GEOLOGY, ENERGY, AND MINERAL (GEM) RESOURCE ASSESSMENT OF THE TWIN COULEE GEM RESOURCE AREA (GRA), MONTANA, INCLUDING THE TWIN COULEE WILDERNESS STUDY AREA (MT-067-212)

PHASE I

Contract No. YA-553-CT2-1055

Prepared for:

U.S. Bureau of Land Management

Prepared by:

Tetra Tech, Inc.
Pasadena, California

September 1983

EXECUTIVE SUMMARY

The U.S. Bureau of Land Management (BLM) has adopted a two-phase procedure for the integration of geologic, energy, and mineral (GEM) resources data concerning Wilderness Study Areas (WSAs). To facilitate this review, certain WSAs with similar geologic environments and mineral characteristics have been grouped together into larger GEM Resource Areas (GRAs). Using these guidelines, the Twin Coulee WSA was grouped into the larger Twin Coulee GRA. This report, which terminates the Phase I activities for the Twin Coulee GRA, is an evaluation and interpretation of existing data concerning the GEM resource potential in the WSA.

The Twin Coulee GRA contains only one WSA, the Twin Coulee WSA (MT-067-212). The Twin Coulee WSA is located in the BLM's Billings Resource Area, Lewistown District, Montana.

The Twin Coulee WSA is considered to have a moderate favorability based on indirect evidence for the potential occurrence of strategic minerals in oil shale (classified 3B); this classification is based upon known occurrences of strategic minerals and oil shale in the WSA (Cox and Cole, 1981; Desborough, Poole and Green, 1981). The WSA is considered to have a moderate favorability based on direct, but quantitatively minimal evidence for the potential occurrence of oil shale (classified 3C); this classification is based on known occurrences of oil shale in the WSA (Cox and Cole, 1981; Desborough, Poole, and Green, 1981). The potential for oil shale resources exists in the Heath Shale. A discrepancy exists between geologic maps for the area which materially affects the resource classifications involving Heath Shale (see Section 3.2). The WSA is considered to have a moderate favorability based on direct, but quantitatively minimal evidence, for the potential occurrence of limestone (classified 3C); this classification is based on known occurrences of the Madison Limestone in the area (Lindsey, 1980; Mineral Resources Development, Inc., 1979). There exists quantitatively minimal direct evidence to support a low favorability classification for the potential occurrence of other GEM resources in the study area (classified 2C). This classification is based on the geologic environment and the inferred geologic processes that have been identified within the WSA.

Additional geologic investigations would help supplement the GEM resource evaluation of the Twin Coulee WSA. Additional detailed geologic mapping and geochemical sampling is needed to confirm the location of the Heath Shale and the potential occurrence of strategic minerals. This mapping will provide specific data to define the location of the Heath Shale relative to the WSA boundary. A small amount of geologic data exists which should be reviewed by BLM personnel to gain additional insight into the potential occurrence of GEM resources within the WSA prior to making land management decisions.

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GEM RESOURCE AREA

TWIN COULEE

1.0 INTRODUCTION

1.1 Purpose of Study

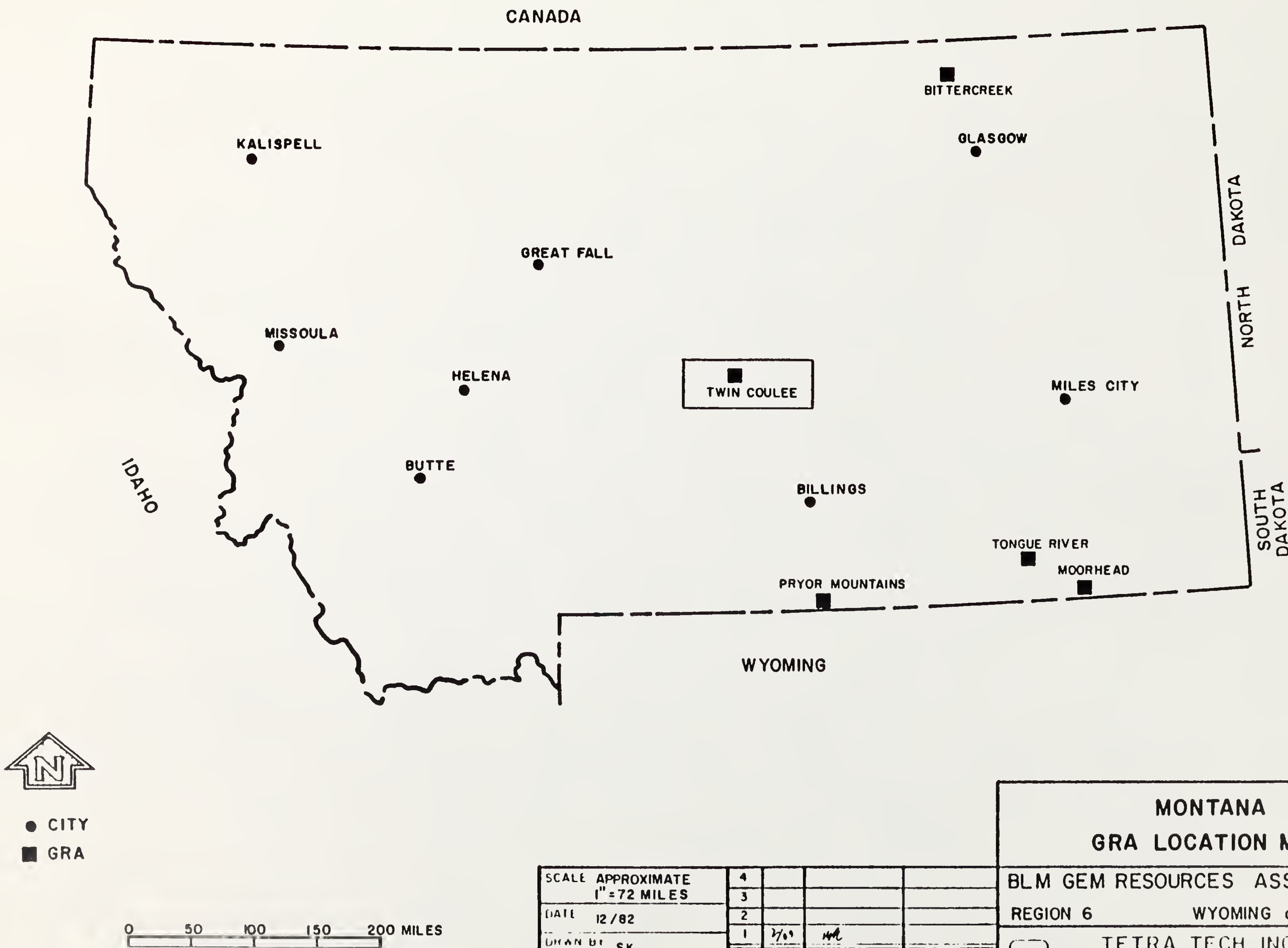
The U.S. Bureau of Land Management (BLM) has adopted a two-phase procedure for the integration of geologic, energy, and mineral (GEM) resources data for suitable/nonsuitable decisions concerning Wilderness Study Areas (WSAs). Phase I consists of a review and evaluation of existing data, resulting in an interpretation of the GEM resource potential in the WSAs. Phase II is designed to generate only the additional data required to support the GEM resource recommendations presented during Phase I. To facilitate this review, certain WSAs with similar geologic and mineral characteristics have been grouped together into larger GEM Resource Areas (GRAs). Using these guidelines, the Twin Coulee WSA was combined into the larger Twin Coulee GRA. This report, which terminates the Phase I activities for the Twin Coulee GRA, is an evaluation and interpretation of existing data concerning the GEM resource potential in the Twin Coulee WSA.

