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BUREAU OF LAND MANAGEMENT

Serial Number

MINERAL REPORT

Mineral Potential Report
For The
Uncompahgre Planning Area

Lands Involved:

Lands encompassing approximately 700,000 acres in
Delta, Gunnison, Montrose, Ouray, and San Miguel Counties,
Colorado

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Table of Contents

TABLE OF CONTENTS I

ACRONYMS AND ABBREVIATIONS IV

SUMMARY AND CONCLUSIONS V

CONCLUSIONS v

Uranium and Vanadium v

Gypsum v

Placer Gold v

Sodium and Potassium vi

Sand and Gravel vi

Table 1 - Summary of Mineral Potential Findings in the Uncompahgre Planning Area ..... *vi*

INTRODUCTION 7

PURPOSE AND SCOPE 7

LANDS INVOLVED 7

Table 2 - Land Status and Mineral Estate within the Uncompahgre Planning Area *8*

MINERAL MANAGEMENT CATEGORIES 9

OVERVIEW OF GEOLOGY 10

REGIONAL GEOLOGY AND PHYSIOGRAPHIC PROVINCES 10

Colorado Plateau Uranium Province 10

Uravan Mineral Belt 10

Figure 1: Colorado Uranium Mining Districts *11*

Figure 2: Regional Location of the Uravan Mineral Belt *12*

STRATIGRAPHY 13

Paleozoic Era Strata 13

Pennsylvanian Period (360-300 Million Years Ago) 13

Mesozoic Era Strata 13

Triassic Period (245-208 Million Years Ago) 13

Jurassic Period (208-146 Million Years Ago) 14

Cretaceous Period (146-65 Million Years Ago) 15

Figure 3: Generalized Geology of West End of Montrose County, CO *16*
Figure 4: Colorado Plateau Stratigraphic Correlation *17*
Figure 5: Composite Generic Stratigraphic Column of Uravan Mineral Belt *18*
Figure 6: View of Jurassic Strata within Planning Area near Uravan, CO *19*
Figure 7: Stratigraphy of Dolores River Canyon within Planning Area *19*
STRUCTURAL GEOLOGY **20**
The Paradox Basin **20**
Figure 8: Structural Elements of Paradox Basin and Adjacent Areas *21*
Figure 9: Cross-section of Paradox Valley Salt Anticline *23*
ENERGY AND MINERAL DEPOSITS **24**
LOCATABLE MINERALS **24**
Uranium and Vanadium **24**
Uranium Isotopes 24
Known Uranium Deposits 24
Mineralogy 26
Figure 10: Eh-pH Diagram of UO2-CO2-H2O System at 25 degrees C and pCO2=10-2 atm *27*
History of Exploration, Development, Production, and Economics 28
Current Demand and Production 32
Figure 11: Location of the White Mesa Mill in relation to the UMB *33*
Figure 12: Location of the proposed Piñon Ridge Uranium Mill *34*
Gypsum **35**
Known Deposits 35
Mineralogy 35
History of Exploration, Development, Production, and Economics 35
Current Demand and Production 35
Placer Gold **35**
Known Deposits 35
History of Exploration, Development, Production, and Economics 35
Current Demand and Production 36
Figure 13: Location map of placer gold areas on the San Miguel River *36*
Figure 14: Placer gold locations along the San Miguel and Dolores Rivers *37*
SOLID LEASABLE MINERALS **37**
Potassium and Sodium **37**
SALABLE MINERALS **38**
Sand, Gravel, Fill, Clay, Riprap, and Moss Rock **38**

OCCURRENCE AND DEVELOPMENT POTENTIAL OF ENERGY & MINERAL RESOURCES 40
LOCATABLE MINERALS 40
Uranium and Vanadium 40
Figure 15: Active uranium projects on Morrison Formation sites within the planning area 41
Uranium Leasing Program 42
Figure 16: Location of DOE lease tracts in Mesa, Montrose, and San Miguel counties 43
Uranium-Vanadium Prices 44
Figure 17: Uranium Pricing Chart from 1988 to present 44
Figure 18: Ferro-Vanadium Price Chart from 1996 to 2005 45
Figure 19: Top World Uranium-Producing Countries for 2008 46
Gypsum 47
Placer Gold 47
SOLID LEASABLE MINERALS 47
Potassium and Sodium 47
SALABLE MINERALS 48
Sand and Gravel 48
Figure 20: Potential Sand and Gravel Deposit Areas with State Permitted and UFO Salable Permit Sites 49
RECOMMENDATIONS 50
APPENDIX A - MAPS 51
Map 1 - The Uncompahgre Planning Area 52
Map 2 - Geology of the Uncompahgre Planning Area 53
APPENDIX B - MINERAL POTENTIAL CLASSIFICATION SYSTEM 54
LEVEL OF POTENTIAL 54
LEVEL OF CERTAINTY 54
APPENDIX C - GLOSSARY 56
APPENDIX D - REFERENCES 58

Acronyms and Abbreviations

Acronym or Abbreviation	Complete Phrase
BLM	Bureau of Land Management
CFR	Code of Federal Regulations
DOE	Department of Energy
FLPMA	Federal Land Policy and Management Act
RMP	Resource Management Plan
UFO	Uncompahgre Field Office
UMB	Uravan Mineral Belt
USFS	United States Forest Service

SUMMARY and CONCLUSIONS

This preliminary mineral potential report assesses the occurrence and development potential for locatable, solid leasable, and salable mineral resources within the Uncompahgre planning area (planning area), for use in preparing the Uncompahgre Resource Management Plan. The planning area is located within the Bureau of Land Management (BLM) Uncompahgre Field Office in southwestern Colorado.

The report provides a general geologic description of the planning area, including physiography, stratigraphy, structural geology, and historical geology. In addition, the report includes a description of mineral resources that are present and a discussion of their development potential over the 15 to 20-year life span of a resource management plan. Two separate reports address the coal, and oil and gas potential in the planning area.

Each mineral resource identified in the planning area received a classification rating of high, moderate, or low, for its development potential using the Mineral Potential Classification System outlined in BLM Manual 3031, Energy and Mineral Resource Assessment (shown in Appendix B).

CONCLUSIONS

The following describes the preliminary findings for mineral resources within the planning area (summarized in Table 1 on page vi):

Uranium and Vanadium - Abundant direct and indirect evidence indicates ***high potential*** for the occurrence of uranium and vanadium deposits within historic mining sites in the planning area.

Where the Chinle Formation and Morrison Formation are present outside of these areas, there is minimal evidence indicating ***moderate potential*** for the occurrence of these two minerals. With the price of uranium (U_3O_8) at $72 per pound and the price of ferro-vanadium at $31 per kilogram as of February 14, 2011, production activity at some historic mines is likely to resume within the next fifteen years.

Gypsum - Abundant direct evidence indicates ***high potential*** for the occurrence of gypsum deposits within the Paradox Valley portion of the planning area.

Where the Paradox Member of the Hermosa Group is present, there are outcrops of high grade (>97% pure CaSO4) gypsum mineralization which have active mining claims located and communication of a mine plan to be submitted.

Placer Gold - Abundant evidence indicates ***high potential*** for the occurrence of placer gold deposits in the San Miguel and Dolores River drainage systems. With the price of gold at $1,413 per

troy ounce as of February 22, 2011, and world political unrest increasing, placer gold mining activity is projected to continue at the same level or increase over the next fifteen years.

Sodium and Potassium - Abundant evidence indicates ***high potential*** in the Paradox Valley area for the occurrence of sodium and potassium deposits within the Paradox Member of the Hermosa Group. With high demand for this resource expected to continue, soda ash, and potash exploration activity in the planning area is projected to increase over the next fifteen to twenty years.

Sand and Gravel - Abundant evidence indicates ***high potential*** for the occurrence of sand and gravel deposits at presently known sites in the planning area. With high demand for these resources likely to continue, production rates are projected to remain at present levels or increase over the next fifteen to twenty years.

Table 1 - Summary of Mineral Potential Findings in the Uncompahgre Planning Area

MINERAL RESOURCE	LOCATION	POTENTIAL	LEVEL OF CERTAINTY
Uranium and Vanadium	Known historic mining sites	High	D
	Chinle or Morrison Formation outside of historic mining areas	Moderate	C
Gypsum	Paradox Valley	High	D
Placer Gold	San Miguel and Dolores River drainages	High	D
Sodium and Potassium	Paradox Member of the Hermosa Group	High	D
Sand and Gravel	Presently known sites in the Uncompahgre planning area	High	D

LEVELS OF CERTAINTY

A. The available data are insufficient and/or cannot be considered as direct or indirect evidence to support or refute the possible existence of mineral resources within the respective area.

B. The available data provide indirect evidence to support or refute the possible existence of mineral resources.

C. The available data provide direct evidence but are quantitatively minimal to support or refute the possible existence of mineral resources.

D. The available data provide abundant direct and indirect evidence to support or refute the possible existence of mineral resources.

INTRODUCTION

PURPOSE AND SCOPE

The purpose of this Mineral Potential Report is to assess and document the occurrence of and development potential for mineral resources within the planning area for the Uncompahgre Resource Management Plan (planning area). The information contained in this report is based upon information and data from published and unpublished agency and industry reports and contacts. No field studies were conducted. Identified mineral resources are classified according to the system found in BLM manuals 3031 - Energy and Mineral Resource Assessment and 3060 - Mineral Reports: Preparation and Review (shown in Appendix B).

This mineral resource assessment provides an intermediate level of detail required for use during land use planning, as described in BLM Manual 3031. It is a preliminary assessment to be used in preparing an Environmental Impact Statement for the Uncompahgre Resource Management Plan (RMP), as required by the National Environmental Policy Act. This report is not a decision document and does not present specific recommendations regarding the management of mineral resources. The conclusions presented in this report should not be used for other purposes.

This report includes the following information for the important known mineral resources found in the planning area, and does not include other undiscovered mineral resources, such as rare earth elements, copper, molybdenum, iron, titanium and others:

- exploration, development, and production of mineral deposits
- classification of the potential for occurrence of each mineral throughout the planning area
- determination of whether the development potential for each mineral resource is anticipated to be high, moderate, or low over the next 15 years.

Two separate reports address the coal, and oil and gas potential of the planning area.

LANDS INVOLVED

As shown in Map 1 on page 52, the planning area for the Uncompahgre RMP encompasses parts of Montrose, Delta, San Miguel, Gunnison, Ouray, and Mesa counties in southwestern Colorado. The planning area is bounded by Utah to the west, the BLM Grand Junction Field Office to the north, the BLM Dolores Field Office to the south, and the BLM Gunnison Field Office to the east.

As shown in Table 2, the planning area contains 675,764 acres of public lands administered by the BLM Uncompahgre Field Office (UFO). In addition, the planning area includes 1,564,303 acres of federal minerals underlying surface lands not administered by the BLM (including state, private, and other federal lands). The planning area does not include lands within the Gunnison Gorge National Conservation Area, which is managed under a separate RMP, or the newly designated Dominguez-Escalante National Conservation Area, which will also operate under a separate RMP. Mineral resource development projections provided in this report are for all lands within the planning area.

Table 2 - Land Status and Mineral Estate within the Uncompahgre Planning Area

SURFACE LAND	ACRES
BLM	675,764
Forest Service	1,248,385
NPS	27,126
State	8550
CDOW	11,563
Private	1,125,345
US Fish and Wildlife	82
Other (including City Lands)	684
Total Surface Land:	**3,097,499**
MINERAL ESTATE	
No Federal Minerals	862,834
[1]All Federal Minerals	2,140,721
Coal Only	55,577
Oil and Gas Only	10,996
Oil, Gas, and Coal Only	8,966
[2]Other	18,407
Total Mineral Estate:	**3,097,501**
Total Federal Minerals	2,234,667
Federal Minerals under BLM Land	669,379
Federal Minerals under Other Federal Lands (including USFS & National Park Service)	1,269,719
Federal Minerals under Private/State/City Lands	294,584

[1]All Federal Minerals - The federal government owns rights to all minerals (including coal, oil, gas, uranium, gravel, sand, and moss rock).
[2]Other - The federal government owns rights to other minerals, either singly or in combination. Other minerals may include uranium, moss rock, gravel, and sand, as well as other minerals not listed in this table.

MINERAL MANAGEMENT CATEGORIES

The BLM recognizes three categories of manageable minerals: locatable, leasable, and salable. Uranium, vanadium, and gold are classified as locatable minerals. Locatable minerals are subject to disposal by mining claim location under authority of the Mining Law of 1872. Leasable minerals (including oil, gas, and potash) are subject to disposal by lease under authority of the Mineral Leasing Act of 1920 (as amended). Salable minerals (such as sand and gravel) are subject to disposal by contract sale or free use permit under authority of the Materials Act of 1947.

OVERVIEW OF GEOLOGY

The geologic history of lands within the planning area involves a complex interplay of tectonic and structural developments from the Precambrian Eon to the present, along with resulting sedimentation patterns. Although geologic structure and stratigraphy are intricately linked, it is possible to separate the two processes for ease of discussion. This section details the formation of pertinent stratigraphic units in the planning area, followed by a discussion of the area's structural geologic history, emphasizing host formations for uranium and vanadium resources.

REGIONAL GEOLOGY AND PHYSIOGRAPHIC PROVINCES

COLORADO PLATEAU URANIUM PROVINCE

The Colorado Plateau Uranium Province was first formally described in 1985 (Granger and Finch 1988), and later expanded upon with a greater emphasis on tectonics (Finch 1991). The boundaries of the area were drawn where differences in regional structures define the Colorado Plateau physiographic province. The province is bounded on the east by Laramide Rocky Mountain deformational structures, which contrast markedly with the flat-lying formations of the stable craton. The province is bounded on the north primarily by the Precambrian Uinta uplift. The western boundary is drawn along thrust faults, related monoclinal folds, and normal faults that define the Basin and Range province. As shown in Figure 8, on page 21, the southern boundary with the Basin and Range is more subtle and broadly defined, especially along the Mogollon Rim (modified from Finch 1996).

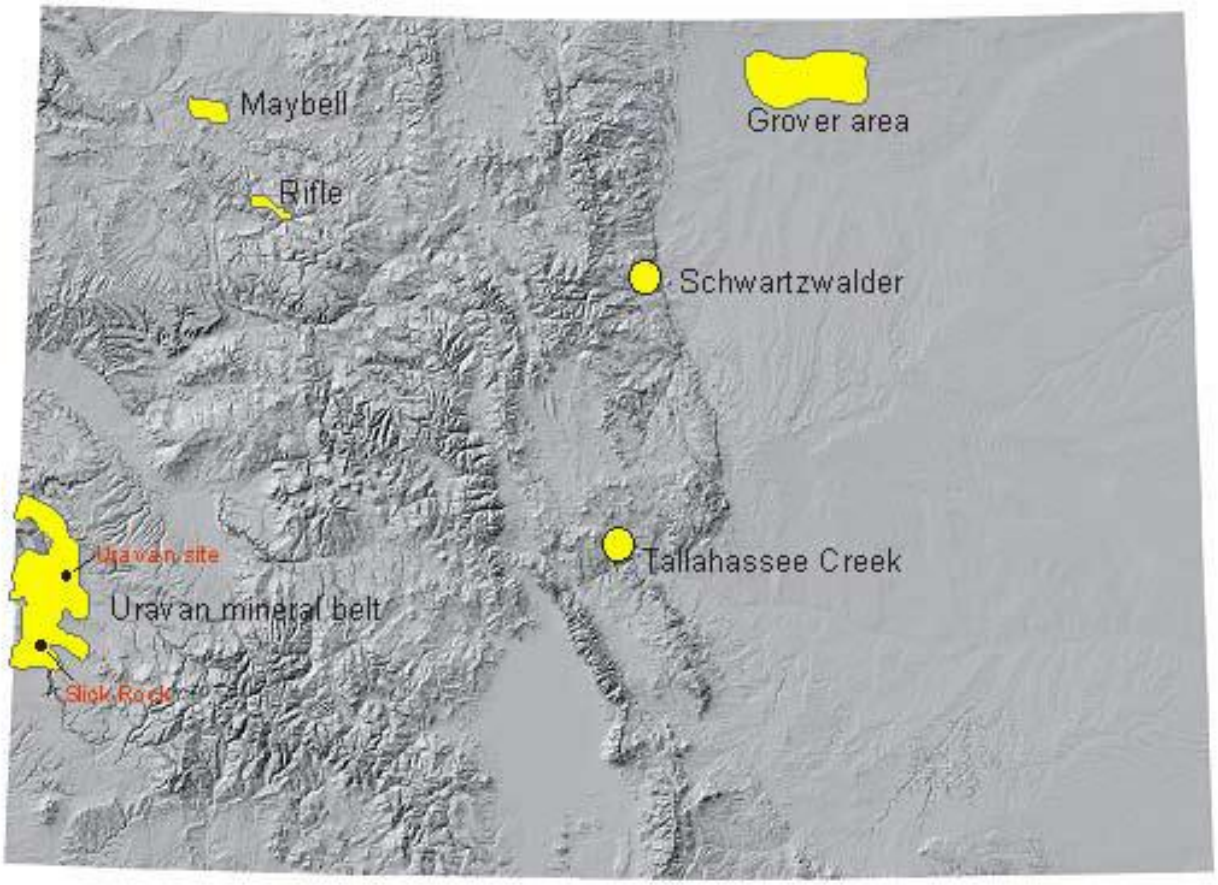
Uravan Mineral Belt

There are 310 known uranium mining districts within the Colorado Plateau Uranium Province, one of which is the Uravan Mineral Belt (UMB). The UMB is an arcuate zone of uranium-vanadium deposits in San Miguel, Montrose, and Mesa counties, Colorado, and Grand County, Utah. As shown in Figure 1 on page 11 and Figure 2 on page 12, a portion of the planning area in southwestern Montrose County lies within the UMB, while the western edge of the northwest-trending Uncompaghre Plateau lies about twenty miles to the northeast of the arc (Gerlitz et al 1988).

