PHASE I

Geology, Energy and Mineral (GEM) Resource Assessment of the Sawtooth GRA, Montana, including the Blind Horse Creek (075-102), Chute Mountain (075-105), Deep Creek/Battle Creek (075-106) and North Fork Sun River (075-107) Wilderness Study Areas

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

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ANCHORAGE, ALASKA
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MINING AND GEOLOGICAL CONSULTANTS

EXECUTIVE SUMMARY

The Sawtooth Geology, Energy, Mineral Resource Area (GRA) is located in northwestern Montana 25 miles west of the town of Choteau. The GRA includes four BLM Wilderness Study Areas (WSAs): Blind Horse Creek (075-102), Chute Mountain (075-105), Deep Creek/Battle Creek (075-106), and North Fork Sun River (075-107). There have been numerous geologic, geochemical and geophysical studies in the area by government agencies, universities and private industries. As a result there is a large amount of data on which to base a Phase I GEM Resource Assessment. The accompanying table summarizes the GEM Resources Classification for the four WSAs in the Sawtooth GRA.

The Sawtooth GRA is within the Montana Disturbed Belt, a region extending along the northern Rocky Mountain front in which the rocks have been pushed or thrust eastward over one another. This has created a complex geologic structure composed of repeated sequences or stacks of rock units. The rocks in the region are all sedimentary; predominantly limestone, dolomite, shale and sandstone. There are few known mineral deposits in the area and there has been no significant mineral production.

By far the greatest resource potential in the four Wilderness Study Areas is for gas and oil. The region is the scene of continuing exploration by private industry which resulted in discovery of the Blackleaf Canyon gas field. This field which has proven reserves of natural gas is immediately adjacent to the Blind Horse Creek (075-102) WSA. The gas occurs in carbonate rocks bounded by two thrust plates which form a type of trap known as a "wedge edge". These structures and the carbonate reservoir rocks occur in

all four WSAs. In addition, studies by the U.S. Geological Survey indicate that hydrocarbon source rocks are present in the Sawtooth GRA. The studies generally suggest that the area is most favorable for natural gas, however, the presence of several oil seeps in the area and oil shows in some wells indicate that there is potential for oil as well.

There are few mineral occurrences in the region and none reported in the four WSAs. The reported occurrences are mainly small titanium bearing-iron deposits. There are occurrences of low-rank coal in the area which local residents have mined in the past. However, the coal beds do not crop out in any of the WSAs. Some of the rocks which occur in the eastern parts of the WSA are potentially favorable host rocks for uranium deposits. The Department of Energy's NURE study of the region suggests that the uranium potential is low, however the data needs to be examined more closely to make a final assessment.

Limestone and dolomite are the most common rock types in the four WSAs. Regional studies by the U.S. Geological Survey indicate that portions of the carbonate units are of very high purity and may be of value as industrial grade high calcium limestone and high purity dolomite. Additional work needs to be done to fully assess this possibility since there is very little data which is site-specific to the WSAs.

There is potential for low temperature geothermal resources in the WSAs, similar to Sun River Springs. The lack of known springs in the WSAs indicates that these resources would have to be explored by drilling.

SAWTOOTH GRA

SUMMARY OF GEM RESOURCES CLASSIFICATION

Resource	Wilderness Study Areas 75-102	75-105	75-106	75-107
1. Locatable				
a. Metallic Minerals	2D	2D	2D	2D
b. Uranium and Thorium	2B	2B	2B	2B
c. Non-Metallic Minerals	4C/2D	4C/2D	4C/2D	2D
2. Leasable				
a. Oil and Gas	4D	4D	4D	4D
b. Geothermal (L)	2B	2B	2B	2B
Geothermal (H)	1B	1B	1B	1B
c. Sodium and Potassium	2D	2D	2D	2D
d. Other (1)	2D	2D	2D	2D
3. Saleable	4D/2D	4D/2D	4D/2D	2D

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1. Includes oil shale, asphalt, phosphate and bitumen.

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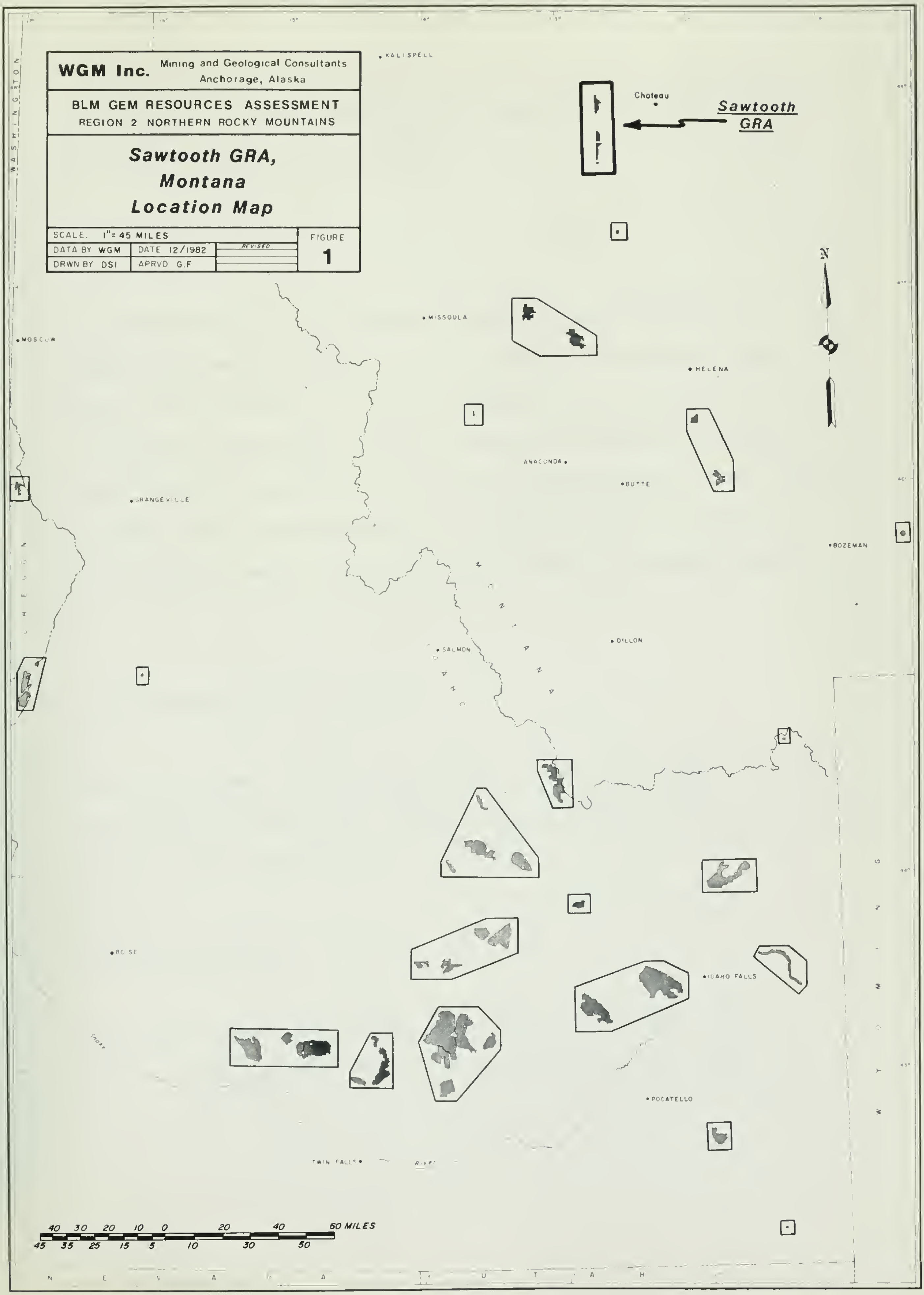
SAWTOOTH GRA, MONTANA

