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PHASE I

Geology, Energy and Mineral (GEM) Resource Evaluation of Livingston GRA, Montana, including the Yellowstone River Island (075-133) Wilderness Study Area

Bureau of Land Management
Contract No. YA-553-CT2-1039

By:

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ANCHORAGE, ALASKA
JULY 1983

WGM INC.
MINING AND GEOLOGICAL CONSULTANTS

EXECUTIVE SUMMARY

The Livingston Geology, Energy and Mineral Resource Area (GRA) encompasses the area around the town of Livingston in south-central Montana. The GRA includes one Wilderness Study Area; a 53 acre island in the Yellowstone River, WSA 075-133.

Bedrock in the area consists of sedimentary rocks 70 to 140 million years old, with older rocks present in the subsurface. The GRA is on the south edge of a regional structure known as the Crazy Mountains Basin. WSA 075-133 is covered entirely by recently deposited river gravels.

There are no metallic mineral occurrences in the Livingston GRA. Optical grade calcite was produced from a few small mines near the GRA during World War II and low rank, subbituminous coal was mined from thin seams in the Eagle Sandstone. Two shallow oil and gas wells were drilled in the GRA. Both were dry holes, but traces of oil were reported at 665 feet in one of them (Sec. 13, T.2S., R.9E.).

The area is considered to have a low favorability for metallic and non-metallic minerals, and geothermal resources. The geologic environment is moderately favorable for the occurrence of uranium deposits, coal, and oil and gas. The rankings are summarized in the attached table.

SUMMARY OF GEM RESOURCES LAND CLASSIFICATION
FOR THE YELLOWSTONE RIVER ISLAND
(075-133) WSA

Locatable Resources:	
a. Metallic Minerals	2C
b. Uranium and Thorium	3B
c. Non-Metallic Minerals	3B-calcite/1C-others
Leasable Resources:	
a. Oil and Gas	3C
b. Low Temperature Geothermal	2B
High Temperature Geothermal	1B
c. Sodium and Potassium	1D
d. Other	3B-coal/2B-others
Saleable Resources	4D

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1.0 INTRODUCTION

The Bureau of Land Management has adopted a two-phase procedure for the integration of geological, energy and minerals (GEM) resources data into the suitable/non-suitable decision making process for Wilderness Study Areas (WSAs). The objective of Phase I is the evaluation of existing data, both published and available unpublished data, and evaluation of the data for interpretation of the GEM resources potential of the WSAs. Wilderness Study Areas are grouped into areas based on geologic environment and mineral resources for initial evaluation. These areas are referred to as Geology, Energy, Mineral Resource Areas (GRAs).

The delination of the GRAs is based on three criteria: (1) a 1:250,000 scale map of each GRA shall be no greater than 8½ x 11 inches; (2) a GRA boundary will not cut across a Wilderness Study Area; and (3) the geologic environment and mineral occurrences. The data for each GRA is collected, compiled, and evaluated and a report prepared for each GRA. Each WSA in the GRA is then classified according to GEM resources favorability. The classification system and report format are specified by the BLM to maintain continuity between regions.

This report is prepared for the Bureau of Land Management under contract number YA-553-CT2-1039. The contract covers GEM Region 2; Northern Rocky Mountains (Fig. 2). The Region includes 50 BLM Wilderness Study Areas

totalling 583,182 acres. The WSAs were grouped into 22 GRAs for purposes of the Phase I GEM resources evaluation.

1.1 Location

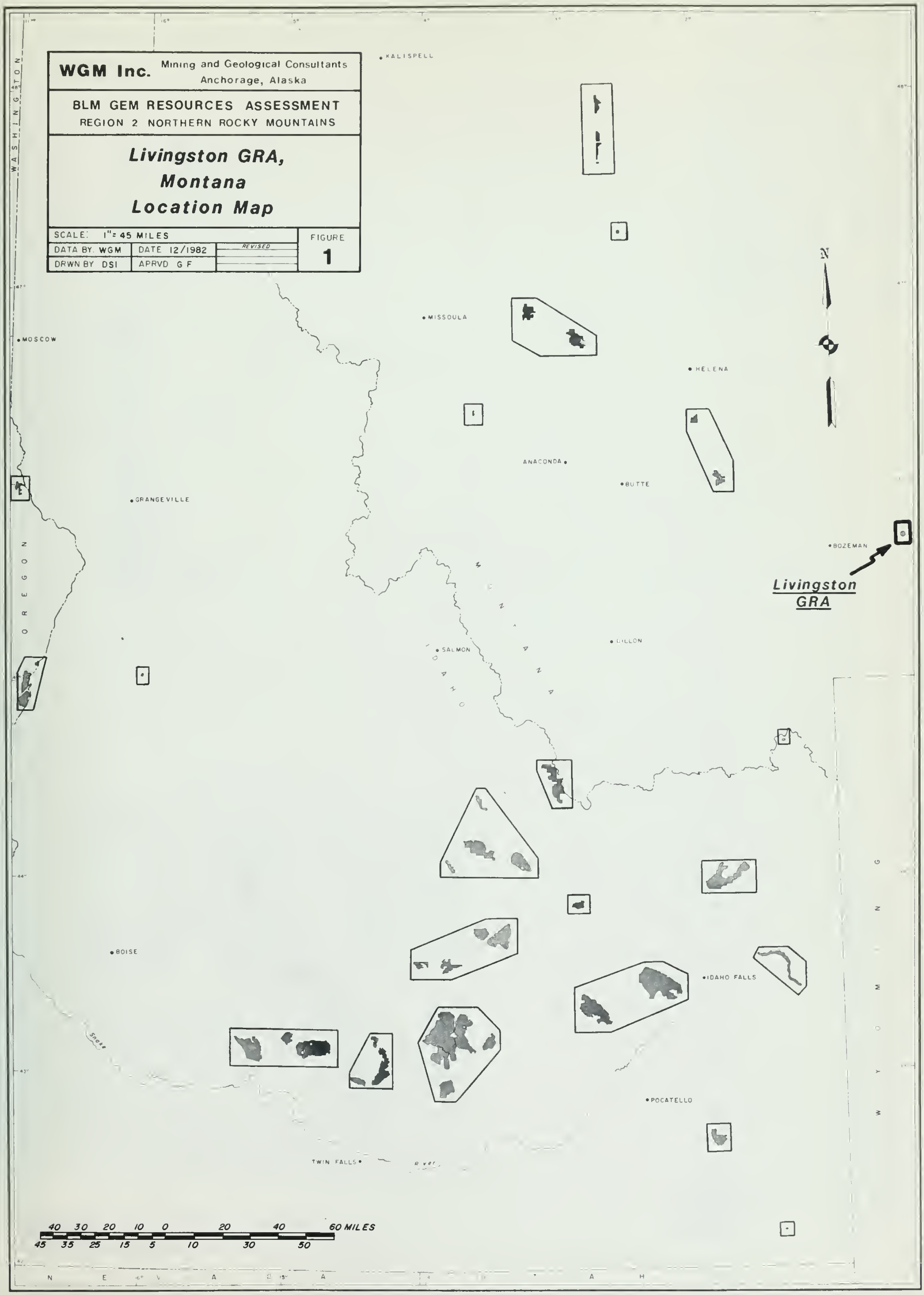
The Livingston GRA is located in northern Park County, southwestern Montana in Tsp. 1-2S. Rs.9-10E. (Fig. 1 and 2). Administratively the area is within the Headwaters Resource Area in the Butte BLM district. The GRA covers approximately 130 square miles. Yellowstone River Island, a 53 acre island in the Yellowstone River is the only WSA in the area.

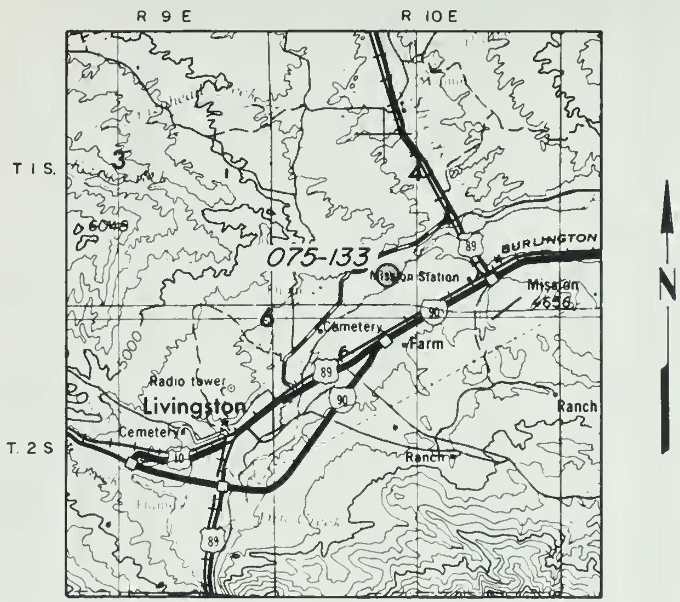
1.2 Population and Infrastructure

Livingston, with a population of 7,000 people, is the largest town in the GRA. The area is well developed and has numerous roads. Interstate Highway 90 crosses the area from east to west and Montana State Highway 89 from north to south. In addition there are numerous secondary roads.

1.3 Basis of the Report

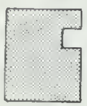
This report is based on a compilation, review and analysis of the available published and unpublished data on the geology, energy and mineral resources of the Livingston GRA. The area has been mapped in detail by U.S. Geological Survey geologists and is within the area covered by the NURE study of the Bozeman NTMS Quadrangle. Other than the NURE data, there is no geochemical data available for the GRA. BLM records were reviewed to determine the status of mining claims and oil and gas leases in the area. Areal photos and LANDSAT images of the area were also examined.


WGM Inc.
Mining and Geological Consultants
Anchorage, Alaska
BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS
Livingston GRA,
Montana
Location Map
SCALE: 1" = 45 MILES
DATA BY: WGM
DATE 12/1982
REVISED
DRWN BY DSI
APRVD G F
FIGURE
1
KALISPELL
MISSOULA
HELENA
ANACONDA
BUTTE
BOZEMAN
Livingston
GRA
MOSCOW
GRANGEVILLE
SALMON
DILLON
BOISE
IDAHO FALLS
POCATELLO
TWIN FALLS
WASHINGTON
OREGON
IDAHO
MONTANA
WYOMING
NEVADA
UTAH
N
60 MILES



BLM Wilderness Study Areas Included in the Livingston GRA.

WSA	NAME	ACREAGE
075-133	Island	53



Approximate Boundary of Wilderness Study Area.

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BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Livingston GRA, Montana
Topographic Map

SCALE 1"= 4 MILES (1 250,000)		FIGURE 2
DATA BY WGM	DATE 9/1982	REVISED
DRWN BY DSI	APRVD G.F	

The data was compiled and reviewed by WGM project personnel and the panel of experts to produce the resource evaluation which comprises this report.

Greg Fernette, Senior Geologist, WGM Inc.	Project Manager
C.G. Bigelow, President, WGM Inc.	Chairman, Panel of Experts
Joel Stratman, Geologist, WGM Inc.	Project Geologist
Jami Fernette, Land and Environmental Coordinator, WGM Inc.	Claims and Lease Compilation

Panel of Experts

C.G. Bigelow, President, WGM Inc.	Regional geology, metallic and minerals, mineral economics.
R.S. Fredericksen, Senior Geologist, WGM Inc.	Regional geology, metallic minerals.
David Blackwell, Ph.D., Professor Geophysics, Southern Methodist University	Geothermal.
Jason Bressler, Senior Geologist, WGM Inc.	Regional geology, metallic minerals.
Gary Webster, Ph.D., Chairman, Department of Geology, Washington State University	Oil and gas.
William Jones, Senior Geologist, WGM Inc.	Metallic minerals, coal, industrial minerals.
J.F. McOuat, President, Watts, Griffis & McOuat Ltd.	Mineral economics, and industrial minerals.
E.F. Evoy, Senior Geologist, Watts, Griffis & McOuat Ltd.	Uranium and thorium.

