LITTLE BOOK CLIFFS/ WILDHORSE AREA

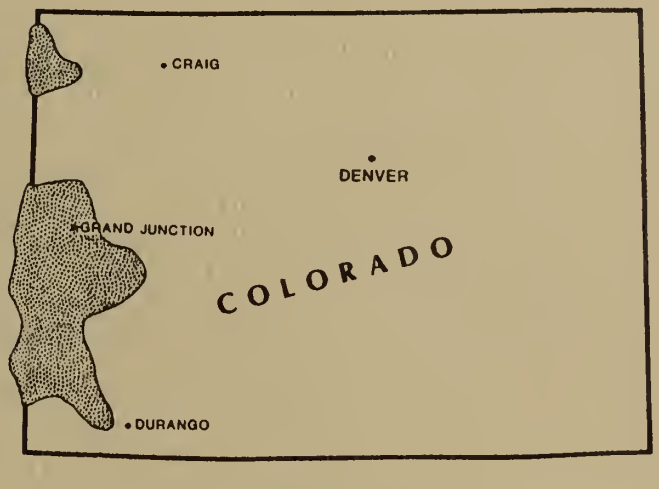
GEOLOGICAL RESOURCE AREA (GRA) 4

FINAL REPORT

PHASE 1: GEM

(GEOLOGICAL, ENERGY and MINERALS)

RESOURCE ASSESSMENT FOR REGION 4, COLORADO PLATEAU



SUBMITTED TO:

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
DENVER SERVICE CENTER
DENVER, COLORADO 80225

MSME/WALLABY ENTERPRISES
A JOINT VENTURE OF
MOUNTAIN STATES MINERAL ENTERPRISES, INC.
and WALLABY ENTERPRISES, INC.

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FOREWORD

This report is one of a series of eleven reports addressing the Wilderness Study Areas (WSA's) located in what has been designated as the Colorado Plateau, Region 4, by the Bureau of Land Management (BLM), Denver Federal Center. The study was under the direction of Mr. Robert J. Coker, the Contracting Officer's Authorized Representative (COAR).

The WSA's have been segregated into eleven G-E-M (Geology, Energy, Minerals) Resources Areas (GRA's). Each designated GRA constitutes one report. The purpose of these reports is to assess the potential for geology, energy and mineral (GEM) resources existing within a WSA and GRA. This information will then be used by BLM geologists in completing the assessment for GEM resources potential within the WSA's, and for the integration with other resource data for the decision on suitability for recommendation of the respective WSA.

The reports were developed and prepared by the Joint Venture team of MSME/Wallaby Enterprises, Tucson, Arizona, by Patricia J. Popp (Geologist), and Barbara J. Howie (Geologist) under the direction of Eric A. Nordhausen (Project Manager) and Richard Lundin (Principal Investigator), under BLM Contract No. YA-553-CT2-1041.

Consulting support was provided by a highly specialized geological team composed of: Ted Eyde, Dr. Paul Gilmour, Dr. Robert Carpenter, Dr. Donald Gentry, Dr. Edger Heylmun, Dr. Larry Lepley, Annon Cook, Walter Heinrichs, Jr., and Charles Campbell. Their contribution is both acknowledged and appreciated. The work of Dr. Gilmour, Dr. Carpenter and Dr. Lepley should receive special acknowledgement. It was from the work of these consultants that this report on the Little Book Cliffs/Wildhorse Area GRA was able to be completed.

EXECUTIVE SUMMARY

The BLM has adopted a two-phase procedure for the integration of geological, energy and minerals (GEM) resources data for suitable/nonsuitable decisions for Wilderness Study Areas (WSA's). The two-phased approach permits termination of a GEM resources data gathering effort at the end of Phase One. The objective of this Phase One GEM resource assessment is the evaluation of existing data (both published and available unpublished data) and their interpretation for the GEM resources potential of the WSA's included in each region. Phase Two is designed to generate new data needed to support GEM resources recommendations.

Over 10 million acres of WSA's require GEM resources data input. These WSA's are unequally distributed in the eleven western states of the coterminous United States. The WSA's are grouped in six large regional areas. The WSA's within the western part of Colorado, and a few crossing into Utah, were included as Region 4, also known as the Colorado Plateau Region. Except for one small area at the southwest extreme of the region and another at the north extreme, the region is within the northern half of the known Colorado Plateau physiographic province.

The 32 WSA's within Region 4 encompass 474,620 acres. These have been geographically segregated within 11 designated GEM Resource Areas (GRA's). This report addresses the Little Book Cliffs and Wildhorse Area, GRA 4. Within the GRA is Little Book Cliffs/Wildhorse WSA (CO-070-066).

The physiography of this GRA includes three distinct regions: the Book Cliffs Escarpment, Grand Valley area, and the area of the southwest bank of the Colorado River. The majority of the rock units are sedimentary. These contain various gas fields localized by associated anticlinal and synclinal structures.

The mineral and energy resources in the GRA include gas, coal, copper, uranium, and sand and gravel. The sedimentary formations previously mentioned contain the gas and coal deposits. Six major gas fields, and one major coal field are contained in these formations. The producing units for the uranium and copper mineralization was unable to be ascertained due to lack of information. Sand and gravel occurs along the Colorado River and it's tributaries.

The Little Book Cliffs/Wildhorse WSA contains sedimentary and structural features that helped create the contained major gas field. In addition, the Little Book Cliffs Coal Field is contained within the WSA (see Figure 1.1 and Overlays A and C).

The classification for the leasable minerals, locatable and salable resources varies. There is high favorability for leasable resources in the WSA in the form of oil, gas, and coal. The WSA has low favorability for locatable minerals. There is, however, high favorability for saleable resources in the form of dimension stone.

Overall, it is recommended that the WSA in the GRA receive additional work to determine the full economic potential of the area. This work should include further research in the unpublished and proprietary literature, a detailed program of

geologic mapping and sampling, and additional geochemical and stratigraphic studies to confirm the occurrence or lack of occurrence of geology, energy or mineralized commodities.

SECTION I

INTRODUCTION

The Little Book Cliffs/Wildhorse Area GRA and WSA (CO-070-066) (Figure I-1) is located in Mesa County, Colorado.

The GRA area includes most of the Book Cliffs and Colorado River Valley, south of DeBeque, Colorado. Located within the GRA is Grand Junction, Colorado, a major urban settlement and regional supply center. A number of other small settlements (Palisade, Cameo, Fruitvale, Clifton, and Rhone), are local supply centers for agricultural, mining, and ranching activities. The outlying communities within the GRA are supplied by road and rail networks from Grand Junction and Denver, Colorado. There are active oil, gas, coal and uranium-vanadium industries located in Grand Junction with activities in exploration, development, and production being a major source of jobs in the area. The Department of Energy operates a major research facility at Grand Junction, and is currently working on many projects that deal with uranium-vanadium potential of the GRA.

The GRA encompasses portions of Townships 8-12 South, Ranges 97-101 West; Townships 1-2 South, Ranges 1 West and 1 East; Townships 1-2 North, Ranges 1-2 West. The entire area is bounded by Longitudes 108° 15' 00" and 108° 40' 54" and Latitudes 39° 00' 00" and 39° 21' 43". It contains approximately 555 square miles (1494 square kilometers or 355,200 acres) federal, state and private lands. The Bureau of Land Management portion of these holdings are under the administration of the Grand Junction District and Resource Area Offices.

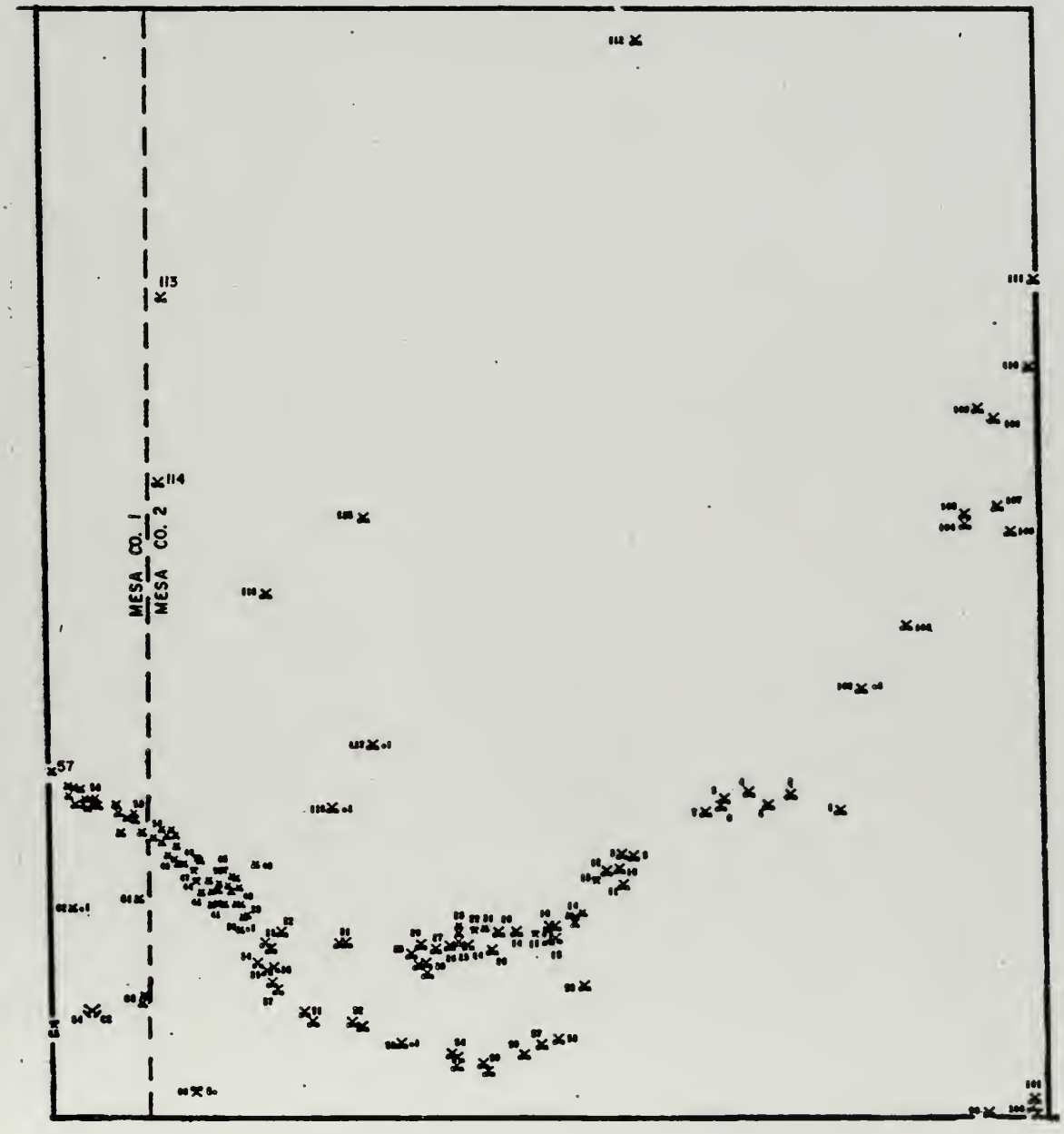
The only WSA included in the GRA is the Little Book Cliffs/Wildhorse Area WSA (CO-070-066). This unit contains 26,525 acres of Federal land.

The Little Book Cliffs/Wildhorse Area WSA is located in the central portion of the GRA and is approximately 3 miles north of Grand Junction, Colorado.