The GEM resource evaluations for this study were performed by Tetra Tech, Inc. for the U.S. Bureau of Land Management, under Contract No. YA-553-CT2-1055. This study was completed in January, 1983.

1.2 Location and Access

This GEM report covers the area identified as the Twin Coulee GEM Resource Area (GRA); the geographic location of the study area is shown in Figure 1.1, "GRA Location Map."

The Twin Coulee GRA contains one Wilderness Study Area (WSA): the Twin Coulee WSA (MT-067-212). The Twin Coulee WSA is located approximately between 46° 45'-46° 50' north latitude and 109° 10'-109° 20' west longitude in Golden Valley County, Montana. The WSA is comprised of approximately 6,870 acres in



MONTANA
GRA LOCATION MAP

BLM GEM RESOURCES ASSESSMENT
REGION 6 WYOMING and MONTANA
TETRA TECH INC
PASADENA, CALIFORNIA
FIGURE 1.1

SCALE APPROXIMATE 1" = 72 MILES	4				
	3				
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Township (T) 11 North (N), Range (R) 20 East (E), of the Prime Meridian (P.M.). The Twin Coulee WSA is in the BLM's Billings Resource Area, Lewistown Distict, Montana. Figure 1.2, "Topographic Map," illustrates the topography of the GRA area, as well as the location of the WSA within the GRA.

Access to the Twin Coulee WSA is from a county road that runs along the eastern margin of the WSA between Lewistown, Montana (U.S. Route 87) and Ryegate, Montana (U.S. Route 12). Jeep trails provide access from the county road into the WSA.

1.3 Basis for Report

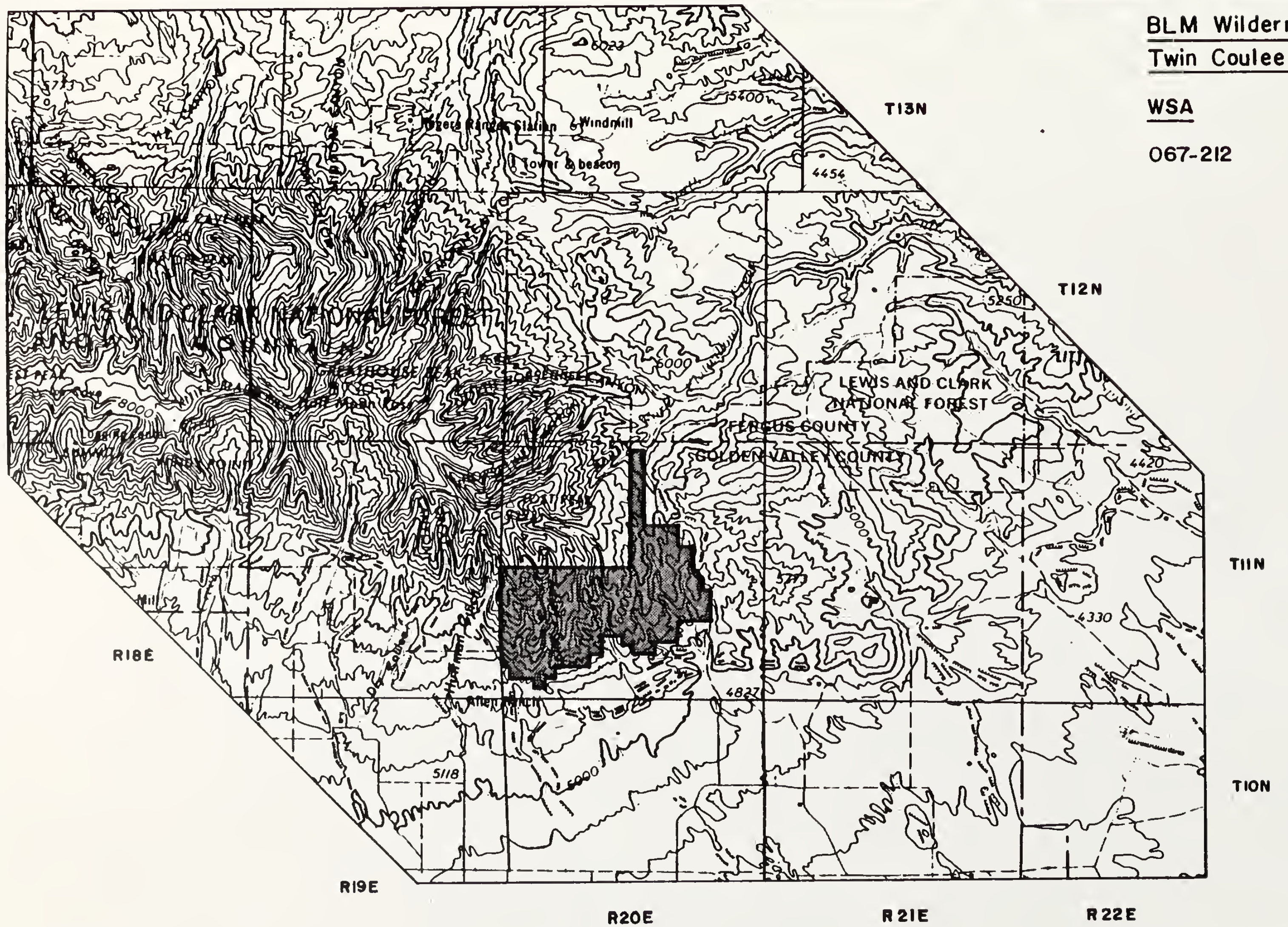
This report is based on an evaluation of existing data (both published and available unpublished data) collected from a variety of different sources. Some of the sources contacted during the preparation of this report include the U.S. Bureau of Land Management (BLM), the U.S. Geological Survey (USGS), the U.S. Bureau of Mines (USBM), the U.S. Department of Energy (DOE), the Wyoming Geological Survey, universities, and other sources.