1.4 Acknowledgements

We would like to thank Dave Williams, BLM-Butte district geologist for loaning areal photos and data on the region to WGM and Jerry Klem, BLM- Billings for the use of BLM LANDSAT images and assistance in gathering land data.

2.0 GEOLOGY

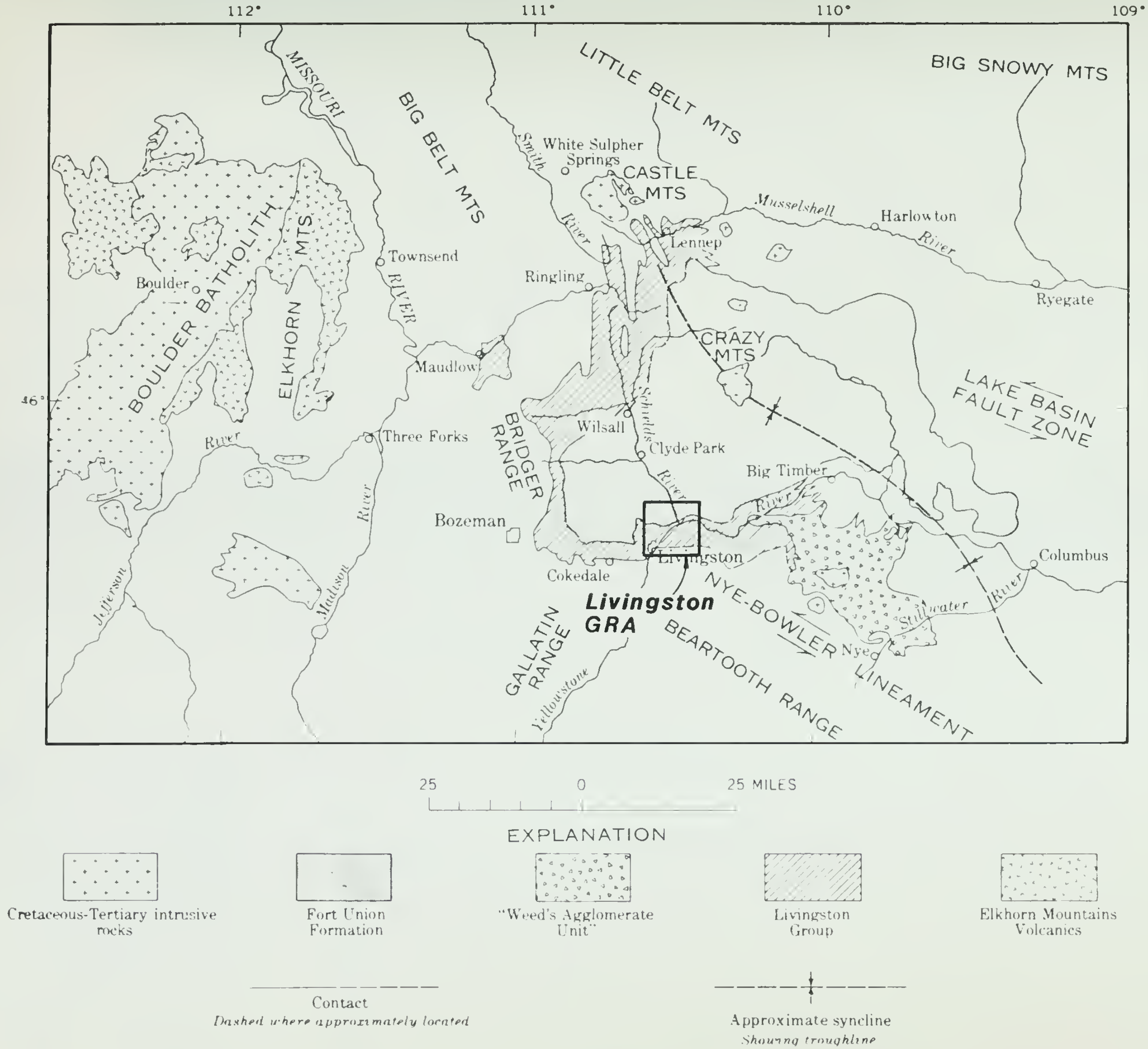
2.1 Introduction

Rocks from Precambrian (older than 600 m.y.) through Tertiary (65-2 m.y.) are exposed in the region (Figs. 3 and 4) and probably occur in the subsurface of the Livingston GRA. However, the rocks which crop out in the GRA are entirely Cretaceous (141-65 m.y.) and younger (Fig. 5). Regionally the GRA lies on the southwest edge of the Crazy Mountain Basin and southeast of the Elkhorn Mountain volcanic pile and the Boulder Batholith (Fig. 3). Brief descriptions of the Pre-Cretaceous rocks are included in Figure 4 (Richards, 1957). The Paleozoic section in the region includes rocks from Middle Cambrian (542-515 m.y.) through Permian (280-251 m.y.) in age and totals over 3,000 feet thick. The Jurassic (195-141 m.y.) section is 700 feet thick. The overall stratigraphic section is nearly complete, with only Silurian (435-395 m.y.) and Triassic (230-195 m.y.) rocks absent (Roberts, 1972).

The eastern half of the GRA has been mapped in detail by Richards (1957). The west half has been the subject of several detailed geologic and stratigraphic studies by Roberts (1964, 1966a, b, and 1972).

2.2 Physiography

The Livingston GRA is in the Middle Rocky Mountains Physiographic province (Hunt, 1974; Alden, 1953). The dominant topographic and geomorphic feature in the GRA is the Yellowstone River valley which is several miles wide. The



Data from Roberts (1972).

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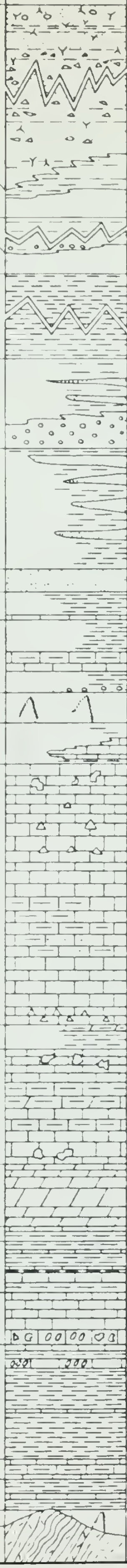
BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Regional Geologic Setting of the Livingston GRA, Montana

AS SHOWN
1/1983
DSI

3

SYSTEM	SERIES	FORMATION AND MEMBER	LITHOLOGY	THICKNESS, IN FEET
TERTIARY ?	Paleocene ?			
CRETACEOUS	Upper Cretaceous	Livingston formation		7000±
				100–1330
		Virgelle sandstone and undivided younger rocks		100±
				2045
		Boulder River sandstone member		100±
	Lower Cretaceous	Colorado shale		815
		Kootenai formation		300
JURASSIC	Upper Jurassic	Morrison formation		400
		Ellis group: Swift formation		80
		Ellis group: Rierdon formation		95
	Middle Jurassic	Ellis group: Piper formation		240
CARBONIFEROUS SYSTEM	PENNSYLVANIAN	Quadrent quartzite		100
		Amsden formation		140
	? MISSISSIPPIAN	Madison limestone		860+
DEVONIAN	Upper Devonian	Three Forks shale		80
		Jefferson limestone		390
ORDOVICIAN		Bighorn dolomite		200
CAMBRIAN	Upper Cambrian	Grove Creek formation		50
		Snowy Range formation		175
		Pilgrim limestone		175
	Middle Cambrian	Park shale		380
		Meegher limestone		65
		Wolsey shale		105
		Flathead quertzite		0–75
PRE-CAMBRIAN		Gneiss, schist, granite		



Data from Richards (1957).

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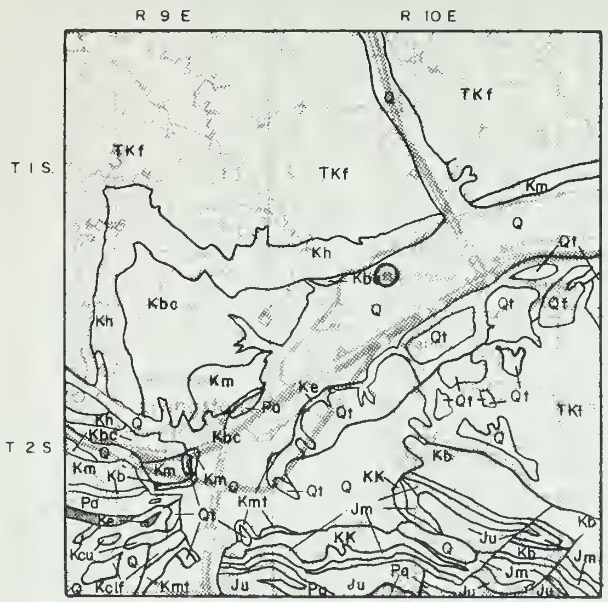
BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Livingston GRA, Montana Stratigraphic Column

SCALE | FIGURE 4
DATA BY | DATE | REVISED
DRWN BY D.S. | APRVD G.F.



Data from Roberts (1964) and Richards (1957).

Approximate Boundary of Wilderness Study Area.

5 4 3 2 1 0 3 6 *Miles*

5 4 3 2 1 0 5 10 *Kilometers*

EXPLANATION

Sedimentary

CENOZOIC

Quaternary

Q	**Younger alluvium, landslide** depasits, alder olluvium
Qt	Older terrace depasits

Tertiary

TKf	Fort Unian Farmatian

MESOZOIC

Upper Cretaceous

Livingston Graup

TKl	TKl Undivided
Kh	Kh Happers Farmatian
Kbc	Kbc Billman Creek Farmatlan
Km	Km Miner Creek Formotian
Kms	Kms Miner Creek Farmation, Sulfur Flats Sandstane
Kc	Kc Cakedale Farmation

Ke	Eogle Sondstone (locally cool bearing)

Cody Shole and Frantier Formatlan

Kcf	Kcf Undivided
Kcu	Kcu Upper member Cady Shale
Kclf	Kclf Lower member Cody Shale ond Frantier Formatian

Lower Cretaceous

Kmt	Mowry and Themopolis Shales
Kb	Calorada Shale
KK	Koatenai Farmation

Jurassic

Jm	Marrisan Formatlan
Ju	Ellis Graup

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BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Livingston GRA, Montana

Geologic Map

SCALE 1" = 4 MILES			FIGURE
DATA BY	DATE 1/1983	REV SED	5
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elevation of the valley floor averages about 4,400 feet above sea level. The valley is flanked by a series of alluvial terraces that rise 60 feet above the present valley floor. Other older terraces extend as much as 400 feet above the river (Richards, 1957).

The hills on either side of the valley comprise a youthful to submature topography dissected by numerous gullies. Maximum relief in the GRA is just over 900 feet. The highest elevation is 6,048 feet, on the crest of a hill three miles north of the town of Livingston (Fig. 2).