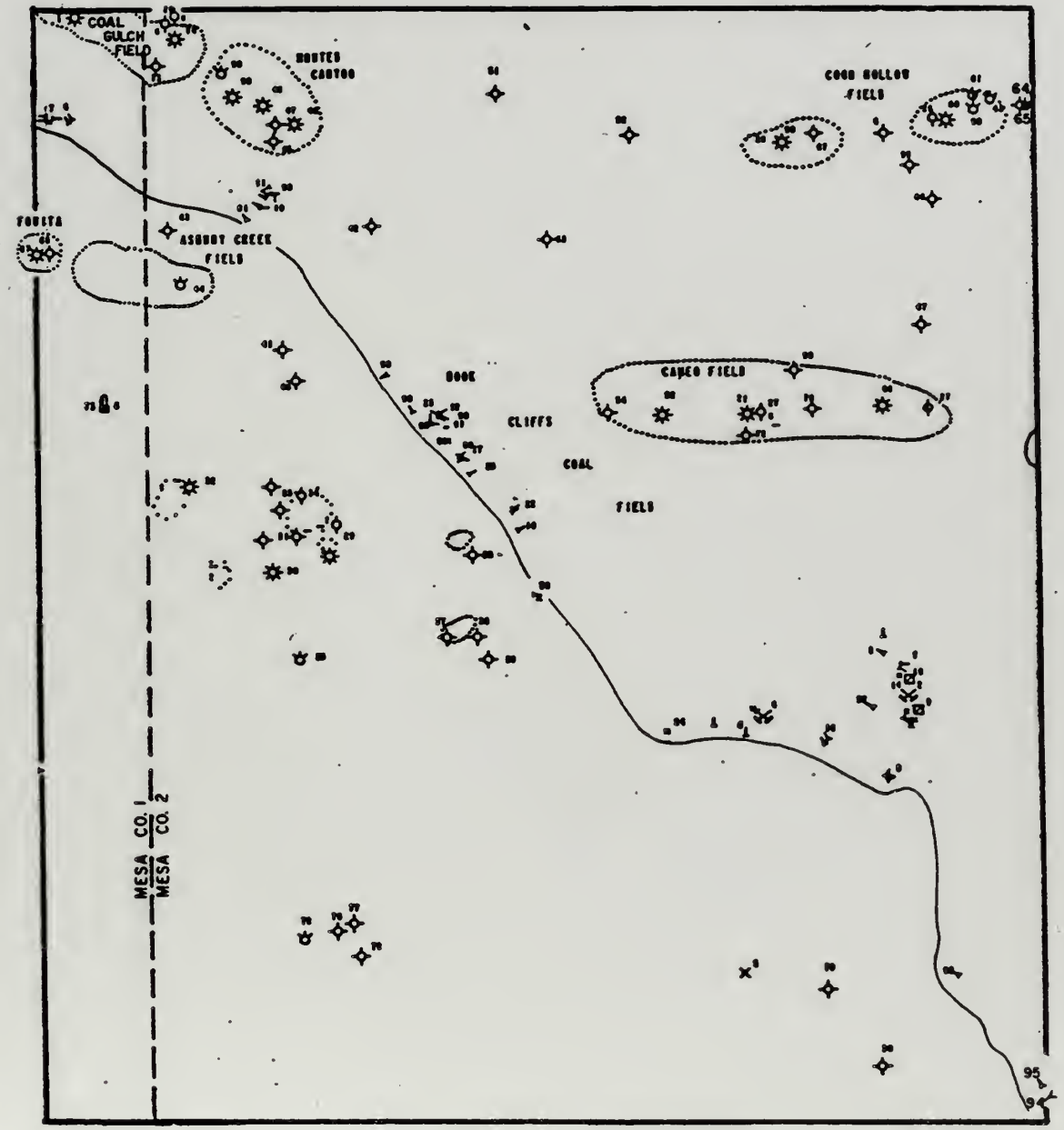
Due to the lack of available data on the WSA, emphasis was placed on gaining an understanding of the mineral potential of the WSA within the GRA. Information on the mineral resources of the GRA was utilized to extrapolate and estimate the potential of the WSA from the existing data that in most cases referred only indirectly to the WSA. The purpose of this contract was to utilize the known geological information within each WSA and GRA to ascertain the GEM resource potential of the WSA. The known areas of mineralization and claims have been plotted as overlays to Figure I-1.

The information contained in this report was obtained from published literature, computerized data base sources, Bureau of Land Management file data, and company files and returned data sheets. The information was compiled into a series of files on the GRA/WSA and a series of maps that covered the entire western portion of Colorado. After a thorough review of the existing data, a program of field checking was carried out by MSME/Wallaby's team of experts. Field investigations in the GRA/WSA were carried out by Dr. Donald Gentry and Mr. Ted Eyde on September 2, 1982. Both of these individuals are registered professional geologists and

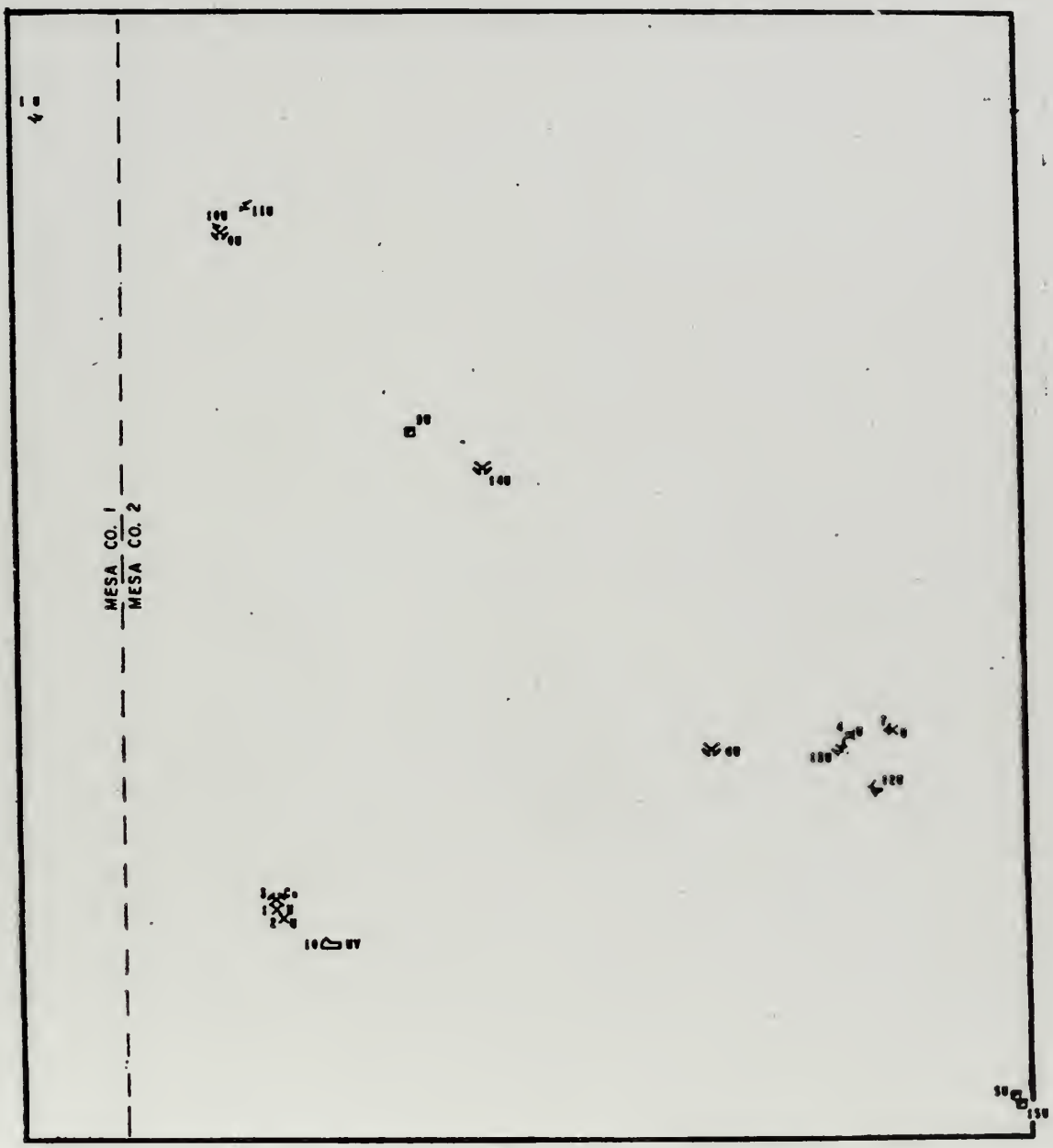
associates of MSME/Wallaby. Further analysis and study was provided through the photographic interpretation services of BLM 1:24,000 aerial photos by Dr. Larry Lepley, registered professional geologist and remote sensing specialist. The aerial photos used are included in Appendix A.



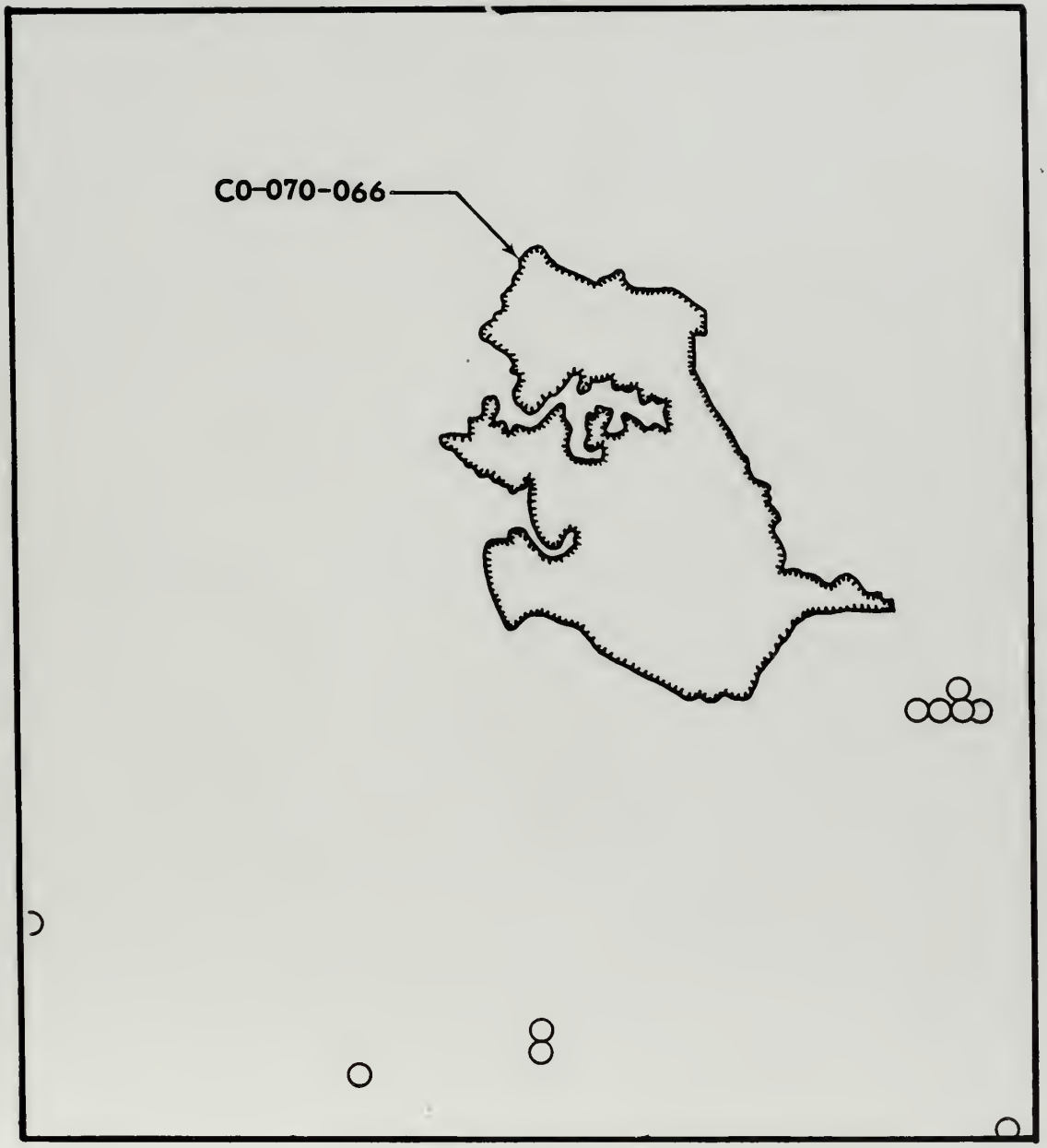
OVERLAY D
SAND, GRAVEL AND
INDUSTRIAL MINERALS