Source Material for Principal Uranium-bearing Strata

The Uncompahgre uplift exposed older sedimentary and Precambrian metamorphic rocks outside of the stable Colorado Plateau block. Within the planning area portion of the UMB, historic mining principally occurred in the Salt Wash Member of the Morrison Formation (as shown in Figure 3 on

page 16, Figure 4 on page 17, and Figure 5 on page 18). The source of uranium for the tabular sandstone is thought to have been various volcanic arcs to the west and south at the edge of the North American plate, which provided silicic ash for the thick fine-grained units lying above the major Triassic and Jurassic host sandstone layers (Finch 1996). Uranium deposits in sandstone beds were most likely precipitated by reduction between uranium-bearing groundwater and underlying saline brine (Finch 1996). Uranium and vanadium deposits generally parallel the attitude of the enclosing rock (Wright and Everhart 1960).



Source: Matthews (2007)

Figure 1: Colorado Uranium Mining Districts

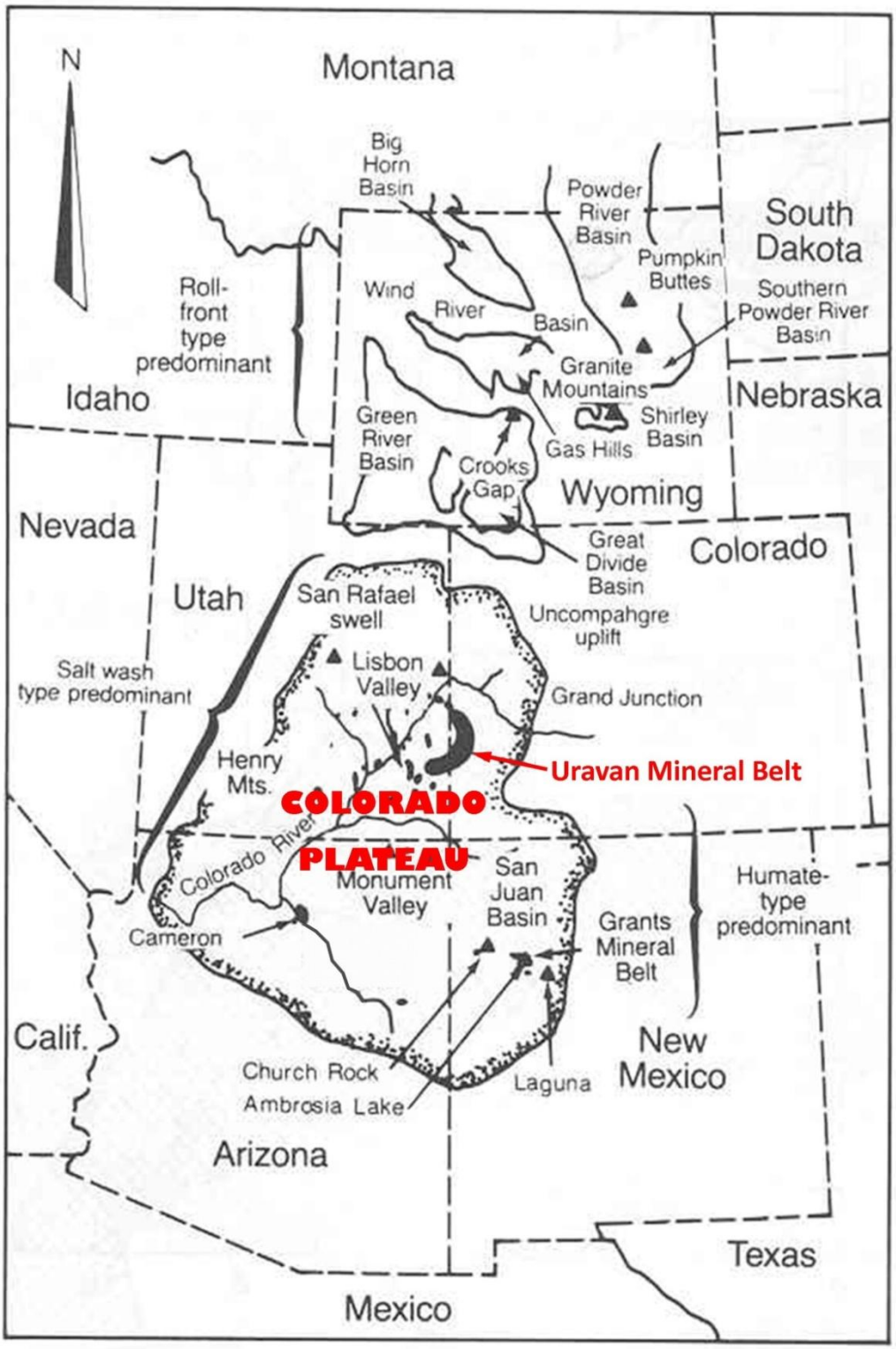


Figure 2: Regional Location of the Uravan Mineral Belt

Figure 4 on page 17 shows a correlative stratigraphic column across the Colorado Plateau from southwest to northeast, with uranium-producing members highlighted in yellow. A generic stratigraphic column on page 18 shows the vertical relationship of the most visible strata for the portion of the UMB within the planning area. In ascending order, the strata are the Chinle Formation, the Wingate Sandstone, the Kayenta Formation, the Entrada Formation, the Wanakah Formation, and the Morrison Formation (which hosts the Salt Wash Member).

STRATIGRAPHY

Figure 3 on page 16 and Map 2 on page 53 illustrate the surface geologic areal relationships of rock formations present in the planning area, and Figure 4 on page 17 shows the stratigraphic correlation of these Colorado Plateau rock formations, demonstrating some of the facies relationships that exist in the area. The stratigraphic evolution of the area, integrating those stratigraphic horizons important to known mineral deposits in the planning area, is discussed below. Figure 5 on page 18 shows the temporal relationship of the various Mesozoic sedimentary formations.

PALEOZOIC ERA STRATA

Pennsylvanian Period (360-300 Million Years Ago)

Hermosa Group - Paradox Formation

The Paradox Formation consists of black shale interbedded with evaporite deposits of gypsum, anhydrite, and salts, remnants of a vast sea that covered the Paradox Valley region in early Pennsylvanian time. The Paradox Basin subsided and the Uncompahgre Mountains were uplifted to the east. Great quantities of seawater were trapped in the subsiding basin and water became increasingly saline in the hot and dry climate. Thousands of feet of evaporites (consisting of anhydrite and gypsum followed by halite) built up during the mid-Pennsylvanian, and storms occasionally washed in sediment from nearby mountains. Fresh seawater periodically refilled the basin, but was unable to flush out the very salty water. These beds (up to 5,000 feet thick in places) lithified to become the Paradox Formation, a member of the Hermosa Group. Compressed salt beds from this formation began to flow plastically later in the Pennsylvanian. Satellite-based measurements indicate that flow of salt and gypsum continues to cause flexing and faulting of overlying sedimentary layers (Furuya and others 2007).

MESOZOIC ERA STRATA

Triassic Period (245-208 Million Years Ago)

Lower Triassic-age sediments in the planning area are characterized by thick, red, clastic sequences deposited in a range of near-shore environments (Gloyn and others 1995).

Moenkopi Formation

The Moenkopi Formation consists of chocolate-colored, fluvial, deltaic, and coastal deposits that include silty, micaceous shale interbedded with sandstone and limestone.

Chinle Formation

The Chinle Formation rests unconformably on the Moenkopi Formation. The depositional regime of the Chinle ranged from fluvial, floodplain, and lacustrine continental environments (Woodward-Clyde Consultants 1982). This formation consists of red, brown, and gray sandstone, conglomerate, and red, purple, and green-gray mudstone (Hahn and Thorson 2002). These deposits form distinctive red upper and green lower units. In Utah, the Moss Back and Shinarump members of this formation are hosts to a large number of uranium deposits that have supported small to medium-sized mining operations (Wood 1968; Gloyn and others 1995).

Jurassic Period (208-146 Million Years Ago)

Jurassic sediments in the planning area were deposited in various continental environments, ranging from eolian (massive windblown sandstone) to fluvial (interbedded sandstone, shale, and siltstone) to lacustrine (freshwater limestone). These sediments are comprised of the Glen Canyon Group, the San Rafael Group, and the Morrison Formation (Hintze 1988).

Glen Canyon Group

The Jurassic Glen Canyon Group consists of Wingate Sandstone, Kayenta Formation, and Navajo Sandstone. The Wingate Sandstone consists of massive, gray-orange to red-brown, eolian, cross-bedded sandstone. It overlies the Chinle Formation unconformably and varies from approximately 250 to 650 feet thick (Hintze 1988).

The Kayenta Formation varies from 0 to 340 feet thick, thinning to the southeast (Hintze 1988; Gloyn and others 1995). It is a very fine to fine-grained, irregularly bedded, locally conglomeratic, fluvial sandstone, siltstone, and shale. It also contains beds of mudstone or lacustrine limestone (Gloyn and others 1995).

In the planning area, Navajo Sandstone varies from 0 to 1,250 feet thick (Hintze 1988; Gloyn and others 1995). This formation thins eastward and consists of massive, white and yellow, eolian sandstone.

San Rafael Group

The San Rafael Group includes the Entrada Sandstone and Wanakah Formation (Hintze 1988). The Entrada Sandstone is recognized overall as a non-marine, cross-stratified sandstone and siltstone. The Wanakah Formation (formally called the Curtis and Summerville formations) ranges up to 200 feet thick (O'Sullivan 1996). The lower part of the formation consists of thin-bedded red mudstone and gray and yellow sandstone, while the upper portion is a marine glauconitic sandstone (Gloyn and others 1995).

Morrison Formation

The Jurassic-age Morrison Formation consists of various members, but not all are present in the planning area. The Morrison is host to extensive uranium deposits where the Salt Wash Member,

particularly in its upper part, is the most prolific uranium-producing horizon, and hosts small to large uranium deposits in channel sandstones (Wood 1968; Woodward-Clyde 1982; Gloyn and others 1995). This member consists of brown, lenticular, fluvial sandstone that is interbedded with red mudstone, and with thin gray limestone at its base. The Salt Wash Member varies from absent to 550 feet thick (Hintze 1988). The youngest member of the Morrison Formation is the Brushy Basin Member. It varies from 200 to 440 feet thick and consists of brown, bentonitic mudstone and brown, conglomeratic sandstone (Hintze 1988). The bentonite was derived from voluminous amounts of volcanic ash that was carried to depositional sites by north and northwesterly flowing paleo-streams (Turner-Peterson and others 1986).

Cretaceous Period (146-65 Million Years Ago)

Cretaceous sediments represent a sustained marine transgression across the Jurassic continental lowlands (Hahn and Thorson 2002). Conglomerate, sandstone, mudstone, and coal were deposited in transitional regimes, while carbonaceous shale and minor limestone reflect deposition in a marine environment.

Burro Canyon Formation

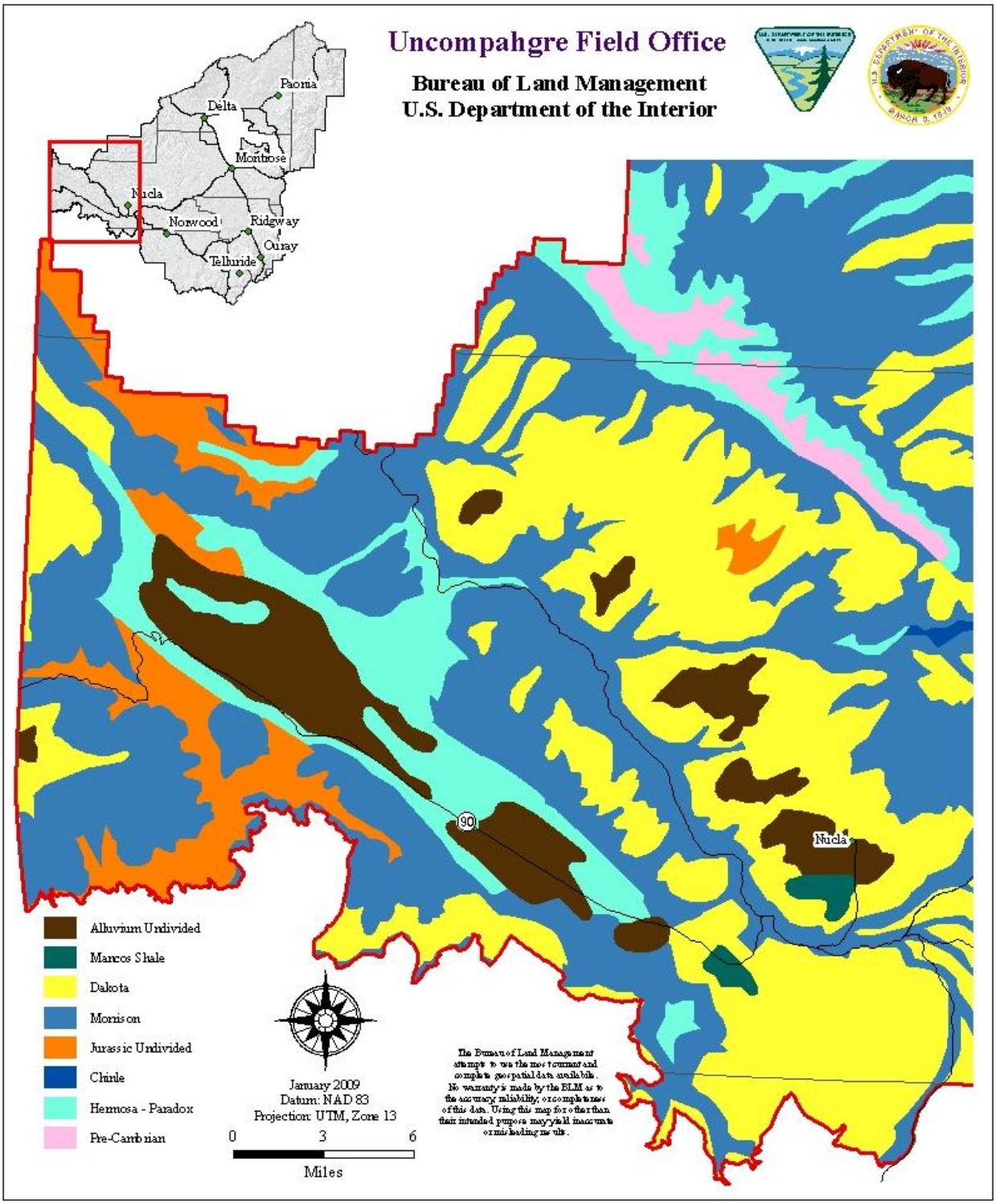
The Burro Canyon Formation is the basal Cretaceous unit found in the area, and varies from 50 to 180 feet thick (Hintze 1988). It consists of brown and gray fluvial sandstone and conglomerate in its lower half, while thin beds of dense gray limestone and variegated green and purple mudstone comprise its upper half (Gloyn and others 1995). It inter-fingers with the underlying Morrison Formation, and is unconformably overlain by the Dakota Sandstone.

Dakota Sandstone

The Dakota Sandstone varies from 30 to 150 feet thick and consists of brown and yellow fluvial sandstone and conglomerate, as well as interbedded green, gray, and black mudstone (Hintze 1988). Some of the sandstones are interbedded with siltstone, claystone, and thin coal seams. These coals are commonly impure, bony, and discontinuous, with an ash content that reaches 30% in many seams, with individual seam thicknesses ranging from two to 15 feet (Gloyn and others 1995). Sandstone from this formation may also be locally suitable for building stone or aggregate for road construction and maintenance.

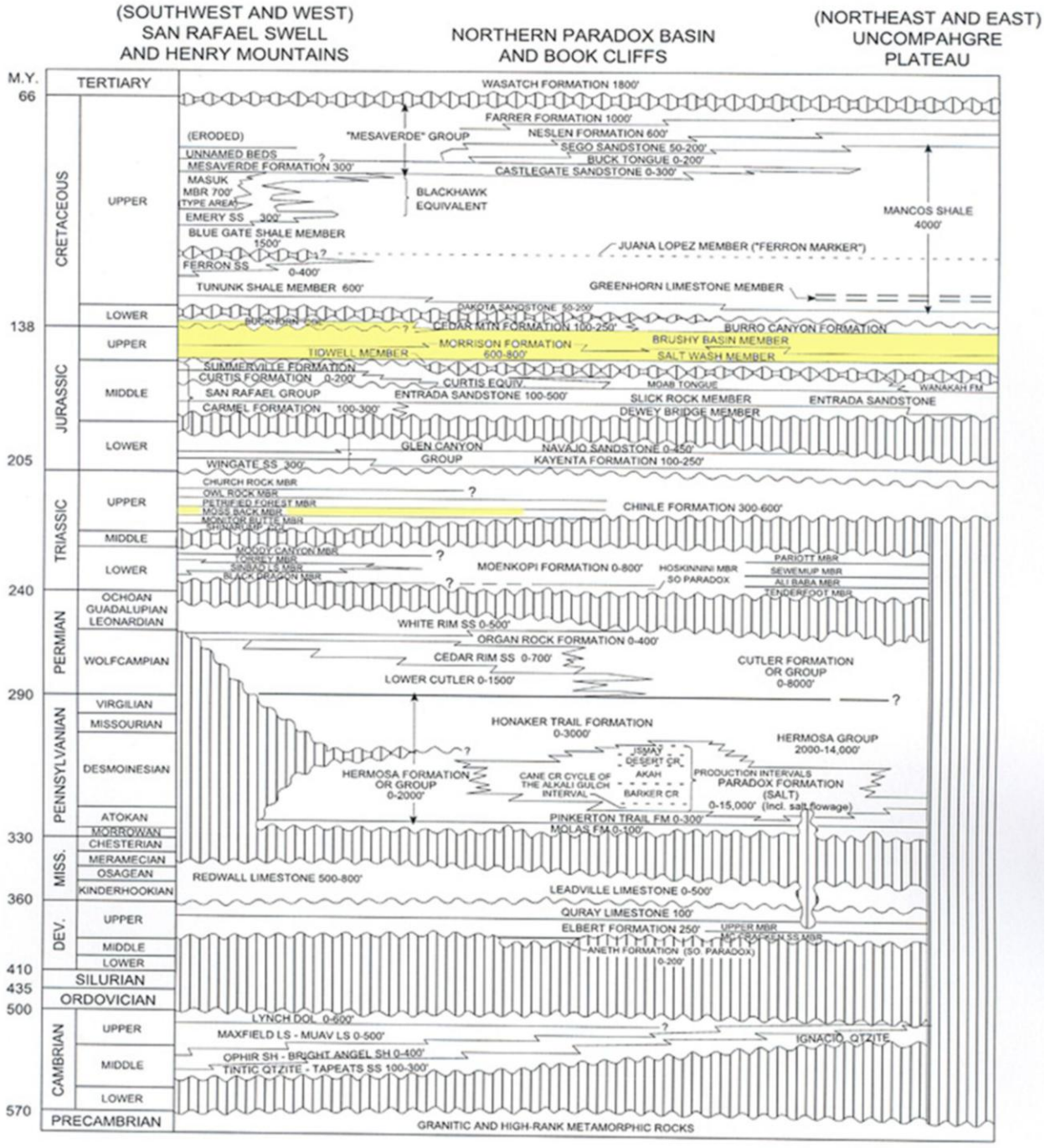
Mancos Shale

Within the planning area, an interval of the Mancos Shale, which exceeds 4,000 feet in thickness, overlies the Dakota Sandstone. The youngest Cretaceous-age formation in the UMB, the Mancos Shale consists of gray thin-bedded fissile shale interbedded with natural gas-producing sandstone and sandy siltstone.