2.3 Description of Rock Units

The Cretaceous and early Tertiary section which underlies the Livingston GRA (Fig. 5) consists of Lower (141-100 m.y.) and Upper Cretaceous (100-65 m.y.) and Paleocene (65-55 m.y.) rocks overlying the Late Jurassic (158-141 m.y.) Morrison Formation. The Lower Cretaceous rocks are 1,250 feet thick and include the Kootenai Formation, Mowry Shale and Thermopolis Shale. The Upper Cretaceous column consists of the Frontier Formation, Cody Shale, Telegraph Creek Formation, Eagle Sandstone, Cokedale Formation, Miner Creek Formation, Billman Creek Formation, Hoppers Formation, and the basal 980 feet of the Fort Union Formation. These units aggregate 10,380 feet in thickness. The Paleocene rocks comprise the upper 5,635 feet of the Fort Union Formation. The descriptions given below are largely taken from Roberts (1972) and Piombino (1979).

The oldest unit which crops out in the Livingston GRA is the Kootenai Formation, a non-marine sequence unconformably overlying the Morrison Formation. The Kootenai has a total of thickness of 245 to 295 feet, and it consists of

two members. The lower portion of the Kootenai is the Pryor Conglomerate Member, which is composed of cross bedded conglomerate, sandstone and conglomeratic sandstone. The unnamed upper member is comprised of variegated siltstone, sandstone, claystone, mudstone, limestone, and tuff interbedded with calcareous sandstone. The Kootenai is assigned a Lower Cretaceous age based on fossil content.

The Thermopolis Shale is a transgressive sequence of sandstone and shale which unconformably overlies the Kootenai. The unit is 465 to 545 feet thick and consists of a lower sandstone member, which fills topographic depressions in the underlying Kootenai, overlain by a middle member of black marine shale and siltstone, and capped by an upper arkosic sandstone unit. The upper member represents a regressive near-shore environment. The middle shale member contains a fairly complete succession of plant microfossils that are the basis for the age and correlation of the formation.

The Mowry Shale conformably overlies the Thermopolis Formation, although the contact between the two units is difficult to recognize because of recessive weathering. The Mowry consists of 430 to 500 feet of siliceous brown shale and mudstone interbedded with siltstone and sandstone. In the Livingston GRA the unit is commonly micaceous, pyritic and often glauconitic, suggesting deposition in a shallow, restricted marine environment. Palynological data indicates that the formation is probably of Lower Cretaceous age.

Over 400 feet of massive ridge forming sandstones of the Upper Cretaceous Frontier Formation overlie the Mowry. There is no evidence of an unconformity at the contact. The sandstones are rich in heavy minerals and have a characteristic salt and pepper appearance. In addition to sandstone, conglomerate, siltstone, and shale with thin interbeds of carbonaceous shale and coal make up the sequence. The lithologies, and sedimentary structures, including ripple marks, cross bedding, and fossil burrow casts indicate that the formation was deposited in shallow, brackish water under generally regressive conditions. Pollen and poorly preserved pelycopods provide the basis for the Upper Cretaceous age determination.

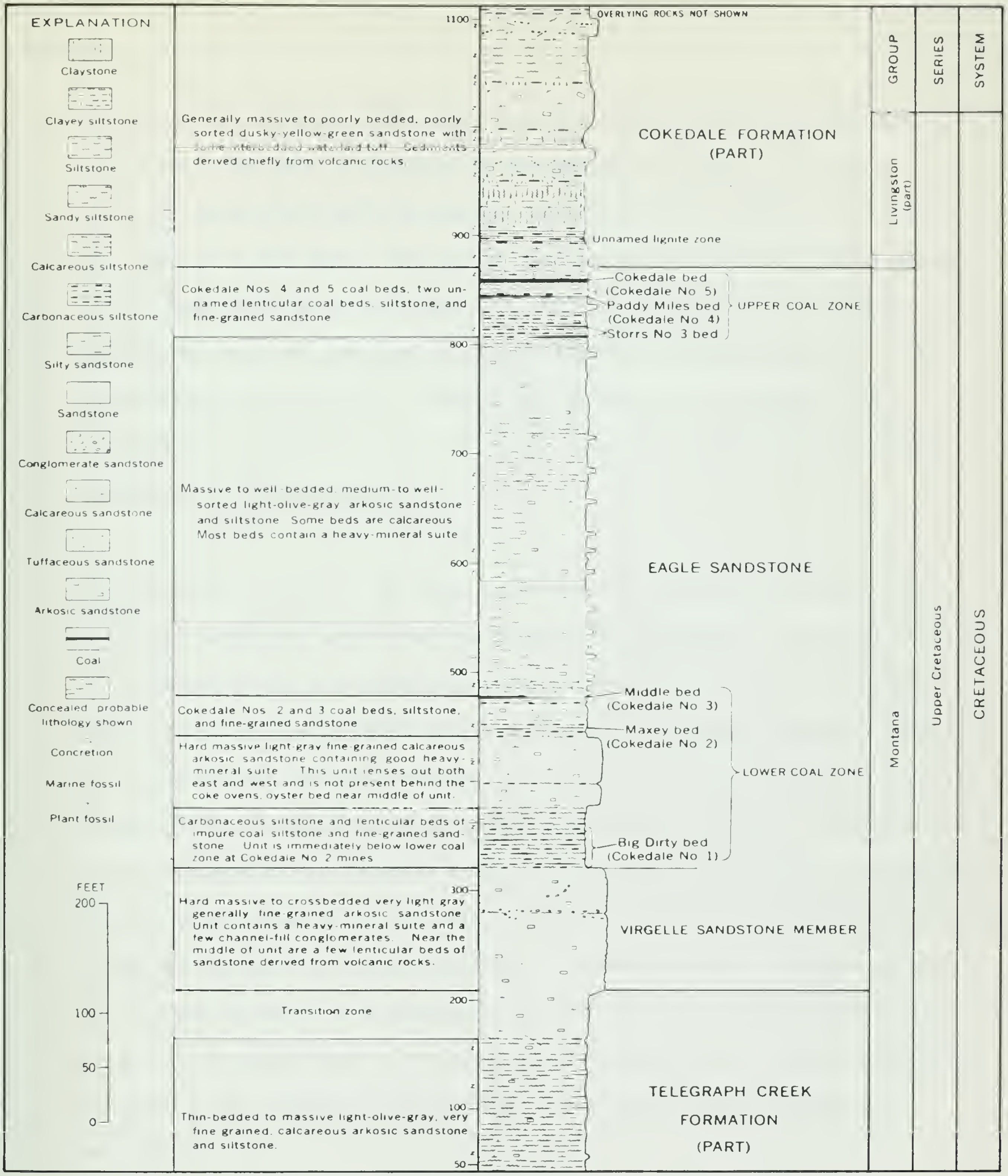
The Frontier is conformably overlain by the Cody Shale which indicates a marine transgression and return to a deeper water environment. The Cody is 1,285 to 1,375 feet thick and is subdivided into three members. These are a lower brown shale and siltstone member, a middle thin-bedded, glauconitic sandstone, known as the Eldridge Creek Member (Roberts, 1964), and an upper gray and brown shale member. The unit is typically pyritic and glauconitic. The Eldridge Creek Member is an excellent marker bed with a distinctive ammonite fauna which gives an upper Coniacian age.

The Telegraph Creek Formation consists of thin beds of sandy siltstone and sandstone which form a shallow water marine unit transitional between the underlying offshore Cody Shale and the overlying nearshore Virgelle Sandstone member of the Eagle Sandstone. The unit is poorly exposed in the Livingston GRA and usually has gradational upper and lower contacts. The formation is composed of about one-third shale and mudstone and two-thirds siltstone and sandstone, which grade upward from shale to sandstone. The

total thickness of the unit ranges from 275 to 295 feet. The age of the Telegraph Creek is defined largely by stratigraphic position.

The Eagle Sandstone Formation is a sequence of sandstone with intercalated beds of coal and carbonaceous siltstone, which represent near-shore terrestrial deposits (Fig. 6). It gradationally overlies the Telegraph Creek Formation and is in turn gradationally overlain by the Cokedale Formation. In the Livingston GRA the unit ranges from 515 to 860 feet thick. The lower 100 feet of the formation comprises the Virgelle Sandstone Member. This member is composed mainly of hard, massive to cross bedded, arkosic sandstone with minor lenses of volcanic derived sandstone. The upper part of the formation includes a lower sandstone unit and an upper carbonaceous unit or coal zone. The sandstones are mainly arkose and siltstone alternating with two coal-bearing interbeds in the lower part. The coal zone consists of coal, carbonaceous siltstone and sandstone. Several of the coal beds are of commercial width and rank (Roberts, 1957). The coal-bearing Eagle Sandstone outcrops in a thin westward trending band extending across the southern part of the GRA and passing underneath alluvium deposited in the valley of the Yellowstone River. It does not appear to underlie WSA 075-133 (Fig. 5).

Most of the upper portion of the Cretaceous section is included in the Livingston Group. The group includes the Cokedale, Miner Creek, Billman Creek, and Hoppers Formations. These formations are a thick section of alternating coarse- and fine-grained, continental, and fluvial clastic sediments derived from the Elkhorn Mountains volcanic pile to the west. These largely non-marine rocks intertongue eastward with the marine Montana Group in the Crazy Mountains Basin (Peterson, 1981).



Section Location
N.W. 1/4 Sec. 26, T.2S., R.8E., at Cokedale, Park County, Montana.

Data from Roberts (1966a)

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BLM GEM RESOURCES ASSESSMENT REGION 2 NORTHERN ROCKY MOUNTAINS	
Livingston GRA, Montana Stratigraphic Section Eagle Sandstone	
SCALE	FIGURE 6
DATA BY / DATE / REVISED	
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The Cokedale Formation conformably and gradationally overlies the Eagle Sandstone. The unit is composed of non-marine siltstone, sandstone, mudstone, water-laid tuff, bentonite, and carbonaceous shale with a total thickness of 1,550 feet. The age of the Cokedale is based on fossil pollen, spores, and fresh water mollusks. In addition, tuffs in the middle part of the Cokedale may be correlative with a distinctive welded tuff bed in the Elkhorn Mountains Volcanics which is dated as 76±2 m.y. based on its geologic relationship to two units which have been radiometrically dated (Robinson and Marvin, 1967).

The Cokedale is overlain by about 1,300 feet of alternating beds of siltstone and sandstone comprising the Miner Creek Formation. The basal portion of the Miner Creek is a prominent ridge-forming unit known as the Sulphur Flats Sandstone Member which consists of tuff, quartzose sandstone, volcanic lithic sandstone, and conglomerate. The upper portion of the Miner Creek is predominantly siltstone with about 30% interbedded sandstone. Zeolites are common throughout the Cokedale as pore space and cavity fillings, generally making up less than 1% of the rock. However, in parts of the Sulphur Flats Sandstone the zeolite content exceeds 1% (Roberts, 1972). The age of the Miner Creek is based on a distinctive pollen and spore flora found in claystones in the upper part of the formation. Large et al. (1982) consider the Cokedale to be a favorable environment for sandstone-hosted uranium deposits.

The Billman Creek Formation is a distinctive grayish-red weathering unit which rests conformably on the Miner Creek Formation. It is a non-marine redbed unit composed of over 65% mudstone and claystone with about 25%

sandstone and conglomerate channel fillings. The age of the formation is based on stratigraphic position, correlation with other units, plant microfossils and fossil vertebrates.

Overlying the Billman Creek Formation is another non-marine unit; the Hoppers Formation. The Hoppers is about 900 feet thick and consists dominantly of volcanic lithic sandstone interbedded with mudstone and siltstone. Zeolites are common as cement in the sandstones. Fossils are rare in the Hopper Formation and the age of the Hoppers is based largely on correlation with other sections.