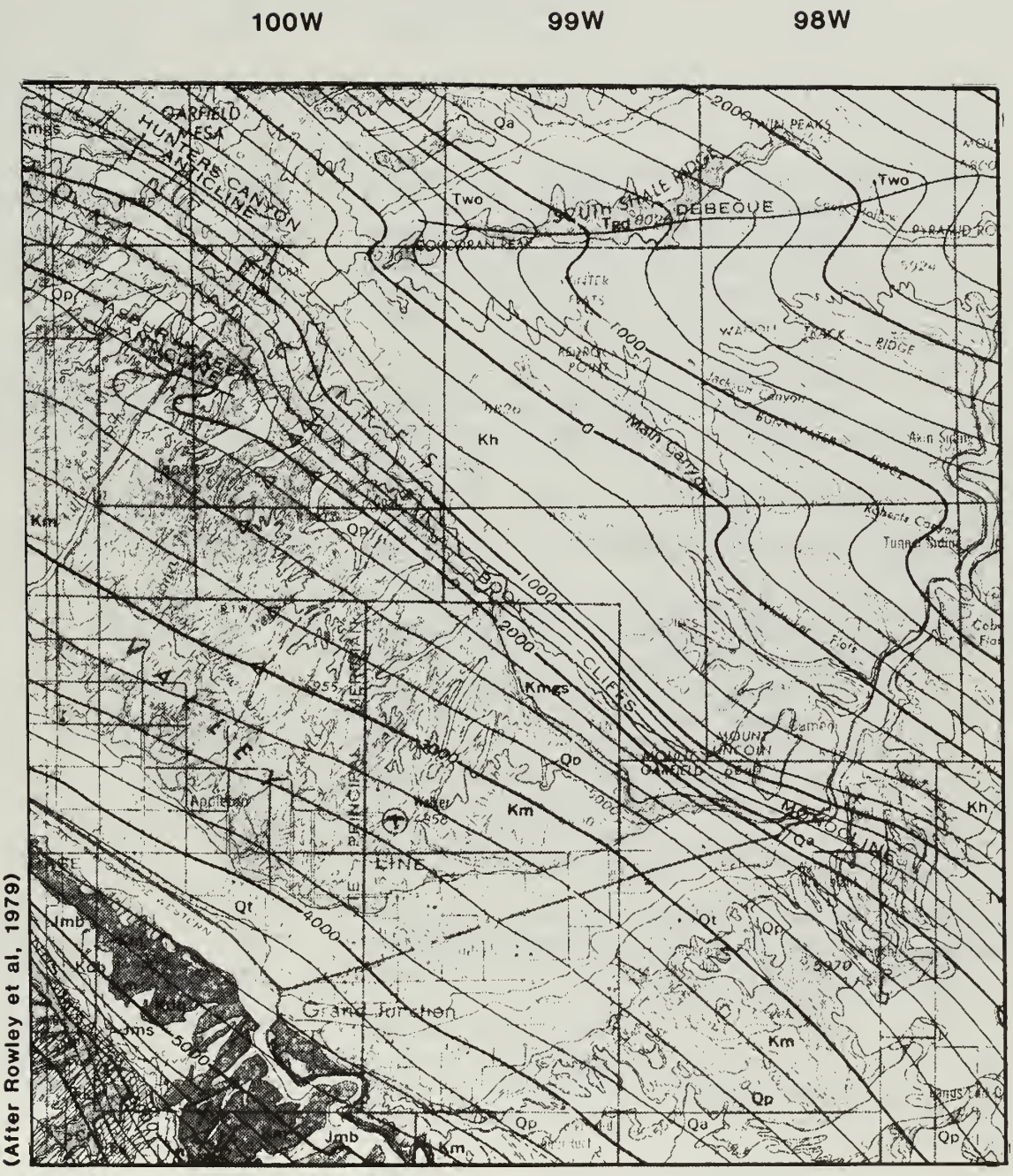
OVERLAY C
COAL, OIL AND GAS



OVERLAY B
MINES, PROSPECTS
AND MINERAL OCCURENCES



OVERLAY A
PATENTED AND UNPATENTED
CLAIMS AND WSA BOUNDARIES



LITTLE BOOK CLIFFS/WILDHORSE AREA GRA

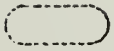
SCALE 1:250,000

FIGURE I-1
GEOLOGIC MAP

EXPLANATION

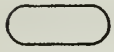
Quaternary (Approximately 2 million years before present (mybp) to present)	Qa, Qae	Alluvial and eolian deposits
	Qt	Terrace gravels
	Qp	Pediment deposits
Tertiary (Approximately 62-2 mybp)	Tgd	Green River Formation - Douglas Creek Member
	Tgdu	Douglas Creek Member, upper tongue
	Tgdl	Douglas Creek Member, lower tongue
	Twr	Wasatch Formation, Renegade Tongue
	Tw	Wasatch Formation, main body
	Two	Wasatch and Ohio Creek Formations
Cretaceous (Approximately) 135-62 mybp)	Kt	Mesaverde Group, Tuscher Formation
	Kf	Mesaverde Group, Farrer Formation
	Kns	Mesaverde Group, Nelson Formation and Sego Sandstone
	Kh	Mesaverde Group, Hunter Canyon Formation & Cozzette Member
	Kmgs	Mesaverde Group, Mount Garfield Formation and Sego Formation
	Kmb	Buckhorn Tongue of Mancos Shale
	Kc	Mesaverde Group, Castlegate Sandstone
	Kb	Mesaverde Group, Blackhawk Formation
	Km	Mancos Shale, undifferentiated
	Kmu	Mancos Shale, upper shale Member
	Kmf	Mancos Shale, Ferron Sandstone Member
	Kml	Mancos Shale, lower shale Member
	Kd	Dakota Sandstone
	Kbc	Burro Canyon Formation
	Kdb	Dakota Sandstone and Burro Canyon Formation
Jurassic (Approximately 195-135 mybp)	Jmb	Morrison Formation, Brushy Basin Shale Member
	Jms	Morrison Formation, Salt Wash Sandstone Member
	Jse	Summerville Formation and Entrada Sandstone
Triassic (Approximately 225-195 mybp)	Trk	Kayenta Formation
	Tr w	Wingate Sandstone
	Tr kw	Kayenta Formation and Wingate Sandstone
	Tr c	Chinle Formation
Precambrian (Approximately 3400-600 mybp)	pЄr	Complex of gneisses and schists

LEGEND


-O OIL FIELD


-G GAS FIELD


-Os OIL SHALE


-C COAL REGION


OIL WELL


OIL & GAS WELL


GAS WELL


SHOW OF GAS

SHOW OF OIL


SHOW OF OIL & GAS

-C COAL DEPOSIT

-C COAL OCCURRENCE


SHUT-IN WELL


CO_2 OR He=HELIUM -RICH WELL


DRY WELL-ABANDONED


MILL


PLANT


NATURAL GAS PROCESSING PLANT


REFINERY


MINERAL OREBODY


MINERAL DEPOSIT


MINERAL OCCURRENCE


PROSPECT


ACCESSIBLE ADIT

INACCESSIBLE ADIT


VERTICAL SHAFT


INCLINED SHAFT

MINE TYPE UNKNOWN

ACTIVE OPEN PIT, OR QUARRY

INACTIVE OPEN PIT, OR QUARRY


ACTIVE GRAVEL OR CLAY (Cl) PIT


INACTIVE GRAVEL OR CLAY (Cl) PIT

EXPLORATION HOLE WITH DATA AVAILABLE

EXPLORATION HOLE WITHOUT DATA AVAILABLE

UNPATENTED MINING CLAIM


PATENTED MINING CLAIM


MINERAL OR OIL & GAS LEASE

O	OIL	Cb	LIGNITE	Ds	DIMENSION STONE
G	GAS	Cp	PEAT	Fe	IRON
Os	OIL SHALE	Ag	SILVER	Mn	MANGANESE
Ot	TAR SANDS	Au	GOLD	Pb	LEAD
Gi	GILSONITE	Cu	COPPER	U	URANIUM
C	COAL	Cl	CLAY	V	VANADIUM
				Zn	ZINC

SECTION II

GEOLOGY

PHYSIOGRAPHY

Within the GRA boundary are valley, cliff and plateau areas along the course of the Colorado River. Three distinct physiographic regions make up the area encompassed by the GRA. The first of these areas is found north of the Colorado River Valley. It consists of a series of high cliffs and deeply cut canyons that form the Book Cliffs Escarpment. Known simply as the Book Cliffs, this area consists of various ridges and mesa tops north of the Colorado River Canyon, and various northeast and northwest trending canyon systems that deeply cut into the plateau. The mesa tops and ridges rise approximately 2,000 feet above the Colorado River Valley floor. Some of the topographic highs (Mount Lincoln, Garfield Mesa, Wagon Track Ridge, Bunkwater Ridge, Redrock Point, Corcoran Peak, South Shale Ridge and Twin Peaks) form prominent features that rise above the relatively flat mesa tops. Topographic relief in this area is approximately 3,000 feet.

The second physiographic region includes the Grand Valley area, which borders the Book Cliffs. The northeast portion of this rolling valley gradually becomes the canyon of the Colorado River. The Grand Valley is characterized by low rolling hills that gently slope from the Book Cliffs Escarpment to the present course of the Colorado River. The valley area narrows into a canyon containing the Colorado River northeast of Grand Junction. Vertical relief in this area is less than 500 feet.

Along the southwest bank of the Colorado River in the vicinity of Grand Junction is the third physiographic area. It consists of a series of northeast trending fluvial systems that have cut canyons in the Uncompahgre Plateau. This plateau is a highland area in western Colorado that rises 3,000 to 5,000 feet higher than the surrounding terrain. These canyons have steep walls, and the resulting ridge and mesa tops form prominent topographic features that rise 500 to 1,000 feet above the valley floor. On the southeast bank of the Colorado is an area that is very similar to Grand Valley. It is characterized by rolling hills that slope down to the Colorado River and the Uncompahgre Plateau. Plateau areas to the east of these rolling hills rise 2,500 to 3,000 feet above the valley floor.

The following descriptions address the physiographic composition of the single WSA within the Little Book Cliffs/Wildhorse Area GRA.

LITTLE BOOK CLIFFS/WILDHORSE AREA WSA (CO-070-066)

Part of the southern edge of this unit is dominated by the 2,000 feet high face of the Book Cliffs Escarpment. The region to the north of this face is a gently sloping plateau region that is highly dissected by five major canyon systems. These canyons (Pine Gulch, Alkalai, Cottonwood, Jerry Creek and Spring Creek) have steep walls that are up to 1,000 feet high. Vertical relief within the WSA is approximately 3,000 feet.

The nearest urban area is Grand Junction, Colorado which is three miles south of the WSA.

ROCK UNITS

Within the Little Book Cliffs/Wildhorse Area GRA is found rock units that represent a large portion of Precambrian, Mesozoic and Cenozoic time. The Precambrian section is represented by a complex of gneisses and schists that indicate periods of volcanic, volcaniclastic and sedimentary deposition. These units have been moderately deformed and intruded by a series of felsic through mafic bodies. The Precambrian sequence is relatively unstudied in this area and has not been extensively dated or correlated to other sections of Colorado (Gilmour, Personal Communication, 1982; Carpenter, Personal Communication, 1982). These units are exposed at the bottoms of deep canyons in the southwest part of the GRA (Cashion, 1973).

The Paleozoic section does not outcrop within the GRA and may be missing. It is thought that it was never deposited on the flanks of the Uncompahgre Uplift, and so may have never been deposited in the southern half of the GRA. Paleozoic units may exist in the northern half of the GRA but have not been encountered in any of the deep drilling of the area (Baars et al, 1981; Schwochow, 1978; Heylmun, Personal Communication, 1982; Cashion, 1973).

The Mesozoic section consists in part of Triassic mudstones, shales, and sandstones of the Chinle, Wingate and Kayenta Formations. Within the GRA, the Triassic Chinle Formation is a siltstone interbedded with lenses of red sandstone, shale, limestone-conglomerate and a basal conglomerate unit that may be the equivalent of the Shinarump Formation in southeastern Utah and Arizona (Cashion, 1973). The Wingate Formation is a massive, thick-bedded eolian sandstone that was probably deposited in a desert environment (Cashion, 1973). The Kayenta Formation consists of a series of fluvial shale, siltstone and sandstone units with occasional beds of limestone and shale-pellet conglomerate (Cashion, 1973).

These units are thought to represent a period of deposition in a near-shore marine or lagoonal environment with periods of terrestrial deposition in a near-shore arid environment (Cashion, 1973; Carter et al, 1965).

Most of the Mesozoic is represented by the Jurassic Morrison Formation, which has units that crop out within the GRA that represent a series of mudstone, shale, conglomerate, fluvial sandstone, and limestone beds (Cashion, 1973). Uranium-vanadium mineralization is associated with conglomeratic units within the upper or Brushy Basin Member of the Morrison (Cashion, 1973; Vanderwilt, 1947). The Morrison Formation units that crop out within the GRA are not known to contain ore-grade uranium-vanadium mineralization. This may be due to the sediments having been deposited in a terrestrial fluvial environment, known to be a poor host for this type of mineralization (Carter et al, 1965; Cashion, 1973). The Morrison Formation is known to contain uranium-vanadium deposits in other areas of western Colorado (Vanderwilt, 1947).