The available literature was reviewed by a Project Team, assembled by the study contractor, comprised of authorities in the field of GEM resource evaluations. The members of the Project Team, and their associated technical disciplines, are identified below:

Mr. Charles S. Robinson	Metallic Minerals/Non-Metallic Minerals
Mr. Rollin E. Phipps	Oil and Gas
Mr. Andrew G. Alpha	Geothermal Resources
Mr. Stuart P. Hughes	Other Minerals
Mr. William A. Gallant	Other Minerals
Mr. Elmer M. Schell	Coal
Mr. John A. Hartley	Oil Shale/Paleontology

BLM Wilderness Study Areas Included in the Twin Coulee GRA

WSA	NAME	ACREAGE
067-212	Twin Coulee	6,870



Approximate Boundary of Wilderness Study Area

NOTE: Contours in 200 ft. Intervals

5 4 3 2 1 0 3 6 Miles

5 4 3 2 1 0 5 10 Kilometers

(USGS, 1954; limited revision, 1965)

Twin Coulee GRA, Montana

TOPOGRAPHIC MAP

BLM GEM RESOURCES ASSESSMENT
REGION 6 WYOMING and MONTANA

TETRA TECH INC
PASADENA, CALIFORNIA

FIGURE 1.2

SCALE	1" = 4 MILES 1:250,000
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2.0 GEOLOGY

2.1 General

The geology of the Twin Coulee GRA is illustrated on three maps: the Montana State Geologic Map (Ross et al., 1955), a 1° x 2° geologic map prepared by Mineral Resources Development, Inc. (1979), and a 1:125,000 geologic map prepared by Lindsey (1980). These maps, together with other available data listed in the references and selected bibliography section of this report, form the basis for certain conclusions arrived at in regard to GEM resources in the study area.

The Twin Coulee WSA occurs on the southeast margin of the Big Snowy uplift. The rocks that crop out within the WSA include the Lodgepole and Mission Canyon Members of the Madison Limestone, and the Big Snowy Group; all of these rocks are Mississippian in age (300-350 million years before present [m.y.B.P.]). Beneath the exposed rocks, and listed in ascending order, are the Precambrian Belt Supergroup rocks of Proterozoic age (1.6 billion years before present), which are overlain by the Flathead Sandstone of Cambrian age (500-600 m.y.B.P.), which is overlain by the Woolsey Shale and Meagher Limestone, which underlie the exposed Mississippian Madison Limestone.

2.2 Physiography

The Twin Coulee WSA falls within the unglaciated plateau section of the Great Plains physiographic province. Elevations within the WSA range from 5,500 to 7,600 feet on the upper flanks of the Big Snowy Mountains. Drainage in the region consists of perennial and intermittent streams that drain the area from north to south and into the Musselshell River. The climate is semiarid in the lowlands to subalpine in the higher areas. The area is heavily timbered. Precipitation occurs primarily as snow during the winter months, while in the summer, rainfall occurs during short, high-intensity storms which are common to much of the western Rocky Mountains.

2.3 Geologic Units

The geologic units that underlie the WSA include rocks from Precambrian Proterozoic through Upper Mississippian in age. The surficial deposits in the region are not mapped in detail but probably consist of alluvial and colluvial deposits. Figure 2.1, "Geologic Map," delineates the geologic formations that occur throughout the GRA. Figure 2.2, "Generalized Stratigraphic Column," is a generalized stratigraphic column that gives a brief description of all the stratigraphic units that underlie the Twin Coulee GRA.

2.3.1 Bedrock Units

The Precambrian Proterozoic rocks of the Newland Formation (part of the Belt Series) are the oldest rocks buried beneath the area and consist of dark gray limey shales (Lindsey, 1980). The Flathead Sandstone of Cambrian age overlies the Precambrian rocks.

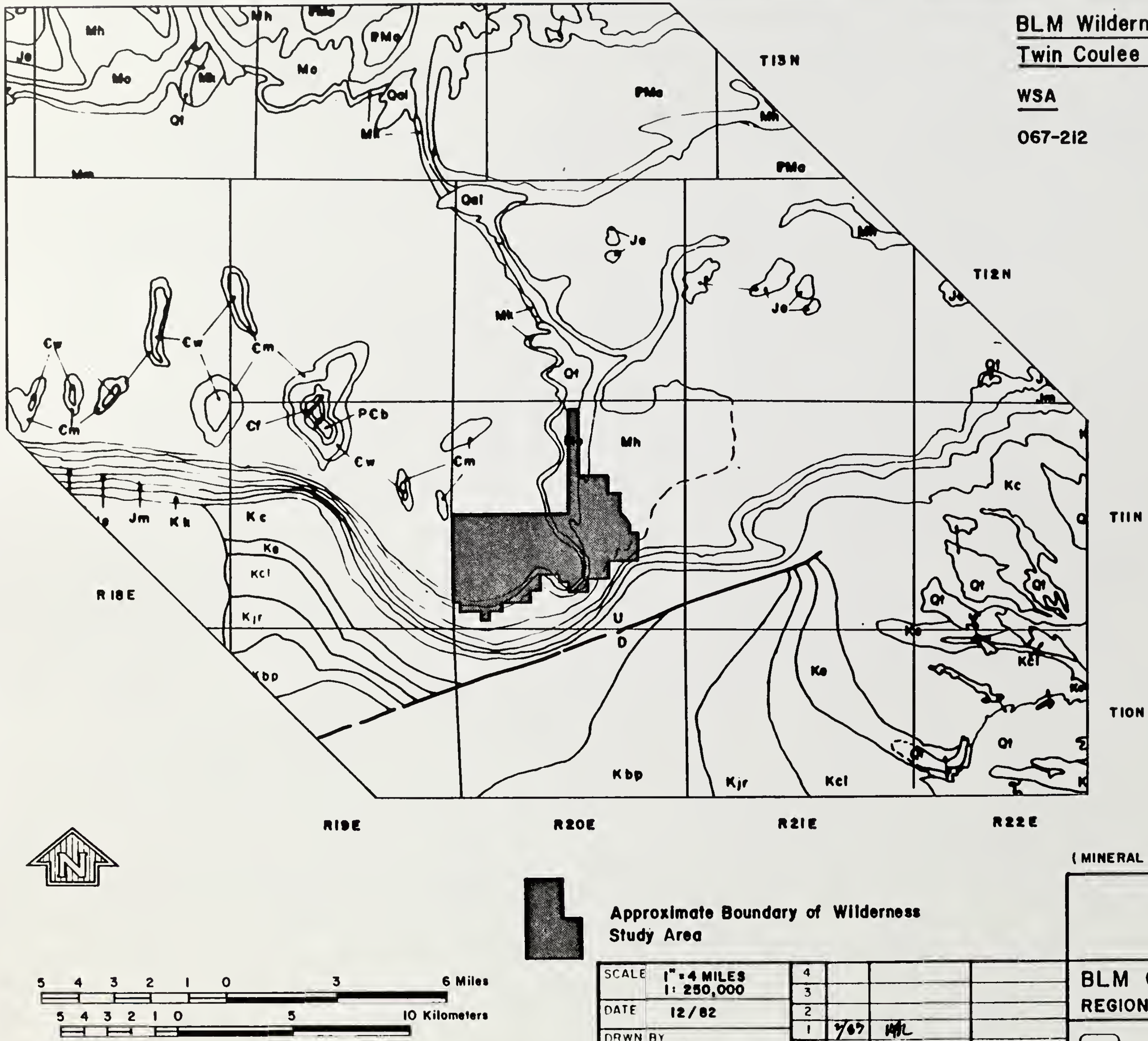
The Flathead Sandstone consists of quartzitic sandstone with a basal quartz pebble conglomerate. Upper and Middle Cambrian Formations include the Woolsey Shale, which consists of fine-grained sandstone, siltstone and shale, and the Meagher Limestone, which consists of fine-grained sandstone, siltstone, and shale interbedded with limestone.