Source: modified from Green (1992)

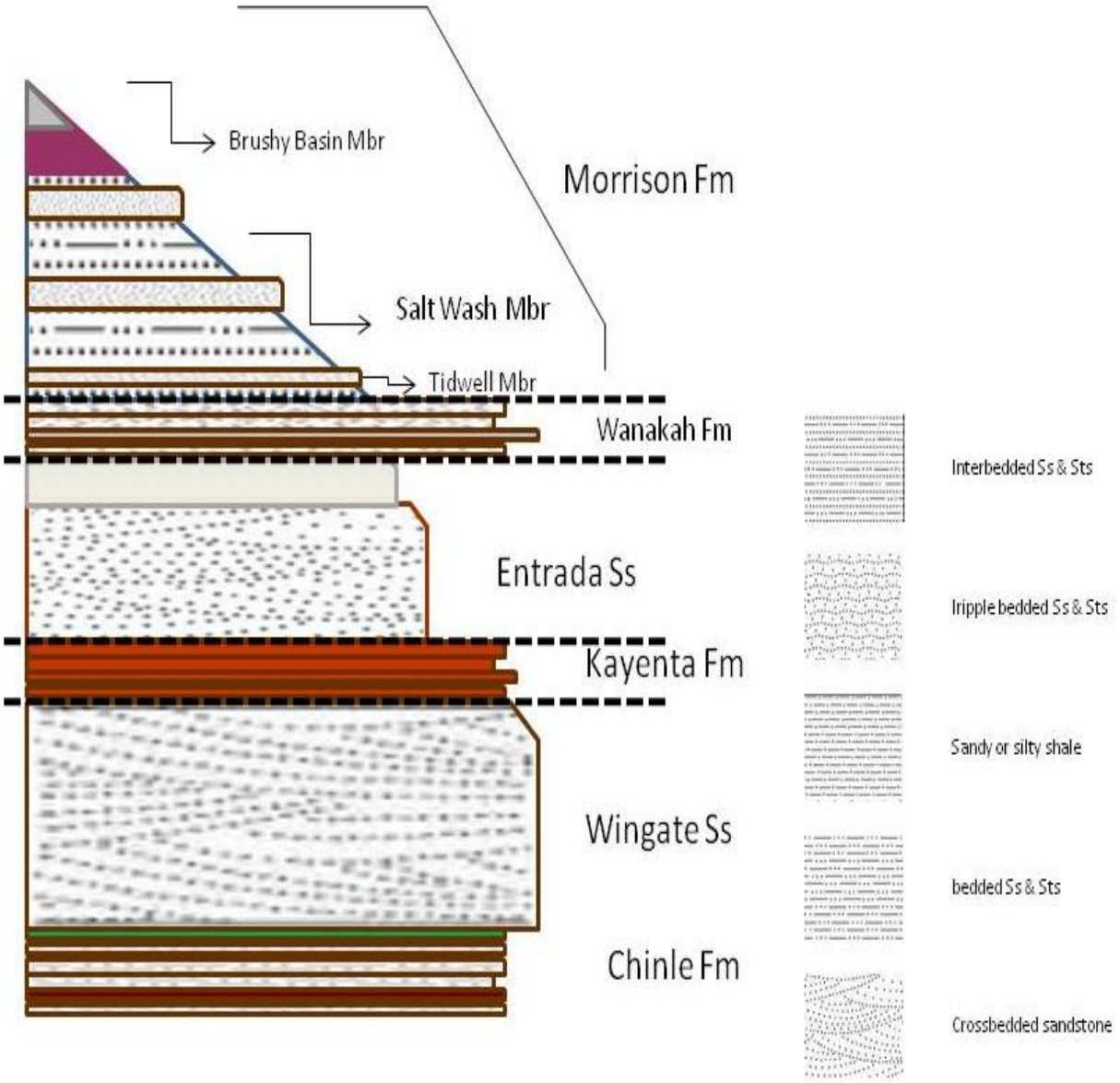
Figure 3: Generalized Geology of West End of Montrose County, CO



Source: Molenaar 1987

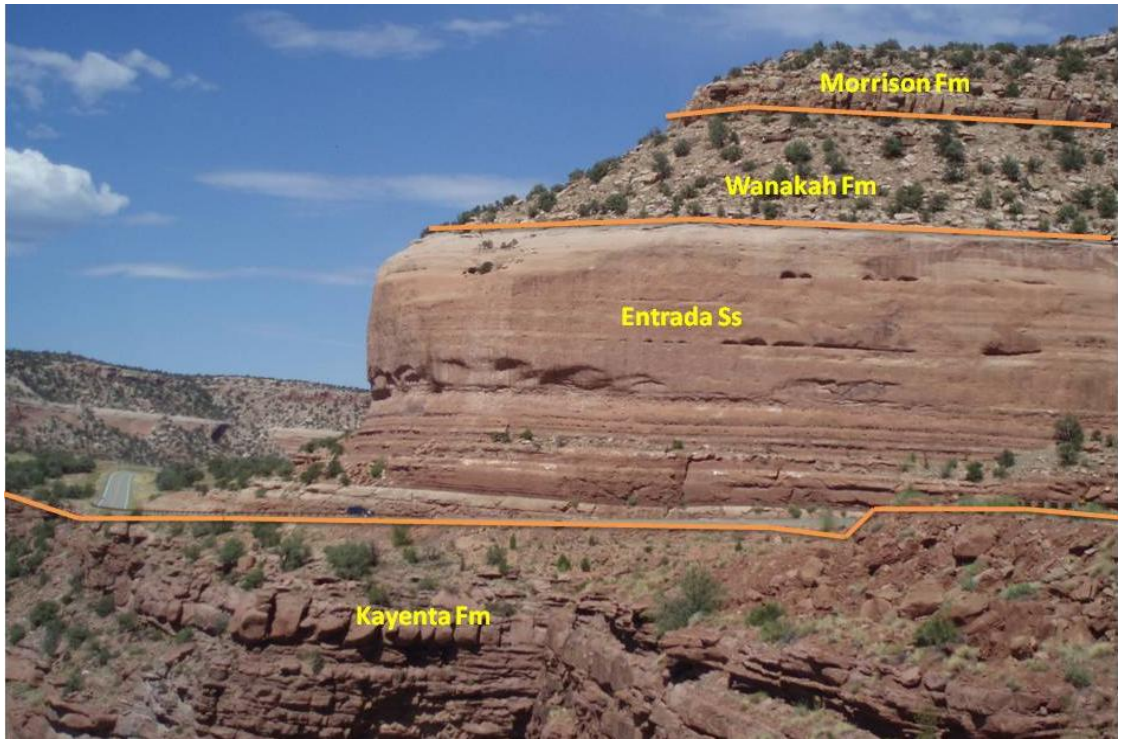
Figure 4: Colorado Plateau Stratigraphic Correlation

Historic uranium-bearing formations are highlighted in yellow.



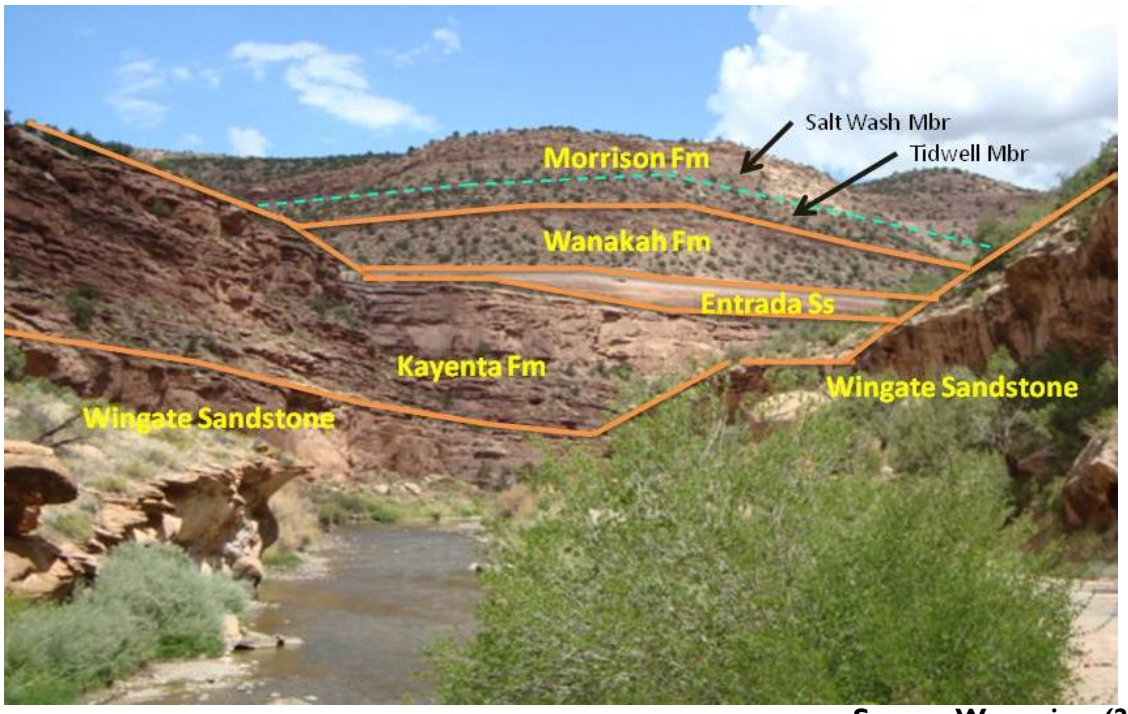
Source: Wegweiser (2008)

Figure 5: Composite Generic Stratigraphic Column of Uravan Mineral Belt



Source: Wegweiser (2008)

Figure 6: View of Jurassic Strata within Planning Area near Uravan, CO



Source: Wegweiser (2008)

Figure 7: Stratigraphy of Dolores River Canyon within Planning Area

STRUCTURAL GEOLOGY

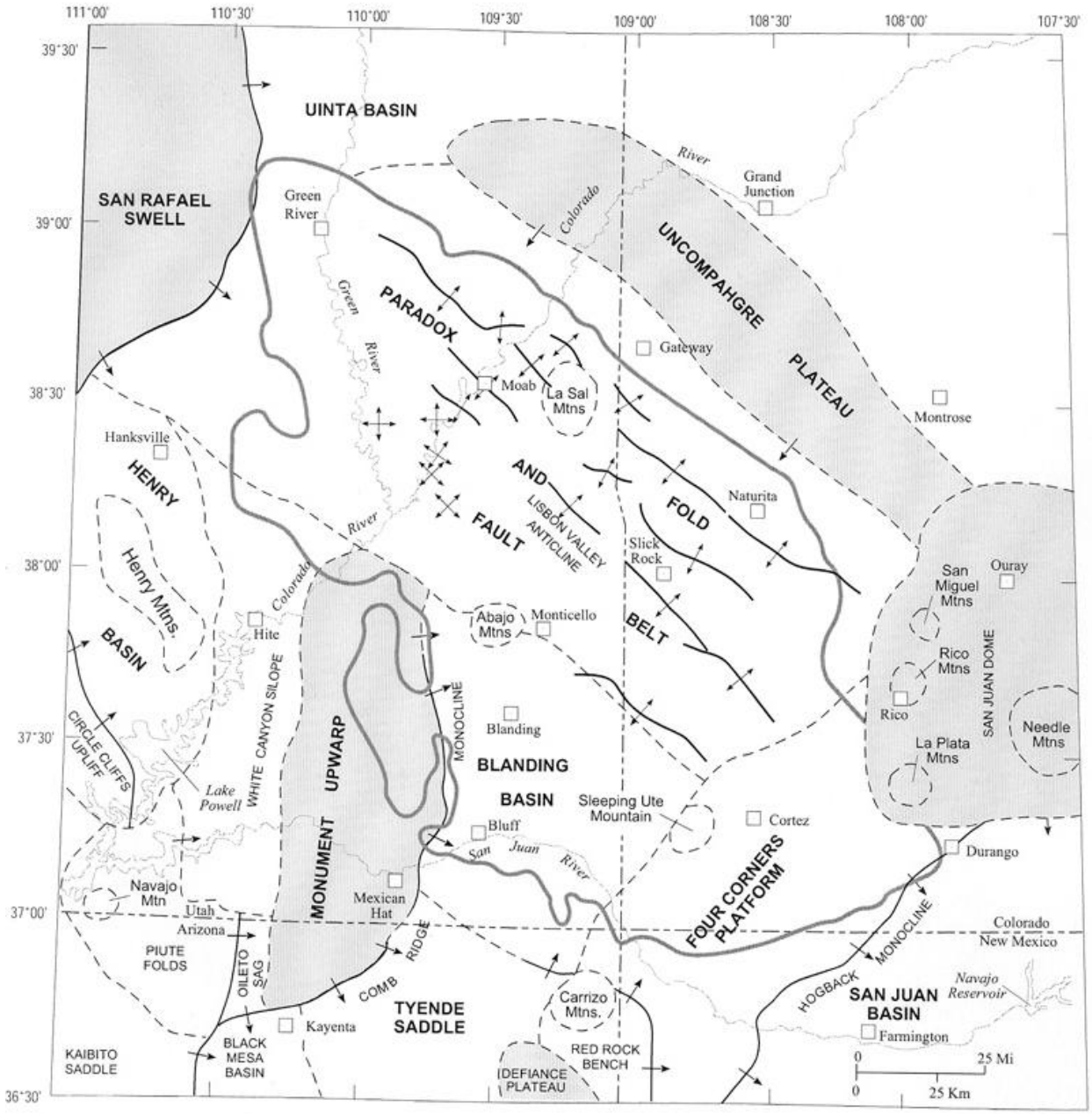
THE PARADOX BASIN

As shown in Figure 8 on page 21, the Paradox Basin is a northwest to southeast-trending, oval-shaped feature, approximately 180 miles long and 100 miles wide, that dominates most of the western portion of the planning area (Merrell and others 1979). The most significant structural activity controlling the deposition of source rocks in the Paradox Basin region occurred during the late Paleozoic through the Permian. The Uncompahgre Uplift was active concurrent with sagging along a Precambrian basement fault and lineament shear zone, creating the Paradox Basin (Hintze 1988). Downwarping occurred along sub-parallel, northwest to southeast trending, northeast dipping, hinge-line fracture zones that were initially sites of monoclinal folding. Rapid subsidence adjacent to the Uncompahgre Uplift produced extensional faults that attenuated the deepening eastern portion of the basin, creating its characteristic asymmetry. The areal extent of the Paradox Basin is defined as the geographic extent of salt deposits hosted in the Paradox Formation (Baars and Stevenson 1981).

The thick accumulation of salts and evaporites set in motion the key structural developments of the Paradox Basin. While evaporites were being deposited in the deep basin, carbonate facies were forming on an adjacent shallower platform at the southwest margin of the basin (Chidsey and others 1996b). The platform developed almost at sea level, so that any sea level fluctuations would either flood the basin or cut off the supply of seawater, thus isolating the basin from the open seaway. During lower sea level stands, intense evaporation occurred under the hot, dry climate of the middle Pennsylvanian, concentrating the salts to form brine. As the density of the brine increased, it sank to the bottom of the rapidly subsiding basin, where it was preserved. Multiple periods of sea level fluctuation caused the accumulation of evaporites during sea level subsidence alternating with carbonate facies that flourished during periods of sea level influx (Chidsey and others 1996b). From a structural standpoint, it should be noted that the distribution of these facies mirrors the northwest to southeast structural fabric of the Paradox Basin.

The rapid uplift of the Uncompahgre Plateau resulted in the erosion of the exposed Precambrian and Paleozoic rocks (Hintze 1988). Depositional thinning and stratigraphic pinch-outs occur over the uplift in several formations, providing evidence for the timing of the upward movement. The position of the current Uncompahgre Plateau closely approximates the location of this ancestral Uncompahgre Uplift. With the rise of the ancestral Uncompahgre Uplift, a thick wedge of Cutler Group clastic sediments (reaching over 10,000 feet in some areas), was shed to the southwest onto the 5,000 to 8,000 feet of evaporites and shales in the deep, northeast trough of the Paradox Basin (Gloyn and others 1995; Cole and others 1996). The overburden pressure from this great thickness of sediments on the underlying evaporites induced ductile flow of the salt, which moved in a southwest direction, away from the thickest accumulations of Cutler sediments. Buried fault scarps along the northwest-trending basement faults acted as buttresses to the flow of salt, forcing it upward into the overlying strata, and forming the salt anticlines of the Paradox Fold and Fault regions (Hintze 1988).

The Paradox Fold and Fault Belt is characterized by high-angle basin faults, and non-piercement and complex piercement salt anticlines (Nuccio and Condon 1996). In some instances, the black, organic shales created mature source rocks that have been juxtaposed against Devonian and Mississippian rock by salt diapirism. In fact, those areas of greatest salt flowage coincide with areas of maximum fracturing of overlying sediments.