The Upper Mesozoic consists of the Cretaceous section, represented within the GRA by the Burro Canyon Formation, the Dakota Sandstone Formation, Mancos Shale Formation, Mt. Garfield Formation, Sego Sandstone Formation, and the Hunter Canyon Formation. These units can be described as a series of shales, sandstones, mudstones and conglomerates with interbedded coal seams (Cashion, 1973). The Burro Canyon Formation consists of a sequence of fluvial sandstone, conglomerate, siltstone,

shale and mudstone units with thin beds of impure limestone (Cashion, 1973). The overlying Dakota Formation is a group of sandstone and conglomerate units with interbedded carbonaceous, non-marine shale and coal units. Plant fossils are usually associated with this unit and coal seams in the Dakota have been mined in other areas of Colorado (Vanderwilt, 1947; Speltz, 1976; Gentry, Personal Communication, 1982; Cashion, 1973). The Mancos Shale consists of black fissle shale beds with thin sandstone units. The overlying Mt. Garfield Formation is a series of shales, sandstones and siltstones with thick, persistent coal seams in the basal portion. The Mt. Garfield Formation is known as a source of high quality coal and has been mined at several locations within the GRA (Vanderwilt, 1947; Gentry, Personal Communication, 1982; Cashion, 1973). The underlying Sego Sandstone Formation is a thick fluvial sandstone with welldeveloped cross-bedding. The entire sequence is thought to represent a period of shallow water marine and lagoonal deposition along a transgressive and regressive shoreline with adjacent fluvial deposition (Young, 1959; Carter et al, 1965; Cashion, 1973).

The Cenozoic stratigraphy is represented by sandstone, shale and siltstone units of the Tertiary Wasatch Formation. This unit unconformably overlies the Cretaceous section and is thought to represent a period of shallow water deposition in a marine or neritic environment (Young, 1959; Cashion, 1973; Carter et al, 1965). Quaternary alluvial, fluvial, and eolian deposits are found along the Colorado River Valley in areas of recent Colorado River or tributary deposition. Quaternary pediment gravels are found along the northern bank of the Colorado and have been exploited in recent times as a source of sand and gravel, with minor placer gold values (Cashion, 1973; Eyde, Personal Communication, 1982; Carpenter, Personal Communication, 1982).

The following description addresses the rock units of the single WSA within the Little Book Cliffs/Wildhorse Study Area GRA.

LITTLE BOOK CLIFFS/WILDHORSE WSA (CO-070-066)

Within the WSA, the entire area consists of outcrops of the Cretaceous Mount Garfield, Sego Sandstone and Hunter Canyon Formations (Cashion, 1973). The Cretaceous Mancos, Dakota and Burro Canyon Formations are known to exist under the WSA, and are the productive horizons for oil and gas deposits in the area (Cashion, 1973; Schwochow, 1978; Heylmun, Personal Communication, 1982; Gentry, Personal Communication, 1982). Outcrops of the Mount Garfield Formation are known to contain coal seams in the vicinity of Coal Canyon and in other locations throughout the WSA (Gentry, Personal Communication, 1982; BLM MRI File Data; Eyde, Personal Communication, 1982; Vanderwilt, 1947; Richardson, 1909). The Sego Sandstone Formation outcrops throughout much of the WSA, forming cliffs and resistant mesa tops along the Book Cliffs Escarpment (Cashion, 1973). Overlying this unit is the Cretaceous Hunter Canyon Formation which, in the WSA, is a unit containing beds of shale, mudstone and siltstone (Cashion, 1973). Pre-Cretaceous units may exist at depth but do not outcrop within the WSA.

STRUCTURAL GEOLOGY AND TECTONICS

Tectonic features found within the GRA include northwest and east-northeast striking high angle fault and joint systems that parallel the axes of the major fold structures that are found in the area (Cashion, 1973). These faults and joint

features may have localized oil and gas deposits within the area and have exposed outcrops of coal-bearing strata (Heylmun, Personal Communication, 1982; Gentry, Personal Communication, 1982).

In the southwest portion of the GRA are northwest striking faults paralleling the course of the Colorado River that were probably active during one or more episodes of the Uncompahgre Event of uplifting and deformation. Local northeast striking fault and joint systems control the orientation of drainages southwest of Grand Junction in Colorado National Monument, and may have localized uranium-vanadium deposits in the Jurassic Morrison Formation (Carpenter, Personal Communication, 1982).

Within the northern part of the GRA, major anticlinal and synclinal features have localized oil and gas deposits. These features have well known oil and gas fields associated with them. The deposits are usually found on the flanks of the anticlines and synclines, or along the trace of the axial planes. Faulting parallel to the axial planes has localized the deposits into a series of pools that formed along structural traps (Heylmun, Personal Communication 1982). The best known of these structural features are the Debeque Anticline, Hunters Canyon Anticline, Asbury Creek Anticline and Book Cliffs Monocline. Other mapped, but unnamed, fold features occur in the Roberts Canyon area in the eastern portion of the GRA (Cashion, 1973). The fold structures within the GRA have been extensively studied by the major oil companies and the USGS (Heylmun, Personal Communication, 1982).

Northeast striking fault and joint systems that cut across local fold features are also considered very important in localizing and delineating specific oil and gas pools (Heylmun, Personal Communication, 1982). Some of these structures are only known from the subsurface drilling and seismic information, and are only generally described in the existing, available information (Cashion, 1973).

In the northern part of the GRA is a major unconformity at the base of the Tertiary where the Wasatch and Green River Formations rest unconformably on the Cretaceous Hunter Canyon Formation (Cashion, 1973).

The southwestern part of the GRA has undergone uplift as a part of the Uncompahgre event. Several periods of erosions or non-deposition have been identified in the Mesozoic section. Unconformities have been identified at the base of the Dakota Formation and at the base of the Jurassic Entrada Formation. The entire Paleozoic section is absent in this area and was probably never deposited on the northeastern flank of the Uncompahgre Highland that existed in western Colorado. As a result, the Triassic Chinle Formation lies directly on the basement Precambrian complex. The Precambrian structures are poorly exposed and have not been extensively studied (Cashion, 1973; Carpenter, Personal Communication, 1982).

Moderate isoclinal folding and shearing are common to the Precambrian units in Colorado (Gilmour, Personal Communication, 1982).

The following description addresses the structural and tectonic characteristics of the Little Book Cliffs/Wildhorse Area WSA.

LITTLE BOOK CLIFFS/WILDHORSE AREA WSA (CO-070-066)

Structural features within the Little Book Cliffs/Wildhorse Area WSA include northwest striking high angle faults paralleling the axes of the Hunters Canyon and Ashbury Creek Anticlines, and a series of east-northeast striking, high angle faults that parallel the axes of the Debeque Anticline and an unnamed anticline in the Roberts Canyon area (Cashion, 1973). These structures have particular importance as they have localized oil and gas pools in the Cameo gas field. Northeasterly striking fault and joint systems have exposed coal seams in the Mt. Garfield Formation in the vicinity of Coal Canyon and have made mining of these deposits feasible. The well-known unconformity at the base of the Tertiary section represents a period of non-deposition or erosion, prior to the deposition of clastic units at the base of the Tertiary.

PALEONTOLOGY

Paleontological occurrences in the GRA are not well known. It is known however, that the Mancos Shale and members of the Mesaverde Group contain marine fish and mollusk remains. Coal-bearing horizons of the Cretaceous Dakota Formation are known to contain fossil plant remains, and the middle members of the Tertiary Wasatch Formation occasionally contain mammal remains (Richardson, 1907; Richardson, 1909; NPS File Data, 1982).

The Triassic Chinle Formation is known to contain reptile, amphibian and plant remains in other areas of Colorado and within the GRA (Stewart et al, 1959; NPS File Data, 1982). The most significant potential host rock sequence for paleontological remains must be the Jurassic Morrison Formation which is well known for its reptile, bird, and mammal fossil remains (Shawe et al, 1968; Craig et al, 1955; NPS File Data, 1982).

LITTLE BOOK CLIFFS/WILDHORSE WSA (CO-070-066)

The WSA has no reported fossil occurrences of major scientific interest (NPS File Data, 1982). Units of the Cretaceous Mancos Shale are known to contain marine fossils at several localities within the WSA (Richardson, 1909; NPS File Data, 1982). Plant remains have been found associated with the coal seams of the Mesaverde Group, and occasional marine fossils have been found in the upper members of the Mt. Garfield Formation (Cashion, 1973; NPS File Data, 1982).

The Tertiary Wasatch Formation that outcrops within the WSA is known to contain marine fossils in other areas of Colorado and Utah but are unknown as a paleontological resource within the WSA (NPS File Data, 1982). A full evaluation of the paleontological resource potential of this area must await further detailed studies of the stratigraphy of the WSA.

HISTORICAL GEOLOGY

During Precambrian time, the southwestern portion of the GRA received sediments from both cratonic and island-arc sources. It appears that this was a time of persistent volcanism and tectonic activity. Marine deposition of eugeosynclinal sediments was interrupted by the ebb and flow of cratonic and island arc volcanism and an extreme period of deformation caused by plate collisions and regional uplifting. The older Precambrian units were metamorphosed, deformed and intruded by a series of mafic to felsic bodies. Some of these intrusives contained anomalous amounts of metals and have mineral deposits associated with them in other parts of Colorado and western United States. Other base and precious metal deposit types, known as exhalative deposits, are commonly found in Precambrian lithologies. These exhalative deposits are found in association with marine basins and rhyolitic volcanic systems and are commonly associated with the older Precambrian lithologies. The younger Precambrian units may exist on the northern flank of the Uncompahgre Uplift but have not been encountered in drilling operations in the northern part of the GRA. In other parts of northwestern Colorado, the younger Precambrian sedimentary section is partially preserved. The environment is that of a predominantly clastic deposition in a marine environment. The Paleozoic section is entirely missing in the southern part of the GRA and has not been found in any of the drilling operations in the northern part of the area. It appears that the Uncompahgre Uplift was a regional topographic high during all of the Paleozoic and was shedding sediments into a series of major basins. It is probable that during Paleozoic time no sediments were deposited in at least the southern portion of the GRA (Baars et al, 1981).

The oldest unit outcropping in the GRA is the Triassic Chinle Formation. The Chinle-Wingate-Kayenta Formations of the Glen Canyon Group represent a time of Triassic sedimentation in a near-shore marine or lagoonal environment with episodes of eolian deposition of cross-bedded beach sand deposits. Certain fluvial and shallow water lacustrine deposits have also been identified in this sequence of sandstone, shale, siltstone, mudstone, limestone and conglomerate. It appears that the Triassic units were deposited along the margins of great, open seas that had existed since Paleozoic time. As the shorelines of these seas moved in response to orogenic episodes, the specific environments in the GRA changed from marine to terrestrial. During these times, shallow-water and near-shore swamps were formed. In other areas of Colorado, these Upper Triassic near-shore sediments are the host of copper-silver "redbed" deposits that were deposited in areas of rapidly changing Eh-pH conditions. The wide distribution of these types of deposits in western Colorado predicts that there is potential for copper-silver "redbed" types of deposits in the Chinle-Wingate-Kayenta lithologies.

Complete sections of the lower Jurassic are found in other areas of Colorado. Within the GRA these units are missing, and the Jurassic Entrada Formation lies unconformably on top of the Triassic Kayenta Formation. The lower and middle Jurassic section is missing and would indicate that the area was undergoing erosion and non-deposition. This may have been a period when the GRA was a terrestrial topographic high that was rapidly being eroded and shedding sediments into shallow Jurassic basins. The Jurassic Summerville and Morrison Formations were deposited in near-shore lagoonal environments or shallow water marine and fluvial systems. Some lacustrine and fresh water fluvial deposits have also been identified from these rocks. As described above in the Triassic Chinle Formation, mineral deposits

have been identified in Jurassic rocks, and are commonly found associated with limey sandstones, shales, and siltstones deposited in shallow, neritic basins that have fluvial channels meandering through them. Copper-silver-uranium-vanadium mineralization occurs in Jurassic units as "roll-front" and organically preciptated "stream channel" deposits. "Roll-front" mineralization consists of elongate, concretionary structures encompassed by rich vein-like concentrations of uranium-vanadium - bearing clay minerals. "Stream channel" deposits occur where uranium-vanadium waters encounter structural traps and clastic organic accumulations and deposit minerals in a reducing environment. Such mineral deposits are very important economically and are known to occur in other portions of the Jurassic section in western Colorado, Utah, Arizona and New Mexico. These deposits are thought to represent an environment similar to that of the present Lower Mississippi Basin. Fossillized plant material from this period is indicative of a tropical environment that was adjacent to an active fluvial or lacustrine system (Shawe, 1968).

During Cretaceous time the area was the site of shallow-water deposition in a lagoonal or swamp environment. The Lower Cretaceous Burro Canyon and Dakota Formations contain thin coal seams that may have economic significance. During most of the Lower Cretaceous, however, the GRA was a part of a beach or littoral environment adjacent to the Mancos Basin of central Colorado (Young, 1959).

Units of the Cretaceous Mancos Shale have been described as sandstone and shale units deposited in a near-shore environment. Thin coal beds in the correlative Blackhawk Formation may have some local economic significance. In the GRA proper, these units are represented by the carbonaceous units of the Mancos upper shale unit (Cashion, 1973).