1. 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 Area (WSAs). The objective of Phase I is the evaluation of existing data, both published and available unpublished 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 delineation 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. 1). The Region includes 50 BLM Wilderness Study Areas



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Anchorage, Alaska

BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Sawtooth GRA,
Montana
Location Map

SCALE 1"= 45 MILES			FIGURE
DATA BY WGM	DATE 12/1982	REVISED	1
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totalling 583,182 acres. The WSAs were grouped into 22 GRAs for purposes of the Phase I GEM resources evaluation.

1.1 Location

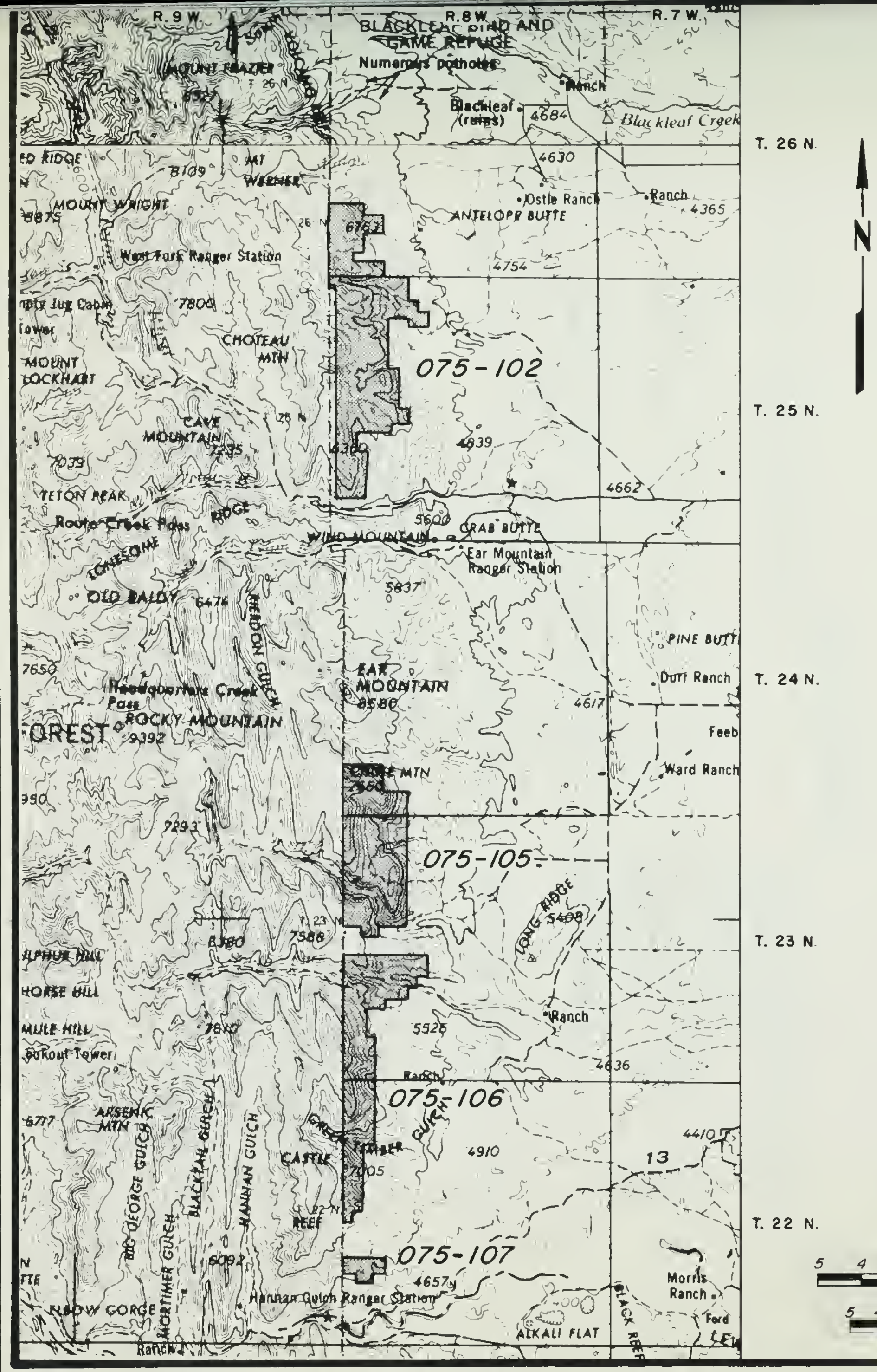
The Sawtooth GRA is in the Headwaters Resource area of the Butte BLM district, northwestern Montana (Fig. 1). The GRA is located at approximately 47°45'N latitude and 11°45'E longitude within Ts.21-26N., Rs.7-9W. It encompasses approximately 327,700 acres and includes the Blind Horse Creek (075-102), Chute Mountain (075-105), Deep Creek/Battle Creek (075-106) and North Fork of Sun River (075-107) Wilderness Study Areas (Fig. 2). Detailed maps of each Wilderness Study Area (WSA) are included in Appendix I.