The uppermost unit in the section, the Fort Union Formation, is over 6,600 feet thick and spans the Cretaceous-Paleocene boundary. The Fort Union has been studied in detail by Piombino (1979). It is subdivided into a lower conglomeratic sandstone, a middle sandstone and mudstone member, and an upper conglomeratic unit. The lithology of the lower member differs markedly from the underlying Livingston Group. The conglomerates are heterolithologic, and include pebbles of both plutonic and metamorphic rocks. This contrasts with the predominance of volcanic rocks in the Livingston Group. The change in pebble lithology indicates a change in the nature and location of the sediment source area. Large, et al. (1982) and Piombino (1979) suggest that the source area is to the south. In the Livingston GRA the formation shows a striking alternation of sandstone and mudstone. The lower part of the formation is assigned, a Late Cretaceous age based on paleontological data. Fossil spores and pollen from fine-grained rocks in the upper part of the formation indicate a Paleocene

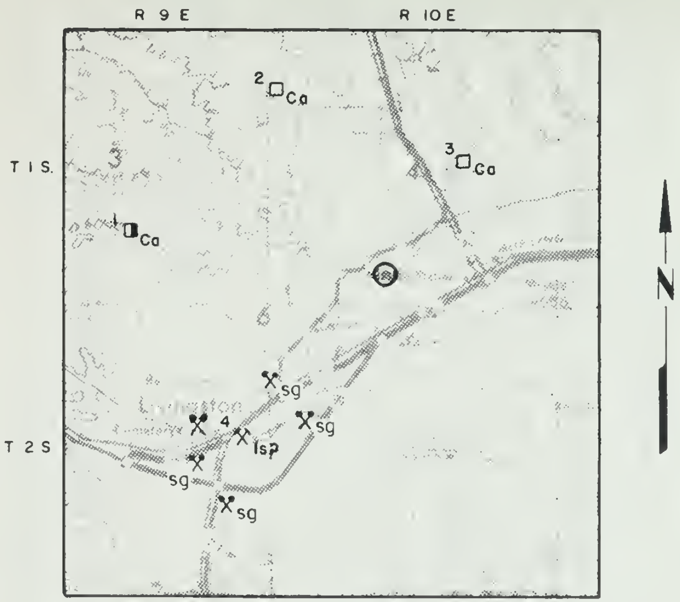
age for the uppermost part of the unit. The upper contact of the Fort Union Formation is eroded.

Quaternary (2 m.y.-present) deposits in the GRA are of Pleistocene (2-0.1 m.y.) and Holocene (0.1 m.y.-present) age. The oldest deposits are interbedded silt, sand and gravel which make up a series of older alluvial terraces. There are several terrace levels ranging from 30 to 160 feet above the present floodplain of the Yellowstone River. Many of the gravel pits near the town of Livingston exploit the older terrace deposits (Fig. 7). Mixed slope-wash and alluvial fan deposits composed of silt, sand, pebbles, cobbles, and boulders overlie much of the bedrock south of the Yellowstone River. These deposits pre-date the older terraces in places (Richards, 1957). The youngest deposits in the GRA consist of unconsolidated alluvium composed of interbedded clay, silt, sand and gravel. These deposits occur along stream valleys and in the floodplain of the Yellowstone River. The surface of WSA 075-133 is solely underlain by these deposits.

There are no intrusive rocks exposed within the GRA. Northeast of the area laccoliths, stocks, sills, and several generations of dikes were intruded in Eocene (55-38 m.y.) time along the axis of the Crazy Mountains Basin (Fig. 3).

2.4 Structural Geology and Tectonics

The outcrop pattern of the rocks in the GRA reflects Late Cretaceous and early Tertiary deformation. Regionally the GRA is located on the southern edge of the Crazy Mountain Basin which was an active depositional site



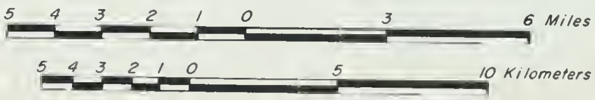
LEGEND

- ■ *Mineral Orebody*
- ◧ *Mineral Deposit*
- □ *Mineral Occurrence*
- ⚒ *Active Quarry*
- *Inactive Quarry*
- *Gravel or Clay Pit*

1 □ Cu — *occurence number* / *commodity*

ca - *Calcite*
ls - *Limestone*
sg - *Sand and gravel*

Approximate Boundary of Wilderness Study Area.



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BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Livingston GRA, Montana

Mineral Occurrences

SCALE 1" = 4 MILES			FIGURE 7
DATA BY WGM	DATE 1/1983	REVISED	
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throughout Cretaceous time. The initial pulses of the Laramide Orogeny began in the Late Cretaceous and continued to the early Eocene producing the major uplifts which bound the Basin. One of these structures, the Nye-Bowler Lineament (Fig. 3) may extend into the southeastern part of the GRA and terminate near Livingston (Wilson, 1936; Alpha and Fanshawe, 1954). This lineament is essentially a long complexly faulted anticline and is the northern boundary of the Bighorn Basin. The Nye-Bowler lineament begins just west of the Pryor Mountains and trends northeastward to the Bear Mountains front near Nye, a distance of 56 miles (Richards, 1957). Alpha and Fanshawe (1954) extend the lineament northeast along the Bear Mountains front 60 miles farther to Livingston. The other major structures in the area are the Livingston Anticline and the Freshman Creek Anticline in the southwest part of the area. These folds are part of a system of arcuate northwest-trending en echelon folds between Livingston and Bozeman (Roberts, 1972) which parallel the axis of the Crazy Horse Basin and may represent the extension of the Nye-Bowler lineament. The folds are convex towards the southwest. In the Livingston area, folding that accompanied thrusting produced asymmetric anticlines with the steepest dips on the southwest flanks. Small displacement normal faults occur along the axis of the folds and in association with other smaller scale folds in the northeast part of the area. Veins of near optical quality calcite are associated with some of these faults (Stoll and Armstrong, 1958).

2.5 Paleontology

A brief description of the fossils in the Livingston GRA is given by Richards (1957) and a thorough, detailed description of the Cretaceous

fossils is given by Roberts (1972). Fossils are present but are not abundant in the GRA. Since many of the units in the section are non-marine, fossil plant remains, pollen, and fresh water mollusks are common. The most distinctive fossil occurrence mentioned by Roberts (1964, 1972) is the presence of the index fossil ammonite, Scaphites depressus, in the Eldridge Creek Member of the Cody Shale.

2.6 Historical Geology

The oldest unit exposed in the Livingston GRA is the Early Cretaceous Kootenai Formation, a non-marine sequence apparently deposited as a result of an uplift to the west during Late Jurassic or Early Cretaceous time (Roberts, 1972). Throughout the Cretaceous, the Livingston region was the site of repeated transgressions and regressions. The Frontier Formation, Eagle Sandstone, and portions of the Livingston Group and Fort Union Formation were deposited during major regressions (Roberts, 1972; Peterson, 1981). The prominent sandstone units such as the lower and upper members of the Thermopolis Shale and the Eldridge Creek Member of the Cody Shale represent near-shore marine deposition during a time of marine transgression (Roberts, 1972).

The presence of volcanic ash and other volcanic detritus in many of the units within the Livingston GRA indicates that volcanism occurred in the region at least intermittently throughout Cretaceous time. In the Livingston area, the volcanic pebbles present in the Virgelle Sandstone Member of the Eagle Sandstone suggest the beginning of uplift to the west during the Laramide orogeny. The first major tectonic pulse of the orogency

took place at the end of Eagle time is recorded by the flood of volcanic debris in the basal part of the overlying Livingston Group. The accumulation of the complex pile of andesitic volcanics in the Elkhorn Mountains began 78-73 m.y. ago, in the Late Cretaceous (Robinson et al., 1968). These volcanics appear to have been a preliminary phase of Boulder Batholith plutonism (Chadwick, 1981). This was accompanied by the withdrawal of the Eagle sea and gradual downwarp of the Crazy Mountain Basin north of the GRA (Roberts, 1972). In the Livingston area, the final uplift during the Laramide orogeny occurred in the early Eocene and was accompanied by major intrusive activity in the Castle Crazy and Little Belt Mountains. Laramide folds and faults which developed during the Laramide orogeny were subsequently modified by normal faulting and volcanism. During this post-Laramide epiorogenic uplift at the end of the Tertiary the Crazy Mountain Basin and adjacent areas were raised about 5,000 feet. This late period of movement may have continued into Holocene time (Roberts, 1972).

3.0 ENERGY AND MINERAL RESOURCES

3.1 Introduction

Data on known energy and mineral deposits and occurrences was compiled during a review of all available data on the Livingston GRA. The principal sources were the U.S. Bureau of Mines MILS Data File, the USGS CRIB Data File, Department of Energy NURE Reports, reports of the Montana Oil and Gas Conservation Commission and Review Reports by Cole, et al. (1982) and Sonderegger and Bergantino (1980), and a mineral report by Reed (1950).

3.2 Known Mineral and Energy Deposits

There are no known metallic mineral deposits in the GRA.

Near optical-quality calcite was produced from several properties north of the Livingston GRA during World War II (Stoll and Armstrong, 1958). These deposits are part of a zone of northwest-trending calcite veins over 60 miles long. Most of the deposits are veins and vugs in andesitic volcanic sandstones (Reed, 1950). There are three calcite prospects/occurrences in the GRA (Fig. 7; Table I; loc. 1-3), but no occurrences are reported in the WSA.

There is no hydrocarbon production in the Livingston GRA. Two wells have been drilled (Fig. 8; Table II; loc. 1-2). Neither well had any production. However, traces of oil were reported at 665 feet in the Yellowstone Oil and Development Company Well (Appendix II).

TABLE I

MINERAL OCCURRENCES IN THE LIVINGSTON GRA, MONTANA

Map No.	Name	Location Sec.	T.	R.	Commodity	Description	Reference
1	Unnamed	27	1S	9E	Calcite	Vein deposit of near-optical quality calcite.	Reed, 1950 and Stoll & Armstrong, 1958
2	Unnamed	7	1S	10E	Calcite	Vein deposit of near-optical quality calcite.	Reed, 1950 and Stoll & Armstrong, 1958
3	Unnamed	14	1S	10E	Calcite	Vein deposit of near-optical quality calcite.	Reed, 1950 and Stoll & Armstrong, 1958
4	Unnamed	14	2S	9E	Limestone	No data. Site may be mislocated.	MILS-Bozeman Quadrangle

TABLE II

ENERGY OCCURRENCES IN THE LIVINGSTON GRA

Oil and Gas Wells[1]

Map No.	Location Sec.	T.	R.	Well	Company	Year Drilled	Total Depth (ft.)	Production	Status (Aug. 1982)
1	13	2S	9E	Yellowstone Oil and Gas Co.	Yellowstone Oil and Gas Co.	1917-18	740	None	Abandoned
2	11	2S	9E	No. 1 Strong	Deerfield Oil Corporation	1959-60 1962	7,009	None	Plugged and abandoned