Rocks of the Mississippian age and younger (i.e. Ellis Group, Amsden, Heath Shale, Otter, and Kibbey Sandstone) crop out in the WSA. The Madison Limestone of Mississippian age has two members: the Lodgepole Limestone and the Mission Canyon Limestone. The Lodgepole Limestone consists of blue gray limestone and is overlain by the Mission Canyon Limestone.

The Big Snowy Group overlies the Madison Limestone and consists of the Kibbey Sandstone, Otter, and Heath Shale formations. The Kibbey Sandstone Formation consists of a sandy calcareous shale overlain by a calcareous sandstone. The Otter Formation consists of a sandy calcareous shale overlain by a calcareous shale with anhydrite or gypsum interbeds. The Heath Shale Formation consists of a calcareous shale interbedded with metalliferous oil shale. The relationship of the southern boundary of the WSA with the position

BLM Wilderness Study Areas Included in the Twin Coulee GRA

WSA	NAME	ACREAGE
067-212	Twin Coulee	6,870



(MINERAL RESOURCES DEVELOPMENT INC., 1979)

Twin Coulee GRA, Montana

GEOLOGIC MAP

BLM GEM RESOURCES ASSESSMENT
REGION 6 WYOMING and MONTANA

TETRA TECH INC
PASADENA, CALIFORNIA

FIGURE 2.1

SCALE	1" = 4 MILES 1: 250,000	4			
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		REVISIONS			

SYSTEM	SYMBOL	FORMATION		GENERAL LITHOLOGIC DESCRIPTION
QUAT-ERNARY	Qal	Alluvium		
	Qt	Terrace Gravel		
TERTIARY	Tfu	Fort Union (upper)		Massive gray to buff sandstone with shale, clay, and coal
	Tful	Fort Union (lower)		Lebo shale member, olive green, gray, and tan sandy shale
CRETACEOUS	Kl	Lance		Interbedded tan and gray sandstone and shale
	Kls	Lennep Sandstone		Andesitic sandstones and massive light colored sandstone
	Kbp	Bearpaw Shale		Dark shale with little sandstone
	Kjr	Judith River		Interbedded gray to brown sandstone and shale
	Kcl	Clagget		Dark gray shale with some sandstone
	Ke	Eagle		Massive tan and white sandstone with some shale locally
	Kc	Colorado Shale		Predominantly dark blue to black shale with some shaley sandstone. Includes Telegraph Creek formation
	Kk	Kootenai		Maroon, greenish-gray, white and brown sandy shale and sandstone
JURASSIC	Jm	Morrison		Variegated clays and shales with some sandstone and nodular limestone
	Je	Ellis Group		Gray marine shales with sandstones and limestone, glauconitic at top, fossiliferous below that. Consists of the Swift, Rierdon and Piper formations
PENNSYL-VANIAN	PMa	Amsden		Interbedded red shale and gray limestone with some sandstone; fossiliferous in part
MISSISSIPPIAN	Mh	Heath Shale	BIG SNOWY GROUP	Fissile black shale with some brown to gray sandstone and gray limestone; fossiliferous in part
	Mo	Otter	BIG SNOWY GROUP	Green to gray shale with gray to white limestone
	Mk	Kibbey Sandstone	BIG SNOWY GROUP	White to red sandstone and siltstone with limestone and gypsum
	Mm	Madison Limestone		Massive gray, dense limestone, fractured and brecciated in the upper part
CAMBRIAN	Єm	Meagher Limestone		Interbedded calcareous shales and thin limestone conglomerate
	Єw	Woolsey Shale		Fissile, micaceous, green shale, with some calcareous, glauconitic shale, fossiliferous in part
	Єf	Flathead Sandstone		Almost pure quartz sandstone, with quartz conglomerate
PRECAM-BRIAN	PЄb	Belt Series Shale		Highly indurated dark gray limey shale

Figure 2.2 Generalized Stratigraphic Column, Twin Coulee GRA (Mineral Resource Development Inc., 1979)

of formation boundaries is poorly known, primarily because the area has not been adequately mapped. Available geologic maps are at a small scale and are inaccurate in relationship to the WSA boundary (Lindsey, 1980; Mineral Resources Development, Inc., 1979)

2.3.2 Surficial Deposits

The surficial deposits have not been mapped in detail within the WSA. Inferences drawn from other areas of similar geology indicate that alluvial and colluvial deposits occur in the study area. The alluvial deposits consist of alluvium deposited along the present stream channels by the present drainage system. Colluvial deposits include slope wash deposits consisting of bedrock materials migrating downslope by creep or sheet wash. Colluvium, which consists of bedrock weathered in place, occurs in areas of relatively flat slopes over bedrock.

2.4 Structural Geology

The geologic structure of the study area is relatively simple but influenced by the deposition of sediments in the area. The axis of the Big Snowy anticline intersects the northern part of the WSA and then plunges to the southeast. This belt of structural weakness has been active from Upper Mississippian time, with the subsidence of a graben structure and the advance of the Big Snowy Sea during Mississippian time. During this period, the Big Snowy Group rocks were deposited; also at this time, the Heath Shale heavy metals were deposited in deep water under anaerobic conditions (Cox and Cole, 1981).