Source: Modified from Kelley (1958a)

Figure 8: Structural Elements of Paradox Basin and Adjacent Areas

Where the salt anticlines breached the surface, collapsed or depressed surficial features were created by the dissolution of the salt deposits. Topographically, these anticlines are typically expressed as large elongate oval-shaped northwest-trending valleys where salt is commonly found at the surface or at shallow depths (Nuccio and Condon 1996). These valleys are enclosed by high walls and bounded by complex marginal structures and include Moab Valley, Spanish Valley, Lisbon Valley, Salt Valley, Fisher Valley, Sinbad Valley, Paradox Valley, and Castle Valley. The anticlines within the Paradox Fold and Fault Belt are prolific structural traps for hydrocarbons, and offer shallow accumulations of sodium and potassium.

During the Pennsylvanian Period, movement of the basement rocks and overlying sediments occurred along the pre-existing faults and lineaments. The relative movements controlled the location of shelf carbonates, provided topographic shoals for carbonate mound development, and created horst blocks that diverted the flow of salt upwards into the overlying sediments (Nuccio and Condon 1996).

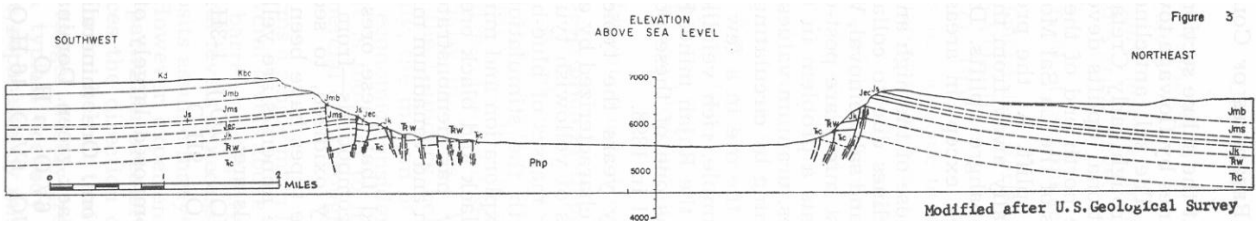
By the Triassic Period, the rate of salt flowage had slowed considerably and by the close of the Jurassic Period, there was no longer an available supply of salt to continue the flowage, and the formation of salt anticlines ceased. Meanwhile, the Uncompahgre Plateau was eroded to a topographically low surface, allowing the deposition of the first Mesozoic age sedimentary rocks across the uplift (Hintze 1988).

The second significant structural event to affect the geology in the western planning area was the Late Cretaceous to Early Tertiary Laramide Orogeny, involving compressional tectonism in western North America and associated rejuvenation of pre-existing structures. In many places, compressional forces dramatically altered the landscape by forming mountain ranges. In the Paradox Basin region, however, the pre-existing lineament and fault systems may have acted as buttresses, deflecting the lateral compressional forces (Baars and Stevenson 1981).

Beginning in the middle Tertiary, the entire Colorado Plateau area underwent uplift and regional tilting towards the north. The Uncompahgre Plateau is a northeast tilted fault block with thousands of feet of vertical relief. The process of incisement and erosion that continues today was set in motion following this last tectonic event. Large rivers, including the Colorado, San Juan, and Dolores, incised deeply into the uplifted Colorado Plateau, creating the characteristic canyons of southeast Utah. Thousands of feet of sedimentary rocks were eroded, exposing both Paleozoic and Mesozoic sediments. In the area of the salt anticlines, groundwater dissolved the salt cores, leading to solution collapse along the anticlinal axes (as shown in Figure 9 on page 23). The removal of these salts has created the elongated, northwest trending valleys characteristic of the Salt Anticline physiographic province (Aubrey 1996).

Between 24 and 48 million years ago, igneous intrusions of the La Sal and Abajo Mountains occurred near the intersection of the Precambrian lineaments in eastern Utah, suggesting another impact of old, deep-seated structures (Hintze 1988). Here the La Sal and Abajo igneous complexes intruded the basinal and fold belt sequences of southeastern Utah. Their emplacement was forceful and arched the overlying sedimentary sequence resulting in the formation of mantled domes, which have now been breached by erosion to expose their igneous cores. Similar features occur in

adjoining portions of Colorado; all appear to be localized at the intersection of major Precambrian lineaments (Hintze 1988).



Source: Wright and Everhart (1960)

Figure 9: Cross-section of Paradox Valley Salt Anticline

ENERGY AND MINERAL DEPOSITS

LOCATABLE MINERALS

URANIUM AND VANADIUM

Pure elemental uranium is a slightly radioactive metal, silvery white in color and almost as dense as gold. Elemental uranium metal does not occur in nature because it readily combines with oxygen to form several uranium oxide minerals and compounds. The most significant property of uranium is its role as the parent element in a radioactive decay series that eventually leads to the formation of a particular isotope of lead. This decay is a natural constant, with half of a given amount of uranium isotope 238 decaying to lead in about 4.5 billion years. The decaying material passes through several element stages (including thorium, radium, radon gas, and bismuth) on its path to forming the stable lead isotope.

Uranium Isotopes

Uranium occurs in three main isotopes, with uranium-238 constituting about 99.3 percent of all natural uranium. Uranium-235 makes up an additional 0.7 percent, while uranium-234 (along with other isotopes) form trace amounts. The Uranium-235 atom is readily split as part of the nuclear fission process, releasing substantial energy. Due to its shorter half-life of approximately 700 million years, uranium-235 is more radioactive than uranium-238, resulting in a changing ratio of uranium-238 to uranium-235 over geological time. In Earth's distant past, a higher percentage of uranium-235 was present than there is today (Cappa 2006).

Known Uranium Deposits

There are four generally agreed upon hypotheses for the origin and source locales of uranium deposits:

1. Syngenetic ores were deposited along with sediments or as an early digenetic event.
2. Deposits leached from overlying or inter-layered tuffs and volcanic rocks.
3. Deposits leached by groundwater from enclosing sands or nearby granitic sources and formed where appropriate Eh-pH conditions prevailed (as shown in Figure 10 on page 27) or groundwater circulation was channeled.
4. Ores are products of ascending hydrothermal fluids derived from underlying magma (Guilbert and Park 1986). Based upon regional geology and the evident mode of deposition, uranium and vanadium deposits within the UMB were deposited as adsorptions on older carbonaceous materials from channeled groundwater circulation. The carbonaceous

materials were syngenetic with the fluvial environment at the time the host formations were originally deposited.

In the Four Corners Region, recoverable uranium reserves are estimated at 4.2 million tons of ore. Of these reserves, approximately 57% are hosted in the Jurassic Morrison Formation, 39% in the Triassic Chinle Formation, and 4% in the Permian Cutler Group (Johnson and Thordarson 1959; Gloyn and others 1995).

Chinle Deposits

The Chinle Formation was deposited in a river-fed swampy, continental environment during the Late Triassic, when plant life was abundant. Although predominantly shale (from low-energy muds), sandstone and conglomerate units (consisting of high-energy fluvial channel deposits) within the formation host most uranium-vanadium mineralization. Uraniferous fluids migrated through the more highly permeable sandstone, encountering intra-formational waters and organic debris (including tree logs and branches) that acted as chemically reducing agents, causing the oxidized ore fluids to eventually precipitate uranium minerals (Johnson and Thordarson 1959). While no uranium-vanadium ore bodies have been found in Chinle strata within the planning area, the formation hosts some of the region's most prolific deposits.

Shinarump Conglomerate

A basal member of the Chinle Formation, the Shinarump Conglomerate hosts numerous copper-uranium deposits in the region, especially in the White Canyon mining area of southeastern Utah, where the copper to uranium ratio can be as high as 13:1, and copper grades range up to 1-2% (Johnson and Thordarson 1959). Deposits in the White Canyon mining area vary from a few tons to more than 600,000 tons and average 0.29% U_3O_8. Known as the Elk Ridge-White Canyon channel system, these deposits typically occur in a series of westerly-trending fluvial channels incised into the subjacent Moenkopi Formation (Chenoweth 1996; Thadden and others 1964). The Shinarump Member also serves as the host stratum for the Oljeto Mesa mining area of Monument Valley, Utah (Johnson and Thordarson 1959).

Moss Back Conglomerate

The Moss Back Conglomerate Member of the Chinle consists primarily of thick, basal fluvial lenses of coarse-grained sandstone interbedded with mudstone and pebble conglomerates, as well as podiform zones of carbonized vegetal trash. Some of the largest high-grade uranium-vanadium ore bodies have been mined in the Lisbon Valley of eastern Utah. Deposits in this area range from 500 to 1.5 million tons and the mined ore averages 0.37% U_3O_8 and 0.34% V_2O_5 (Gloyn and others 1995). The deposits are typically comprised of tabular bodies elongated parallel to the trend of the paleo-channel host and incised into the underlying Moenkopi Formation (Chenoweth 1996). Uranium deposits of the inter-river Cane Creek, White Canyon, and Indian Creek regions also derive from the Moss Back Member (Gloyn and others 1995).

Morrison Deposits

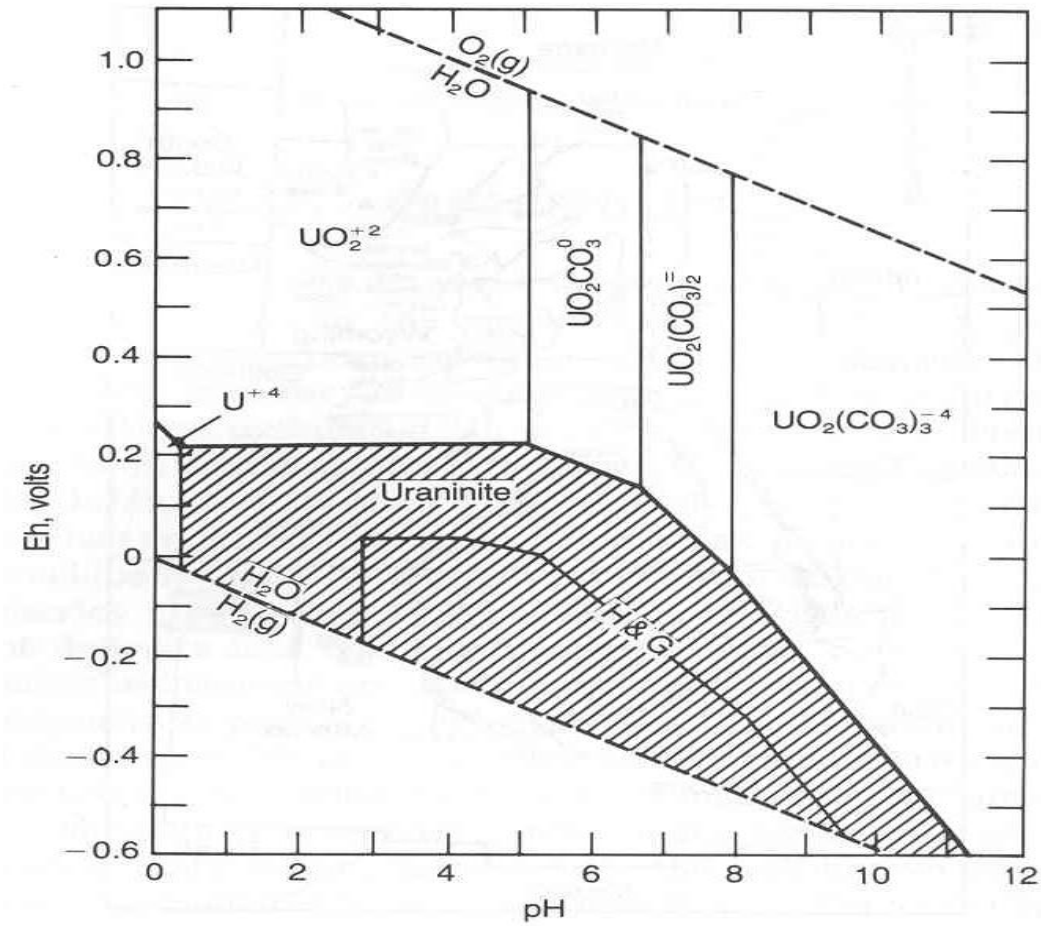
Within the planning area, the Salt Wash Member of the Jurassic Morrison Formation hosts uranium and vanadium deposits with larger reserves and higher grades, more closely clustered than similar deposits occurring in other formations (Chenoweth 1981; Johnson and Thordarson 1959).

There is no apparent relationship between the distribution of uranium and regional geologic structure, except to the extent that tectonic history has controlled sedimentation, geomorphology, and igneous activity, and given that the ore deposits lie within the uplifted tectonically positive regions between structural basins. Deposit margins are generally gradational and deposits normally form a single roll front unit, but can split or contain lenses, necessitating mining at several layers (Wright and Everhart 1960).

Mines typically follow a single-level plan. Some deposits are elongate in a common direction normal to the trend of the Uravan Mineral Belt (Wright and Everhart 1960). Deposits range from a few tons to in excess of 100,000 tons. Deposits typically consist of lenses and pods separated by mineralized rock or waste. In roll-front type deposits, the mineralization cuts sharply across bedding planes. Rolls are narrow and elongated, with the long axis generally parallel to the direction of original sediment deposition prior to lithification.

Mineralogy

Principal ore minerals after pitchblende and coffinite are carnotite [$K(UO_2)_2(VO_4)_2 \cdot 3H_2O$], tyuyamunite [$Ca(UO_2)(VO_4)_2 \cdot 8H_2O$], gummite (a mineraloid mixture of hydrous oxides of uranium, thorium, and lead), and a variety of orange, yellow, blue, and black vanadium oxides such as montroseite (VO(OH)). Pitchblende and uraninite are terms often used synonymously to describe a black-colored mineral with the chemical formula UO_2. However, pitchblende is more properly applied to a non-crystalline mixture of uraninite that contains numerous impurities, such as lead and thorium oxides. Associated minerals include minor amounts of pyrite, marcasite, galena, sphalerite, chalcopyrite, bornite, chalcocite, covellite, and other sulfide minerals. Minor amounts of native selenium and the molybdenum oxide ilsemannite are also common (Guilbert and Park 1986). Figure 10 shows the solubility field for uraninite at specific conditions with regard to Eh, pH, and carbonate mineral species.



Source: Guilbert and Park (1986)

Figure 10: Eh-pH Diagram of UO2-CO2-H2O System at 25 degrees C and pCO2=10-2 atm

This diagram shows the reduction – oxidation (Eh) and pH stability field where uranium could form a precipitate in an aqueous solution. Uraninite solution boundaries are drawn at 10-6*M (mole)* (0.24 ppm) dissolved uranium species. The "H & G" zone denotes the boundary of the uraninite mineral stability field. The shading separates the U+6 ion dominance and solubility (above) from U+4 dominance and Uraninite (UO_2) precipitation (below). Carbonate complex ions (represented as CO_3 species) are important transport media in roll-front type uranium deposits as represented in the Uravan Mineral Belt.

History of Exploration, Development, Production, and Economics

Uranium mining in Colorado goes back to 1871 when pitchblende ore (Uraninite) was taken from the dump of the Wood Mine near Central City (Wright and Everhart 1960). Uraninite is the black oxide mineral of uranium (UO_2). The UMB (shown in Figure 1 on page 11 and in Figure 2 on page 12) is an arcuate zone of uranium-vanadium deposits in San Miguel, Montrose, and Mesa counties, Colorado, and Grand County, Utah. In the early 20th century, it was the most productive uranium area in the United States. In Colorado, the mineral belt includes the Slick Rock, Gypsum Valley, Uravan, and Gateway mining districts (Fischer and Hilpert 1952).

Discovery of the radioactive mineral carnotite is believed to have occurred in 1898, when Gordon Kimball mined ore from Roc Creek in Montrose County, Colorado and packed it twelve miles by burro to Paradox Valley. Kimball's ore assayed at 21.5% U_3O_8 and 15% V_2O_5, and he received $2,500 (in 1898 dollars) for ten tons. The discovery was the first in what would become the highly productive Uravan Mining District. At the time, the vanadium value was greater than the uranium value.

In 1899, ore from the Roc Creek deposit was shipped to France, where M. M. C. Friedel and E. Cumenge identified the new mineral and named it carnotite after French mineralogist Adolphe Carnot. Some of the Roc Creek carnotite was sent to Marie and Pierre Curie in Paris to aid in their early investigations into the properties of uranium and radioactivity.

Once carnotite was found to contain radium, prospectors rushed to southwest Colorado (and southeast Utah), and found carnotite-bearing sandstones of the Jurassic Morrison Formation in Mesa, Montrose, and San Miguel counties. Carnotite ore was at first shipped to Europe for processing, but by 1913, the Standard Chemical Company had built a radium processing plant in Montrose County that for a time became the world's largest supplier of radium.

By 1913, half of the world's uranium came from mines in San Miguel, Mesa, and Montrose counties. Standard Chemical Company was the main producer, opening a radium operation in 1910, and moving it to Uravan in 1913, where it became known as the Joe Junior Mill. The National Radium Institute plant opened in Long Park (twelve miles west of Naturita, Colorado) around 1915 and a mill opened at Saucer Basin around 1920. Pitchblende was hand-picked from gold-silver ores in the Central City region during this time and over 100,000 pounds of pitchblende was shipped from the region before 1917 (Wright and Everhart 1960).

Although radium was discovered in 1898, it had been derived from European pitchblende, and the radium content of carnotite was not known. Carnotite was suspected to contain radium as early as 1903, based upon the anomalously high radioactivity of carnotite ores (Fleck and Haldane 1909). However, it was not until 1911 that the radium content of carnotite was confirmed by the Marie Curie laboratory in Paris (Fleck and Haldane 1913). Although no more than a trace of radium was present in the ore, newly discovered medical applications had made radium worth $100 per milligram, making the radium in the carnotite ore worth much more than vanadium or uranium. Forstall reported that radium was worth $80 per milligram or $2,400,000 per ounce in 1913 dollars. Montrose, Rio Blanco, San Miguel, Dolores, and Mesa counties, Colorado reportedly had

the most easily treatable carnotite ore in the world. Montrose County produced 95% of the radium ore in the state (Forstall 1913).