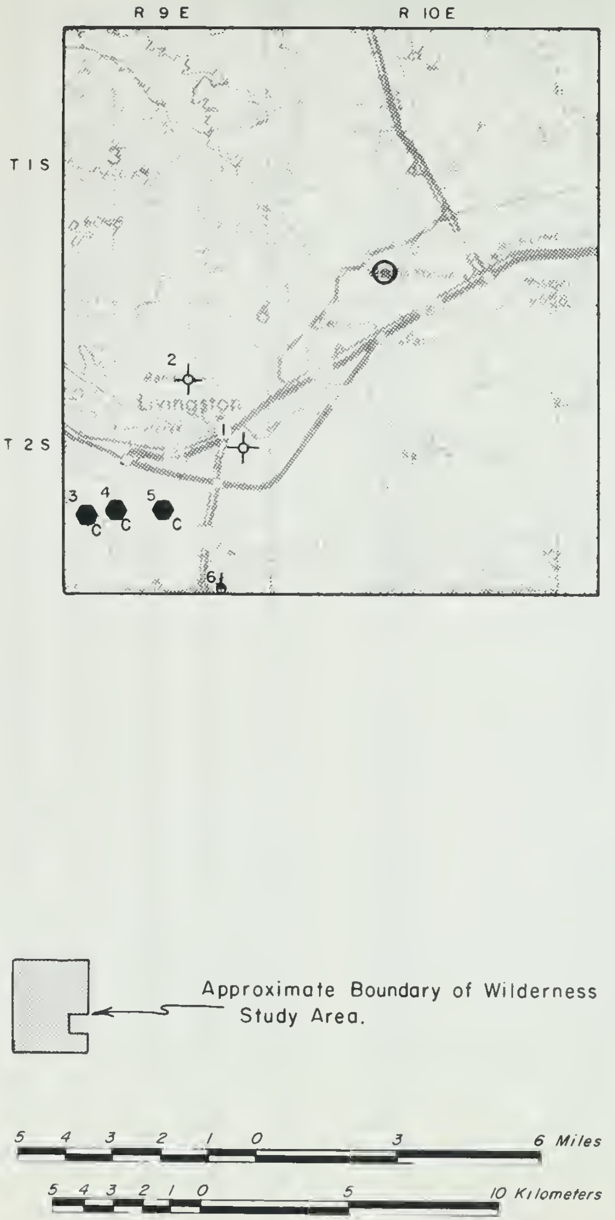
Coal Occurrences

Map No.	Name	Location Sec.	T.	R.	Description	Reference
3	Kangley Mine	28	2S	9E	Small mine developed on Cokedale bed in Eagle Sandstone. Low rank coal.	Roberts, 1966a
4	Spangler Mine	28	2S	9E	Small mine developed on Cokedale bed in Eagle Sandstone. Low rank coal.	Roberts, 1966a
5	Williams Mine	27	2S	9E	Small mine developed in Big Dirty bed in Eagle Sandstone. Low rank coal.	Roberts, 1966a

Thermal Springs[2]

Map No.	Name	Location Sec.	T.	R.	Source Rock	Observed Temp (C^o)	Reservoir Temp (C^o)	pH	Specific Conductance	Total Dissolved Solids
6	Carters Bridge	1	3S	9E	Madison	28	40	7.8	850	600

1. Data from Montana Oil and Gas Conservation Commission.
2. Data from Sonderegger and Bergantino (1981, Table II).



LEGEND

- oil well
- oil and gas well
- gas well
- well with show of gas
- well with show of oil
- well with show of oil and gas
- shut in well
- dry hole—abandoned
- tight hole or well in progress as of July, 1982
- Oil field
- Gas field
- Oil shale
- Oil show or seep
- Coal deposit
- Coal occurence
- Thermal water
- Geothermal area
- Uranium occurence / deposit
- Thorium occurence / deposit

WGM Inc. Mining and Geological Consultants
Anchorage, Alaska

BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Livingston GRA, Montana

Energy Resource Occurrence Map

SCALE 1"= 4 MILES			FIGURE 8
DATA BY WGM	DATE 1/1983	REVISED	
DRWN BY DSI	APRVD G.F		

There are three formerly producing coal mines located in the southwest corner of the Livingston GRA (Roberts, 1964). These are the Spangler, Kangley, and Williams Mines (Fig. 8, Table II; loc. 3-5). All three produced small amounts of subbituminous coal from the Cokedale district (Calvert, 1912; Roberts, 1964). The coal beds are within the Eagle Sandstone Formation (Fig. 6). This unit outcrops in the western part of the GRA and may be present beneath the surface alluvial cover over the WSA.

There is one warm spring in the southern part of the GRA (Fig. 8; Table II; loc. 6).

One limestone quarry is present near Livingston. No sample or production data for the quarry are available. Chelini (1965) reports an analysis of a sample of Mission Canyon Limestone (No. 54, p. 44) several miles south of Livingston that ran 2.07% MgO and 51.93% CaO, however this unit does not outcrop in the GRA. It is possible that the quarry shown on the MILS Map is mislocated. There are at least five sand and gravel pits shown in the MILS file and on topographic maps of the area (Fig. 7). All but one pit is in older terrace gravels.

3.3 Known Mineral and Energy Prospects, Occurrences and Mineralized Areas

Roberts (1972) reports trace amounts of whitneyite (copper arsenide) in many of the Cretaceous clastic units within the Livingston GRA. Roberts suggests that the copper minerals are derived from the Jardine Mining District south of the GRA, an area with reported copper and arsenic occurrences. In a general way these very weakly mineralized volcaniclastic sediments are

similar to known sediment-hosted copper deposits (Gustafson and Williams, 1981).

The zeolite minerals heulandite, analcime, laumontite, and clinoptilite occur in amounts ranging from 1 to 3% in the Sulphur Flats Sandstone Member of the Miner Creek Formation (Roberts, 1972). No data on the extent and distribution of the zeolites are given.

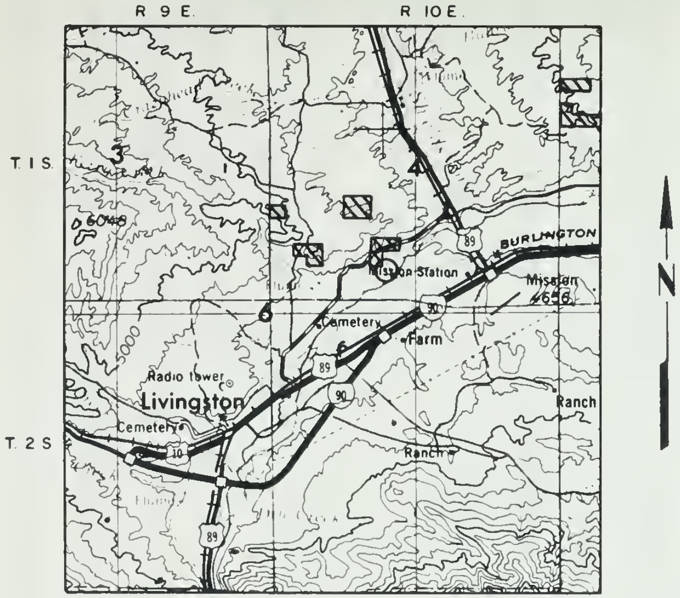
3.4 Mining Claims, Leases and Material Sites

The locations of patented and unpatented mining claims, mineral, oil and gas leases, and material sites were researched in the public information office at the BLM State office in Billings. Unpatented mining claims status is based on a review of a BLM mining claim computer printout dated August 30, 1982. All other land status is taken from BLM Master Title and oil and gas plats current to August 4, 1982.

There are no patented or unpatented mining claims or mineral leases in the Livingston GRA. There are scattered oil and gas leases but none are within the Yellowstone River Island WSA (Fig. 9).

3.5 Mineral and Energy Deposit Types

Based on the geologic environment and known mineral and energy occurrences within the Livingston GRA there appear to be six deposit types which would serve as models for evaluation of the Yellowstone River Island WSA. These are: (1) calcite, (2) uranium, (3)coal, (4) geothermal, (5) oil and gas,



LEGEND

 AREA COVERED BY OIL AND GAS LEASES

 AREA COVERED BY OIL AND GAS LEASE APPLICATION

Notes: 1) Area of search: T 1 S, R 10 E

2) Data current to: Aug. 4, 1982

3) Source of Data: BLM Status Plats

WGM Inc. Mining and Geological Consultants, Anchorage, Alaska	
BLM GEM RESOURCES ASSESSMENT REGION 2 NORTHERN ROCKY MOUNTAINS	
Livingston GRA, Montana **Oil and Gas Lease Status**	
SCALE 1"= 4 MILES (1 250,000)	FIGURE 9
DATA BY WGM · DATE /198 · REVISED	
DRWN BY DSI · APRVD GF	

and (6) sand and gravel. The overall geologic environment does not appear to be favorable for metallic mineral deposits, however there is no geochemical or other geological data available on which a complete evaluation can be based.

The calcite deposits mined during World War II occur along northwest-trending structures. All of the known deposits are exposed at the surface, but some are undoubtedly concealed beneath surface cover. Since the Yellowstone River Island WSA is along the trend of the known deposits it is quite possible that calcite deposits may be present beneath surficial alluvium covering the WSA.

Although there are no known uranium occurrences in the Livingston GRA the geologic environment is favorable for uranium mineralization (Large et al., 1982). A water anomaly and several airborne radiometric anomalies were delineated in the general Livingston area during a NURE reconnaissance of the Bozeman NTMS quadrangle (Bolivar, 1978). However, the only geochemical samples collected in the Livingston GRA were two well water samples which contain 4 ppb uranium. These values are well below the regional background (Large et al., 1982).

Uranium ore found in the continental arkosic sandstone deposits of the western United States has provided about 95% of domestic production and accounts for more than 95% of known domestic reserves. Individually, the deposits are smaller than those in Proterozoic conglomerates, but they are more widespread and their grade is much higher, averaging about two

kilograms U_3O_8 per ton. Ultimate production from such deposits in the Laguna-Mt. Taylor-Ambrosia Lake area of New Mexico may rival that of the Blind River conglomerate deposits. Sandstone deposits are being mined in the Colorado Plateau, the Wyoming Basin area, and the Texas coastal plain.

Typically the host rocks are gray, arkosic sandstones, derived from granitic or older sedimentary rocks, and deposited from streams under continental conditions; a braided stream environment is most favorable. The rocks are medium- to coarse-grained and contain carbonaceous debris and minor pyrite. Commonly they are cut by clayey interbeds, and bound by more impervious strata. The formational unit nearly always contains volcanic ash and detritus as disseminations in the sandstone, or as tuffaceous beds or bentonitic muds.

Major sandstone uranium deposits have been found in structural or erosional basins, and on the flanks of uplifts. The dip of the host sediments is characteristically gentle.

The ore occurs in sand lenses and in sand-filled channel scours, as blanket-like deposits generally concordant with the sedimentary structure, or as roll front deposits that are arcuate in section and hence discordant with the bedding. In plan view the blanket-like deposits appear as irregular masses whose dimensions may be measured in hundreds of thousands of feet; whereas, the roll front bodies tend to be more sinous and lenticular.

The uranium is believed to have been derived from the host sediments, from the contained volcanic debris and/or from neighboring granitic masses, and carried in solution by circulating ground water to a point where it is deposited in a reducing environment, at or below the ground water table. Sedimentary structures or lithologic changes that affect permeability therefore influence ore deposition, but there is no evidence of igneous or tectonic activity exerting depositional control.

The common ore minerals are uraninite and coffinite. Vandium, molybdenum and selenium occur in most deposits in traces or in significant quantities, and in the Uravan camp in Colorado the vandium content of the ores exceeds that of uranium by a ratio of 5 to 6:1. Of interest in this regard is that uranium, in the presence of adequate vanadium, will form hydrous uranium vandates which are stable in the zone of oxidation, thus encouraging the presence of surface or near-surface deposits. Copper sulphide minerals are also common accessories. The ore minerals form coatings on sand grains and matrix material, imparting a dark gray to black color to the sandstone. In general, the darker the ore becomes, the higher the grade is likely to be.

The carbonaceous material almost always present in ore sands is commonly coalified leaf and wood fragments, but asphaltic material, similar to dead oil of petroliferous rocks, is sometimes present. The carbonized fossil wood is replaced by uranium minerals.