1.2 Population and Infrastructure

There are no towns within the Sawtooth GRA. The town of Choteau is located approximately 15 miles east of the GRA. Paved roads partially cross the GRA along the Teton and Sun Rivers.

1.3 Basis of Report

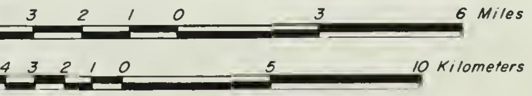
This report is based on a review, compilation and analysis of the available published and unpublished data on the geology, energy and mineral resources of the Sawtooth GRA. This area has been the focus of numerous government and university studies as well as exploration by private industry. The GRA is located in the Choteau NTMS quadrangle which has been the subject of a



BLM Wilderness Study Areas Included in the Sawtooth GRA.

WSA	NAME	ACREAGE
075-102	Blind Horse Creek	4927
075-105	Chute Mountain	3085
075-106	Deep Creek / Battle Creek	3086
075-107	North Fork Sun River	196

▨ Approximate Boundary of Wilderness Study Area.



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BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Sawtooth GRA, Montana

Topographic Map

SCALE 1"=4 Miles (1:250,000)
DATA BY
DATE
REVISED
DRWN BY DSI
APRVD
FIGURE 2

U.S. Geological Survey CUSMAP study and a Department of Energy NURE study. Consequently, a considerable amount of geologic, geochemical and geophysical data are available. In addition, BLM records of mining claims and oil and gas leases were compiled and records of oil and gas well data at the Montana Oil and Gas Conservation Board were reviewed. The data was compiled and reviewed by WGM project personnel and the panel of experts to produce the resource evaluation which follows.

Personnel involved in the project and their general areas of responsibility are listed below:

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., Professional of 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, Industrial minerals.

E.F. Evoy, Senior Geologist, Watts, Griffis & McOuat Ltd.	Uranium and thorium.

1.4 Acknowledgements

We would like to acknowledge a number of individuals whose assistance contributed to the completion of this report. Dave Williams and Bill Weatherly, geologists at the Butte BLM office provided data, areal photos and discussions of the area. Jerry Klem, BLM-Billings, was extremely helpful in the land compilation and in gathering data on oil and gas wells. Dr. Syd Groff and Don Lawson at the Montana Bureau of Mines and Geology gave freely of their knowledge of the area. Irv Kranzler, consulting geologist, Billings, Montana, provided information on oil and gas exploration activity.

We would like to acknowledge the assistance of Milestone Petroleum Inc. for providing information on the oil and gas potential of the area. In particular we would like to thank Mr. James L. Cannon, Geological Explorationist with Milestone Petroleum, for taking the time to review the geology of the Blackleaf Canyon gas field and to give us his insight into the hydrocarbon potential of the Sawtooth GRA.