From 1910 to 1922, the Uravan Mineral Belt of Colorado and Utah (shown in Figure 2 on page 12) supplied about half of the world's radium, with vanadium and uranium as byproducts. Prospectors realized that the carnotite ores of southwestern Colorado contained radium that was easily mineable. In 1913, Standard Chemical Company built the Joe Junior radium processing plant and town site on the San Miguel River at what would later become the town of Uravan. The amount of radium in the typical carnotite ores of the Uravan district is very small. It took about 200-300 tons of high-grade (about 2 percent U_3O_8) carnotite ore to produce one gram of radium. U_3O_8 is the customary compound used to report uranium content in ores, even though it is not an ore mineral. Because of its bright color, U_3O_8 is known as *yellowcake*. However, during this period radium was selling for $160,000 to $120,000 per gram (31 grams = about one ounce). The mines were forced out of business in 1923, when rich pitchblende deposits in the Belgian Congo forced down the price of radium. Mining revived in 1935 when the government stockpiled uranium for nuclear weapons programs (Wright and Everhart 1960).

The company town of Uravan was established in 1936 when U.S. Vanadium Corporation moved its plant to the former site of the Joe Junior Mill. The company expanded the Joe Junior site and named it Uravan after the uranium and vanadium minerals for which the area was known. At one time, over 800 people lived along the tree-lined streets, enjoying housing, schools, medical facilities, tennis courts, and a recreation center and pool provided by the U.S. Vanadium Corporation.

Throughout the 1930s and 1940s, production of vanadium brought some prosperity to Uravan and all of southwestern Colorado. Prior to 1937, the uranium in the carnotite ores mined around Uravan was considered a contaminant and ended up in mine and mill waste piles. U.S. Vanadium Corporation installed a uranium recovery circuit in their mill in 1937 and used the uranium, just like the vanadium, as a steel hardener. Vanadium was considered a strategic mineral and a government-buying program encouraged continued exploration and development. Pre-1946 production of vanadium from Uravan and the surrounding districts was 636,166 tons at a weighted average grade of 1.9 percent V_2O_5 resulting in the production of 24,138, 822 pounds of V_2O_5 (Chenoweth 1981). Known as redcake due to its distinctive color, V_2O_5 is the customary compound for reporting the vanadium content of ores.

World War II Demand

The entry of the United States into World War II in December 1941 changed the picture in the Uravan district dramatically. The government realized that in order to win the war, they needed a superior weapon. The nuclear fission process was barely understood when the government initiated the Manhattan Project, the goal of which was to develop an atomic bomb. The Manhattan Engineers District (the Manhattan Project division focused on acquiring uranium) purchased all the uranium-rich waste piles from Uravan Mineral Belt mines and mills, and contracted with the United States Vanadium Company to process the ores for uranium. Approximately 850 tons of uranium acquired for the Manhattan Project came from the Uravan district, while 4,150 tons came from the

Shinkolobwe Mine in the Congo and 1,000 tons was contributed by the Port Radium Mine in Canada (Amundsen 2002).

World War II ended with the dropping of two atomic bombs produced by the Manhattan Project on Hiroshima and Nagasaki, Japan in August 1945, and the production of uranium at Uravan ceased for a short period. In 1947, the newly created Atomic Energy Commission contracted with the United States Vanadium Company, which was bought by Union Carbide Nuclear Corporation in 1955 to produce uranium for the Cold War effort.

From 1946 to 1958, Montrose County led the state in uranium ore production (accounting for 57% of Colorado's total output and representing 97% of the county's total mineral production value in 1957). In contrast, between 1946 and 1958, Montrose County had a total precious and base metal production value of approximately $550,000 in 1960 U.S. dollars (Del Rio 1960).

The U.S. Bureau of Mines reports that uranium production in Mesa County for 1956 was 561,754 pounds of U_3O_8 from 88,597 tons of ore produced from 106 operations, with an average grade of 0.32% U_3O_8. During 1957, these figures were 704,784 pounds of U_3O_8 from 122,028 tons of ore produced from 109 operations, with an average grade of 0.29% U_3O_8. The county was a leading producer of vanadium-bearing ores from 1946-1958 (Del Rio 1960).

San Miguel County was the third-ranking producer of uranium ores in Colorado from 1955 to 1958, with a total of 1,921,486 pounds of U_3O_8 produced from 69-140 operations, with a dollar value for the period of over eight million in 1960 U.S. dollars.

Early in the 20th century, the Curies announced the supposed beneficial uses of radium, and the development of uranium ores began in Colorado. During the uranium boom of the 1940s and 1950s, geologic guidelines and recognition criteria for finding area uranium deposits held that:

- Most deposits occur where the Salt Wash Sandstone is more than 240 feet thick.
- Most deposits occur where the Salt Wash Sandstone is about 50% sandstone and 50% mudstone.
- There are proportionally more uranium deposits in the Uravan Belt than in other areas.
- More uranium-bearing minerals occur in the upper Salt Wash Member sandstone.
- Most deposits occur in sandstones that are 20-30 feet thick.
- Tan, brown, and gray sandstone is more likely to contain desirable mineral deposits than red sandstone.
- Scour and fill bedding is favorable for mineral deposition. Abrupt small-scale cross bedding; thin, discontinuous mudstone layers; petrified wood; and conglomerate, consisting of mudstone, pebbles, and cobbles, typify this.
- Greenish-grey mudstone frequently occurs immediately below mineral bearing sandstone. Sometimes this greenish-grey mudstone is less than 1-foot thick.

- Abundant fossilized wood is favorable for mineral deposition. These are informally known as "hot logs." (Wright and Everhart 1960)

Vanadium Boom

Beginning in 1909, the demand for vanadium skyrocketed with the advent of Henry Ford's new Model T automobile. When added to steel, vanadium makes the final product much stronger, and allows for lighter weight steel in thinner sections to meet the same specifications of much heavier steel, which does not contain vanadium.

Vanadium processing mills sprang up during the period of interest preceding World War II. Trucks took ore from mines in the surrounding area, rich in uranium and vanadium, to the processing plant at Uravan. Between 1936 and 1984, the Uravan plant milled 42 million pounds of vanadium. The mildly radioactive tailings (byproducts of the extraction) were deposited in huge piles above the canyon next to the plant. The total production from the United States Vanadium Company mill at Uravan up to late 1945 was 1,782,000 pounds of U_3O_8 (Goodknight and others 2005).

Post-War Activity

The Atomic Energy Commission ended its uranium contract in December 1970. From 1947 to 1970, the mill at Uravan produced 23.9 million pounds of U_3O_8 (commonly referred to as "yellowcake") and 9.7 million pounds of vanadium oxide (V_2O_5) for the Atomic Energy Commission. In addition, 123.4 million pounds of V_2O_5 was sold on the open market to the steel industry. In the 1970s, the Uravan district began a new expansion to serve the growing needs of the nuclear power industry. In 1976, the mill was expanded to process 1,300 tons per day. However, declining demand for nuclear power, low prices for uranium, and an increasing supply from Canada, Australia, and other countries spelled the eventual decline of the long-lived town of Uravan and the surrounding mines and mills of the UMB.

In total, approximately 84 million pounds of uranium oxide and 220 million pounds of vanadium oxide were produced from the Uravan Mining District between 1936 and 1984.

With the end of the Cold War and subsequent release of uranium from nuclear weapons stockpiles, and as a result of recession in the 1980s as well as other factors, the price of uranium slipped from its high of $40 per pound in the late 1970s to below $10 per pound during the 1980s and 1990s.

Uravan Site Reclamation

Since 1983, Umetco Minerals Corporation has been involved in a fifteen-year, $70 million reclamation project. In 1984, the Uravan mill was closed and the town abandoned. Contaminated soil and process wastes were removed, town structures and two mills were dismantled, and tailings were capped. Groundwater treatment, revegetation, and other reclamation work continue.

The DOE conducts site reviews every five years (with the fourth review conducted in September 2010) to determine whether remedial actions at Uravan continue to protect human health and the environment or the DOE needs to take additional actions.

Current Demand and Production

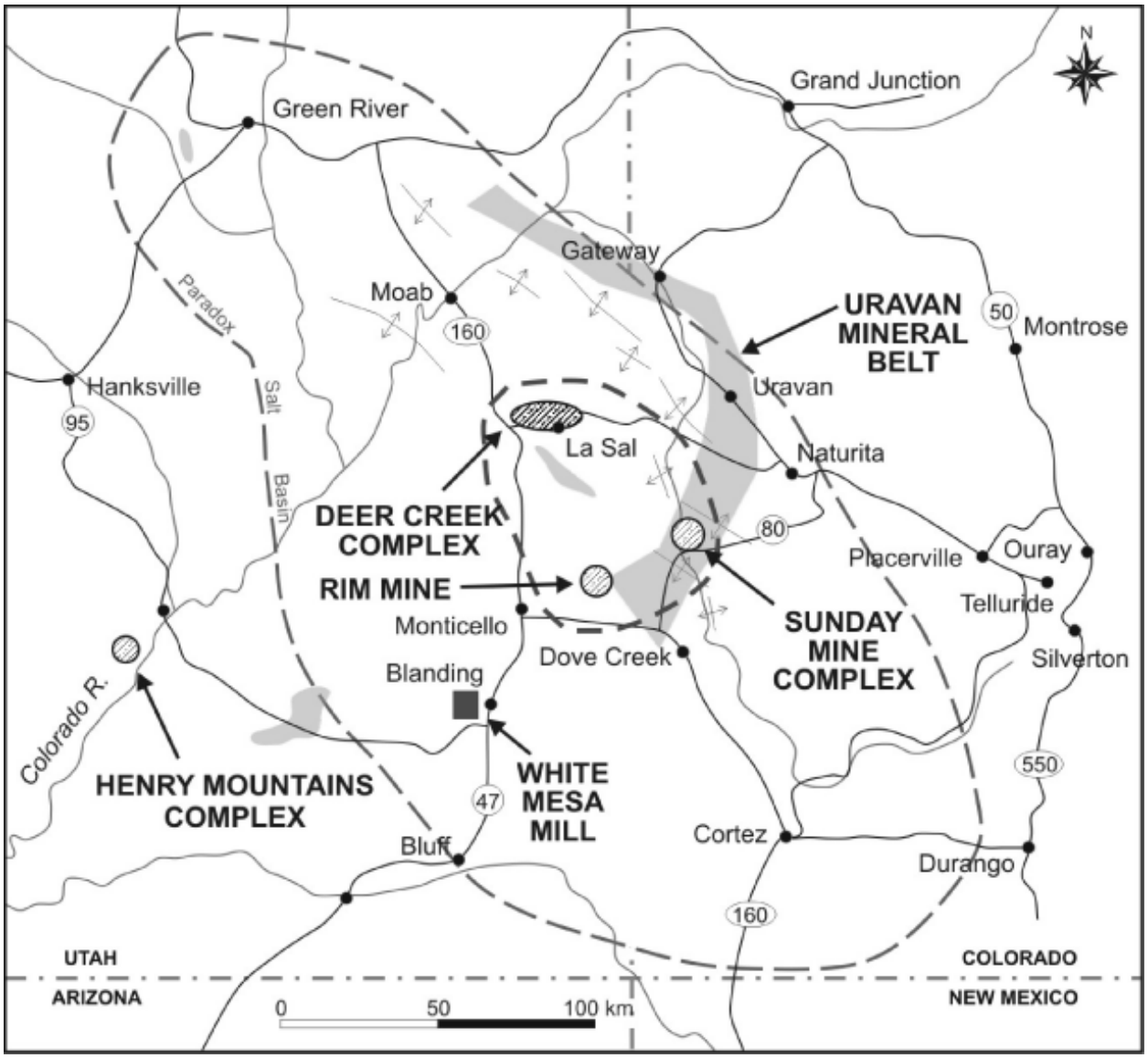
As uranium stockpiles dwindled and worldwide economies improved, the demand for uranium has increased, with the price climbing dramatically in 2000. While the worldwide demand for uranium is 180 million pounds per year to supply 435 nuclear reactors, worldwide production in 2005 was only 110 million pounds, a 70 million pounds per year shortfall. Increased demand for uranium will likely continue as China plans to build 20 new reactors over the next ten years and India plans to build 17 within the next two years (Matthews 2010).

Cotter Corporation

With uranium and vanadium prices on the rise, Cotter Corporation reopened four uranium mines in the Uravan district during 2003 and 2004, and transported the ore to their processing mill in Cañon City, Colorado. Cotter closed the mines abruptly in November 2005, citing increased costs that made operations unprofitable. The Cotter mines produced 394,236 pounds of uranium oxide and 1,746,251 pounds of vanadium oxide from 2003 through 2005. On June 8, 2010, Colorado Governor Bill Ritter signed the Uranium Processing Accountability Act, requiring uranium mills in the state to reclaim existing toxic wastes before beginning new projects. On June 30, 2010, Cotter announced plans to shut down rather than refurbish the Cañon City milling facility, which has operated since 1958.

Denison Mines Corporation

In July 2006, Denison Mines Corporation (formerly the International Uranium Corporation) announced plans to reopen four uranium mines in the Uravan district. Three would be located in Colorado and a fourth in Utah. Denison also owns the White Mesa Mill, the country's only operating uranium mill located near the town of Blanding in southeastern Utah (and shown in Figure 11 on page 33). According to a May 2010 press release, the mill had ceased the processing of conventional ore during 2009, but resumed in March 2010. The mill continued to process alternate feed materials throughout the same period.



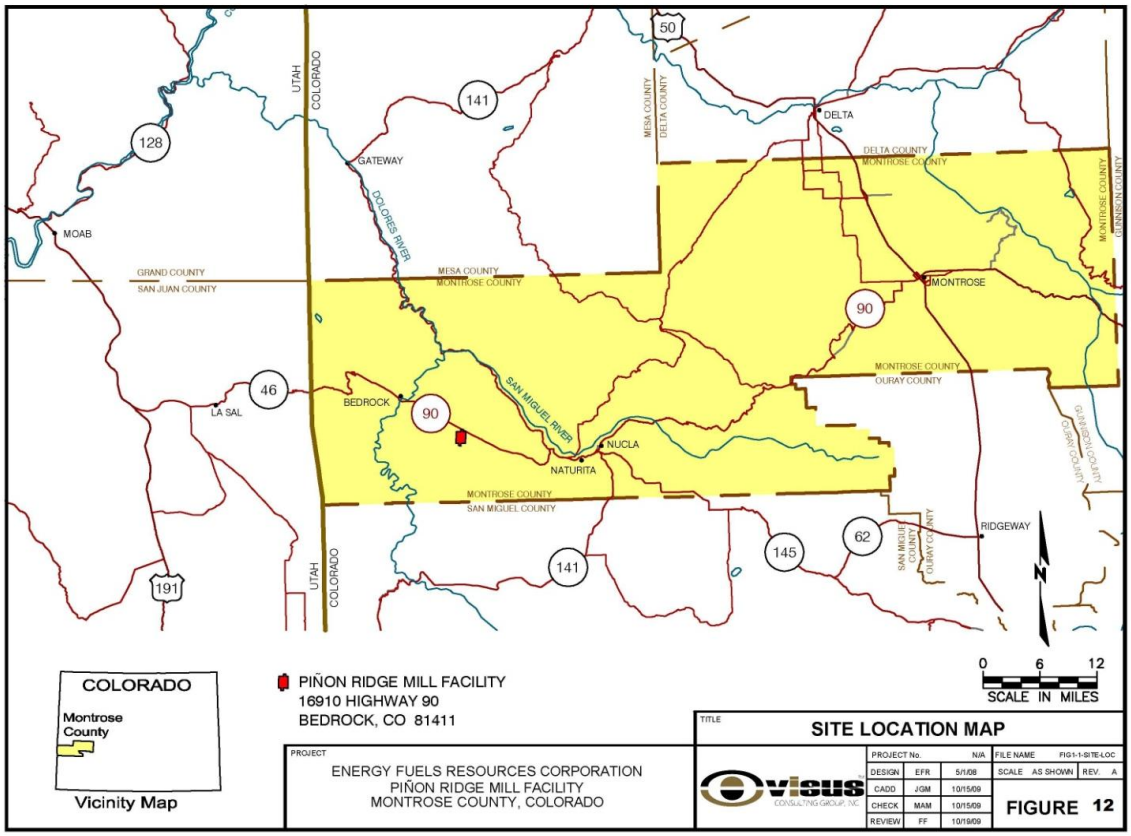
Source: internet – content.edgar-online.com

Figure 11: Location of the White Mesa Mill in relation to the UMB

Energy Fuels Corporation Uranium Processing Mill

Energy Fuels Corporation recently announced plans to build the first uranium/vanadium processing mill in the United States in 25 years. Located on private land at Piñon Ridge twelve miles west of Naturita (see Figure 12), the mill would process up to 1,000 tons per day of uranium and vanadium ores derived from company-owned and other mines in the Uravan area. Planning for the Piñon Ridge mill began in 2007 (Dion 2008; Kral 2008). Through an agreement with the Nuclear Regulatory Commission, the state of Colorado has sole responsibility for reviewing and approving or denying the license application.

Energy Fuels submitted a mill license application in April 2009 and held two public meetings in early 2010. Montrose County Commissioners provided comments to the Colorado Department of Public Health and Environment (CDPHE) in April 2010, and CDPHE was given 270 days from the receipt of comments to determine whether the application would be rejected, or a license would be issued as requested or issued with conditions (CDPHE 2010). On January 5, 2011, after CDPHE consulted with other regulatory agencies as part of the review process, and prepared a written analysis of the project along with a justification for the decision, approved the radioactive materials license for the Piñon Ridge Mill (CDPHE 2011).



Source: internet – content.edgar-online.com

Figure 12: Location of the proposed Piñon Ridge Uranium Mill

GYPSUM

Known Deposits

While the Paradox Valley area has known potential for the occurrence of gypsum deposits in Paradox Formation strata (shown in Figure 5 on page 18 and Map 2 on page 53), there are no known commercial gypsum deposits in the planning area.

Mineralogy

Gypsum is a very soft (Mohs scale hardness of 2) mineral composed of calcium sulfate dihydrate with the chemical formula of $CaSO4 \cdot 2H20$.

History of Exploration, Development, Production, and Economics

Gypsum is an evaporite mineral present in the Paradox Formation of the Hermosa Group at the surface in Paradox Valley. There is no history of exploration, development, or production for gypsum from this formation within the planning area. However, a recent inquiry has been submitted to the UFO regarding submitting a mining plan of operations to mine gypsum in Paradox Valley three to five miles east of Bedrock, Colorado (Cluff 2010).