Some degree of sandstone alteration is present in all orebodies, and although not identical from place to place, is characterized by evidence of a change from an oxidizing environment to a reducing environment. Commonly

the altered rock is reddish-brown or greenish-yellow due to oxidized iron, pyrite is absent, fossil wood is bleached and partially destroyed, and feldspar grains may be partially kaolinized. In contrast the unaltered rock is gray, contains pyrite and coalified wood, and shows less evidence of feldspar alteration. In the case of roll front deposits, long tongues of alteration, measured in miles, may extend down-dip along a sand lens, and the roll front orebodies mark the interface between oxidizing and non-oxidizing conditions within that lens. Several orebodies may occur at various places along the forward edge of such an alteration zone. Moreover, overlying or underlying sand lenses, separated by relatively impermeable barriers, may have separate tongues of alteration whose extent will be controlled by the stratigraphic and lithologic conditions of that lens. Such conditions may produce orebodies at two or more stratigraphic horizons within the same formational unit.

The important deposits in the United States are in rocks of Triassic, Jurassic and Eocene age, but similar mineralization is known from Permian through Tertiary strata. There is no apparent reason why the age of the host rock should be a limiting factor in the search for deposits of this type.

Large et al. (1982, p. 28-30), suggest that the Cretaceous section in the Livingston-Crazy Mountains area is favorable for the occurrence of sandstone-hosted uranium deposits. The most favorable unit is the Fort Union Formation, a thick sequence of deltaic and fluvial sedimentary rocks with minor volcanic rocks (Piombio, 1979). Uranium could have been derived from volcanic source areas to the south or from plutons in the Crazy

Mountains and concentrated in structurally controlled zones of high ground water (Large et al., 1982). The Livingston Group, particularly the Cokedale Formation and Eagle Sandstone, contain numerous coal and lignite beds which could accommodate uranium accumulation.

The coal deposits which were mined in the Livingston GRA occur in the Eagle Sandstone and include the Big Dirty and Cokedale beds (Fig. 6). Little more is known about these mines. It appears most of their production was sub-bituminous coal for domestic use (Roberts, 1966). If the Eagle Sandstone projects beneath the Yellowstone River Island WSA, than subsurface coal deposits may be present in the WSA.

No oil and gas resources have been discovered yet in the Livingston GRA. Walsh (1957) and Hadley (1972) summarize the history of the oil and gas exploration of the Crazy Mountains Basin. According to them, oil seeps were noted in the late 1880s along the Absaroka Range approximately 60 miles southeast of Livingston. Oil exploration ultimately led to the discovery of oil and gas in shallow Lower Cretaceous sands at Dean Dome (approximately 55 miles southeast of WSA 075-133) and gas at the Mud Creek, Rapelje and Lake Basin Fields (approximately 70 miles northeast of WSA 075-113).

Although some test wells have been drilled on potential oil- and gas-bearing structures near the Livingston GRA, relatively few shows of oil or gas have been encountered. All wells were plugged and abandoned (Walsh, 1957). Two wells have been drilled within the GRA (Table I, Appendix II): (1) a well drilled within the GRA in Sec. 13, T.2S., R.9E. (Fig. 8) reported a trace of

oil at 665 feet before being abandoned at 740 feet and (2) a well drilled in Sec. 11, T.2S., R.9E. (Fig. 8) to a depth of 7,009 feet and re-entered to 6,150 feet reported no shows.

The hydrocarbon potential for the Crazy Mountains Basin is uncertain but thought to be significant by some individuals (Hadley, 1972). Much of the basin is under oil and gas leases including a few acres adjacent to WSA 075-113 (Fig. 9). According to Hadley (1972) only 128 wells had been drilled within the 4,224 square miles comprising the Crazy Mountains Basin, an average of one well per 33 square miles. One third of these tests reported shows of oil or gas (Hadley, 1972). Drilling within the basin since 1972 has continued at a slow pace because no major discoveries have been made within the Basin. Many known surface structures remain untested by drilling. Hadley (1972) reported dips of strata in some wells differ at depth from those recorded at the surface and thus drilling in the basin based on surface data alone may not be the proper prospecting technique.

Geologic mapping around and within the Livingston GRA (Richards, 1957: Roberts, 1964) has shown the presence of structures which could form potential traps for hydrocarbons. The stratigraphic section contains formations known to be reservoir beds in producing areas to the southeast and northeast in the Crazy Mountains Basin. Potential source beds are recognized in the Livingston GRA, but analyses of strata for source rock characterizations and thermal maturation have not been made. However, known production in other parts of the Crazy Mountains Basin and similarity to known source rocks suggests that potential oil and gas source beds in the Livingston area are most likely the Jurassic and Cretaceous shales and

possibly some Paleozoic shales and shaley limestones. Also Cretaceous coals could be a source of methane gas. Probable reservoir beds are sandstones of Paleozoic, Jurassic and Cretaceous age. Thus, the Livingston GRA including WSA 075-113 is a potential hydrocarbon resource bearing area.

In the most recent geothermal classification of the United States (Muffler, 1979), geothermal resources were divided into six categories. These are:

1. Conduction-dominated regions
2. Igneous-related geothermal systems
3a. High temperature (150°C) hydrothermal convection systems
3b. Intermediate temperature (90-150°C) hydrothermal convection systems
4. Low temperature (90°C) hydrothermal convection systems
5. Geo-pressured geothermal energy systems

For the purposes of this Wilderness Study Area assessment these classes can be reduced to two: (1) high temperature (less than 150°C) hydrothermal convection systems and (2) low/intermediate temperature (40-150°C) hydrothermal convection systems. Geopressured geothermal energy systems do not exist in the area discussed. At the present time, and for the foreseeable future, a naturally warm fluid and sufficient porosity and permeability of the host rock to allow fluid movement, are necessary for practical use of geothermal energy; thus, conduction-dominated and "magma-tap" geothermal systems are not included in this evaluation.

Based on present requirements for use of hot fluids in electrical generating techniques, geothermal systems with temperatures of less than 150°C do not

have significant potential for electrical exploitation. These systems, however, can be considered to have a significant potential for low and intermediate temperature geothermal utilization for space heating, material processing, etc. if their minimum temperature exceeds 40°C. At the lower end of the spectrum, as the energy content of the resource becomes less, or the drilling depth necessary for exploitation becomes greater, there is a very ill-defined cutoff. For example, shallow ground water temperatures of the order of 10-20° can be used for heat pump applications, and in some cases these are considered geothermal resources. However, for the purpose of this discussion, a lower temperature of approximately 40-60°C is considered a cutoff for a geothermal resource. Another important aspect of a geothermal resource is transportability which depends on the temperature of the system. At lower temperatures it is not feasible to consider long-distance transportation of the geothermal energy whereas for the electrical grade resources long transportation distances are of course feasible. It is clear that a 40°C warm spring, no matter what its flow, has relatively little resource potential if it is located 10 to 20 miles from the nearest possible spot of application. For the purposes of this report geothermal resources are classified in terms of observed or expected system temperature.

The area of western Montana and southern Idaho within GEM Region 2 can be divided into six provinces of different geothermal significance (Table III).

TABLE III

GEOTHERMAL PROVINCES IN GEM REGION 2

1. Montana Thrust/Foothills
2. Montana Basin and Range
3. Central Idaho Basin and Range
4. Idaho Batholith/Blue Mountains
5. Southeastern Idaho Basin and Range
6. Snake River Plains

The Livingston GRA is in the Montana Basin and Range province. Although western Montana is classed physiographically as part of the northern Rocky Mountains, the Cenozoic structural geology is similar to the Basin and Range province of the southwestern United States. Western Montana is blocked into north-northwest trending ranges separated by valleys which have topographic expressions controlled by horst and graben structures. The normal fault systems in western Montana have been active as late as Pliocene-Pleistocene time (Pardee, 1950), and one of the major active seismic zones in the western United States, the Intermountain Seismic Belt (Smith, 1978), more or less marks the eastern boundary of this province. There has been no volcanic activity, however, in the province for approximately the past 30-37 m.y. Typical heat flow values in this province are 75 to 90 milliwatts per square meter (Blackwell, 1969: Blackwell and Robertson, 1973). Typical geothermal gradients range from 25 to 40°C/km. Geothermal data are reasonably complete on a reconnaissance basis for this area. There are numerous hot springs in southwestern Montana which have been discussed in some detail by Robertson et al. (1976) and are shown on the resource map by Sonderegger and Bergantino (1981). Geochemical reservoir temperatures and measured surface temperatures of these systems generally indicate maximum

temperatures of between 75 and 150°C. Typically these hot springs are associated with major fracture zones in granitic plutons or with major fracture/fault zones such as the range-bounding faults (especially when major cross structures intersect these zones). The available data suggest that the likelihood of electrical grade temperature (150°C) resources in this province is small. On the other hand, on a relative basis, the low/moderate temperature resources in the area are significant based on the many known hot and warm springs.

The Yellowstone River Island WSA (075-133), a small island in the middle of the Yellowstone River (Fig. 2), is in or just to the east of the Intermountain Seismic Belt (Smith, 1978). The Livingston GRA lies astride the boundary between the Crazy Mountains Basin to the north and the Beartooth Plateau to the south (Fig. 3). The Beartooth Plateau is an uplift of Precambrian basement rocks and the structure is typical of the central Rocky Mountains rather than the northern Rocky Mountains structures typical of the rest of western Montana. Heat flow in the Beartooth Plateau is normal (Blackwell, 1969: Sass et al., 1971). Gradients are normal to low in areas where heat flow values have been determined (1 to 2°F/100 ft.). No heat flow or geothermal gradient data are available for the the Crazy Mountains Basin. There are hot and warm springs around the margins of the Beartooth Plateau including Hunters Hot Springs and Carter Bridge Warm Springs which are on the south edge of the Crazy Mountains Basin and are about 10 miles east and 8 miles southwest respectively from the WSA (Fig. 8). The flow rate of Hunters Hot Spring is 4,920 liters per minute with an observed temperature of 59°C and an estimated reservoir temperature (geochemical) of 78°C. Carters Bridge Warm Spring has a flow rate of 5,680 liters per minute

with an observed temperature of 28°C and an estimated reservoir temperature of 40°C (Table II, loc. 6, Sonderegger and Bergantino, 1981). The geothermal resources in the area are associated with stratigraphic aquifers in the Paleozoic, Mesozoic and Cenozoic sedimentary and volcanic sequence above the basement. No late Cenozoic volcanic rocks are present in or near the WSA. Sonderegger and Bergantino (1981) have rated the area along the valleys of the Yellowstone and Shields River within the Livingston GRA as having high geothermal potential.

The Yellowstone River Island WSA is underlain by a thick sequence of sedimentary rocks including several aquifers. Water in these aquifers may be in the low to intermediate temperature geothermal range. It is very unlikely that temperatures above 150°C will exist in the sedimentary section beneath the WSA and no major fault structures with possible deep fluid circulation are found in it.

The majority of the sand and gravel pits are in older alluvial terraces. There is no data to indicate the reason for the preference of one type of alluvium over the other. The older terraces are all located above the present-day river level. WSA 075-133 is entirely underlain by recent alluvium.

3.6 Mineral and Energy Economics

From the discussion in Section 3.4 above, it can be seen that the best potential for economically significant resources in WSA 075-133 is for oil and gas, sand and gravel, and uranium deposits.

The recent deregulation of natural gas prices and the increasing price of oil during the past nine years have lead to increased domestic exploration in an effort to lessen United States reliance on imported oil. Numerous environments which would not have been explored in the past are being evaluated today. The lack of systematic, thorough hydrocarbon exploration in the Livingston GRA, the generally favorable geologic setting and the well developed infrastructure make the development of any existing oil or gas deposits in the GRA economically attractive.