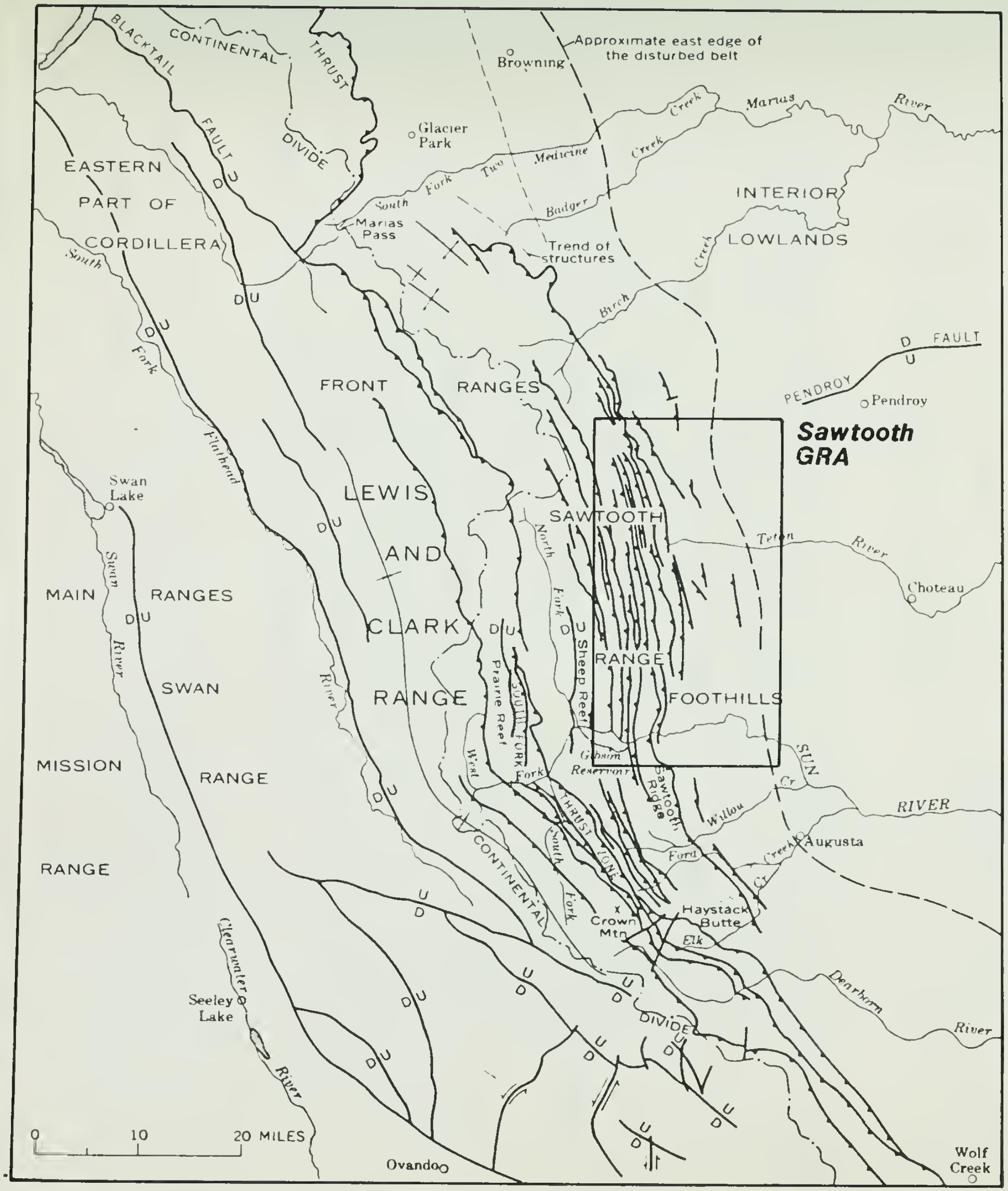
2.0 GEOLOGY

2.1 Introduction

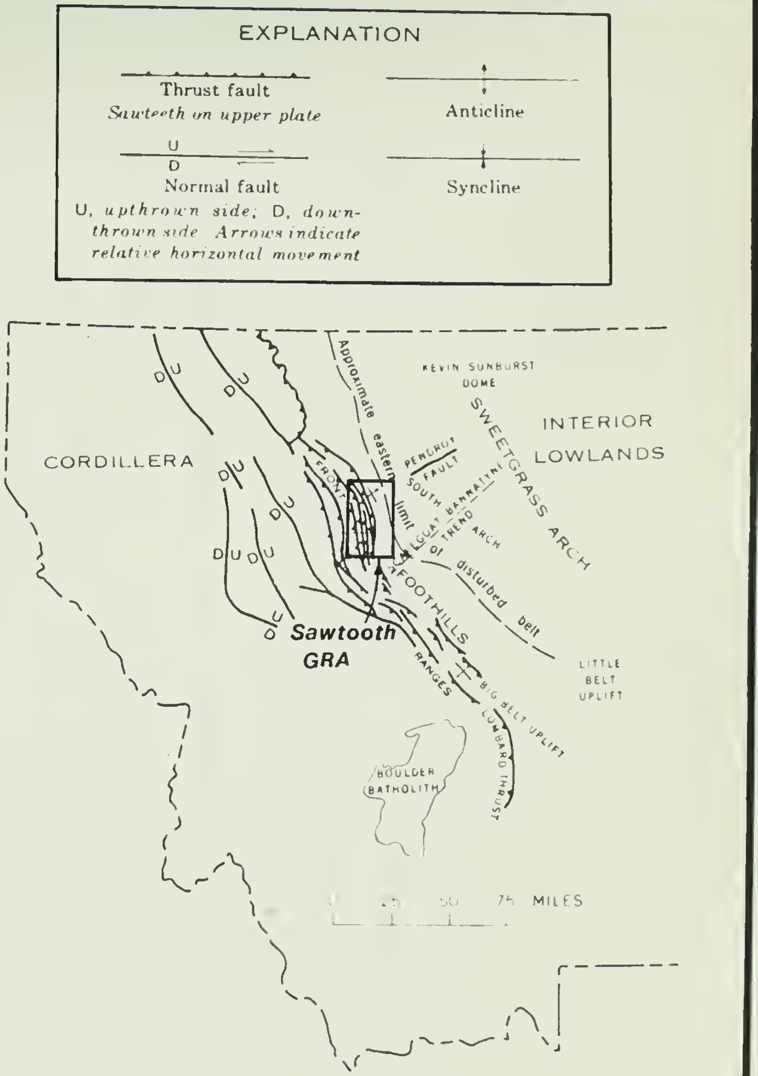
The Sawtooth GRA is located near the eastern edge of the Disturbed Belt of Montana (Fig. 3). The area has two principal geologic provinces. The western part of the GRA, the Sawtooth Range, is made up of complexly thrust faulted sedimentary rocks of Paleozoic (600-230 m.y.) and Jurassic (195-141 m.y.)-Cretaceous (141-65 m.y.) age. East of the Mountains the GRA is underlain by folded Cretaceous sedimentary rocks.

2.2 Physiography

The Sawtooth GRA is mainly in the Northern Rocky Mountains physiographic province (Hunt, 1974). The lower relief eastern part of the area is in the High Plains section of the Great Plains province (Hunt, 1974). The landscape is comprised mainly of north-trending carbonate ridges separated by narrow valleys underlain by clastic sedimentary rocks (Mudge, 1972a). The drainage pattern is a structurally controlled trellis type with the major drainages flowing to the east. The principal watersheds are the Sun River, Deep Creek and Teton River. The highest elevation in the GRA is Mt. Werner at 8,109 feet near the north end of the area. Relief in the mountainous western part of the area is 2,500 to 3,000 feet. The lowest elevation is about 4,300 feet in the northeast part of the GRA.



Data from Mudge (1972b).