The area was positive (above sea level) through Upper Pennsylvanian (270-300 m.y.B.P.) and Triassic (180-225 m.y.B.P.) time, and negative (below sea level) during Jurassic (135-180 m.y.B.P.) and Cretaceous (70-135 m.y.B.P.) time. It was during the Jurassic and Cretaceous ages that thick marine sediments were deposited in the area (Rocky Mountain Association of Geologists, 1973). The Big Snowy Mountains were then uplifted by tectonic folding during the Laramide orogeny. Geophysical studies indicate that the uplift was caused by broad tectonic folding rather than by intrusion of a magmatic mass (Long, 1981A).

2.5 Engineering Geology

The engineering geology in the study area consists primarily of factors associated with limestone bedrock. Excavation difficulties are associated with the massive nature of the limestone and rockfall hazards in cliff areas. Some flash flooding may occur along the perennial and intermittent streams in the area.

2.6 Paleontologic Resources

No known vertebrate paleontologic resources occur within the WSA. The Morrison Formation, known for the common occurrence of vertebrate remains, crops out to the south of the WSA in the GRA. Common invertebrate paleontologic remains occur throughout the stratigraphic section in the GRA (Schram and Schram, 1979; Zidek, 1980).

2.7 Historical Geology

The geologic history of the Twin Coulee area is the same as that of the northern Rocky Mountains. The basement Precambrian rocks consist of proterozoic metasedimentary rocks, the history of which is not well understood. At the end of Precambrian time, and throughout the Paleozoic era (225 m.y. B.P.), there were repeated advances and retreats of the sea; these advances and retreats were especially notable during Upper Mississippian time, with the deposition of the metallifferous Heath Shale. Marine deposits of sandstone, shale, and limestone were formed at the end of the Paleozoic era. During the deposition of the Paleozoic sediments, stratigraphic traps for hydrocarbons may have developed along facies changes, unconformities, and lithologic boundaries. Marine, marginal marine (evaporites), and terrestrial red-bed deposits were formed as the seas fluctuated back and forth over the area in response to the Big Snowy uplift. Marine conditions returned in Jurassic time, only to retreat at the end of the Jurassic period. A major marine invasion started in early Cretaceous time and continued until the start of the Laramide orogeny, near the end of the Cretaceous period. The Tertiary (2-70 m.y.B.P.) period was a period of repeated uplift, accompanied by folding (i.e. Big Snowy uplift), thrusting, high-angle faulting, and the deposition of thick terrestrial sediments in the inter-mountain basins. Volcanism was active in the mid to late Tertiary time, and thick volcanic deposits accumulated locally, and volcanic ash was distributed widely. The Quaternary (2-3 m.y.b.p.) period is noted for the widespread continental and valley glaciation in the mountains, glacial outwash and sediment deposits along the flanks of the mountains, and extensive erosion by streams.

3.0 ENERGY AND MINERAL RESOURCES

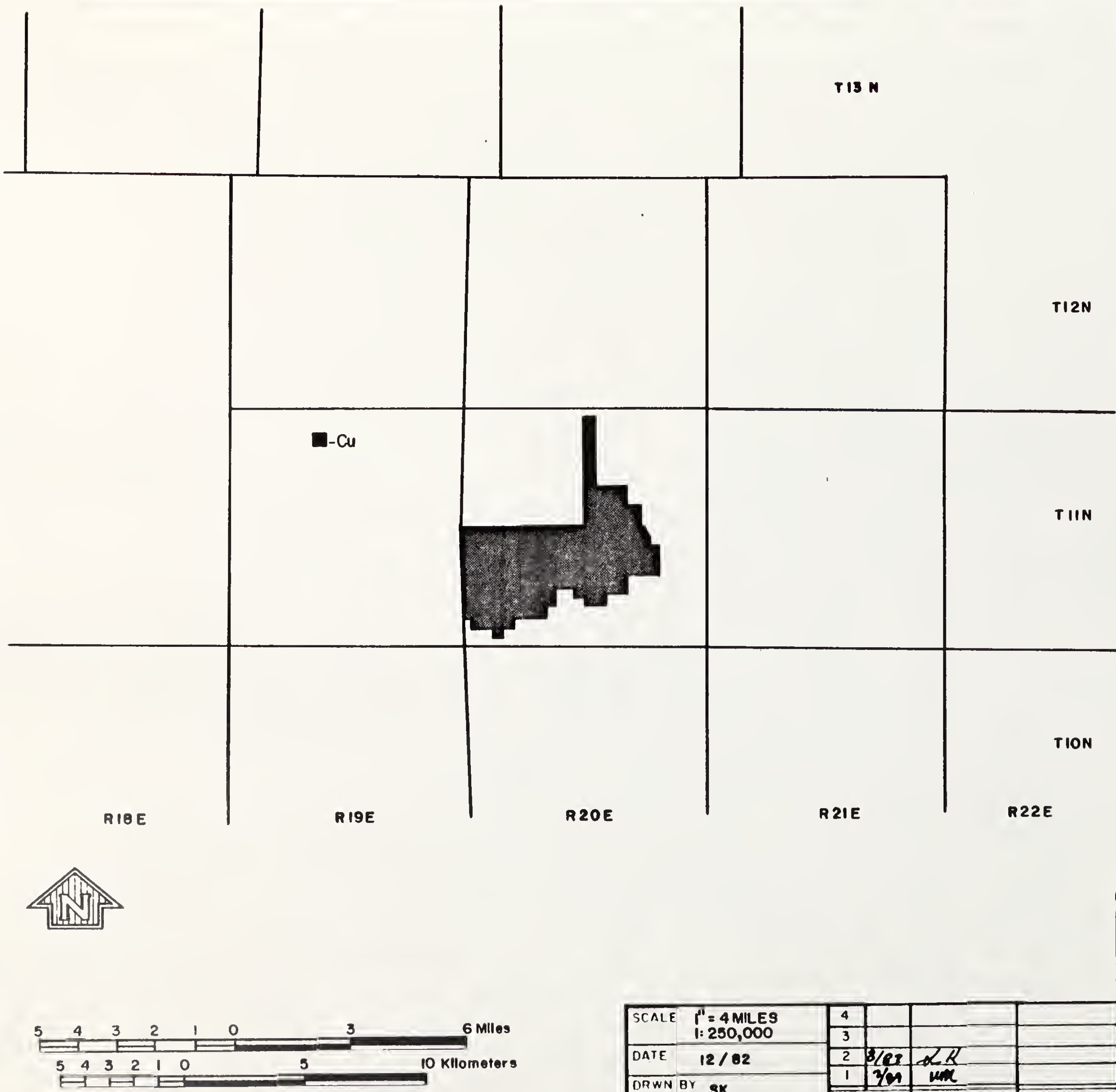
3.1 General

The Twin Coulee WSA contains known resources of limestone, oil shale, and metals and strategic minerals. Figure 3.1, "Mineral Occurrence Map," illustrates the known past and present occurrences of GEM resources in the Twin Coulee GRA. Information for this figure came from the USGS' Computerized Resource Information Bank (CRIB), the USBM's Mineral Availability System (MILS), and the Petroleum Information Corporation (PI).