The Cretaceous Mesaverde Group units outcrop throughout the central and northern portions of the GRA and represent a period of cyclical deposition of shale, coal, limestone and sandstone units in a near-shore marine environment adjacent to the deep-water basins where the bulk of the Mancos Shale unit was deposited (Richardson, 1909). The Mount Garfield Formation contains thick persistent coal beds in its lower units. The upper members of this formation also contain thin, discontinuous coal seams of minor economic importance (Gentry, personal communication; 1982). These units were also laid down in a near-shore swamp or lagoonal environment. The Upper Cretaceous Hunter Canyon Formation represents a change in depositional environment. This sequence of sandstones and shales is thought to represent inland deposition in lacustrine or fluvial environments (Young, 1955).

The Hunter Canyon Formation is unconformably overlain by the Tertiary Wasatch Formation. This unconformity may represent a period of uplift and erosion prior to the formation of the Uinta sedimentary basin. Within the GRA are found thin lenses of the basal conglomeritic Ohio Creek Formation. The Wasatch Formation represents a period of shallow water terrestrial lacustrine deposition. The thin sandstone, shale and siltstone units sometimes contain local oil shale beds (Weeks, 1925).

The area was uplifted and subjected to erosion in Middle Tertiary times with the formation of the ancestral Colorado River Valley. Quaternary pediment, terrace gravel and aeolian deposits formed on the exposed Cretaceous surfaces and alluvial deposits were formed along the various fluvial systems that were established.

LITTLE BOOK CLIFFS/WILDHORSE WSA (CO-070-066)

The Precambrian-Cretaceous section is present under the WSA according to available drilling information. No other information on the lithologies is currently available. Within the boundaries of the WSA, only the Cretaceous and Tertiary units are exposed. The near-shore environments of the Mt. Garfield Formation characterize the Cretaceous section in this area. Isolated outcrops of the Tertiary Wasatch Formation cap the mesa tops and represent a period of fluvial or lacustrine deposition adjacent to major terrestrial lake systems.

Figures II-1 through II-10 provide a pictorial summary of the GRA and WSA.

FIGURE II-1
Power plant and
coal mine S of WSA.

LITTLE BOOK CLIFFS

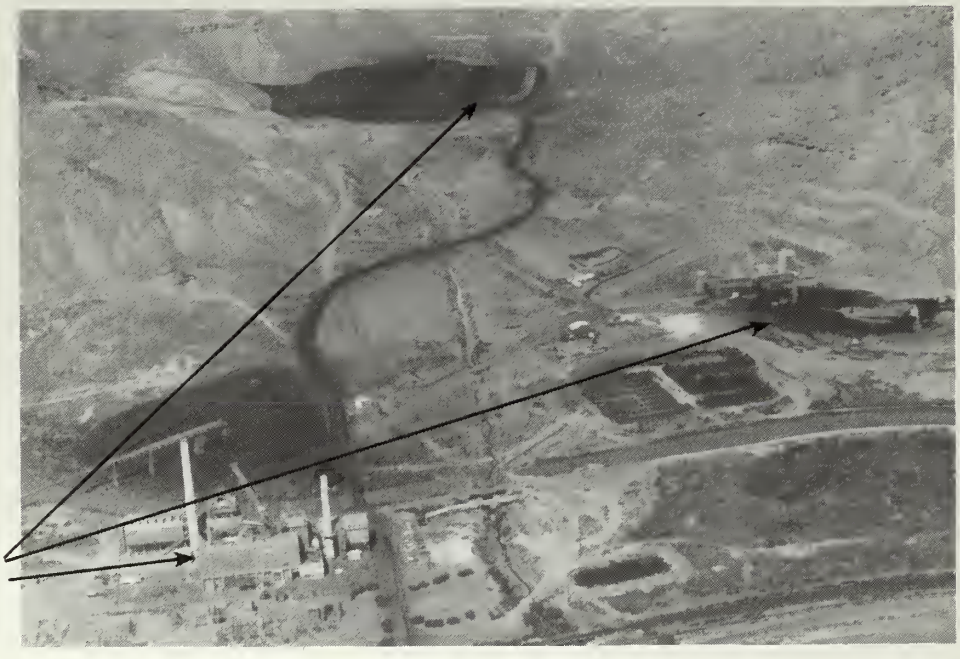


FIGURE II-2
Power plant and
mine - looking N.

LITTLE BOOK CLIFFS

FIGURE II-3
Oil drilling site N of WSA.

LITTLE BOOK CLIFFS

FIGURE II-4
Drill site - drilling completed. Coal Canyon just outside WSA.

LITTLE BOOK CLIFFS

FIGURE II-5
Coal outcrop along SW side.

LITTLE BOOK CLIFFS

FIGURE II-6
Old coal mine west and south of WSA.

LITTLE BOOK CLIFFS

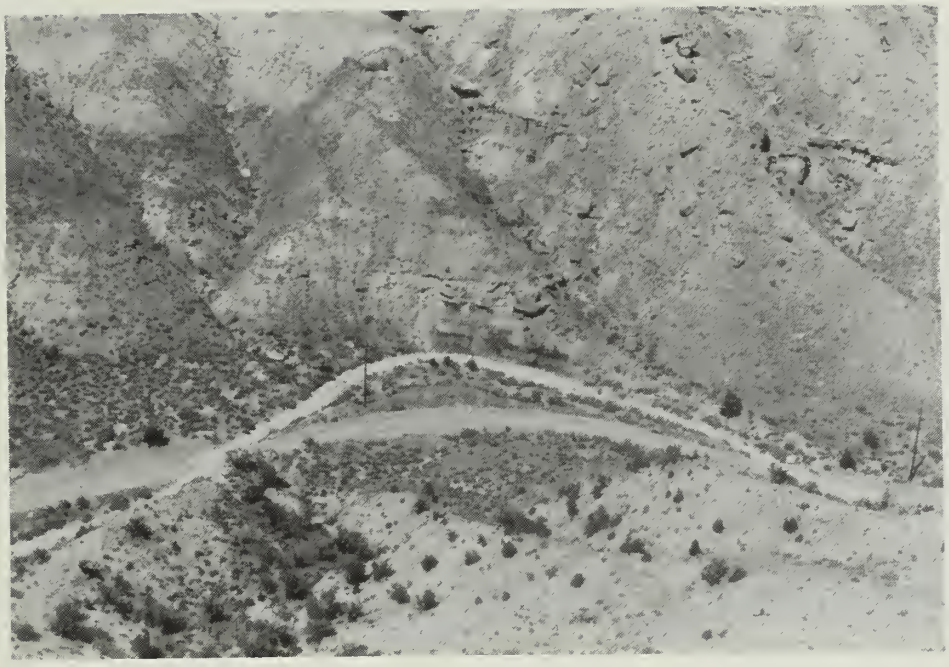


FIGURE II-7
Coal outcrop looking north.

LITTLE BOOK CLIFFS

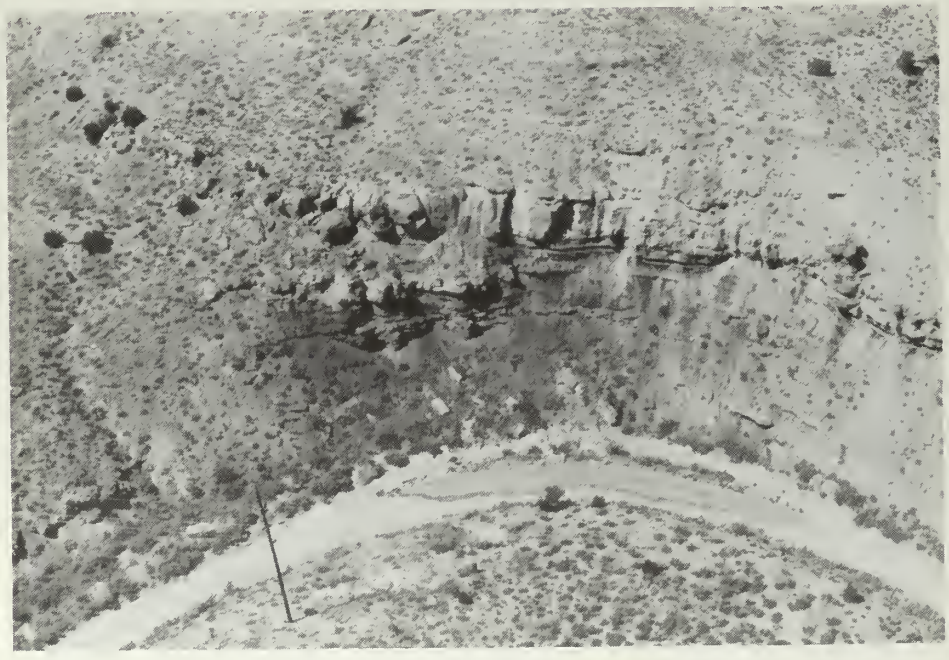


FIGURE II-8
Coal outcrops. Coal Canyon just outside WSA.

LITTLE BOOK CLIFFS

FIGURE II-9
Gearhart coal mine
S of WSA.

LITTLE BOOK CLIFFS

FIGURE II-10
Coal outcrop
S of WSA in
Gearhart mine.

LITTLE BOOK CLIFFS

SECTION III

ENERGY AND MINERAL RESOURCES

KNOWN MINERAL DEPOSITS

The known mineral deposits in the Little Book Cliffs/Wildhorse GRA consists mostly of coal, gas wells, sand and gravel, some uranium and copper deposits.

The gas wells in the GRA occur mostly in the major gas fields contained in the GRA. These gas fields, Hunter Canyon, Asbury Creek, Cameo, Coon Hollow, Coal Gulch and Fruita, are located in the northern portion of the GRA. A few smaller, scattered gas fields contain wells in the western portion of the GRA. Of the 55 wells known in the GRA, 12 are producing, 35 are dry, and 8 are abandoned, or shut-in (Overlay C, Appendices B and D). In addition, 6 oil or gas wells are visible on the aerial photos in Appendix A (Lepley, 1982, Personal Communication; photo numbers 3-6-36, and 3-5-8 Appendix A). A gas well marked on the Round Mountain Quadrangle topographic map (Appendix A), is seen in aerial photograph 3-6-38 (Appendix A). The production horizon, cumulative production, and type of trap for the six aforementioned gas fields are summarized as follows:

Gasfield	Productive Horizon (all Cretaceous)	Cumulative Production in million cubic feet (as of 1-1-78)	Type of Trap
Asbury Creek	Dakota, Buckhorn Tongue	2,406,841	Stratigraphic Structural
Cameo	Dakota, Buckhorn Tongue	29,238	Stratigraphic Structural
Coal Gulch	Mesaverde, Dakota	110,614	Unknown Stratigraphic
Coon Hollow	Mesaverde	S1	Unknown
Fruita	Buckhorn	607,228	Unknown
Hunter Canyon	Cozzette Member	1,879,115	Stratigraphic

(Schwochow, 1978)

The coal in this GRA occurs mostly in Coal Canyon, which contains part of the Bookcliffs Coal Field (Overlay C and Appendix B). The status of the 40 coal mines in this GRA is unknown.

Two distinct coal mines, the Cameo and Gearhart (T10S, R98W, section 27 and T11S R98W, Section 6, respectively) are visible in the aerial photos in Appendix A (numbers 3-7-24, 3-8-28, 3-8-30). In addition, the Cameo mine is noted on the USGS 7-1/2 minute topographic map for Cameo, Colorado (Appendix A), and the Gearhart

Mine is noted on the USGS 7-1/2 minute topographic map for Round Mountain, Colorado (Appendix A). The Cameo Mine, owned by GEX Colorado, Inc., produced 207,208 tons as of 1980 (Colorado Div. Mines Rept., 1980). More current production statistics for the Cameo and Gearhart mines are not available.

The majority of the sand and gravel deposits occur in the southern portion of the GRA along the Colorado River and it's tributaries. Of the 74 locations on Overlay D, 69 of the sand and gravel operations are inactive (or, have been abandoned or reclaimed), and 8 are active. The active sand and gravel mines are shown on overlay D (#13, #17, #22, #44, #45, #47, #48, #60; see also Appendices B and D).

The uranium mines and one copper deposit are scattered throughout the GRA. Of the 15 uranium mines, 10 are coal producers as well. Of the 15, 1 is inactive, with the status of the other 14 unknown. The active copper mine, owned by the Colorado Copper Company (Overlay B, T1S, R1W, section 14, #3) is located in the southwest section of the GRA. Production statistics on the uranium and copper mines are not available.

The following addresses the known mineral deposits in the Little Book Cliffs/Wildhorse WSA.

