003). No copper mineralization was present in the pit, but jasper, malachite, and azurite were observed in float along the margins of the pit. Jasper veins cut across the diabase and pegmatite in the pit in layers 0.5 to 3 in. thick.

At sample locality DMT005 a 16 ft by 16 ft by 16 ft pit was dug into a 45 ft-thick, pink, medium-grained granite dike crosscutting diabase. Disseminated malachite, azurite, and minor chalcopyrite are present in the tailings and float over the width of the dike in a 20 ft long area. An adit 20 ft below the pit is 6 ft high by 4 ft wide and extends westward into the hillside for 58 ft, then turns south for 5 ft. The first 10 ft of the adit is well-timbered for support in alluvium, and the rest of the adit runs through diabase outcrop. Float outside of the adit consists of sparsely mineralized granite dike rock, similar to the granite found in the pit above.

To the east, on strike with the granite dike (DMT006), an adit and pit penetrated pegmatite and diabase. The adit is 3 ft wide by 4 ft high and extends eastward for 25 ft into diabase. The prospect pit above the adit is 6 ft wide by 8 ft long by 4 ft deep, although the pit has been partially filled by soil. Two 2 to 3 in.-thick pegmatite dikes are exposed in the pit and crosscut the diabase in sharp contact. No mineralization was observed.

Three trenches are present in the Brushy Basin Member of the Salt Wash Formation (sec. 10, R. 14 W., T. 51 N.; DMT007) in a bentonite prospect. The trenches are about 15 ft wide by 6 ft deep by 25 ft long, and have bentonite along their edges.

A prospect in the Salt Wash Member of the Morrison Formation (sec. 30, R. 99 W., T. 14 S). consists of two small bulldozed areas about 200 ft apart. No mineralization was observed in the tailings, and no carbonaceous debris was present.

Sand and gravel prospects occur along the Gunnison River outside of the WSA.

Mining claims and leases

Information on mining claims and leases taken from Mountain States Mineral Enterprises and Wallaby Enterprises (1983) indicate that there are 61 unpatented load claims within the WSA, in sections 2, 10, 25, 26, 34, and 35, T. 15 S., R. 98 W., and in sections 11, 24, 25, and 26, T. 14 S., R. 99 W. No patented claims are present in the WSA.

Mineral resource types

There are five mineral resource types within the Dominguez Canyon WSA: coal in the Dakota Sandstone, Cu and amethyst in diabase and pegmatite, bentonite in the Brushy Basin Member of the Morrison Formation, uranium in the Salt Wash Member of the Morrison Formation, and Ba in sedimentary rocks.

The only known coal deposit in the WSA occurs in the Cretaceous Dakota Sandstone (Mountain States Mineral Enterprises and Wallaby Enterprises, 1983). The Dakota was deposited on swampy deltaic margins of a sea, resulting in the deposition of sandstone interbedded with black organic shale and coal beds.

Mineralization occurs along the contact between diabase and pegmatite or medium-grained granitic dikes in Big Dominguez Creek and consists of disseminated azurite, malachite, minor chalcopyrite, amethyst, and some jasper. Because the chemical analyses of the unmineralized diabase dikes showed no anomalous concentations of Cu, the source of the Cu was probably related to the intrusion of the pegmatite and granite dikes.

The Brushy Basin member of the Salt Wash Formation was deposited under fluvial and lacustrine conditions. Volcanic activity during the deposition of the Brushy Basin Member resulted in the input of volcanic ash and later alteration led to formation of the bentonite deposits.

Uranium in the Salt Wash Member was deposited in channel systems 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).

High Ba in the stream-sediment concentrates in the WSA is most likely related to authigenic barite or barite nodules in the underlying sedimentary rock. It is presently unknown which formation(s) may have contributed to the Ba anomaly.

Mineral economics

Mineral economics are effected by a variety of factors, including access, transportation, grade, recovery, volume, extraction methods, demand, and present day market values. All of the known prospects and mineralized areas within the Dominguez Canyon WSA have low economic promise 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 suggested 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.

Potential for copper resources is considered low because of the very sparse nature of mineralization. Bentonite resources in the Brushy Basin Member of the Salt Wash Formation also have low potential because of the small area of occurrence. Potential for uranium resources is considered low for many different reasons discussed earlier in this report. Until a source for the high Ba in the stream-sediment concentrates can be located, the potential for Ba is also considered low. Further work may however, change this classification. Dimension stone in the WSA is abundant, but because it is readily available outside of the WSA in areas with much easier access, these deposits are not considered economic.

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 Dominguez Canyon WSA

Resource	Classification	Comments
METALS		
Precious (Au, Ag)	2C	Ag mineralization in pegmatite and diabase dikes; prospects
Base (Cu, Pb, Zn)	2C	Cu mineralization associated with Ag in pegmatite and diabase dikes; prospects
URANIUM-THORIUM	2D	Classification for uranium potential in 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 samples; source for barite unknown
OIL AND GAS	1D	Classification for Precambrian rocks
OIL AND GAS	2D	Lack of stratigraphic section favorable for oil and gas occurrences
COAL	1D	Classification for Precambrian
COAL	2C	With the exception of one locality, WSA lacks coal-bearing units
GEOTHERMAL	2B	WSA lacks evidence of heat-providing bodies; however, source of Ag and Cu unknown
Na/K	2C	
BULK COMMODITIES		
Sand and Gravel	2C	Sand and gravel deposits occur outside of the WSA
Building stone	2C	Wingate and Entrada Formations may contain favorable units for building stone
Bentonite	2D	Brushy Basin Member of the Morrison Formation contains favorable units; prospects

RECOMMENDATIONS FOR FURTHER WORK

Because of the large size of the Dominguez Canyon WSA and the limited time available for this study, efforts were concentrated on geologic mapping, stream-sediment, rock, and water sampling, and appraisal of the Salt Wash Member of the Morrison Formation for uranium potential. It should be noted that except for Ba and one occurrence of U, none of the mineral occurrences in the WSA had a chemical signature in the stream-sediment, rock, or water samples.

The coal deposit in the Dakota Sandstone should be mapped in detail and sampled. Analysis of BTU, ash, and sulphur content of the deposit should be made and chemical variations should be noted.

Additional mapping of the Precambrian rock might isolate other diabase and pegmatite bodies with copper mineralization. None of these deposits, if they exist, are likely to have a moderate or high potential for resources because they have no expression in the chemistry of the stream-sediment samples.

Detailed mapping of the Brushy Basin Member of the Morrison Formation should be carried out, to show location and extent of bentonite deposits.

A likely source for the Ba anomaly in the stream-sediments is barite, and a close examination of the rocks in the areas of the highest Ba anomalies might identify the source of the barite. Representative thin sections of the various formations might also help delineate a source for the Ba.

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