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BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Regional Geologic Setting of the Sawtooth GRA, Montana

SCALE AS SHOWN			FIGURE
DATA BY	DATE 1/1983	REVISED	3
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2.3 Rock Units

The Sawtooth GRA is underlain by rocks of Cambrian (600-500 m.y.), Devonian (395-345 m.y.), Mississippian (345-310 m.y.), Jurassic and Cretaceous age (Fig. 4). The geology of the region has been studied by several members of the U.S. Geological Survey and by graduate students from several universities. C.F. Deiss studied the structure and stratigraphy of the area in the 1930s (Deiss, 1933, 1935, 1938, 1939 and 1943) and was succeeded by M.R. Mudge after 1956 (Mudge, 1959, 1968 and 1972a,b,c). Students from Massachusetts University and Yale studied the southern part of the area (Merrill, 1965; Cobb 1941). Graduate students from Washington State University studied the northern part of the GRA around Blackleaf Canyon (Ore, 1959; Hansen, 1960; Osborne, 1963).

The stratigraphic nomenclature used in this report (Fig. 4) is that of Mudge (1972a). Rock units have been grouped by age on the geologic map (Fig. 5) following Mudge, et al. (1977a, b) and Mudge and Earhart (1980). The layered rocks in the Sawtooth GRA are marine carbonate and clastic sedimentary rocks. There are no reported intrusives within the GRA although sills are common to the west. The Paleozoic m.y. rocks are marine transgressive to regressive sequences (Mudge, 1972a). The Mississippian carbonates are unconformably overlain by Jurassic rocks, a hiatus of 130 million years. The Mesozoic (230-65 m.y.) rocks are dominantly mudstone and sandstone of both marine and non-marine origin.

The oldest units within the Sawtooth GRA are Middle (542-515 m.y.) and Upper Cambrian (515-500 m.y.) rocks which crop out in a thin belt in the Allan

ERA	SYSTEM	SERIES	GRP.	FORMATION	MEMBER	THICKNESS (FT.)
Mesozoic	Cretaceous	Upper Cretaceous	Montana	Two Medicine Formation		1,000 +
				Virgelle Sandstone		150-200
				Telegraph Creek Formation	Upper member	80
					Middle member	90
					Lower member	170
			Colorado	Marias River Formation	Kevin Shale Member	850-1,050±
					Ferdig Shale Member	200-350
					Cone Calcareous Member	100
					Floweree Shale Member	30
		Lower Cretaceous		Blackleat Formation	Vaughn Member	300-500
					Tatt Hill Member	225-600
					Flood Shale Member	150-550
				Kootenai Formation		650-800
	Jurassic	Upper Jurassic		Morrison Formation		200-550
			Ellis	Switt Formation	Sandstone member	60-97
					Shale member	22-58
				Rierdon Formation		120-350
		Middle Jurassic		Sawtooth Formation	Siltstone Member	23-44
					Shale member	3-85
					Sandstone member	0-20
Paleozoic	Carboniferous Mississippian	Upper Mississippian	Madison	Castle Reet Formation	Sun River Dolomite	0-450
		Lower Mississippian				250-475
				Allan Mountain Formation	Upper member	200-350
					Middle member	150-200
					Lower member	160-225
	Devonian	Upper Devonian		Three Forks Formation		50-589
				Jefferson Formation	Birdbear Member	150-235
					Lower member	300-650
				Maywood Formation	Upper member	49-159
		Middle Devonian			Lower member	26-229
	Cambrian	Upper Cambrian		Devils Glen Dolomite		100-400
		Middle Cambrian		Switchback Shale		70-253
				Steamboat Limestone		229-239
				Pagoda Limestone		250-360

Data by: Mudge (1972a)

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BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Sawtooth GRA, Montana

Stratigraphic Column

SCALE:			FIGURE
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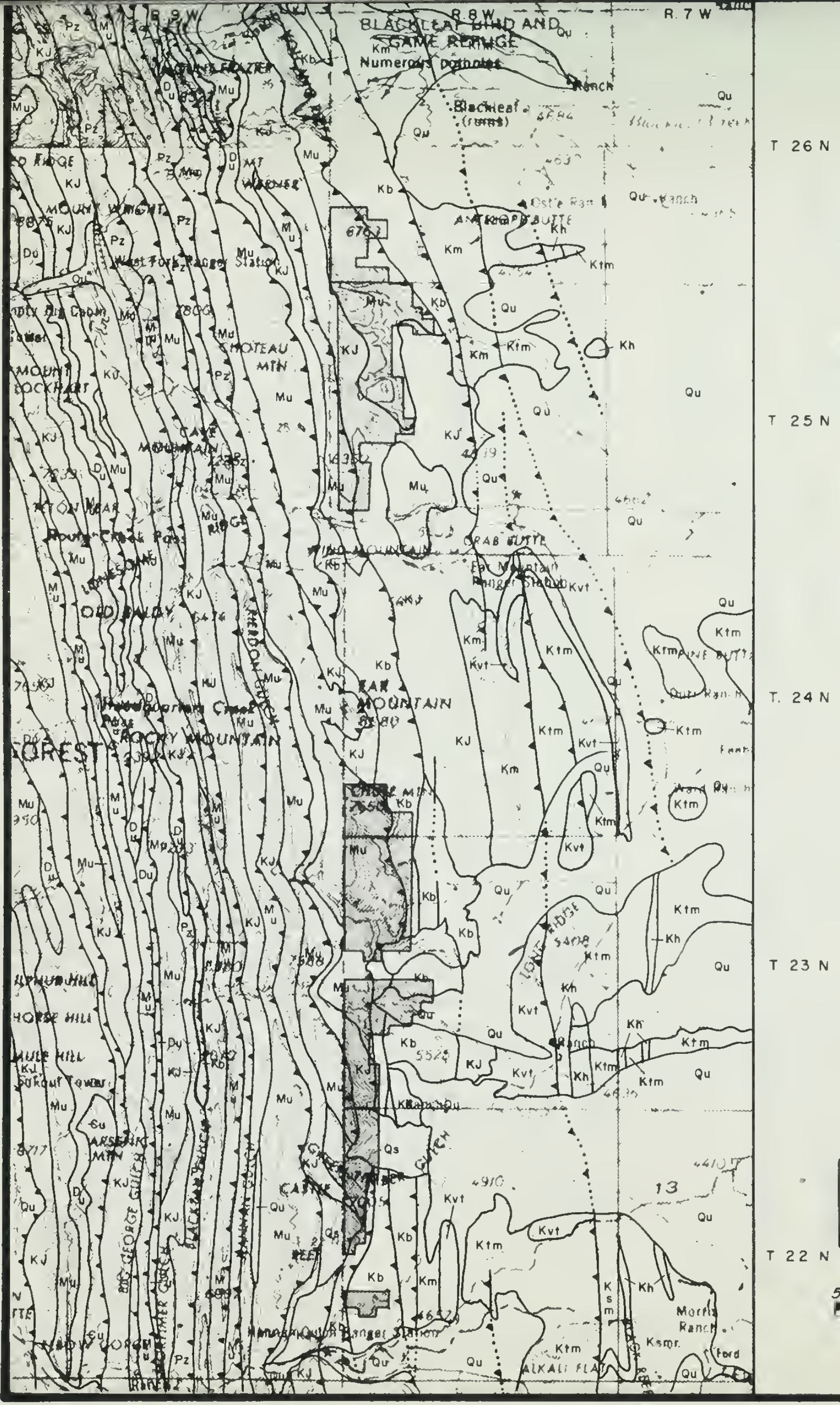