3.2 Known Resources

Abundant outcrops of limestone in the Madison Limestone occur throughout the Twin Coulee WSA. However, the quality and thickness of the limestone in the WSA is probably not significantly different from other vast limestone reserves that have been identified throughout the state. No known quarries were identified within or in the vicinity of the WSA.

Metalliferous oil shales have been identified in the Heath Shale of the Big Snowy Group by Cox and Cole (1981), and by Desborough, Poole, and Green (1981). There are considerable discrepancies, however, in the respective geologic maps of the area (Lindsey, 1980; Mineral Resources Development, Inc., 1979). These discrepancies have important implications as to the quantity of oil shale resources; unfortunately, these discrepancies cannot be resolved without detailed field verification and sampling. The discrepancies concern the location of the upper and lower contact of the Heath Shale.



BLM Wilderness Study Areas Included in the Twin Coulee GRA

WSA	NAME	ACREAGE
067-212	Twin Coulee	6,870

● Oil Well
☼ Gas Well
✹ Oil & Gas Well
⚒ Mine
Inactive Mine
■ Ore Body
Deposit
Approximate Boundary of Wilderness Study Area

COMMODITY

Cu Copper

(USGS,1982;USBM,1982;PI,1982)

Twin Coulee GRA, Montana

MINERAL OCCURRENCE MAP

BLM GEM RESOURCES ASSESSMENT
REGION 6 WYOMING and MONTANA

TETRA TECH INC
PASADENA, CALIFORNIA

FIGURE 3.1

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		3			
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		1	7/84	[illegible]	
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Cox and Cole (1981) indicate great lateral variation in the oil shale beds of the Heath Shale, and that the grade ranges from 0 to 19.6 gallons per ton, with an average grade below 10 gallons per ton. The units in the middle of the Heath Shale were found to have the highest oil yields. This interval was generally 2-50 feet thick and yielded 9.8-14.9 gallons per ton. The grade (gallons per ton) in this area is in general lower than that found in the Piceance Basin, Colorado, but the WSA has not been adequately explored.

These shales contain anomalous concentrations of vanadium, nickel, zinc, selenium, and molybdenum. No production from the Heath Shale of oil shale or any of these accompanying metalliferous resources is known in Montana.

Copper deposits are known to occur in the Twin Coulee GRA. The copper deposit illustrated in Figure 3.1 appears to occur in the Cambrian units that underlie the WSA.

3.3 Potential Resources

The Little Mountain area of the Bighorn and Pryor Mountains has produced uranium in the past from paleokarst horizons at the top of the Madison Limestone in contact with the Amsden Formation. This contact was exposed to erosion and to mineralized groundwater solutions (Worchola and Stockton, 1982). The contact between the Madison Limestone and the Big Snowy Group rocks (marine) is exposed in part of the Twin Coulee WSA. It is not known, however, whether karst topography was developed on the Madison Limestone surface, whether the surface was exposed to potential source rocks, or whether marine conditions during Big Snowy time submerged much of the area in a less favorable (for uranium deposition) marine environment; this last alternative is likely. The occurrence of uranium in marine sedimentary rocks, except for some black shales and phosphatic shales, is almost unknown as most known sedimentary uranium deposits in the Western United States occur in terrestrial environments (i.e. Crooks Gap, Wyoming).

3.4 Land Status

Unpatented claims and oil and gas leases blanket much of the southern border of the WSA. The unpatented claims have beeen staked primarily for metalliferous oil shale (Spielman, 1983). Figure 3.2, "Claim and Lease Map," illustrates the locations of any oil and gas leases, patented claims, or unpatented claims in the Twin Coulee GRA. As shown, there are no patented claims in the WSA.

3.5 Deposit Types

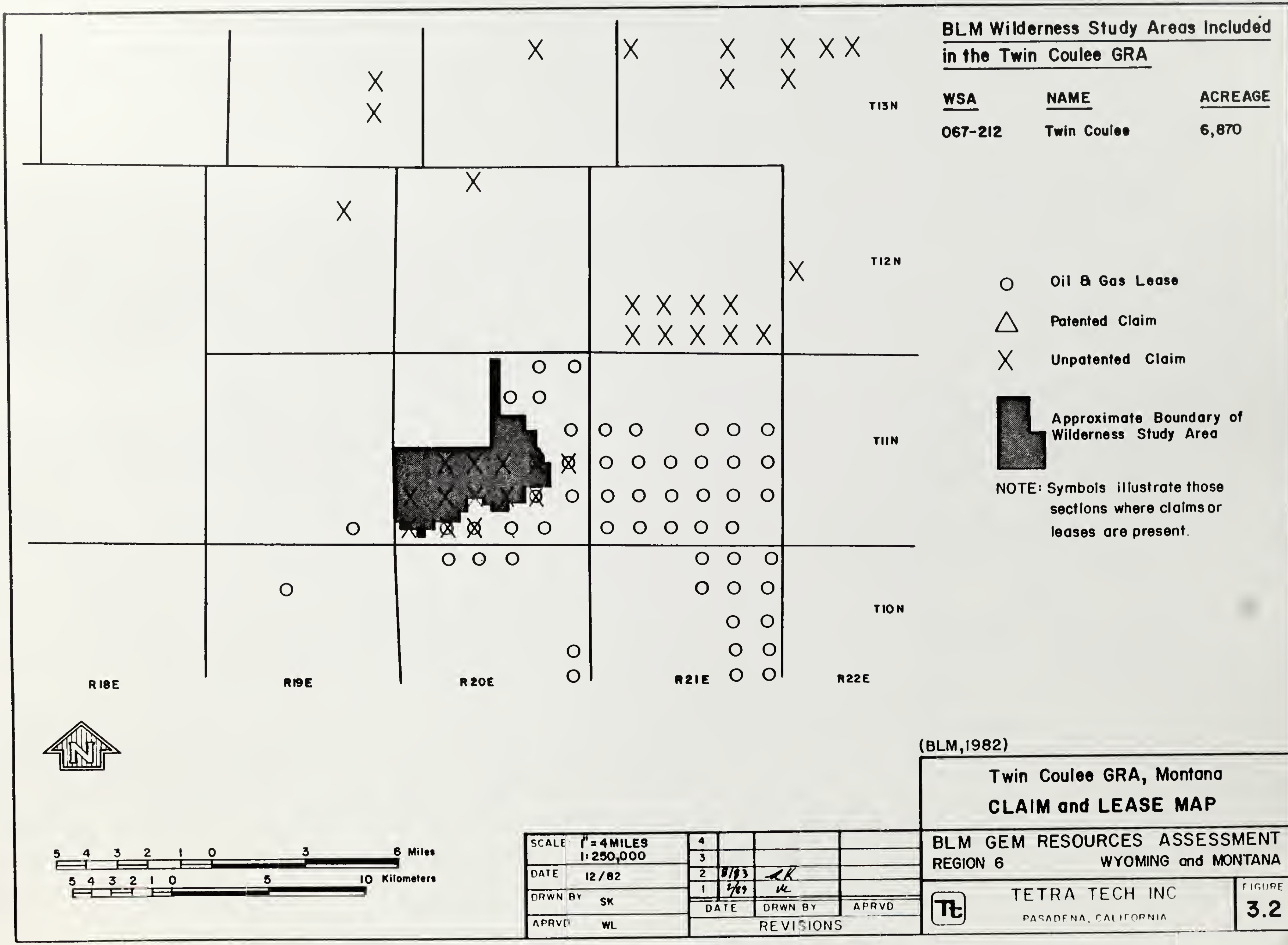
The metalliferous oil shales occur as beds within otherwise similar shales. Facies changes affect the quality of oil shale and likewise the metalliferous content. Variability in metallic mineral concentrations is dependent upon these and other factors (Cox and Cole, 1981). Depositional environments and other factors affecting oil shale and mineral concentrations have been recently investigated (Desborough, Poole, and Green, 1981).