Current Demand and Production

Gypsum is used for wallboard in the construction industry and its demand depends on the status of that industry. At present, the construction industry is down in the U.S., but it is booming in Asia. Current demand is expected to remain high for export to Asia and will increase as the U.S. economy recovers from the current recession.

PLACER GOLD

Known Deposits

Placer gold deposits in the planning area consist of random occurrences of gold particles that have eroded out of gold vein deposits, washed down to the Dolores, San Miguel, and Uncompahgre rivers, and become entrapped in riverbed sand, gravel, and cobble. Seasonal snowmelt and precipitation serve as an intermittent transport system to replenish these deposits.

History of Exploration, Development, Production, and Economics

Often, the first indicator to early prospectors of gold potential in the area came from the chance discovery of a placer gold deposit. Explorers would find particles of gold as they made their way up river drainages, which ultimately would lead them to a source (typically a gold-quartz vein in bedrock). These hard rock quartz vein gold deposits typically occurred on public lands adjacent to the planning area within the Uncompahgre and San Juan National Forests.

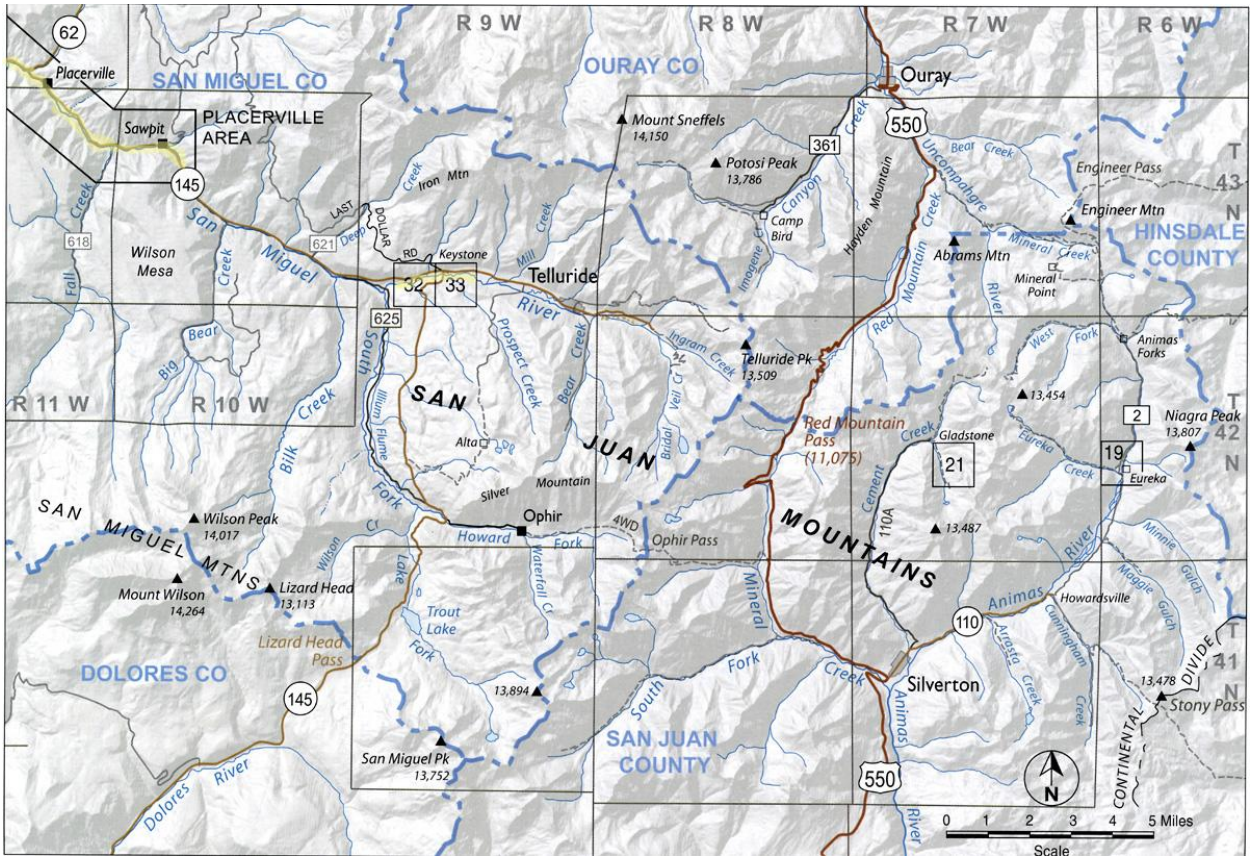
Over time, the location of gold deposits can vary widely due to periodic movement downstream within a riverbed during snowmelt and high precipitation events. Gold exploration involves retrieving sand and gravel material from riverbeds and using gravity to extract the gold. The most

efficient and profitable extraction process has generally involved using a sluice box or suction dredge system. Most of the placer work has taken place in three areas (as shown in Figure 13 on page 36 and Figure 14 on page 37) (Parker, Jr. 2009):

- Along the San Miguel River for about six miles downstream from Sawpit
- Along Cottonwood Creek for about six miles
- On the Dolores River for about nine miles upstream from Roc Creek.

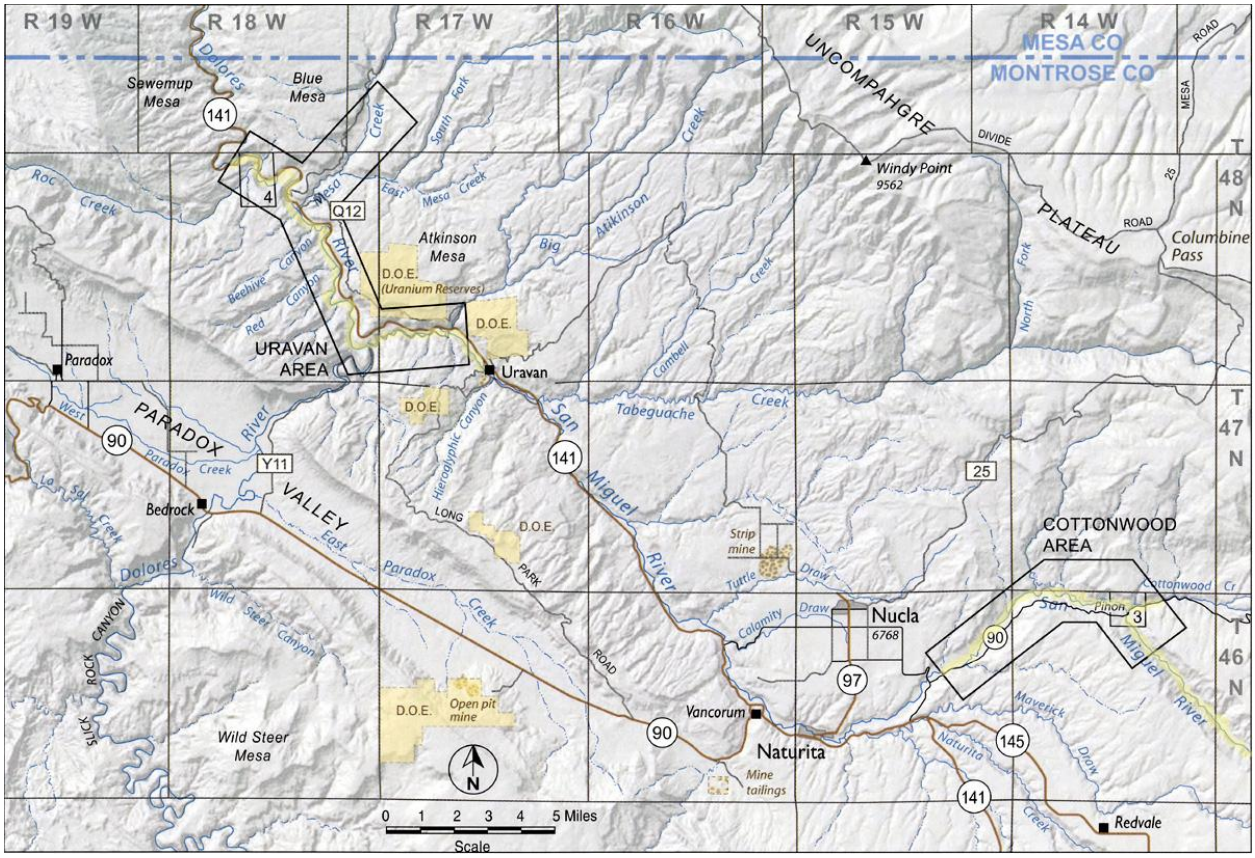
Current Demand and Production

As in the past, gold production from placer deposits today is sporadic and not typically reported. In the Dolores, San Miguel, and Uncompahgre river systems, placer gold is not present in quantities large enough to justify commercial operations. Currently gold production involves small-scale panning, sluicing, and suction dredging operations by individuals and prospecting clubs. Currently, the two main prospecting areas are up-stream from the Piñon Bridge on the San Miguel River and on the Dolores River downstream from the confluence with the San Miguel River.



Source: Parker, Jr., 2009

Figure 13: Location map of placer gold areas on the San Miguel River.



Source: Parker, Jr., 2009

Figure 14: Placer gold locations along the San Miguel and Dolores Rivers

SOLID LEASABLE MINERALS

POTASSIUM AND SODIUM

Potash is the common name given to potassium carbonate and variously mined and manufactured salts containing potassium in a water-soluble form. Potash is used for the manufacture of glass, soap, and soil fertilizer, and is important for agriculture because it improves water retention, yield, nutrient value, taste, color, texture, and disease resistance of food crops. It has wide applications for fruit and vegetables, rice, wheat and other grains, sugar, corn, soybeans, palm oil and cotton, all of which benefit from potassium's quality enhancing properties. The name derives from the old method of making potassium carbonate (K_2CO_3) by leaching wood ashes and evaporating the collected solutions in large iron pots, leaving a white residue called "pot ash." Later, potash became the term widely applied to naturally occurring potassium salts and the commercial product derived from them.

Soda ash or trona is a mixture of sodium salt and carbonate minerals (Na_2CO_3). Soda ash is used in the manufacturing of glass containers, fiberglass, specialty glass, flat glass, powdered detergents, and medicine, and as a food additive, in photography, cleaning and boiler compounds, and the control of pH in water.

The oldest sedimentary formation within the UFO is found in the western portion of the planning area. Here the Hermosa Group outcrops in the center of the Paradox Valley (see Figure 3 on page 16 and Map 2 on page 52). During Pennsylvanian time, sediments filled accommodation space created by the rapidly subsiding Paradox Basin. The resulting thousands of feet of evaporites, carbonates, and black shale constitute the Hermosa Group (shown in the stratigraphic correlation chart on page 17). Flowage of these evaporites formed prominent structural anticlines and fractures in overlying sediments. At depth, these Pennsylvanian strata, particularly the Paradox Member, are potential valuable hosts to soda ash and potash deposits (Wengerd 1958).

Although the potential exists for the occurrence of sodium and potassium mineral deposits in the Paradox Member of the Hermosa Group, there has been no reported mineral exploration, development, or production on BLM-administered lands within the planning area as of the date of this report.

SALABLE MINERALS

SAND, GRAVEL, FILL, CLAY, RIPRAP, AND MOSS ROCK

Sand, gravel, fill material, clay, riprap, and decorative moss rock are, by nature, common commodities. Known mineral deposits such as sand and gravel occur throughout the planning area, in areas where major rivers formerly ran and have since migrated. Development and production occur in open pits, with sand and gravel extracted and separated using screening techniques to obtain various sizes. The UFO currently has two riprap areas, two fill sites, one clay pit, six gravel pits (authorized by free-use permits to Montrose, Ouray and Delta counties), and one commercial, non-competitive split-estate gravel pit.

Production is reported annually. The free-use sites consist of erratic use as conditions demand, with a few thousand tons extracted one year followed by no use for many years thereafter. The non-competitive site is currently in use for the last phase of a road improvement project, during which up to 50,000 tons have been extracted over the past year. Once completed, the project site is expected to be reclaimed and the surface used to construct a residential housing development. Decorative moss rock is sold on a personal, small quantity basis, with over a hundred permits typically sold per year.

In general, sand and gravel deposits develop from transport in fluvial systems. Rock is eroded and carried downhill by gravity and water, where creeks, streams, and rivers eventually capture them.

As the flowing water moves the material, it gets broken down into smaller constituent parts, such as sand, gravel, pebbles, cobbles, and boulders. The fluvial water systems deposit these materials along the path or course of the system. As the fluvial course changes over time, these mineral material deposits become abandoned in the former river channels as perched benches (see Figure 20 on page 49).

OCCURRENCE AND DEVELOPMENT POTENTIAL OF ENERGY & MINERAL RESOURCES

LOCATABLE MINERALS

URANIUM AND VANADIUM

The uranium-vanadium mineral resource potential of the planning area is classified according to the system outlined in BLM Manual 3031 (shown in Appendix B). Under this system, occurrence potential ratings are based on the geologic likelihood of a mineral's presence in a particular area. The ratings do not reflect the economic feasibility of developing a resource.

The potential for development of uranium-vanadium mineral resources from the Morrison Formation in the UMB part of the planning area as projected over the life of the RMP, for twenty years, is rated as high (H) occurrence potential with a high (D) level of certainty (as shown in the location map on Figure 15 on page 41). The likelihood for development is based on communication with industry experts and government officials familiar with the specific resources, current or past activities in the area, as well as considerations such as mineral occurrence potential, historic development, commodity price and demand, and other factors as described. The projected development may be directly affected by planning decisions that restrict or preclude mineral exploration and/or development activity. The development rating is also affected by the status of the land in which the commodity is found. Resources found in National Parks, National Monuments, National Recreational Areas, National Conservation Areas, and Wilderness Areas are generally not available for mineral development, except in a few areas where there may be valid existing rights. For that reason, these areas are considered to have a low development potential.

Historically, uranium and vanadium mining occurred over much of the western portion of the planning area (Chenoweth 1996), with most production taking place within the Salt Wash Member of the Morrison Formation (see Figure 15).

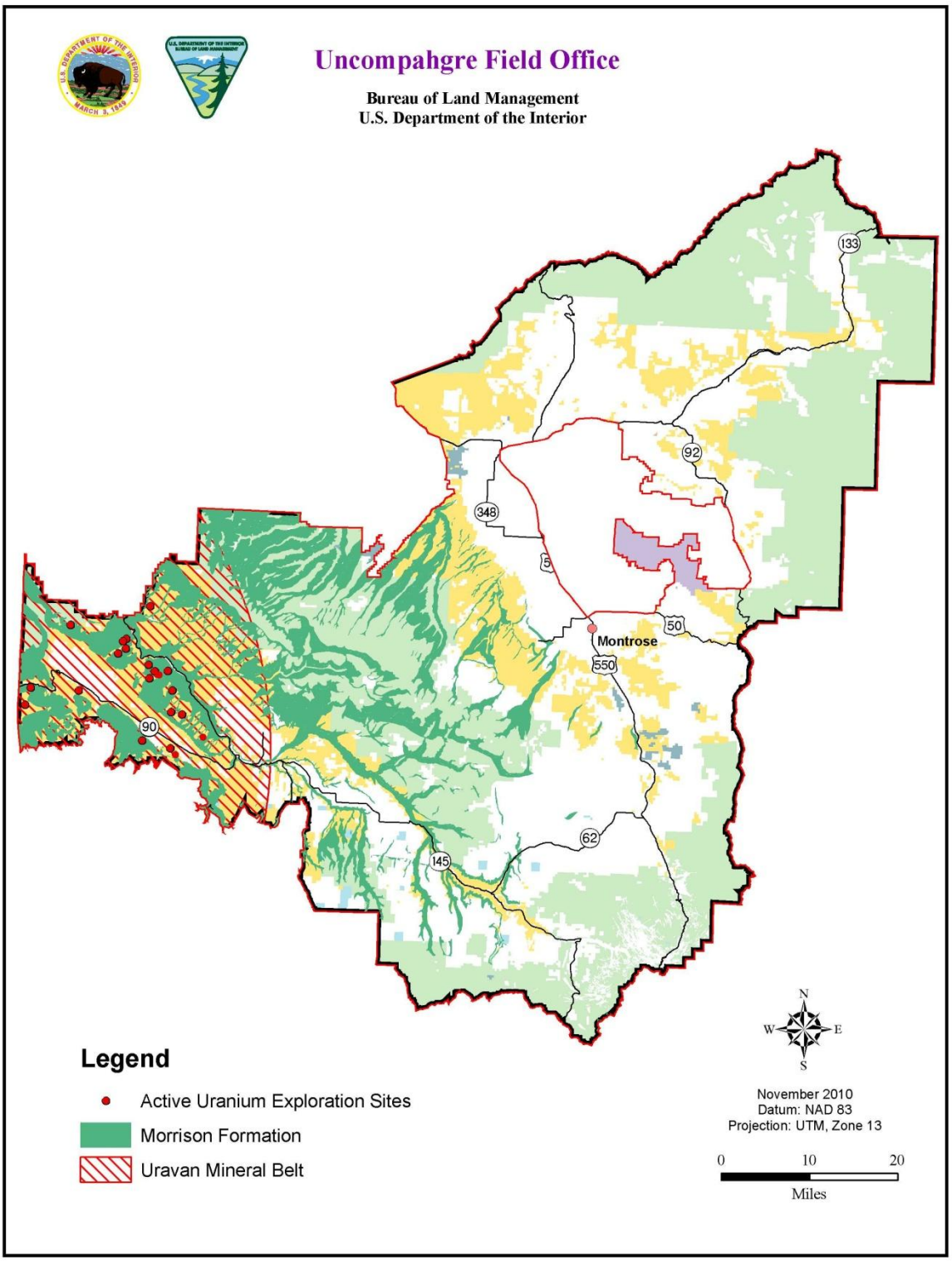


Figure 15: Active uranium exploration sites on the Morrison Formation within the planning area

The UMB in the planning area is rated as high (H) for uranium and vanadium occurrence potential with a high (D) level of certainty. Outside the UMB within the aerial extent of the Morrison and Chinle formations, the potential has been classified as moderate (M) with a minimal (C) level of certainty.