LITTLE BOOK CLIFFS/WILDHORSE WSA (CO-070-066)

The known mineral deposits in this WSA consist of a gas field and a known coal field. The Cameo Gas Field is contained in the northern portion of the WSA (Overlay C). Two gas or oil wells appear to be within the boundaries of the WSA. One is located in T9S, R99W, section 34 (Aerial photo 3-6-38, Appendix A) and is noted in pencil on the USGS 7-1/2 minute Round Mountain Quadrangle map (Appendix A). The second well is located in T9S, R99W, section 15 near the extreme northern border of the WSA between Redrock and East Redrock Canyon (Aerial photo 3-5-10, and USGS 7-1/2 minute Winter Flats Quadrangle map, both in Appendix A). In addition, five wells included on Overlay C are on or near the border of the WSA (#53, #54, #55, #71, #72 - see Appendices B and D). The status of these wells is unknown.

The WSA also contains the Book Cliffs Coal Field. There are however, no known coal mines in the WSA. As previously mentioned, there are a number of coal mines close to the west and south borders of the WSA (Overlay C).

Tributaries of the Colorado River dissect the WSA. There are, however, no known deposits of sand and gravel in this WSA despite the presence of the tributary systems.

KNOWN PROSPECTS, MINERAL OCCURRENCES, AND MINERALIZED AREAS

The known prospects, mineral occurrences, and mineralized areas are shown on the overlay in the GRA. Exposed coal beds are noted in T11S, R98W, sections 3-6 (Aerial photo 3-8-28, Appendix A). There is no published information on further prospects.

The following addresses the known prospects, mineral occurrences and mineralized areas in the Little Book Cliffs/Wildhorse WSA.

LITTLE BOOK CLIFFS/WILDHORSE WSA (CO-070-066)

The prospects in this WSA are mostly for coal. Exposed coal beds and coal drilling are noted on the Round Mountain Quadrangle map and on aerial photo 3-7-30 (Appendix A). In addition, exposed coal beds in Coal Canyon, part of which is in the southern portion of the WSA, are seen in aerial photos 3-8-28, 3-8-30, and 3-8-32 (Appendix A).

On or near the northwest border of the WSA are four mines or prospects, possibly for coal. (Lepley, 1982, Personal Communication, aerial photo 3-5-11, Appendix A).

MINING CLAIMS, LEASES AND MATERIAL SITES

In the Little Book Cliffs/Wildhorse Area GRA, there are 26 unpatented mining claims, of which, 19 are lode claims, 6 are placer claims and 1 tunnel site (Overlay A). These claims are located in sections 35 and 36, T10S, R98W; section 6, T11S, R97W; section 1, T11S, R98W; section 2, T12S, R97W; section 35, T1S, R1W (Ute P.M.); section 35, T1S, R1E (Ute P.M.); and section 6, T2S, R1E (Ute P.M.). This information was obtained from the Bureau of Land Management's June 14, 1982, Geographic Index (Appendix C).

There are no patented claims located within the GRA.

Information on leases and material sites was not obtained for the GRA.

LITTLE BOOK CLIFFS/WILDHORSE WSA (CO-070-066)

As of June 14, 1982, there were no unpatented or patented mining claims, leases or material sites located within the WSA.

MINERAL DEPOSIT TYPES

The mineral deposits found in the Little Book Cliffs/Wildhorse GRA consist of gas, coal, copper, uranium and sand and gravel.

The GRA contains six major gas fields, along with numerous other smaller gas fields. The fields are located in the middle to northern section of the GRA.

The coal is found in the GRA in the Book Cliffs Coal Field, which is also a part of the Cretaceous Mesaverde Group (Speltz, 1976). The coal is mainly high-volatile C bituminous, with some high-volatile B present (Landis, 1959). In the 255 square miles of the Book Cliffs Coal Field, 2,293 million tons of bituminous coal is estimated to have been originally present (Landis, 1959).

The coal in the Mesaverde Group formed during the Cretaceous in a large geosyncline along the general line of the present Rocky Mountain range. As seas advanced and retreated, a trough through the geosyncline filled with erosion material from mountains to the west. Large marginal areas were subjected to non-marine deposition which changed as shorelines changed. It is thought coal was deposited in these marginal areas. The formation of the Rocky Mountains, along with other orogenic episodes, caused the region to break up into the principal coal fields of the state (Yingst, 1960).

Four of the most exploited coal seams occur in the Mt. Garfield Formation of the Mesaverde Group. These four seams are the Anchor (oldest), Palisade, Cameo, and carbonera (Schwochow, 1978). The Anchor is a small seam which does not have as much economic importance of the other three. The Palisade coal consists of several seams, usually having only one minable seam in any one location (Schwochow, 1978). Most of the seams are characterized by local irregularities in thickness. The Cameo seam is the most economically important, as it accounts for two-thirds of the fields production. Occupying a high position on the cliffs, coal seams in the Cameo are sometimes separated by shaly sandstones, and are intruded in some areas by sandstone dikes (Schwochow, 1978). The carbonera coal seams occur as discontinuous lenses above the Cameo (Schwochow, 1978).

The GRA contains some uranium deposits. Unfortunately, the formation in which these deposits occur was not ascertained due to lack of information. Uranium has been known to occur in western Colorado in the Jurassic Morrison Formation and in the faulted contact between the Triassic Chinle and Wingate Formations.

No information was available on the producing formation for the copper mine contained in the GRA. However, copper mineralization is known to occur south of the GRA as mineralized veins in both the igneous Precambrian rocks, and in the faulted area between the sedimentary Triassic Chinle-Wingate Formation (Schwochow, 1978).

Sand and gravel occurs mostly as Quaternary sediments along the Colorado River and its tributaries.

The following addresses the mineral deposit types of each WSA in the Little Book Cliffs/Wildhorse Area GRA.

LITTLE BOOK CLIFFS/WILDHORSE WSA (CO-070-066)

The mineral deposits in the WSA include gas and coal. The southern portion of the WSA contains the Cameo Gas Field, which is discussed at length in the preceding segment on the gas fields in the GRA (please refer to the discussion for information on the Cameo). Likewise, the WSA contains the Book Cliffs Coal Field, which is discussed in detail in the preceding segment on the coal fields in the GRA (please refer to the above discussion for information on Little Book Cliffs).

MINERAL ECONOMICS

The mineral resources found in this GRA include coal, gas, uranium, copper, and sand and gravel. Coal is produced from the Cretaceous Book Cliffs Coal Field. Two coal mines, the Cameo and Gearhart, are present in the GRA. As of 1980, the Cameo Mine produced 207,208 tons of coal (McCaulley, 1980). Production statistics for the Gearhart Mine were not available. Coal production for Colorado mines is currently at an all time high. Approximately 20,000,000 tons of high-grade low-sulphur coal was produced from open pit and underground operations (Colo. Div. Mines Rept., 1980 and Schwochow, 1978). The future looks encouraging for coal as more and more utilities are switching back to coal for power generation (Schwochow, 1978; Colo. Div. Mines Rept., 1980). Changes in technology and improvements in combustion/distillation techniques will increase the demand for Colorado coal, and coal by-products (Gentry, Personal Communication, 1982).

Gas in the GRA is produced mostly from gas fields located in Cretaceous sedimentary formations. Cumulative production as of 1-1-78 for six major gas fields is summarized in Section III under "Known Mineral Deposits". Specific information on reserves and potential was not available for any of the gas fields contained in the GRA. These deposits will have continuing importance as long as the United States is a net importer of oil and gas. Current demand for petroleum products will maintain current levels or increase in the future (Petroleum Times Price Report, Oct. 1982). Exploration activity in western Colorado has slackened in the last six months with the number of active rigs drilling dropping approximately 15% (Heylmun, Personal Communication, 1982). Areas of current drilling activity include the Paradox Basin of Colorado and Utah, and areas north of the Colorado River in Mesa, Garfield and Moffat Counties, Colorado (Heylmun, Personal Communication, 1982).

Sand and gravel contained in the GRA is considered a "high place value" industrial mineral. "High place" minerals are of economic value only when the deposits are readily accessible, and in close proximity to a market (Eyde, Personal Communication, 1982).

The economic viability of the mineral resources in the Little Book Cliffs/Wildhorse WSA is summarized as follows:

WSA	Mineral Potential	Accessibility	Economic Potential [a]
Little Book Cliffs	Oil, Gas	Good	Good
Wildhorse WSA (CO-070-066)	Uranium-Vanadium	Good	Good
	Coal	Good	Good
	Copper	Good	Poor

[a] The economic potential rating is notwithstanding market demand fluctuations.

SECTION IV

LAND CLASSIFICATION FOR GEM RESOURCES POTENTIAL

After thoroughly reviewing the existing literature and data base sources, MSME/ Wallaby personnel plotted all known and documented mineral occurrences, mines, prospects, oil and gas fields, sand and gravel operations, processing facilities, mining claims, mineral leases, and the locations of anomalous geochemical samples from the National Uranium Resources Evaluation - Hydrological Stream Sediment Reconnaissance - Airborne Radiometric and Magnetic Survey (NURE-HSSR-ARMS) programs. This plotted information and the data bases on each WSA were made available to a multi-faceted team of experts which made three successive evaluations of the GEM resource potential of each of the WSA's.

The team or panel of geological experts was comprised of:

Dr. Paul Gilmour: Base and precious metal deposits in western U.S. and Canada, expert on Precambrian mineral resources.

Mr. Ted Eyde: Base and precious metal deposits in western U.S., expert on industrial mineral resources.

Mr. Annan Cook: Base and precious metal deposits in western U.S., expert on porphyry deposits and mine evaluation.

Mr. Edward Heylmun: Oil, gas and oil shale deposits of western U.S.

Dr. Robert Carpenter: Mineral deposits of Colorado and western U.S., expert on geology of Colorado.

Dr. Donald Gentry: Expert in coal and oil shale deposits of Colorado and western U.S.

Dr. Larry Lepley: Expert in remote sensing and geothermal resources;

Mr. Walter E. Heinrichs: Geophysics and base and precious metal deposits of western U.S., expert on porphyry copper deposits.

As indicated earlier, Dr. Gentry and Mr. Ted Eyde made certain field investigations as result of the base data analysis phase. The purpose of the field investigations was to either verify the existing data or assess relatively unknown areas. Dr. Lepley reviewed all aerial photographs for observable anomalies, which were then investigated by the field team, or verified against the existing base data.

The evaluations were then made on the basis of examination of the data bases, field investigations and the individual experiences of the members of the panel in such areas as base and precious metal, industrial and energy mineral deposits; oil and gas deposits; and geothermal resources. In the course of these evaluations, every attempt was made to objectively rate the potential for a particular commodity within the respective study area. In this effort, the evaluation criteria proposed by the Bureau was rigorously used. The classification scheme used is shown in Table IV-1. In many cases the lack of information did not allow for a full determination

TABLE IV-1
RESOURCE RATING CRITERIA

CLASSIFICATION SCHEME

1. The geologic environment and the inferred geologic processes do not indicate favorability for accumulation of mineral resources.

2. The geologic environment and the inferred geologic processes indicate low favorability for accumulation of mineral resources.

3. The geologic environment, the inferred geologic processes, and the reported mineral occurrences indicate moderate favorability for accumulation of mineral resources.

4. The geologic environment, the inferred geologic processes, the reported mineral occurrences, and the known mines or deposits indicate high favorability for accumulation of mineral resources.

LEVEL OF CONFIDENCE SCHEME

A. The available data are either insufficient and/or cannot be considered as direct 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 in support or refute the possible existence of mineral resource.

of the GEM resource potential and the panel was forced to leave some areas unranked or classified for some commodities. The situation thus arises where there is an area that has been unclassified for a commodity, despite a reported occurrence, because it is next to an area where there is insufficient data to make a meaningful attempt at classification. Nonetheless, each resource has been additionally rated as to what level of confidence the panel of experts attached to the selected classification level. This is denoted by the letter associated with each rate classification. These are defined in Table IV-1.

A further restraint on this classification and delineation effort comes in the area of the lack of subsurface information. Some areas are very well known from past exploration efforts and have an abundance of subsurface information. Other areas are practically unknown due to an absence of any past exploration or development efforts.