Legend

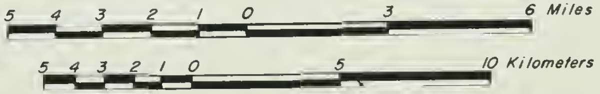
UNIT	AGE	DESCRIPTION
Qu	Quaternary, Pleistocene	Undifferentiated Alluvium, glacial and lacustrine deposits.
Qs	Quaternary	Landslide deposits.
Ksmr	Upper Cretaceous	St. Mary River Formation.
Kh		Horsethief Sandstone.
Ktm		Two Medicine Formation.
Kvt		Virgelle Sandstone and Telegraph Creek Formation.
Km		Marias River Shale.
Kb	Lower Cretaceous	Blackleaf Canyon Formation.
KJ	Lower Cret. & Jurassic	Undifferentiated Kootenai, Morrison, Swift, Reardon and Sawtooth Formations.
Pz	Paleozoic	Unnamed Paleozoic rocks.
Mu	Mississippian	Madison Group, including Castle Reef and Allan Mountain Formations.
Du	Devonian	Three Forks, Jefferson and Maywood Formations.
Ꞓu	Cambrian	Devils Glenn Dolomite, Switchback Shale, Steamboat Limestone, and Pagoda Limestone.

SYMBOLS

———	Geologic contact
▲—▲—▲ ··▲···▲	Thrust fault, dotted where inferred. Teeth on upper plate.

Compiled from Mudge and Earhart (1979), Mudge, Earhart, and Rice (1977) and Mudge (1972a).

▨ Approximate Boundary of Wilderness Study Area.



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BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Sawtooth GRA, Montana

Geologic Map

SCALE: 1" = 4 MILES (1:250,000)		FIGURE
DATA BY.	DATE 9/1982	REVISED
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thrust zone in the southwest part of the GRA (Fig. 5). These units are the Pagoda Limestone, Steamboat Limestone, Switchback Shale, and Devils Glenn Dolomite. The Pagoda Limestone averages 250 to 360 feet thick and is composed of a lower gray-green shale and argillaceous limestone unit and an upper gray-brown, bedded limestone. The Steamboat Limestone is typically about 230 feet thick. It is composed mainly of thin bedded limestone and dolomitic limestone with some dolomitic mudstone. Well preserved trilobites and some brachiopods occur in shale beds and locally in the upper part of the limestone. The Switchback Shale is the uppermost shale in the Cambrian sequence, and varies from 70 to 250 feet in thickness. It is composed of non-calcareous green-gray, clay shale with minor carbonate, sandstone and conglomerate interbeds which locally contain brachiopod debris. The youngest Cambrian unit in the GRA is the Devils Glenn Dolomite. It ranges from 100 to 400 feet in thickness and is composed of a distinctive thin bedded, fine-grained dolomite. Intraformational breccia, possibly formed by evaporite solution, occurs near the top of the unit. Portions of the Devils Glenn Dolomite are of high enough purity to be used for producing magnesium carbonate (Earhart, 1978).

The Cambrian strata are unconformably overlain by Devonian rocks. The contact indicates some erosion between Cambrian and Devonian times and locally shows angular discordance (Mudge, 1972a).

Devonian rocks in the Sawtooth GRA comprise three formations which crop out in the western part of the area. These are the Maywood, Jefferson and Three Forks Formations. The Maywood Formation has two distinct members: (1) a lower mudstone of Middle Devonian (370-360 m.y.) age based on charophyte

(green algae) fossils and ranging from 25 to 230 feet in thickness, and (2) an overlying thinly bedded finely crystalline limestone and dolomitic limestone which ranges from 50 to 160 feet in thickness. Spiriferid brachiopods in fossiliferous beds within the upper member indicate an Upper Devonian (360-345 m.y.) age. The Jefferson Formation consists mainly of dark dolomite of early Late Devonian age. The formation ranges from 450 to 800 feet in thickness. It also has two distinct members: (1) a dark lower unnamed member and (2) an upper member, the Birdbear, which is somewhat lighter in color. Stromatoporoid, brachiopod and fish teeth faunas are the basis for dating the formation. The youngest Devonian unit is the Three Forks Formation. This unit consists largely of intraformational dolomite breccia which generally thickens from south to north in the area. These breccias probably formed by evaporite solution during a marine regression. In the northern part of the Sawtooth GRA, along the Teton River, the evaporite solution breccias are overlain by a thin black shale unit that may be equivalent to the Eckshaw and Bakken formations in the Sweetgrass Arch and Alberta Foothills areas . The Three Forks is mainly Late Devonian in age but the upper few feet are Early Mississippian (345-332 m.y.).