The last uranium and vanadium mines in the region closed in 1990 due to declining commodity prices. The local mine closures were part of a national and international trend in which the high level of domestic uranium mining and exploration that commenced in the late 1940s and early 1950s underwent an abrupt drop in the early 1980s. The drop in uranium demand was due to a number of factors, including:

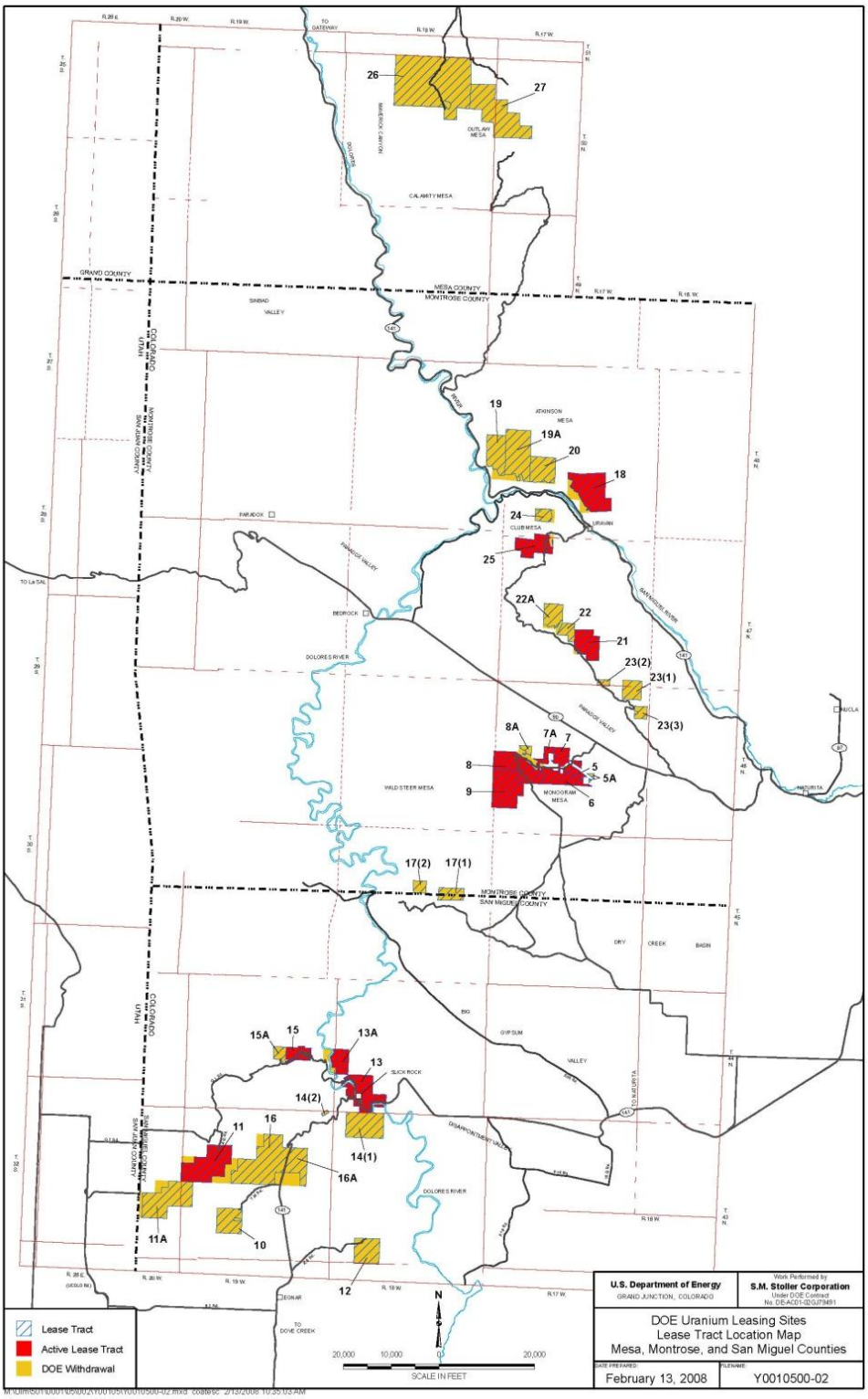
- an excess of international inventories
- competition from higher-grade, readily accessible Canadian and Australian uranium deposits
- low-cost domestic extraction by solution mining
- the recovery of uranium as a byproduct of other commodities
- an accompanying decline in the price of vanadium (an important by-product or co-product) in a significant number of mines within the planning area.

Because past mining did not completely remove all potential uranium and vanadium resources in the area, the potential for new economically profitable mines in the region remains strong. It is reasonable to expect that new exploration, coupled with modern mining and milling methods, will extract additional uranium and vanadium from UMB mines.

According to a 2004 USGS report, the UMB area is believed to have substantially higher probability of hosting these sandstone uranium deposits and is delineated as favorable. However, owing to the lack of grade and tonnage information about existing deposits, no estimates concerning the possible number of undiscovered deposits that might be present could be concluded. Previous experience has shown that exploration and development activity related to these deposits is extremely sensitive to price fluctuations, which suggests that future increases in price above $15 per pound U_3O_8 level would be a sufficient stimulus (Spanski et al 2004).

Uranium Leasing Program

The U.S. Department of Energy (DOE) Office of Legacy Management currently administers the Department's Uranium Leasing Program, managing 32 lease tracts containing approximately 25,000 acres, all located within the Uravan Mineral Belt in southwestern Colorado (see Figure 16 on page 43). These public lands are withdrawn to the DOE for the management of uranium and vanadium resources. DOE has the jurisdiction for these resources, and the surface management of other resources like grazing and recreation is under BLM jurisdiction. The leasing program is managed under the authority and in accordance with Title 10, Code of Federal Regulations, Part 760, in cooperation with the BLM and the State of Colorado.

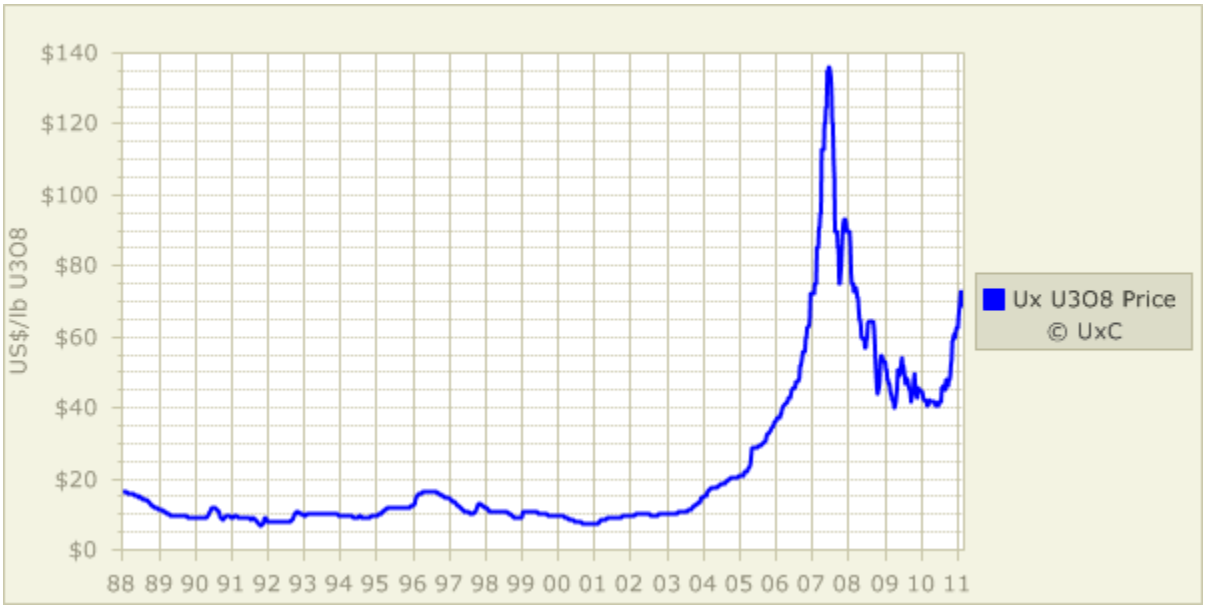


Source: DOE, 2007

Figure 16: Location of DOE lease tracts in Mesa, Montrose, and San Miguel counties

Uranium-Vanadium Prices

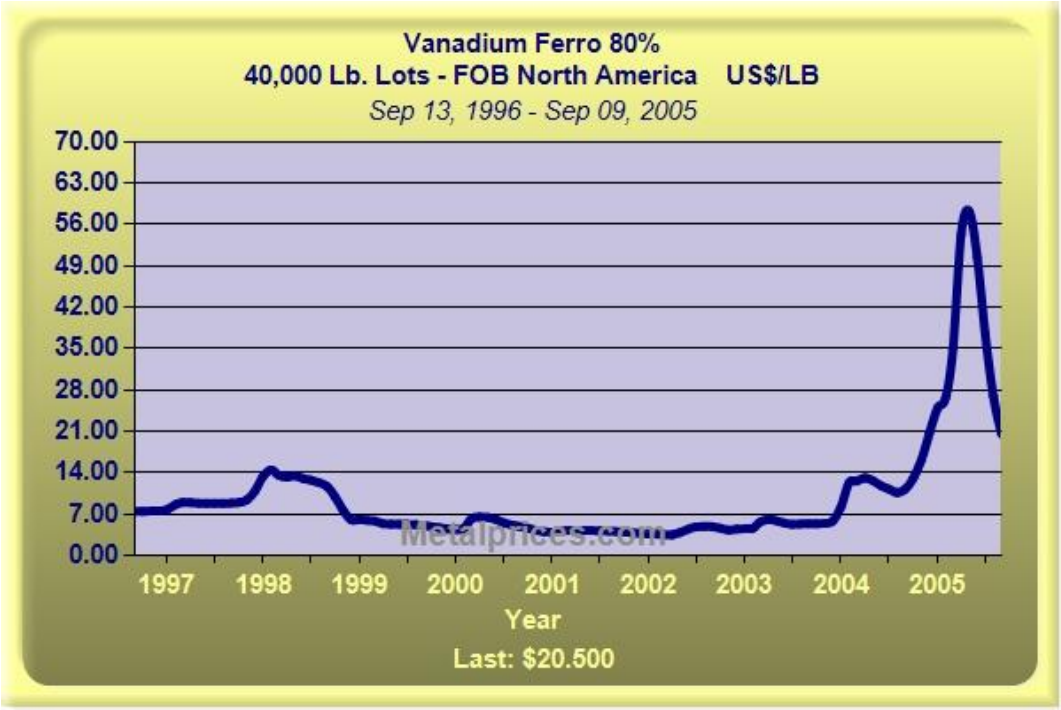
As of February 14, 2011, the spot price for U_3O_8 was $72.25 per pound (as shown in Figure17), and prices could increase in the years to come (Ux Consulting Company, LLC 2010). Note the significant increase starting in about year 2005, and peaking in 2007 at over $130/lb U_3O_8. In addition, the price of ferro-vanadium skyrocketed in recent years to an all time high of over $56 per pound as shown in Figure 18 on page 45. As the current global financial crisis eases and the demand for steel once again increases, the price for ferro-vanadium is expected to increase likewise. The price for ferro-vanadium as of February 14, 2011 is selling at approximately $31 per pound (Metal-Pages, 2011). At this price, vanadium would be sought after as a co-product, and possibly the primary metal, particularly because of the relatively high ratio of vanadium to uranium in most of the Salt Wash deposits in the planning area. Based on current prices and global production (shown in Figure 19 on page 46), and with current interest expected to continue, it is reasonable to suggest that development of existing reserves is likely in the next 15 to 20 years.



Source: UX Consulting Company, LLC (2011)

Figure 17: Uranium Pricing Chart from 1988 to present

The sensitivity of mining operation profitability to commodity market prices is demonstrated by the case of the Sunday Mine in Big Gypsum Valley just south of the planning area. The Sunday Mine re-opened in 1997 at a time when uranium oxide prices briefly rose above $15 per pound . The mine closed again in 1999 after prices dropped back into the $10- $11 per pound range (Cappa 2006). Future interest in development and exploration will be entirely a function of market dynamics. At low U_3O_8 price levels, development potential is extremely low. Should price increase into the high teens or above, there is a strong expectation that some existing mines with proven reserves will re-open, and exploration for new deposits of similar size and grade, which are highly likely to be present in favorable areas, will resume (Spanski et al 2004).



Source: Metal-Prices 2011

Figure 18: Ferro-Vanadium Price Chart from 1996 to 2005

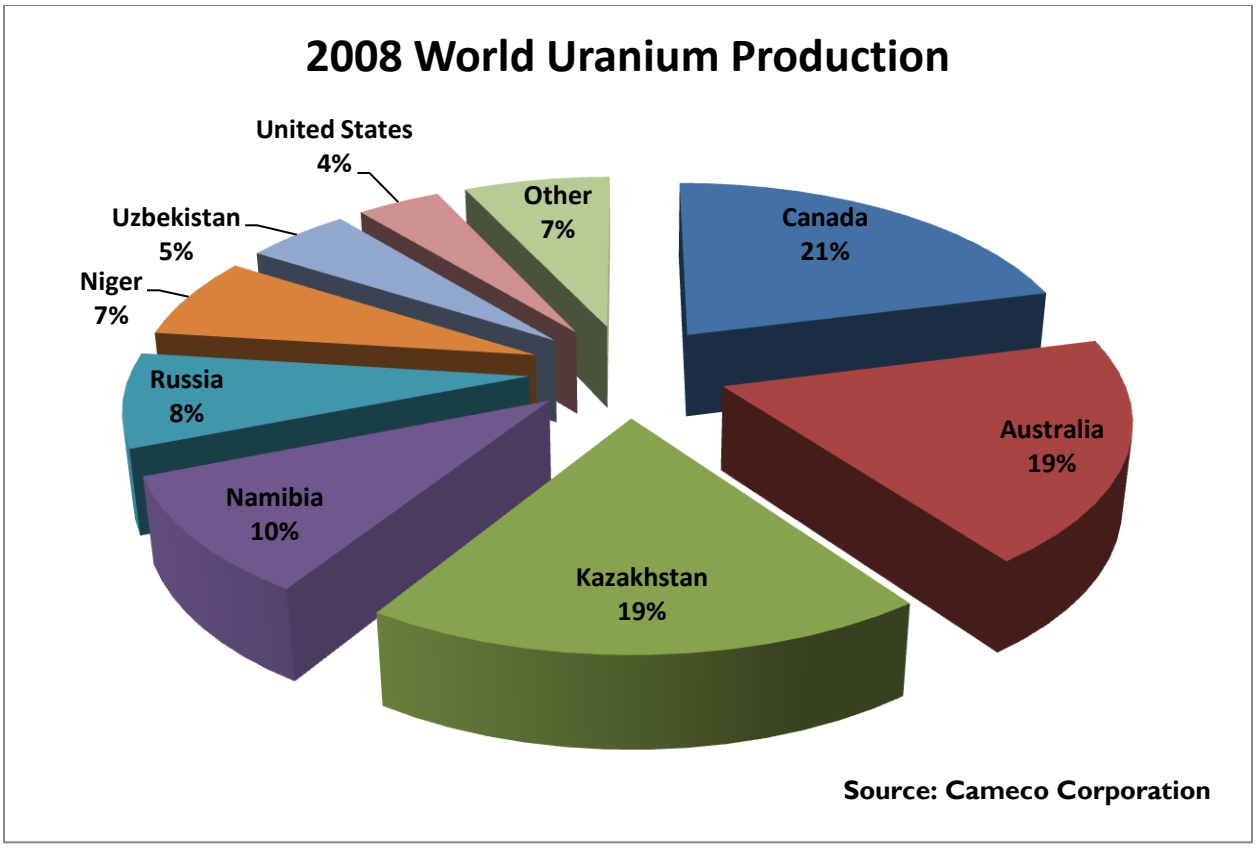


Figure 19: Top World Uranium-Producing Countries for 2008

GYPSUM

As allowed by the 1872 Mining Law, gypsum is a locatable mineral. To date there has been minor exploration conducted, but there has been no development and no production of gypsum in the planning area. Recently this office has received an inquiry from an operator regarding how to proceed with permitting a gypsum mine operation on public lands administered by the BLM in Paradox Valley approximately 4 miles east of Bedrock, Colorado. This area has gypsum mineralization outcropping at the surface where the Paradox Member of the Hermosa group is exposed (see Figure 3 on page 16 and Map 2 on page 53). The operator reports that the material is of exceptional purity (Cluff, 2010). The gypsum resource occurrence and development potential is high (H), with a high degree of certainty (D).

PLACER GOLD

Another locatable mineral resource in the planning area is placer gold, mined along the San Miguel, Uncompahgre, and Dolores Rivers in western Colorado. The activity is primarily centered in Piñon, Colorado east of Nucla, with minor activity occurring along the Dolores River toward the western planning area boundary (as shown in Figures 13 and 14 on pages 36 and 37, respectively). The gold primarily comes from gold-quartz veins above the town of Telluride, Colorado. Both independent operators and mining clubs use up to 4-inch intake diameter suction dredges to extract gold from the riverbeds. The BLM considers such activity casual use and does not require formal authorization. In order to track placer gold mining activity, the UFO requires users to submit a notification of use. Over 75 notices were received in 2009.

Placer mining activity largely depends upon the price of gold. As recently as February 2011, the price of gold was at an historic high of $1,413 per troy ounce (GoldPrice.org 2011). It is anticipated that as the price fluctuates, so will the activity level. In the short term, robust placer mining activity can be expected in the planning area. The historic nature of the mineral ensures a high degree of certainty that placer gold resources are present within the San Miguel River system into the Dolores River, giving the area a high potential rating.

SOLID LEASABLE MINERALS

POTASSIUM AND SODIUM

Recently, commodity prices for sodium as soda ash (trona) and potassium as potash have risen to historic levels along with other natural resources. Should these levels remain stable, there will be continued interest in soda ash and potash potential for the western portion of the planning area.