The WSA's, for the most part, are not well known geologically. For this reason, our expert team had to extrapolate geologic information from adjacent areas to make any sort of reasonable classification with some level of confidence. The following pages address those resources considered to be leasable, locatable and/or salable with associated maps locating the resource area (Figures IV-1 through 3):

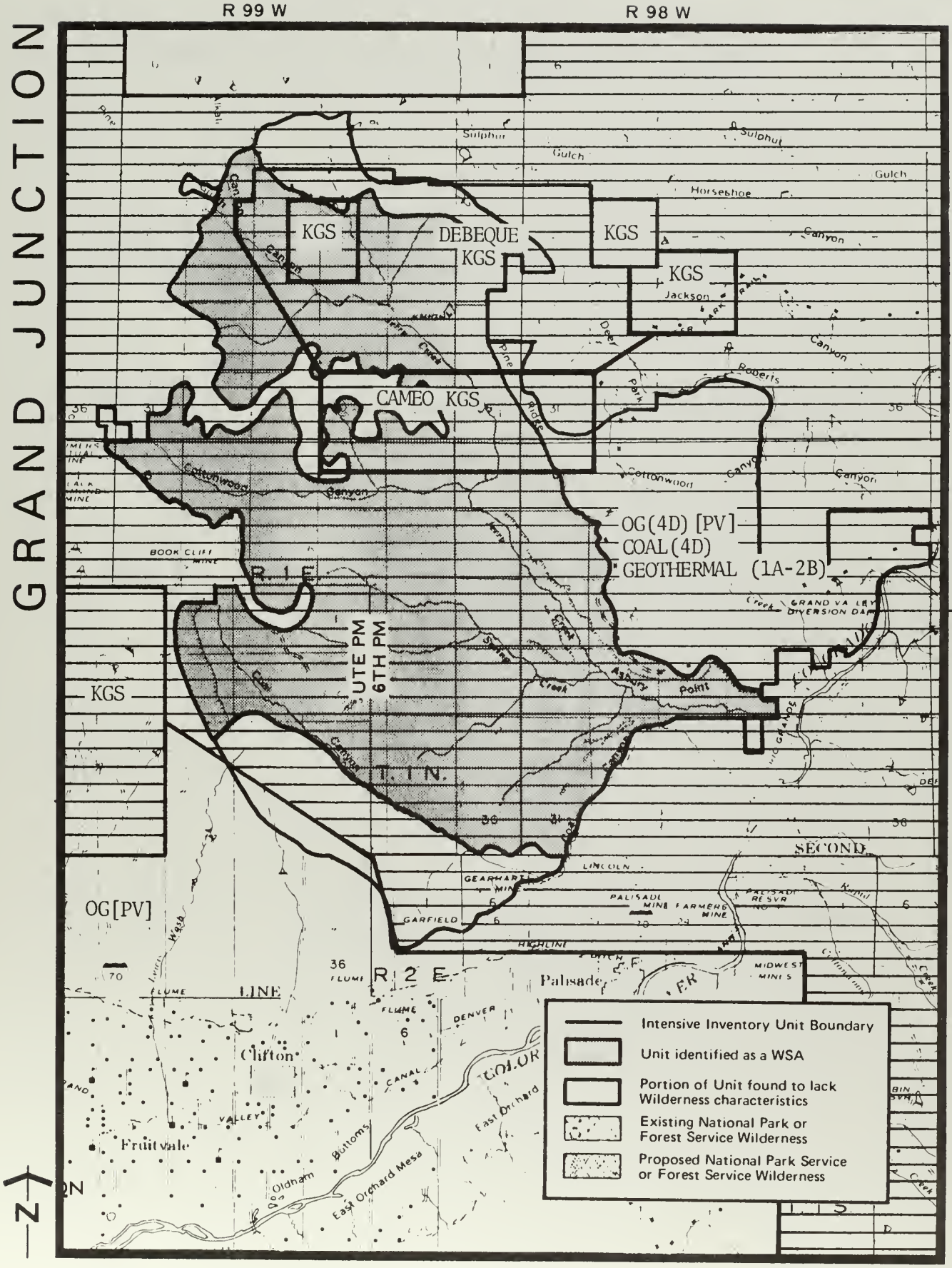
- **LEASABLE RESOURCES**

LITTLE BOOK CLIFFS/WILDHORSE WSA (CO-070-066)

Resource	Classification	Comments
Oil & Gas	4D	The Cameo anticline extends across the northern half of the WSA. Production from the Cameo Oil and Gas field, located on the Cameo anticline, is from the Cretaceous Dakota-Buckhorn sequence.
Coal	4D	The Mt. Garfield and Sego facies of the Mesaverde group have yielded coal. These units extend into the WSA.
Geothermal	1A-2B	Unknown potential.

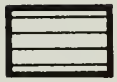
CO-070-066

Little Book Cliffs/ Wildhorse WSA



MMS/LEASABLE RESOURCES
Figure IV-1

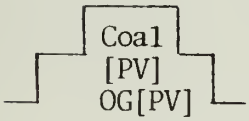
LEGEND FOR MINERALS MANAGEMENT SERVICE CLASSIFICATIONS



Defined KGS and/or Coal Leasing Areas

Areas Prospectively Valuable for Sodium or Potassium

Defined Oil Shale Leasing Area



Areas Identified as Prospectively Valuable for Coal or Oil, Gas

Coal [NPV]
OG [NPV]

Areas Identified as Not Being Prospectively Valuable for Coal, or Oil, Gas

LOCATABLE RESOURCES

LITTLE BOOK CLIFFS/WILDHORSE WSA (CO-070-066)

Resource	Classification	Comments
Precious Metals	1A	
Base Metals	1A	
Locatable Energy Minerals	3C	Uranium-Vanadium potential associated with Cretaceous Mancos Shale
Other Locatable Minerals		Unknown

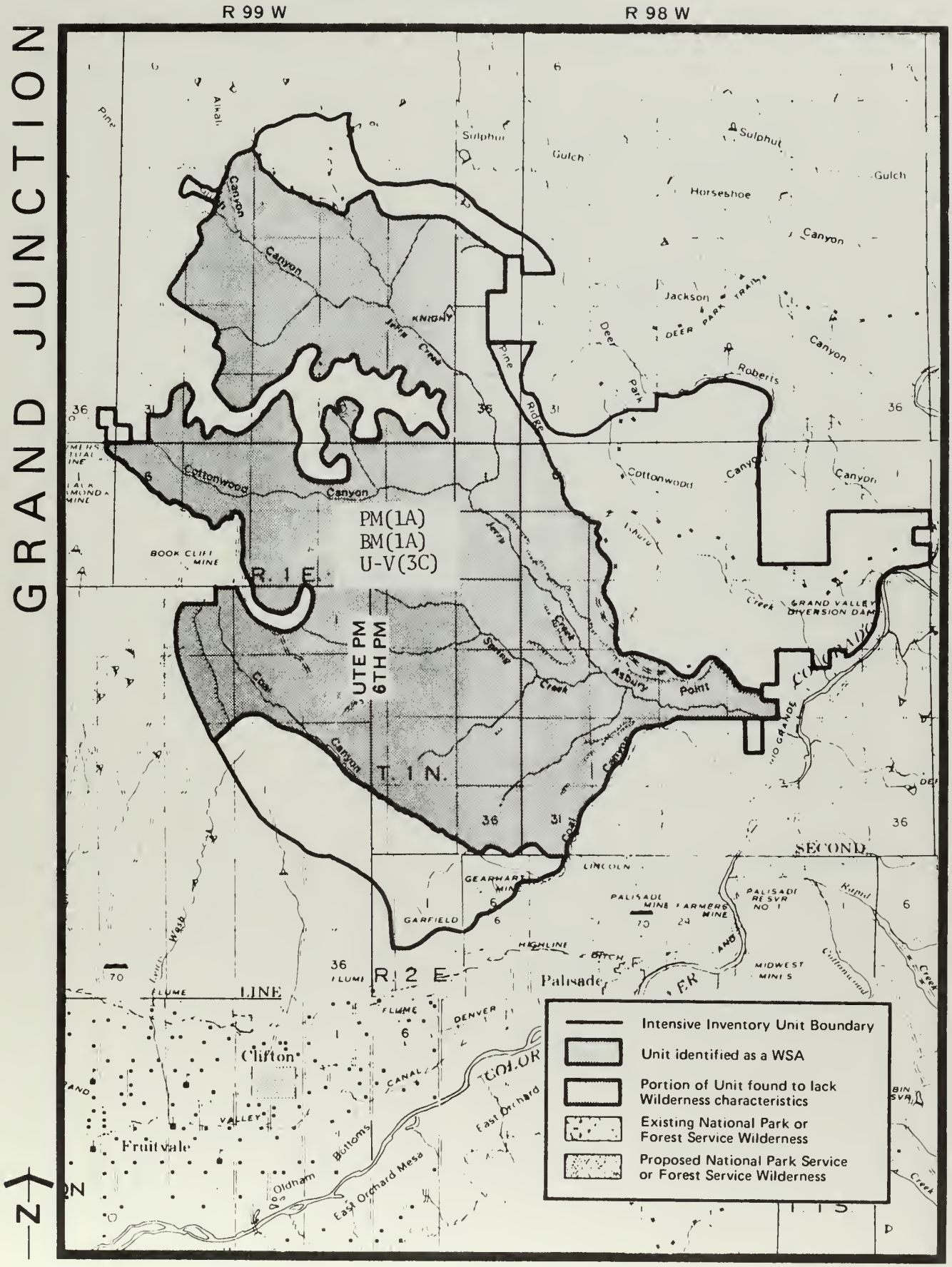
SALABLE RESOURCES

LITTLE BOOK CLIFFS/WILDHORSE WSA (CO-070-066)

Resource	Classification	Comments
Bentonite	3C	The Mancos Shale may contain favorable units for bentonite. The economic potential is rated as low to moderate.
Dimension Stone	4D	Deposits known in the Hunter Canyon Formation. Possibly in the Mt. Garfield and Sego Sandstone. There are no existing developments in the WSA. The economic potential is rated as low to moderate.

CO-070-066

Little Book Cliffs/ Wildhorse WSA

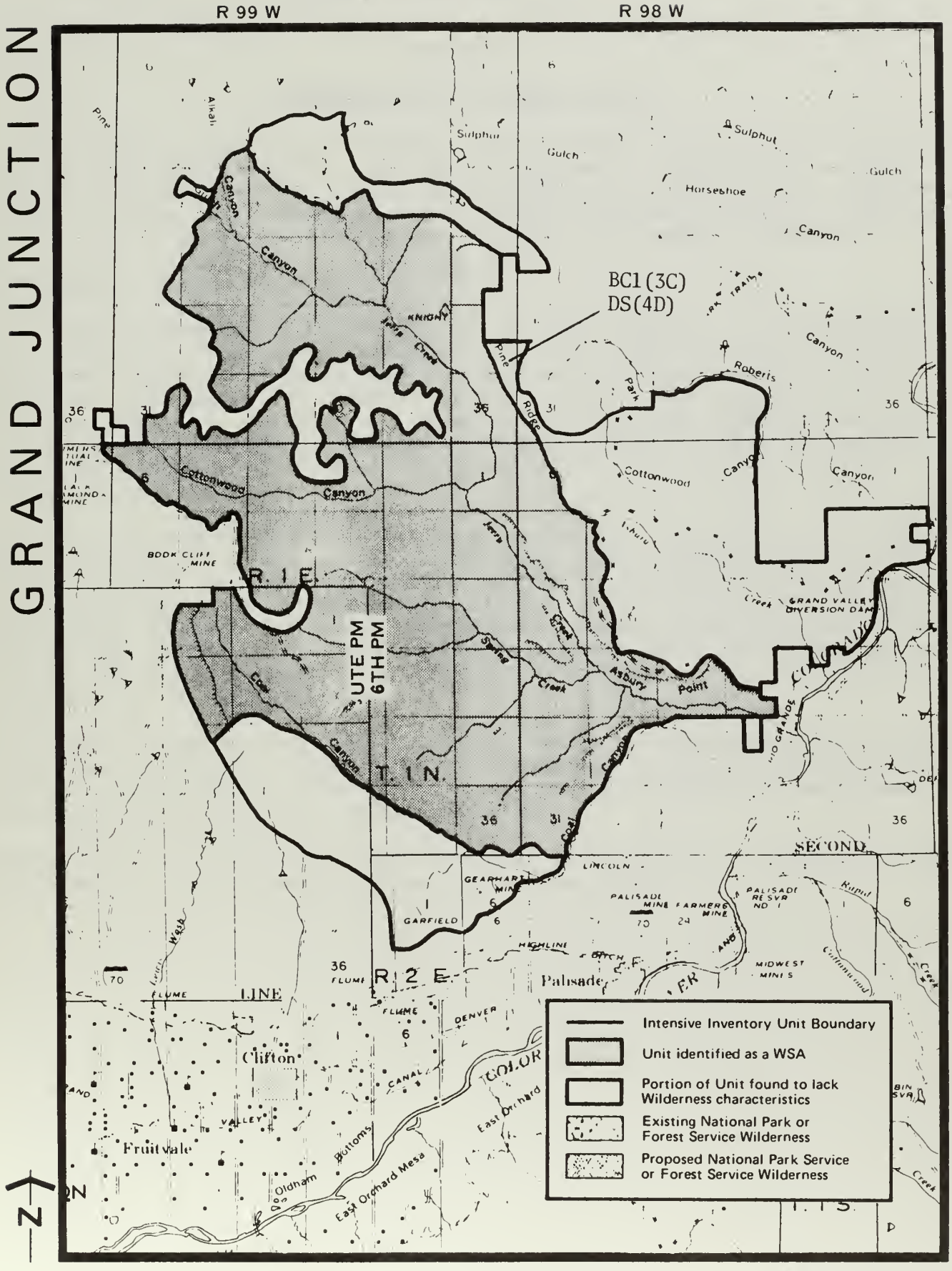


(After BLM, 1980)

LOCATABLE RESOURCES
Figure IV-2

CO-070-066

Little Book Cliffs/ Wildhorse WSA



SALABLE RESOURCES
Figure IV-3

SECTION V

RECOMMENDATIONS FOR FURTHER STUDY

In the course of analyzing, assessing and evaluating the WSA in the Little Book Cliffs/Wildhorse Area GRA - both in the field and in available data - certain unknowns were uncovered that should be investigated in order that the WSA GEM resources be more fully documented. This section recommends the type of studies and data gathering that should be made to inventory more completely the WSA.