Uranium may occur in the contact zone of the Madison Limestone with the overlying Big Snowy Group. Comparing the potential occurrence of uranium in geologic environments similar to the Pryor Mountains, suggests that a favorable environment for uranium occurrences exists where well developed karst terrain occurs with abundant reductant material in a terrestrial environment accessible to abundant uraniferous source rock. The limited information available in the area, the lack of an extensive post-depositional terrestrial environment, and a sequence of marine sediments overlying the Madison Limestone indicate a low favorability for uranium occurrence.

3.6 Resource Economics

3.6.1 Strategic Minerals

Vanadium, nickel, and zinc are strategic minerals identified in metalliferous oil shales of the Heath Shale. Processing technology is not presently available for the extraction of these metals from oil shale. It is important,


BLM Wilderness Study Areas Included in the Twin Coulee GRA
WSA
NAME
ACREAGE
067-212
Twin Coulee
6,870
Oil & Gas Lease
Patented Claim
Unpatented Claim
Approximate Boundary of Wilderness Study Area
NOTE: Symbols illustrate those sections where claims or leases are present.
T13N
T12N
T11N
T10N
R18E
R19E
R20E
R21E
R22E
5 4 3 2 1 0 3 6 Miles
5 4 3 2 1 0 5 10 Kilometers
(BLM,1982)
Twin Coulee GRA, Montana
CLAIM and LEASE MAP
BLM GEM RESOURCES ASSESSMENT
REGION 6
WYOMING and MONTANA
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PASADENA, CALIFORNIA
FIGURE
3.2
SCALE 1" = 4 MILES 1:250,000
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however, to develop potential reserves of strategic minerals because of the danger of depending on foreign sources for materials which are critical to defense applications. In this resource area (strategic and critical minerals), availability may be more important than economics. Potential economic resources may exist if current sources of supply are cut off or if demand increases.

3.6.2 Oil Shale

At present, no market exists for shale oil in the United States. The marketability is based primarily on matching the production cost of shale oil with the production costs of classical oil stratigraphic exploration. When production costs of crude oil exceed those of shale oil, a market for shale oil will be developed. The marketability of the oil shale which may occur within the WSA will depend upon the tonnage and grade of the oil shale found, and whether the Heath Shale is exposed within the WSA (see Section 3.2). This information is as yet unknown.

4.0 LAND CLASSIFICATION FOR GEM RESOURCE POTENTIAL

4.1 General

The Twin Coulee WSA has potential occurrences of the following GEM resources: limestone, oil shale, and strategic minerals. The WSA has a low favorability for the potential occurrence of any other GEM resource.

In order to better evaluate the occurrence or potential occurrence of resources in the GRA, a 2-part resource classification scheme has been adopted as requested by contract. Each resource or potential resource within the GRA will receive an alpha-numeric classification. The number designation will range from 1 to 4, and will indicate the favorability of the geologic environment, geologic processes, and mineral occurrences for the presence of a particular resource or group of resources. The letter designation will range from A to D, and will indicate the level of confidence to be associated with the numerical designation. Figure 4.1, "Land Classification Map," illustrates the areas of potential GEM resources with their assigned classifications for the WSA within the Twin Coulee GRA. Figure 4.2, "Resource Classification Scheme," provides a detailed description of the number and letter designations used in the resource classification scheme.