The Devonian-Mississippian boundary in the area is defined by a slight disconformity at the top or within the upper part of the Three Forks Formation. Mississippian rocks in the area belong to the Madison Group which contains important hydrocarbon reservoirs in the Sawtooth GRA and in other parts of Montana; thus, the Madison has received considerable study (Mudge et al., 1962). The Madison Group crops out over most of the western half of the GRA and makes up many of the ridges in the Sawtooth Range. The Madison has an aggregate thickness of 900 to 1,200 feet and consists almost entirely of

shallow water marine limestone and dolomite (Smith and Gilmour, 1979). The Madison Group tends to thicken from south to north in the Sawtooth GRA (Mudge et al., 1978). As previously noted, in the northern part of the GRA, the Eckshaw shale occurs at base of the Madison Group spanning the Devono-Mississippian boundary. The Eckshaw is believed to be the source rock for gas reserves in the Blackleaf Canyon field (J. Cannon, Milestone Petroleum, pers. comm. 1982). Mudge, Sando and Dutro (1962) divide the Madison into two formations: (1) the Allan Mountain Limestone and (2) the Castle Reef Dolomite. These units are farther divided into several members based on faunal (brachiopod and coral) zones. The Allan Mountain Limestone of Early Mississippian age has three unnamed members and is composed principally of thin bedded, dark gray limestone. The overlying Castle Reef Dolomite, consisting mainly of thick bedded light gray dolomite, is divided into: (1) an unnamed Early Mississippian member and the overlying Late Mississippian (332-310 m.y.) Sun River Member. The Sun River consists of dolomitized crinoidol grainstone with a significant vuggy, intergranular porosity (Nichols, 1980). Many of the pores are filled with dead oil. The Sun River is the reservoir rock for significant reserves of natural gas in the northern part of the Sawtooth GRA and locally is saturated with oil (Montana Geol. Soc., 1979).

The Castle Reef Dolomite is unconformably overlain by Jurassic rocks. The unconformity is erosional and regional evidence suggests that upper Paleozoic and lower Mesozoic rocks were deposited and eroded during the time interval between the units (Mudge, 1972a). The Jurassic rocks present in the Sawtooth GRA belong to the Ellis Group and the Morrison Formation.

The lowermost rocks belong to the Ellis Group which consists of: (1) the basal Sawtooth Formation, (2) the Rierdon Formation, and (3) the Swift Formation (youngest). The Sawtooth Formation ranges from 50 to 225 feet thick. It consists of three members. A thin basal sandstone unit overlies Mississippian rocks along the Sun River but is absent to the north. The sandstone is locally conglomeratic with pebbles derived from the underlying Mississippian rocks. The middle member is composed of dark gray pyritic shale and some siltstone which thickens northward. The upper member is a prominent unit of gray and brown siltstone. The Sawtooth locally contains cephalopod fossils which provide the basis for assigning it a Middle Jurassic (176-158 m.y.) age. The Rierdon Formation consists mainly of claystone, siltstone and shale with scattered thin limestone beds ranging from 150 to as much as 500 feet in thickness. Phosphatic nodules occur in the lower part of the unit. The Rierdon is disconformably overlain by the Swift Formation. The Swift is comprised of a lower dark gray shale member and an upper thin bedded sandstone member which have a total thickness of 75 to 120 feet. Both the Rierdon and the Swift Formations are dated as Late Jurassic (158-141 m.y.) on the basis of fossils (Mudge, 1972a).

The conformably overlying Late Jurassic Morrison Formation consists of two distinct facies referred to as the western and eastern facies by Mudge (1972a). The western facies, which crops out in the Sawtooth Range, is mainly red-brown mudstone with thick channel sandstone lenses. The eastern facies which crops out in the low relief area east of the mountains and in the easternmost line of ridges, consists of gray-green interbedded siltstone and sandstone. The western facies ranges up to 550 feet thick whereas the

eastern facies is a maximum of 200 feet thick. The two facies grade laterally into one another.

Fossils occur locally in the Morrison Formation within the Sawtooth GRA, but its age is based primarily on lithologic correlation.

The Jurassic-Cretaceous contact is a low-relief unconformity of regional extent marked by channels and basal conglomerate at the Cretaceous boundary. Cretaceous rocks underly most of the lower relief eastern part of the Sawtooth GRA. Cretaceous and Jurassic rocks also crop out at the bases of ridges and in valleys in the Sawtooth Mountains but are undifferentiated on the geologic map (Fig. 5) because they are too thin to map separately. The eight Cretaceous formations in the GRA are (from oldest to youngest) the Kootenai, the Blackleaf and the Marias River Formations which comprise the Colorado Group, the Telegraph Creek, the Virgelle, the Two Medicine and the Horse Thief Formations which make up the Montana Group, and the St. Mary River Formation (Cobban, 1955). The complete Cretaceous section is up to 8,000 feet thick.

The Kootenai Formation consists of variegated non-marine mudstone with numerous poorly sorted sandstone beds and lenticular basal conglomerates (Mudge and Shepard, 1968). It ranges from 650 to 800 feet thick and locally contains fossil mollusks. In the Sweetgrass Arch area, the base of the Kootenai is a distinctive non-calcareous, thin bedded, quartz sandstone known as the Sunburst Member (Mudge, 1972a).

The Blackleaf Formation is about 665 feet thick and is made up of three members: (1) the lowermost Flood Shale Member, (2) the Taft Hill Member, and (3) the upper Vaughn Member. The Flood Shale Member is mainly dark gray to black marine shale with thin sandstone beds in its upper and lower parts. The overlying Taft Hill Member is a prominent marine clastic unit composed of thin bedded gray sandstone with interbeds of dark gray mudstone and sandy shale. The uppermost Vaughn Member ranges from 300 to 700 feet thickness, and is composed of alternating beds of non-marine mudstone with thin interbeds of sandstone and bentonitic mudstone. The bentonite beds, usually 1-2 inches thick, occur sparsely in the unit. Fossils are uncommon in most of the Blackleaf Formation, however, pelecypods are found in the Taft Hill Member wich give an Early Cretaceous (141-100 m.y.) age for the unit.