The Paradox Member of the Hermosa Group located in the northern and central portions of the Paradox Basin appears to have the highest potential for soda ash and potash development in the planning area (see Figure 3 on page 16) (Wengerd 1958). To date there has been no exploration, development or production of sodium and/or potassium in the planning area. However, in the Paradox Basin portion in the Dolores Field Office area, which is located immediately south of the

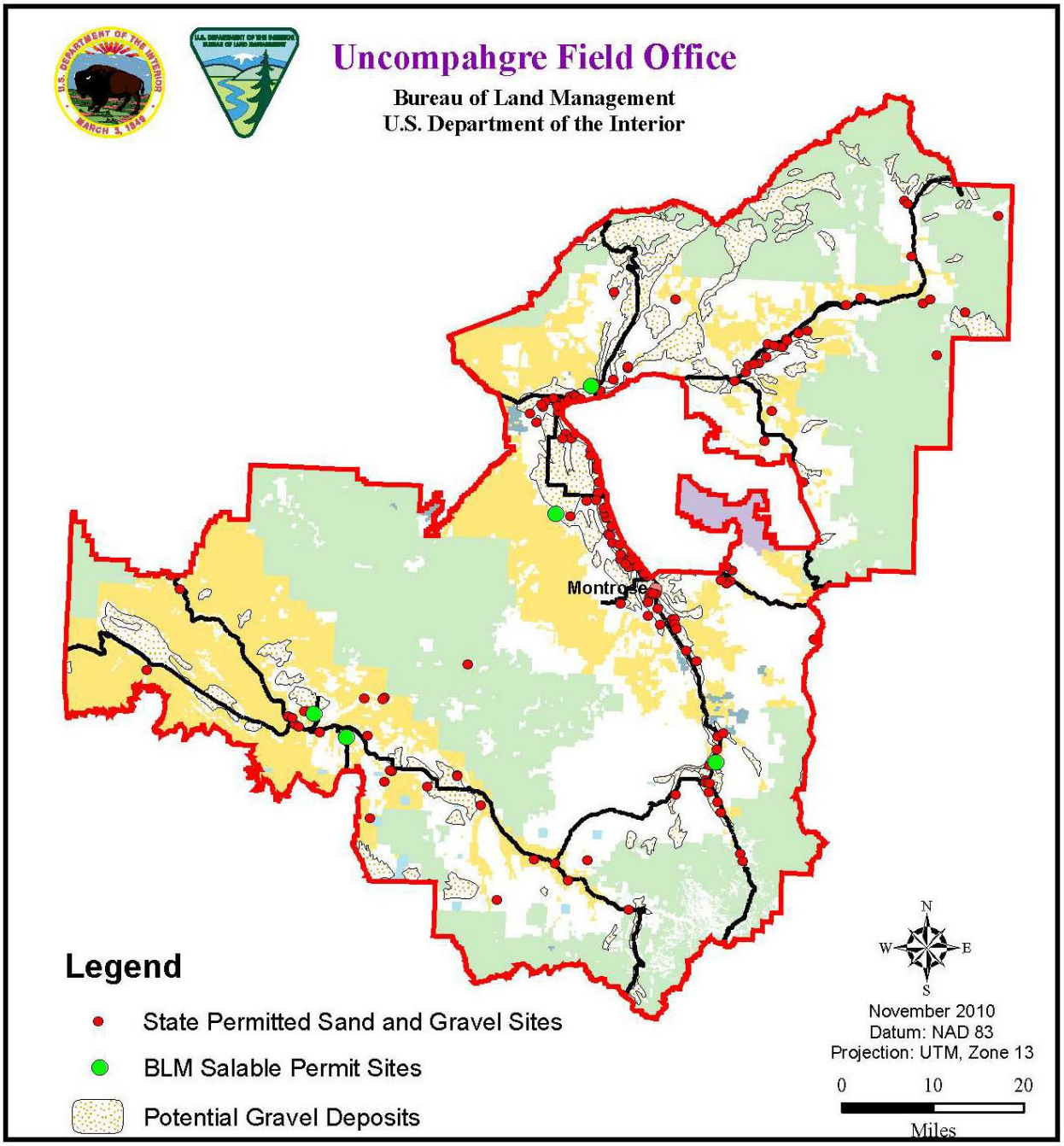
planning area, there are presently 21 prospecting permit applications filed by RM Potash, a subsidiary of Red Metal Ltd. Also, Dakota Salts, LLC, a subsidiary of Sirius Minerals has shown an interest in submitting prospecting permit applications for potash in the Paradox Basin. Therefore, in summary, in the planning area, the Paradox Valley area is designated as having high potential (H) for sodium and potassium solid non-energy leasable mineral deposits with a high degree of certainty (D).

SALABLE MINERALS

SAND AND GRAVEL

Sand and gravel provide raw materials for most construction and paving activities. Sand and gravel deposits are found along the San Miguel, Uncompahgre, and Gunnison Rivers and their major tributary valleys. Other sources include widespread glacial outwash, colluvium, and alluvial fans (see Figure 20 on page 49).

There are six county free-use permitted gravel pits and one private, non-competitive gravel pit, two riprap sites, two fill locations, and one clay area scattered across the planning area. In addition, there is currently a sales area for moss rock. Future demand for mineral materials will vary depending upon market conditions, which differ according to economic conditions and construction activity. It is expected that as the current recession ends, construction activity will increase and economic conditions will improve, resulting in an increased demand for construction materials including gravel from areas within the UFO's planning area. There is a high degree of certainty (D) that high potential (H) for sand and gravel deposits exist in a wide variety of locations within the planning area.



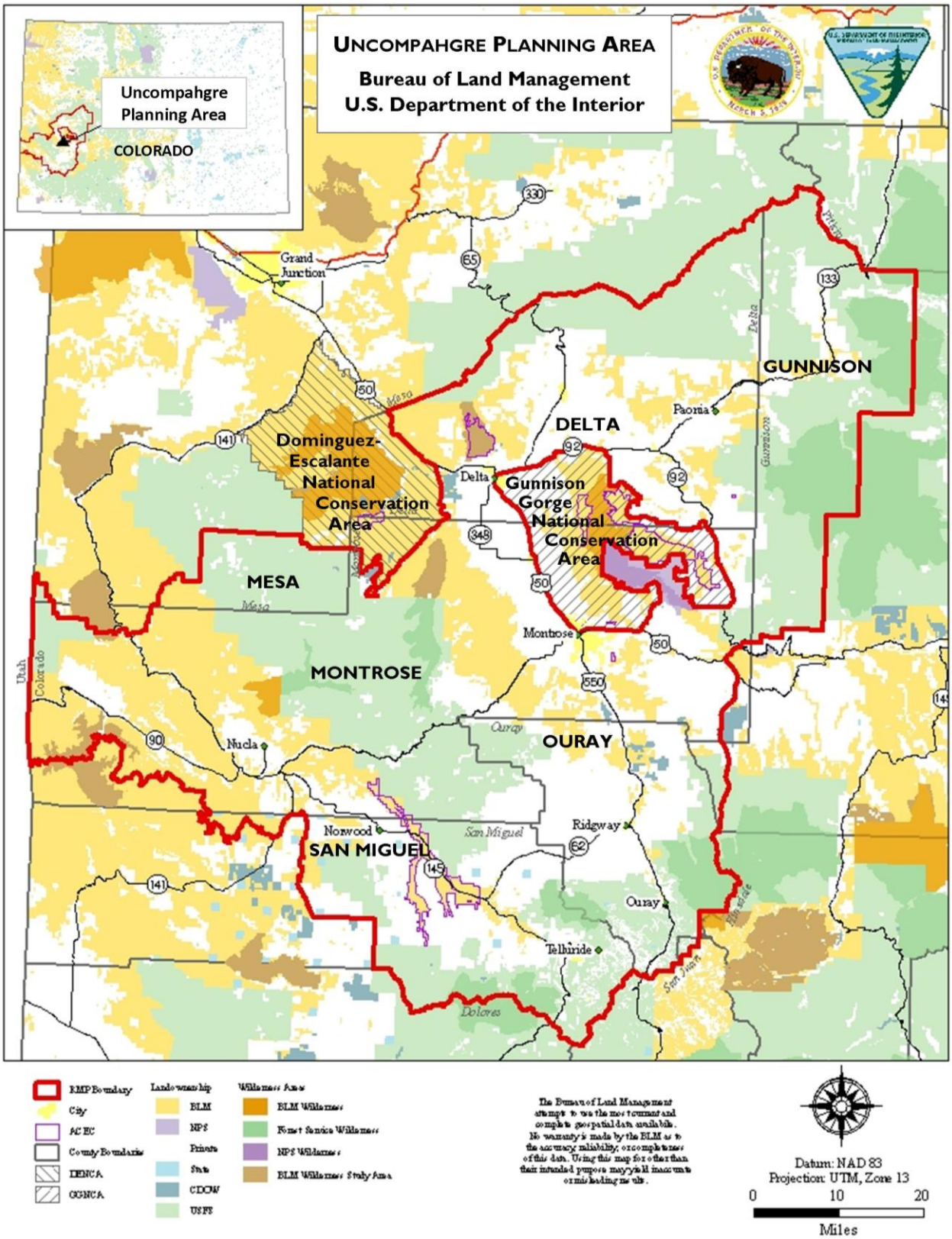
Source: CDRMS, 2010

Figure 20: Potential Sand and Gravel Deposit Areas with State Permitted and UFO Salable Permit Sites

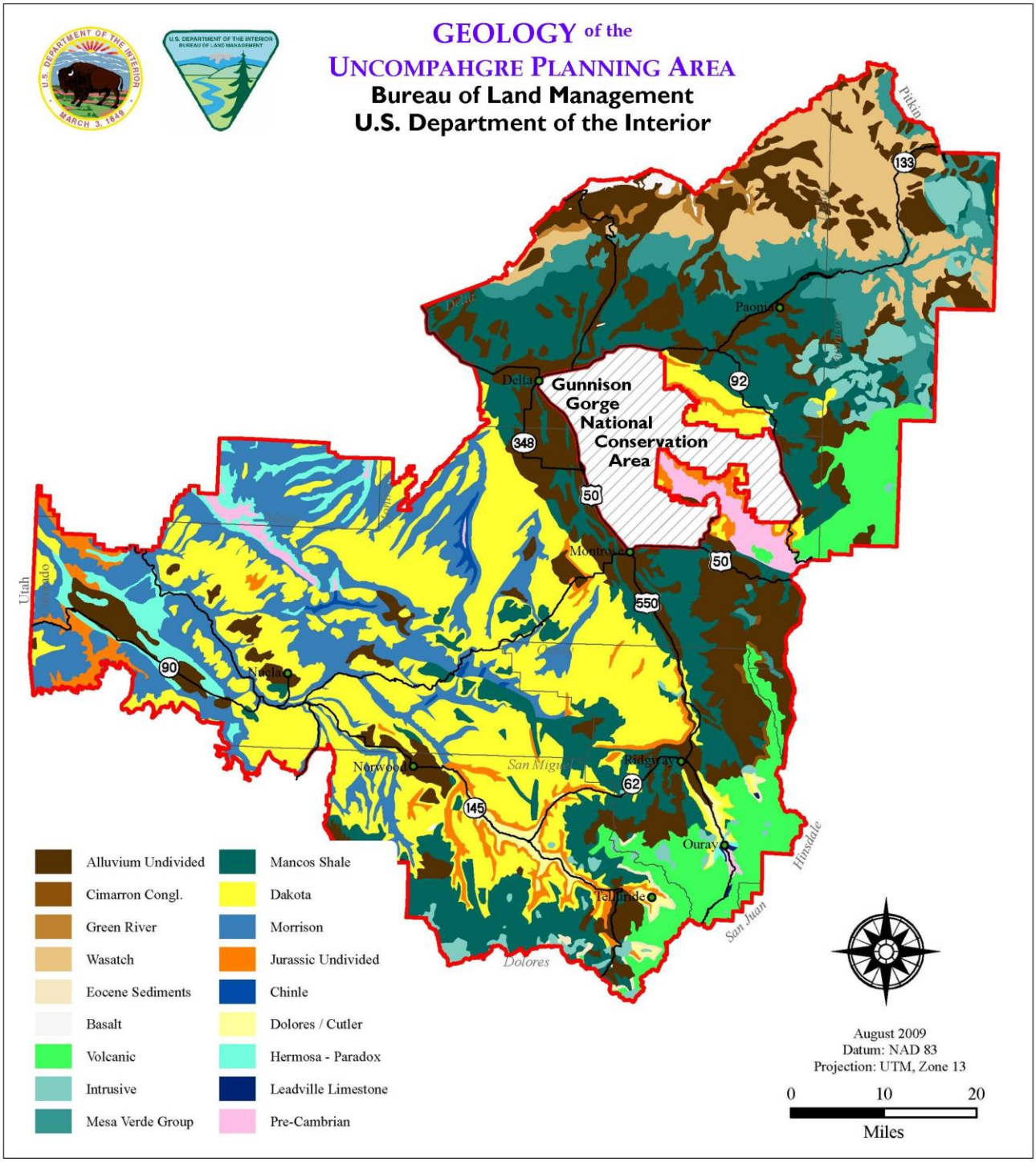
Recommendations

No recommendations or stipulations have been developed at this time. However, appropriate recommendations or stipulations related to the management or future development of mineral resources within the Uncompahgre planning area will be developed through the RMP process.

Appendix A – Maps



Map 1 - The Uncompahgre Planning Area



Source: modified from Green (1992)

Map 2 - Geology of the Uncompahgre Planning Area

Appendix B – Mineral Potential Classification System

The following mineral potential classification system found in BLM Manual 3031.3 was used to classify the mineral potential for lands within the planning area:

LEVEL OF POTENTIAL

O. The geologic environment, the inferred geologic processes, and the lack of mineral occurrences do not indicate potential for accumulation of mineral resources.

L. The geologic environment and the inferred geologic processes indicate Low Potential for accumulation of mineral resources.

M. The geologic environment, the inferred geologic processes, and the reported mineral occurrences or valid geochemical/geophysical anomaly indicate moderate potential for accumulation of mineral resources.

H. The geologic environment, the inferred geologic processes, the reported mineral occurrences and/or valid geochemical/geophysical anomaly, and the known mines or deposits indicate high potential for accumulation of mineral resources. The "known mines and deposits" do not have to be within the area that is being classified, but have to be within the same type of geologic environment.

ND. Mineral(s) potential not determined due to lack of useful data. This notation does not require a level-of-certainty qualifier.

LEVEL OF CERTAINTY

A. The available data are insufficient and/or cannot be considered as direct or indirect evidence to support or refute the possible existence of mineral resources within the respective area.

B. The available data provide indirect evidence to support or refute the possible existence of mineral resources.

C. The available data provide direct evidence but are quantitatively minimal to support or refute the possible existence of mineral resources.

D. The available data provide abundant direct and indirect evidence to support or refute the possible existence of mineral resources.

O/D. **(**Determination of No Potential) This class shall be seldom used, and when used, should be for a specific commodity only. For example, if the available data shows that the surface and subsurface rock type in a respective area is batholithic igneous intrusive, one can conclude with reasonable certainty that the area does not have potential for coal.

Appendix C – Glossary

Carnotite - A bright greenish yellow secondary vanadium and uranium mineral usually occurring as crusts and flakes in sedimentary rock of arid climates.

Craton - An old and stable part of the continental lithosphere.

Diapir - An anticlinal fold in which a mobile core, such as salt or gypsum, intrudes vertically upward along a fracture or zone of structural weakness through more dense and brittle overlying rock; the process is known as *diapirism*.

Isotope - Different types of atoms of the same chemical element, each having a different number of neutrons.

Lineament - Any long natural feature on the surface of the earth, such as a fault, especially as revealed by aerial photography.

Locatable mineral - Those mineral deposits authorized to be claimed by U.S. citizens under the General Mining Law of 1872 (as amended), including gold, silver, iron, tungsten, zeolite, and cement grade limestone.

Leasable mineral - Minerals that may be acquired on federal public lands under the Mineral Leasing Act of 1920 (as amended), including sodium, oil, gas, oil shale, coal, sodium, potash, geothermal, native asphalt, bitumen, and bituminous rock phosphate. Subject to exploration and development through leases, permits, or licenses issued by the BLM.

Mineral - A naturally occurring solid chemical substance formed through geological processes, which has a characteristic chemical composition, highly ordered atomic structure, and specific physical properties.

Ore - A mineral-bearing rock mined and refined to extract valuable metals (including uranium and gold) for commercial sale.

Paradox Basin - A large elongate evaporite basin containing sediments from alternating cycles of deep marine and very shallow water.

Paradox Valley - One of a series of valley-forming anticlines within the Paradox Basin.

Piercement structure - A dome or anticlinal fold in which a mobile plastic core has ruptured the more brittle overlying rock.

Pitchblende - Common name attributed to the radioactive mineral uraninite due to its black color.

Potential - Likelihood for the occurrence of a concentration of one or more mineral resources in a particular area.

Radioactive decay - Certain elements (such as uranium) give off atomic particles (electrons, protons, and neutrons) that over time lead to changes in the atomic weight and number of the parent element.

Roll-front - The dissolution of uranium from nearby strata, transport into permeable and porous sandstones or conglomerates, and precipitation to form a front. Typically represents the largest of the sandstone-hosted uranium deposits and one of the largest uranium deposit types.

Salable mineral - Commodities with relatively low unit value, but may have high bulk commercial or industrial value and importance and include common varieties of sand, stone, crushed rock and gravel, pumice, cinders, and ordinary clay used chiefly for roadways and other construction. These minerals are obtainable under the Materials Act of 1947 (as amended) and disposed of at BLM discretion by contract or permit.

U_3O_8 (Triuranium octoxide) - Occurs naturally as the olive-green-colored mineral pitchblende and is the most common chemical form of uranium found in nature. U_3O_8 is very stable and has low solubility in water.

Uncompahgre Plateau - A large and distinctive uplifted portion of the Colorado Plateau rising to elevations around 10,000 feet and extending some 70 miles between the Gunnison and Uncompahgre Rivers to the east and the San Miguel and Dolores Rivers to the west.

Yellowcake (also called *urania*) - Name given to a uranium concentrate powder containing about 80% uranium oxide obtained from leach solutions as an intermediate step in the processing of uranium ores.

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