Production of sand and gravel is the second largest non-fuel mineral industry in the United States (Tepordei, 1980). Sand and gravel are used primarily as aggregate in the construction industry. They are high-bulk, low-value commodities and as such are sensitive to transportation costs (Dunn, 1975). Although WSA 075-133 is underlain entirely by sand and gravel, the location of the area in the middle of the Yellowstone River would add significantly to mining costs and make the deposits economically unattractive unless they had some special characteristics.

Uranium exploration and development in the United States have declined for the past several years because of poor uranium prices due to severe excess producing capacity (White, 1982). The excess of production over consumption is expected to continue for the next several years. Ultimately, however, nuclear power will contribute to a larger share of United States energy production and presently marginal environments will again be explored.

4.0 LAND CLASSIFICATION FOR GEM RESOURCES POTENTIAL

4.1 Explanation of Classification Scheme

In the following subsection the land in the Livingston GRA is classified for geology, energy and mineral (GEM) resources potential. The classification scheme used is shown in Table IV. Use of this scheme is specified in the contract under which WGM prepared this report.

The evaluation of resource potential and integration into the BLM classification scheme has been done using a combination of simple subjective and complex subjective approaches (Singer and Mosier, 1981) to regional resource assessment. The simple subjective approach involves the evaluation of resources based on the experience and knowledge of the individuals conducting the evaluations. The complex subjective method involves use of rules, i.e. geologic inference, based on expert opinion concerning the nature and importance geologic relationships associated with mineral and energy deposits (Singer and Mosier, 1981; Table II).

The GEM resource evaluation is the culmination of a series of tasks. The nature and order of the tasks was specified by the BLM, however they constitute the general approach by which most resource evaluations of this type are conducted. The sequence of work was: (1) data collection, (2) compilation, (3) evaluation, and (4) report preparation. No field work was done in the Livingston GRA.

TABLE IV

BUREAU OF LAND MANAGEMENT GEM RESOURCES LAND CLASSIFICATION SYSTEM

CLASSIFICATION SCHEME	LEVELS OF CONFIDENCE
1. The geologic environment and the inferred geologic processes do not indicate favorability for accumulation of mineral resources.	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.
2. The geologic environment and the inferred geologic processes indicate low favorability for accumulation of mineral resources.	B. The available data provide indirect evidence to support or refute the possible existence of mineral resources.
3. The geologic environment, the inferred geologic processes, and the reported mineral occurrences indicate moderate favorability for accumulation of mineral resources.	C. The available data provide direct evidence, but are quantitatively minimal to support or refute the possible existence 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.	D. The available data provide abundant direct and indirect evidence to support or refute the possible existence of mineral resources.

4.2 Classification of the Yellowstone River Island (075-133) Wilderness Study Area

4.2.1 Locatable Minerals

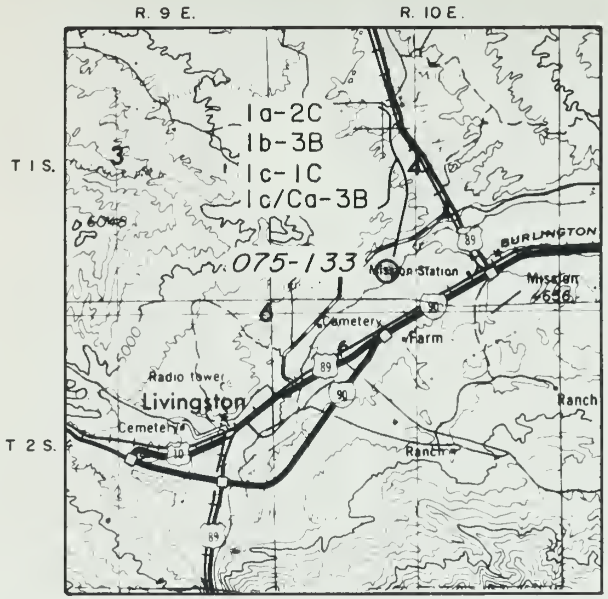
Locatable minerals are those which are locatable under the General Mining Law of 1872, as amended, and the Placer Act of 1870, as amended. Minerals which are locatable under these acts include metals, ores of metals, non-metallic minerals such as asbestos, barite, zeolites, graphite, uncommon varieties of sand, gravel, building stone, limestone, dolomite, pumice, pumitice, clay, magnesite, silica sand, etc. (Maley, 1983).

4.2.1a Metallic Minerals. All of WSA 075-133 is classified as having low potential for metallic minerals based on limited direct evidence (2C). Metallic mineral occurrences are absent regionally in the formations likely to underlie the WSA at a reasonable depth.

4.2.1b Uranium and Thorium. The entire area of WSA 075-133 (1b, Fig. 10) is classified as moderately favorable for uranium and thorium based on indirect evidence (3C). The presence of nearby possibly favorable source rocks and the possible presence of favorable sandstone host rocks beneath the surface alluvium form the basis for the foregoing classification.

4.2.1c Non-Metallic Minerals. There is some possibility that subsurface deposits of calcite occur below the surface alluvium; thus, WSA 075-133 (1c/Ca, Fig. 10) is classified as moderately favorable for mon-metallic minerals based on indirect evidence (3B). WSA 075-133 (1c, Fig. 10) is

BLM LAND CLASSIFICATION SYSTEM FOR GEM RESOURCES



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.

LEVELS 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 QUANTITATIVLEY 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.

EXPLANATION

1 a - 4D

- 1 — Area I.D. Number
- a — Commodity
- 4 — Classification
- D — Level of Confidence

a) Metallic Minerals
b) Uranium and Thorium
c) Non-Metallic Minerals

Note: Ca=Calcite

WGM Inc. Mining and Geological Consultants, Anchorage, Alaska

BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Livingston GRA, Montana
Wilderness Study Area
Land Classification
Locatable Resources

SCALE: 1" = 4 MILES (1 250,000)			FIGURE
DATA BY. WGM	DATE 9/1982	REVISED	10
DRWN BY DSI	APRVD G.F		

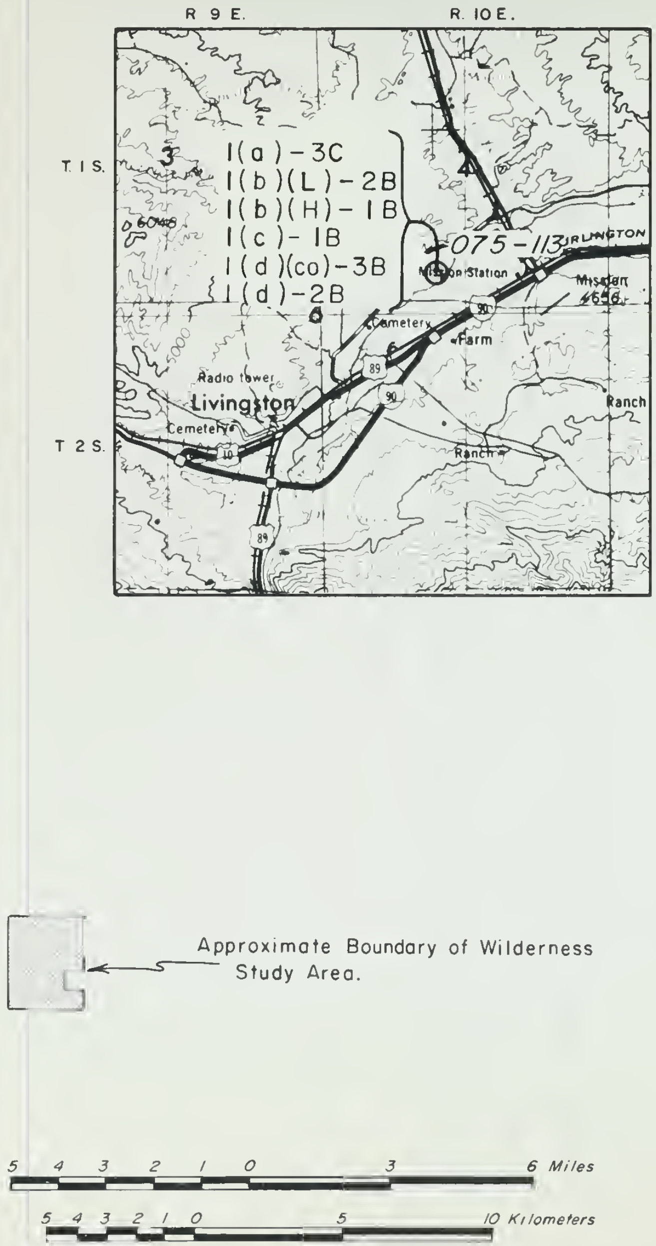
unfavorable for other non-metallic minerals, based on the geology of the WSA and on the regional absence of non-metallic occurrences in similar environments elsewhere in the region (1C).

4.2.2 Leasable Resources

Leasable resources include those which may be acquired under the Mineral Leasing Act of 1920 as amended by the Acts of 1927, 1953, 1970, and 1976. Materials covered under this Act include: asphalt, bitumen, borates and sodium and potassium, carbonates of sodium and potassium, coal, natural gas, nitrates of sodium and potassium, oil, oil shale, phosphate, silicates of sodium and potassium, sulfates of sodium and potassium, geothermal resources, etc. (Maley, 1983).

4.2.2a Oil and Gas. WSA 075-133 (1a, Fig. 11) is classified as moderately favorable for oil and gas resources based on limited direct evidence (3C). The basis of the classification is the favorable regional and local geologic setting of the WSA, and the presence of potential source and reservoir rocks in the area as outlined in Section 3.4.

4.2.2b Geothermal. Based on indirect evidence, all of WSA 075-133 (1b, Fig. 11) is classified as having low favorability for the occurrence of low temperature geothermal resources (2B) and as unfavorable for the occurrence of high temperature geothermal resources (1B). The classification is based on the geology and hydrology of the area as outlined in Section 3.4



BLM LAND CLASSIFICATION SYSTEM FOR GEM RESOURCES

CLASSIFICATION SCHEME

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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.

LEVELS 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 QUANTITATIVLEY 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.

EXPLANATION

1(a)-4D — Area I.D. Number; Commodity; Classification; Level of Confidence

a) oil and gas

b) Geothermal: high temperature (H), Low temperature (L)

c) Sodium and Potassium

d) others: Asphalt (As) bitumen (bt), phosphate (ph), coal(co). No specific commodity designation indicates that the rating applies to all of the above.