4.2 Strategic Minerals

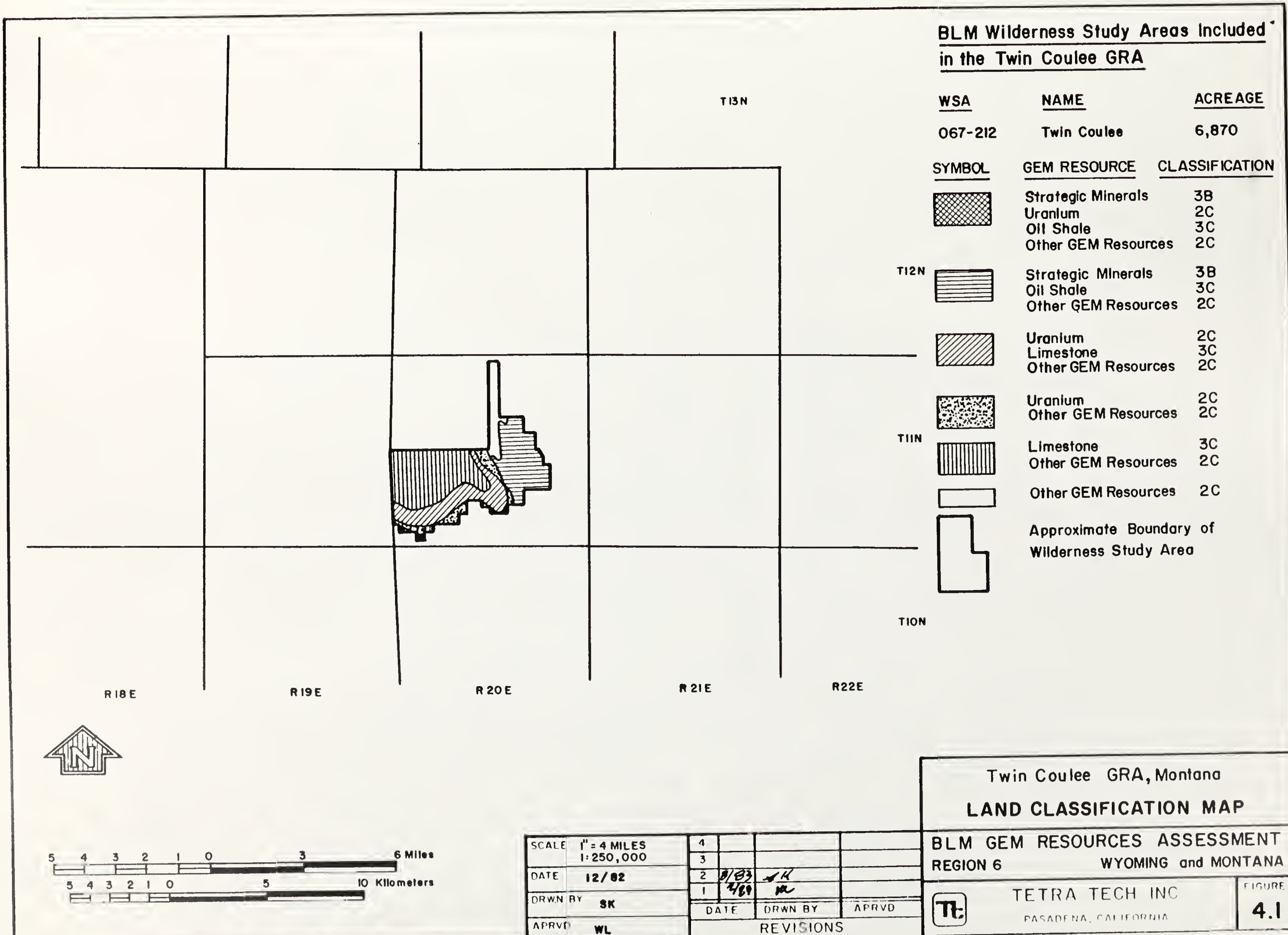
The Twin Coulee WSA is considered to have a moderate favorability based on indirect evidence for the potential occurrence of strategic minerals associated with oil shale in the Heath Shale (classified 3B). This classification is based upon the occurrence of metalliferous oil shale in the region (Cox and Cole, 1981; Desborough, Poole and Green, 1981). Verification of the Heath Shale occurrence within the WSA boundary is needed.

4.3 Industrial Minerals

The Twin Coulee WSA is considered to have a moderate favorability based on direct but quantitatively minimal evidence for the potential occurrence of limestone (classified 3C); this classification is based upon the occurrence of the Madison Limestone in the area (Lindsey, 1980; Mineral Resources Development, Inc., 1979). This resource has a low marketability at this time.

4.4 Uranium

The Twin Coulee WSA is considered to have a low favorability based on direct but quantitatively minimal evidence for the potential occurrence of uranium (classified 2C). The potential occurrence of uranium is associated with the contact between the Madison Limestone and Big Snowy Group. The low favorability classification for this resource is based on the apparent lack of a favorable geologic environment, adequate source rock, or the accumulation of uranium.


BLM Wilderness Study Areas Included in the Twin Coulee GRA
WSA
NAME
ACREAGE
067-212
Twin Coulee
6,870
SYMBOL
GEM RESOURCE
CLASSIFICATION
Strategic Minerals 3B
Uranium 2C
Oil Shale 3C
Other GEM Resources 2C
Strategic Minerals 3B
Oil Shale 3C
Other GEM Resources 2C
Uranium 2C
Limestone 3C
Other GEM Resources 2C
Uranium 2C
Other GEM Resources 2C
Limestone 3C
Other GEM Resources 2C
Other GEM Resources 2C
Approximate Boundary of Wilderness Study Area
T13N
T12N
T11N
T10N
R18E
R19E
R20E
R21E
R22E
N
5 4 3 2 1 0 3 6 Miles
5 4 3 2 1 0 5 10 Kilometers
SCALE 1" = 4 MILES 1:250,000
DATE 12/82
DRWN BY SK
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APRVD
Twin Coulee GRA, Montana
LAND CLASSIFICATION MAP
BLM GEM RESOURCES ASSESSMENT
REGION 6
WYOMING and MONTANA
TETRA TECH INC
PASADENA, CALIFORNIA
FIGURE
4.1

Numerical 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.

Letter Classification Scheme (Level of Confidence)

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 to support or refute the possible existence of mineral resources.

Figure 4.2 Resource Classification Scheme

4.5 Oil Shale

The Twin Coulee WSA is considered to have a moderate favorability based on direct, but quantitatively minimal evidence for the potential occurrence of oil shale (classified 3C); this classification is based upon reported occurrences of oil shale in the area (Cox and Cole, 1981; Desborough, Poole and Green, 1981). The potential oil shale resource is most likely to occur in the Heath Shale Formation. Verification of the Heath Shale within the WSA boundary is needed.

4.6 Other GEM Resources

Quantitatively minimal direct evidence exists to support a low favorability classification for the potential occurrence of other GEM resources in the study area (classified 2C). This classification is based upon the geologic environment and inferred geologic processes that have been identified in the WSA.

5.0 RECOMMENDATIONS FOR FURTHER WORK

5.1 Work Recommended to Complete Data Base

A number of investigations could be implemented to generate additional data to supplement the conclusions of this Phase I report for the Twin Coulee GRA. Detailed field verification of the Heath Shale occurrence within the WSA is critical, otherwise discrepancies in the literature cannot be resolved (see Section 3.2). These mapping discrepancies could affect the order of magnitude of the oil shale resource potential of the Heath Shale Formation within this WSA. In addition, preliminary evaluation of the uranium potential along the Madison Limestone and the Big Snowy contact could be performed by geologic mapping and scintillometer-spectrometer traverses. This evaluation would help identify paleokarst horizons, reductant zones, and overall similarity of the Twin Coulee GRA to the Little Mountain and Pryor Mountain uranium areas (Worchola, and Stockton, 1982).

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