LITTLE BOOK CLIFFS/WILDHORSE WSA (CO-070-066)

Since this area has potential for oil, gas and coal resources, it is recommended that every effort be made to ascertain the full extent of this potential. Cooperative agreements should be made with various oil and gas producers to obtain proprietary information not available to this study. Such information as the projected reserves of the area, the importance of structural zones in localizing oil and gas pools, and the exact identification of pay zones within the generally favorable lithologies is of vital importance in the exact areal delineation of sub-surface potential.

In addition, a detailed program of geologic mapping and sampling should be carried out to fully delineate the extent of the coal bearing horizons in the adjacent Cretaceous Dakota section. Any sampling carried out under such a program must include analysis of the coal material for the ash and sulphur content as well as BTU content. Much work has already been done on lithofacies reconstruction in the Cretaceous in adjacent areas. Studies of this nature would be useful in determining the probable northeastern extent of the coal measures and thus, the viability of the coal as a minable resource.

The outcrops of the Tertiary Wasatch Formation should be sampled for their kerogen content and correlated to other units in northwestern Colorado and eastern Utah. Examination of the Wasatch units should be made by paleontologists for environments favorable for the preservation of mammal remains.

Examination of the outcrops of the Mancos Shale for specialty or structural clays should be made in the course of any geologic mapping program.

SECTION VI

REFERENCES AND SELECTED BIBLIOGRAPHY

REFERENCES

Baars, D.L., et al, 1981, Tectonic evolution of the Paradox Basin, Utah and Colorado: in Geology of the Paradox Basin; Rocky Mtn. Assoc. Geologists; Field Conf., Guidebook, 1981, pp. 23-31.

Bureau of Land Management, 1982, Mineral Resources Inventory, File Data, BLM Grand Junction District Office.

Carpenter, Dr. R., 1982, Personal Communication, Expert on the geology of Colorado.

Carter, W.D., and Gualtieri, J.L., 1965, Geology and uranium/vanadium deposits of the LaSal quadrangle, San Juan County, Utah, and Montrose County, Colorado, USGS Prof. paper 508.

Cashion, W.B., 1973, Geologic and structure map of the Grand Junction quadrangle, Colorado and Utah; USGS Miscellaneous Investigation Series, I-736, scale 1:250,000.

Craig, L.C., et al, 1955, Stratigraphy of the Morrison and related formation, Colorado Plateau region - a preliminary report; USGS Bull. 1009-E, pp. 125-168.

Colorado Div. of Mines Report, Metals - Nonmetals; 1980.

Eyde, T., 1982, Personal Communication, Expert on industrial mineral resources.

Gentry, Dr. D., 1982, Personal Communication; expert in coal and oil shale deposits.

Gilmour, Dr. P., 1982, Personal Communication; expert on Precambrian mineral resources.

Gunter, C.E., 1962, Oil and gas potential of upper Cretaceous sediments, southern Piceance Basin; in Exploration for Oil and Gas in Northwestern Colorado; Rocky Mtns. Assoc. Geol., 1962 Field Conf. Guidebook, pp. 114-117.

Heylmun, E., 1982, Personal Communication, Knowledgeable on oil, gas and oil shale deposits of western U.S.

Landis, E.R., 1959, Coal resources of Colorado; USGS bull. 1072-C.

Lepley, Dr. L., 1982, Personal Communications, expert in remote sensing and photo interpretation.

National Park Service (NPS), 1982, File Data.

Petroleum Times Price Report, Oct. 15, 1982.

Richardson, G.B., 1907, The Book Cliffs Coal Field between Grand River, Colorado and Sunnyside, Utah, USGS, Bull. 316.

Richardson, G.B., 1909, Reconnaissance of the Book Cliffs Coal Field between Grand Junction, Colorado and Sunnyside, Utah, USGS Bull. 371.

Schwochow, S.D., 1978, Mineral resources survey of Mesa County, a model study; Colorado Geological Survey, Resource Series 2, 110p.

Shawe, D.R., et al, 1968, Stratigraphy of Slick Rock district and vicinity, San Miguel and Dolores Counties, Colorado; USGS Prof. Paper 576-A.

Speltz, C.N., 1976, Strippable coal resources of Colorado; location, tonnage, and overburden; USBM IC-8713.

Stewart, J.H., et al, 1959, Stratigraphy of Triassic and associated formations in part of the Colorado Plateau region; USGS Bull. 1046-Q, pp. 487-576.

Vanderwilt, J.W., 1947, Mineral Resources of Colorado; Colorado Mineral Reserve Board, 547 p.

Weeks, H.J. 1925, Oil and water possibilities of part of Delta and Mesa Counties, Colorado; Colorado Geologic Survey Bull. in No. 28.

Yingst, P.O., 1960, Coal resources of Colorado; Colorado School of Mines, Mineral Indust. Bull.; Vol. 3, No. 5, pp 1-8.

Young, R.G., 1959, Cretaceous deposits of the Grand Junction area, Garfield, Mesa and Delta Counties, Colorado; in Rocky Mtn. Assoc. Geol. Symposium on Cretaceous rocks of Colorado and adjacent areas, pp. 17 - 25.

BIBLIOGRAPHY

Cashion, W.B., 1973, Geologic and structure map of the Grand Junction quadrangle, Colorado and Utah; U.S.G.S. Miscellaneous Investigation Series, I-736, scale 1:250,000.

Craig, L.C., et al, 1955, Stratigraphy of the Morrison and related formations, Colorado Plateau region - a preliminary report; U.S.G.S. Bull. 1009-E, pp 125-168.

Dubbin, C.E., 1950, Petroleum geology of Colorado; Colo. Sch. Mines, Quart. Vol. 45, No. 13, p 1-12.

Enrich, E.B., 1930, Report of the Garmesa Gas Field, Garfield and Mesa Counties, Western Colorado. Prepared for the Fulton Petroleum Corp., 9 p. (Twps. 7 and 8S, RS 102-103W).

Erdmann, C.E., 1934, The Book Cliffs coal field in Garfield and Mesa Counties, Colorado; U.S.G.S. Bull. 851, 150 p.

Hart, Stephen S., 1976, Geology for planning in the Redlands area, Mesa County, Colorado; Colo. Geol. Surv., Map Series 5.

Gow, Kenneth L., 1950, Douglas Creek gas field [Colorado]; in Petroleum Geology of the Unita Basin, Utah Geol. Soc. Guidebook, No. 5, pp 139-146.

Jones, D.C., 1976, Coal mines and coal fields of Colorado; Colo. Geol. Sur., Information Ser. 1, scale 1:500,000.

Jones, D.C. and Murray, D.K., 1976, Coal mines of Colorado, statistical data; Colo. Geol. Surv., Information Series #2.

Jones, D.C., et al, 1978, Coal resources and development map of Colorado; Colo. Geol. Surv., Map Series 9, scale 1:500,000.

Jones, D.C. and Murray, D.K., 1976, Oil and gas fields of Colorado, Statistical Data; Colo. Geol. Sur., Information Series #3.

Jones, D.C., 1975, Oil and gas fields in Colorado; Colo. Geol. Surv., Open File Rept. 79-9.

Kelley, Vincent C., 1956, Influence of regional structure and tectonic history upon the origin and distribution of uranium on the Colorado Plateau; U.S.G.S. Prof. Paper 300, pp 171-178.

Krampert, Edward W., 1934, Geological characteristics of producing oil and gas fields in Wyoming, Colorado and northwestern New Mexico; In Problems of Petroleum Geology (Sidney Powers memorial volume), pp 719-733, Am. Assoc. Pet. Geol., Tulsa, Oklahoma.

Krey, Max, 1962, North flank of the Uncompahgre arch, Mesa and Garfield Counties, Colorado; in Exploration for oil and gas in northwest Colorado, Rocky Mtn. Assoc. Geol., 1962 Field Conf. Guidebook. Denver, pp 111-113.

Lakes, Arthur, 1970, Sketch of the oil fields of Colorado; Min. Eng. World, Vol. 26, p 419.

Lakes, Arthur, 1907, Oil Shale in Colorado, Book Cliffs district; Min. Rept.; Vol. 55, p 266.

Lakes, Arthur, 1904, The Book Cliff Coal Mines; Coal Seams near Grand Junction, Colorado, which Exhibit Interesting Peculiarities in their Locations Formations; Mines Miner., Vol. 24, No. 6, Pp 289-291.

Lakes, Arthur, 1902, The Western Oil Field of Mesa & Rio Blanco Counties; Geologically Favorable to oil; Mines Miner., Vol. 22, pp 388-389.

Landis, E.R., 1959, Coal resources of Colorado; U.S.G.S. Bull. 1072-C.

Mapco, unknown, Oil and gas development maps of Colorado; Mapco Diversified, Inc., Denver, Colorado.

Murray, D.K., 1980, 1979 Summary of coal resources in Colorado; Colo. Geol. Surv., Spec. Publ. 13.

Owen, A.E., 1956, San Arroyo-Bar-X area, Grand County, Utah and Mesa County, Colorado, in Intermountain Assoc. of Petroleum Geologist, 7th Ann. Field Conf., pp 195-198.

Quigley, W.D., 1960, Bar-X, San Arroyo, Westwater Creek gas fields, Colorado [abstr]; AAPG Bull., Vol. 44, No. 6, p 960.

Richardson, George B., 1909, Reconnaissance of the Book Cliffs coal field between Grand Junction, Colorado and Sunnyside, Utah; U.S.G.S. Bull. 371.

Richardson, George B., 1907, The Book Cliff Coal Field between Grand River, Colorado, and Sunnyside, Utah; U.S.G.S. Bull. 316, pp 302-320. U.S.G.S. Bull. No. 371, 54 p.

Schwochow, Stephen D., 1978, Mineral resources survey of Mesa County - a model study; Colo. Geol. Surv., Resource Series 2, 110 p.

Speltz, C.N., 1976, Strippable coal resources of Colorado; location, tonnage, and characteristics of coal and overburden; USBM IC-8713.

Young, R.G., 1955, Sedimentary facies and intertonguing in the Upper Cretaceous of the Book Cliffs, Colorado and Utah; GSA Bull., Vol. 66, No. 2, p 177-201.

Young, R.G., 1959, Cretaceous deposits of the Grand Junction area, Garfield, Mesa and Delta Counties, Colorado; in Rocky Mtn. Assoc. Geol. Symposium on Cretaceous rocks of Colorado and adjacent areas, pp 17-25.

Young, Robert G., 1973, Cretaceous stratigraphy of Four Corners area, in Guidebook of Monument Valley and vicinity, Arizona and Utah; N.M. Geol. Soc., Ann. Field Conf., Guidebook #24.

U.S. Department of Energy, Aerial radiometric and magnetic survey, Grand Junction National Topographic Map, Colorado, Rockies Wrap-Up-Project, Geodata International, Inc., 1981, 201 p., 108 fiche; Contract No. 80-447-S; PR No. 81-66; 5/15/81, Report No. GJBX-112(81).

U.S. Geological Survey and Colorado Geological Survey, 1977, Energy resources map of Colorado; U.S.G.S. Misc. Geol. Inv. Map I-1039.

Zapp, A.D., and Cobban, W.A., 1960, Some late Cretaceous stand lines in northwestern Colorado and northeastern Utah; U.S.G.S. Prof. Paper 450-B, pp B246-B249.