WGM Inc. Mining and Geological Consultants, Anchorage, Alaska

BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Livingston GRA, Montana
Wilderness Study Area
Land Classification
Leasable Resources

SCALE: 1"=4 MILES (1 250,000)			FIGURE
DATA BY WGM	DATE 9/1982	REVISED	11
DRWN BY DSI	APRVD G.F		

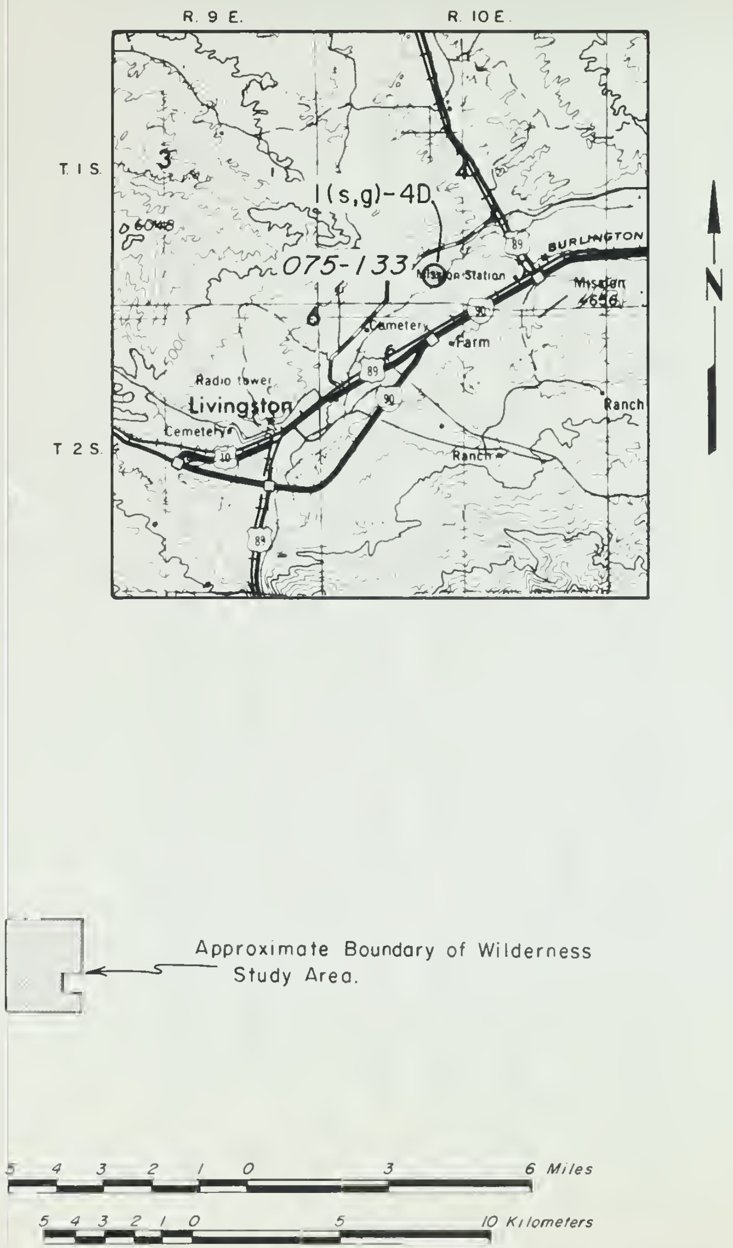
4.2.2c Sodium and Potassium. The entire area of WSA 075-133 (1c, Fig. 11) is classified as unfavorable for the occurrence of sodium and potassium based on direct evidence (1D). The classification is based on the geologic environment of the WSA.

4.2.2d Others. All of WSA 075-133 (1d (co), Fig. 11)is classified as moderately favorable for the occurrence of coal based on indirect evidence (3B). The Eagle Sandstone may be present in the subsurface. WSA 075-133 is classified as having low favorability for the occurrence of other leasable resources in the subsurface of the WSA based on indirect evidence (2B).

4.2.3 Saleable Resources

Saleable resources include those which may be acquired under the Materials Act of 1947 as amended by the Acts of 1955 and 1962. Included under this Act are common varieties of sand, gravel, stone, cinders, pumice, pumicite, clay, limestone, dolomite, peat and petrified wood (Maley, 1983).

The entire area of WSA 075-133 (1, Fig. 12) is classified as highly favorable for the occurrence of sand and gravel based on direct evidence (4D). However, within the Livingston GRA, abundant sand and gravel resources exist much closer to the major population centers.



BLM LAND CLASSIFICATION SYSTEM FOR GEM RESOURCES

CLASSIFICATION SCHEME

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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.

LEVELS 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 QUANTITATIVLEY 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.

EXPLANATION

1(ls) - 4D

- 1 — Area I.D. Number
- (ls) — Commodity
- 4 — Classification
- D — Level of Confidence

s	Sand
g	Gravel
st	Stone
c	Cinders
p	Pumice
pt	Pumicite
cl	Clay
ls	Limestone
dl	Dolomite
P	Peat
pw	Petrified wood

WGM Inc. Mining and Geological Consultants
Anchorage, Alaska

BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Livingston GRA, Montana
Wilderness Study Area
Land Classification
Saleable Resources

SCALE 1" = 4 MILES (1 250,000)			FIGURE
DATA BY WGM	DATE 9/1982	REVISED	12
DRWN BY DSI	APRVD GF		

5.0 RECOMMENDATIONS FOR FURTHER WORK

Given the small size and geomorphic setting of the Yellowstone River Island WSA there are very few practical recommendations for additional work to evaluate the GEM resources potential of the WSA. All of the following recommendations would probably be conducted by industry exploration teams if they are interested in the Livingston GRA or surrounding area.

A. Characterization of potential source beds and reservoir beds in the Livingston area should be made. These analyses would permit the designation of those units then known to be source beds and reservoir beds, eliminating those recognized as not of positive character.

B. Thermal maturation analyses should be made of strata in the Livingston area. This will allow the recognition of the types of hydrocarbons to be expected in exploration of the area.

C. Seismic studies should be made of the Livingston area. This will allow the interpretation of subsurface structures, determination of conformity or differences of structures between surface and subsurface, and help locate the most favorable drilling sites. Hadley (1972) reported geophysical studies had been made for most of the Crazy Mountains Basin, which probably includes the Livingston area. These studies are in petroleum company files and probably confidential. New studies should probably be made using modern equipment and techniques.

Because the possible low and intermediate geothermal resources underlying the Yellowstone River Island WSA are likely to be generally distributed in the underlying aquifers, the exploitation of the resources, if it occurs, will not have to be site-specific. The small area of the WSA is decreases the likelihood of interest in development of any low to intermediate geothermal resources that might underlie the WSA. Therefore, the development of geothermal energy in the WSA might not take place even if the surrounding area were developed. If the resources are deeply buried, then exploitation could occur by directional drilling from the land on either side of the river. If desired, evaluation of the resources in a preliminary way could be accomplished by drilling a hole 500-1,000 feet deep in the surrounding area to determine the temperatures, heat flow and geothermal gradient of waters present in the various aquifers.

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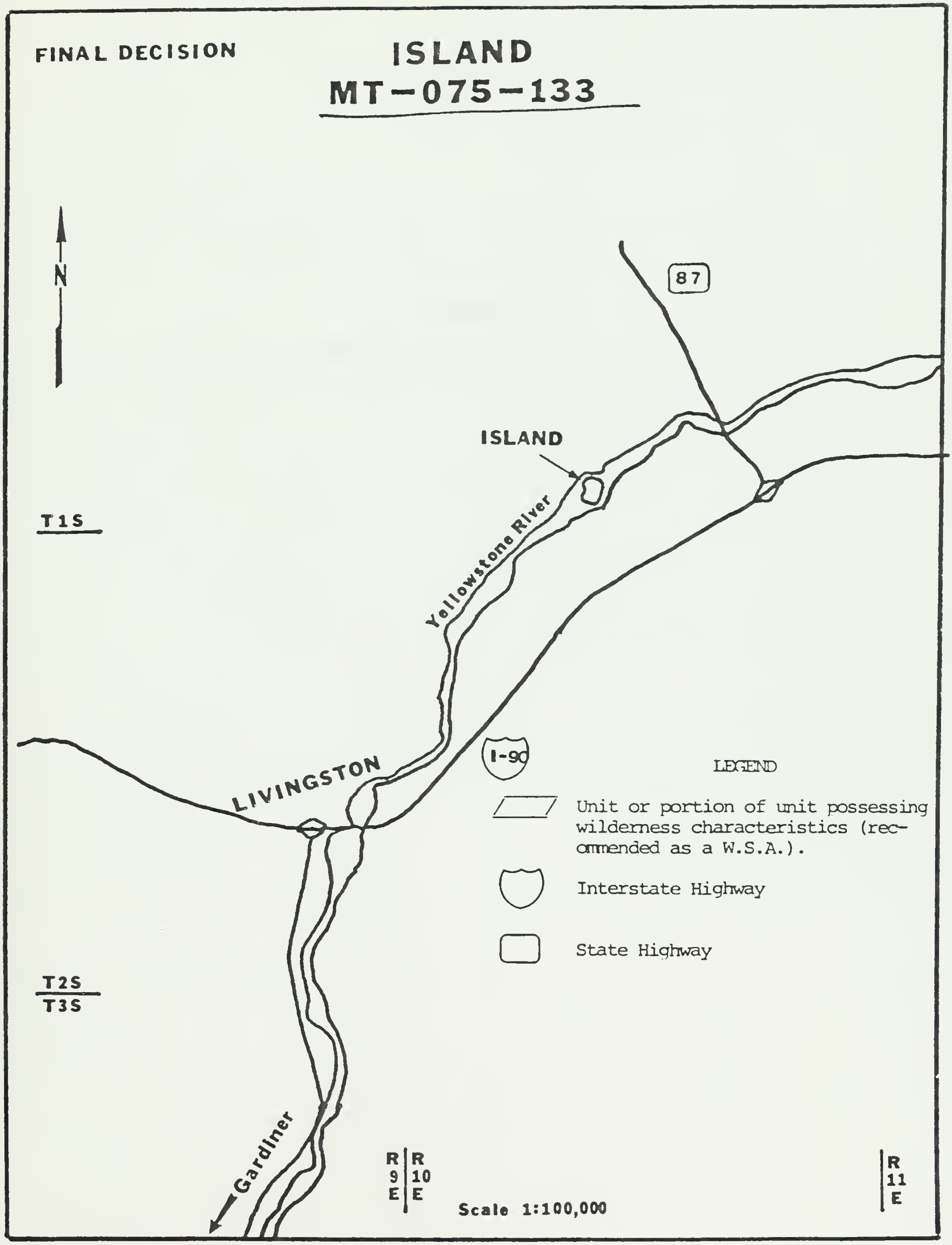
APPENDIX I

WILDERNESS STUDY AREA MAP


FINAL DECISION
ISLAND
MT-075-133
N
87
ISLAND
T1S
Yellowstone River
I-90
LIVINGSTON
LEGEND
Unit or portion of unit possessing wilderness characteristics (recommended as a W.S.A.).
Interstate Highway
State Highway
T2S
T3S
Gardiner
R 9 E
R 10 E
R 11 E
Scale 1:100,000

APPENDIX II

SUMMARIES OF OIL AND GAS WELL DATA

GEM PROJECT - OIL AND GAS WELL SUMMARY SHEET

GRA Livingston

Well: Strong No. 1

Company: Deerfield Oil Corporation

Location: Sec. 11 T. 2S R. 9E

Date Drilled: Oct. 1959 - Jan. 1960

Elevation: 4,674 feet

Status: Dry and abandoned

Total Depth: 7,009 feet

Production: None

Notes:

Well cleaned out and re-entered to 6,150 feet by Montana Power Company in 1962

Log:

Electric Log Tops

Eagle	2,693
Mowry	4,536
Newcastle	5,335
Dakota Sand	5,663
Greybull	5,760
Fuson	5,802
Lakota	6,030
Morrison	6,095
Swift	6,435
Rierdon	6,550
Piper Limestone	6,699
Tensleep	6,870

Source of Data:

M.O.G.C.C.

Date Checked: 8-4-82 By: GF/JPF

GEM PROJECT - OIL AND GAS WELL SUMMARY SHEET

GRA: Livingston

Well: Yellowstone O&D Company

Company: Yellowstone Oil and Development Company

Location: Sec. 13 T. 2S R. 9E

Date Drilled: Dec. 1917 - June 1918

Elevation: No data

Status: Dry and abandoned

Total Depth: 740 feet

Production: None

Notes:

Trace of oil and 665 feet.

Log:

None given.

Source of Data:

M.O.G.C.C.

Date Checked: 8-4-82 By: GF/JPF

Form 1279–3
(June 1984)

BORROWER'S CARD

DATE LOANED	BORROWER

USDI – BLM