The Marias River Shale, the upper formation in the Colorado Group, is 1,200 to 1,300 feet thick and a slight disconformity marks its contact with the Blackleaf Formation. The disconformity represents the transition from Lower to Upper Cretaceous (100-65 m.y.) time. The Marias River Shale consists of four members: (1) the Floweree Shale, (2) the Cone Member, (3) the Ferdig Shale, and (4) the Kevin Member. The Floweree Shale, the basal member of the Marais River Shale is a thin 30 to 40 foot thick, unit of non-calcareous dark-gray shale with sparse beds of chert pebble conglomerate. The overlying Cone Member is gray calcareous siltstone and shale with thin beds of calcarenite. A widespread 7-foot thick bed of bentonite occurs near the upper part of the Cone. The Cone Member typically has a kerosene odor when freshly broken (Mudge, 1972a), and it is correlative with the Greenhorn Shale which is known to contain petroleum (J. Cannon, Milestone Petroleum pers. comm., 1982). The Cone is overlain by the Ferdig Shale Member which

consists of a lower nodular siltstone and sandy shale, succeeded by bedded sandstone and siltstone and an upper light gray sandstone. The top of the Marais River Shale is the Kevin Shale Member. This member is composed mainly of dark-gray calcareous shale, siltstone, and claystone characterized by numerous limestone concretions and bentonite beds. The Kevin Member is 750 to 900 feet thick and is the thickest member of the Marais River Shale. Fossils are not abundant in the Marais River but do occur in limestone concretions and limey beds.

The succeeding Montana Group rocks are estimated to be about 3,700 feet thick (Mudge, 1972a). The Montana Group includes four formations: (1) the Telegraph Creek, (2) the Virgelle, (3) the Two Medicine and (4) the Horse Thief. All are Upper Cretaceous in age. The Telegraph Creek Formation is made up mainly of sandstone and sandy shale and comprises the transition between the underlying Marias River Shale and the overlying Virgelle Sandstone. The Telegraph Creek thickens from 340 feet to 550 feet going from west to east. It is divisible into a lower thin bedded calcareous sandstone, a middle sandstone with sandy shale and siltstone beds and an upper thick bedded sandstone and sandy shale. The Virgelle Sandstone is a well sorted, fine-grained, poorly indurated, micaceous arkose from 150 to 200 feet thick. It has sparse iron-rich beds which weather to form distinctive cap rocks. To the east and locally within the Sawtooth GRA, the Virgelle contains titaniferous magnetite lenses (Wimmler, 1946, Earhart et al., 1981). The Two Medicine Formation consists of up to 2,000 feet of non-marine mudstone and sandstone with carbonaceous and volcaniclastic beds in the lower part. In the eastern part of the Sawtooth GRA the Two Medicine grades(?) laterally into the Horse Thief Sandstone which is composed of massive cross-bedded sandstone.

The Cretaceous section is capped by the St. Mary River Formation which crops out in the eastern part of the Sawtooth GRA. It has a thickness of about 900 feet. Green-gray mudstone with lenticular beds of sandstone make up most of the formation (Cobban, 1955). Reddish mudstone is prominent in the upper part of the unit.

Tertiary (65-2 m.y.) rocks crop out to the west of the Sawtooth GRA but are absent within the GRA. A variety of surficial deposits of Pleistocene (2-.01 m.y.) and Holocene (0.01 m.y. to present) age are present, including alluvium, colluvium, glacial and landslide deposits. Only the landslide deposits which occur just north of Sun River, are shown separately on Figure 5.

There are no igneous rocks present in the Sawtooth GRA. However, the aeromagnetic data (Fig. 6) suggests that there may be a buried intrusive in the west-central part of the GRA (Kleinkopf, 1980).

2.4 Structural Geology and Tectonics

The structural geology of the Sawtooth GRA has been studied in detail by Deiss (1943), Mudge (1970, 1972b) and more recently by Reed (1982a,b). In addition, numerous studies have been conducted by oil company geologists which have not been published.

The major unconformities in the stratigraphic column are between the Cambrian and Devonian, and between the Mississippian and Jurassic rocks. The Cambrian-Devonian unconformity is exposed in the western part of the Sawtooth GRA (Mudge, 1972a). Locally it appears to be a disconformity and

is often difficult to recognize. In places the basal Devonian rocks fill erosion channels up to 20 feet deep in the underlying Devils Glenn Dolomite. North of the GRA the Devils Glenn is completely eroded away (Mudge, et al. 1977). The Mississippian-Jurassic unconformity is in part localized in the Montana Disturbed Belt since rocks representing the missing systems are present elsewhere in Montana and Alberta. Upper Mississippian evaporite bearing rocks are present in the subsurface east of the Sawtooth GRA and probably were also deposited in the GRA. The Mississippian surface is very irregular and locally deeply weathered indicating a prolonged period of exposure before deposition of the Middle Jurassic rocks (Mudge, 1972a). The top of the Madison contains numerous small pelecypod borings. The variations in thickness of the Castle Reef Dolomite appears to be due to erosion. In places as much as 700 feet of the unit may have been removed.

The Sawtooth GRA has two principal structural provinces; a western province in the Sawtooth Mountains, characterized by thrust faulting, and an eastern province characterized by folding (Fig. 5). The structures in the Sawtooth Range consist of closely-spaced westerly dipping thrust faults. Most of the thrust plates have Mississippian rocks at their base, although some have rocks of Devonian or Cambrian age. The Paleozoic rocks are thrust over Jurassic and Cretaceous rocks. Mudge (1972b) estimates the stratigraphic throw to be 3,000 to 6,000 feet. Thrust plates are stacked one atop the other so that in the subsurface a given unit may be repeated two, three or four times. The gas production at Blackleaf Canyon is from lower Madison thrust slices (Hurley, 1959, Montana Geol. Soc., 1979). Folds are common in the east edge of the Sawtooth Range. Asymetrical anticlines, some synclines and overturned folds are present. Open symmetrical folds characterize the

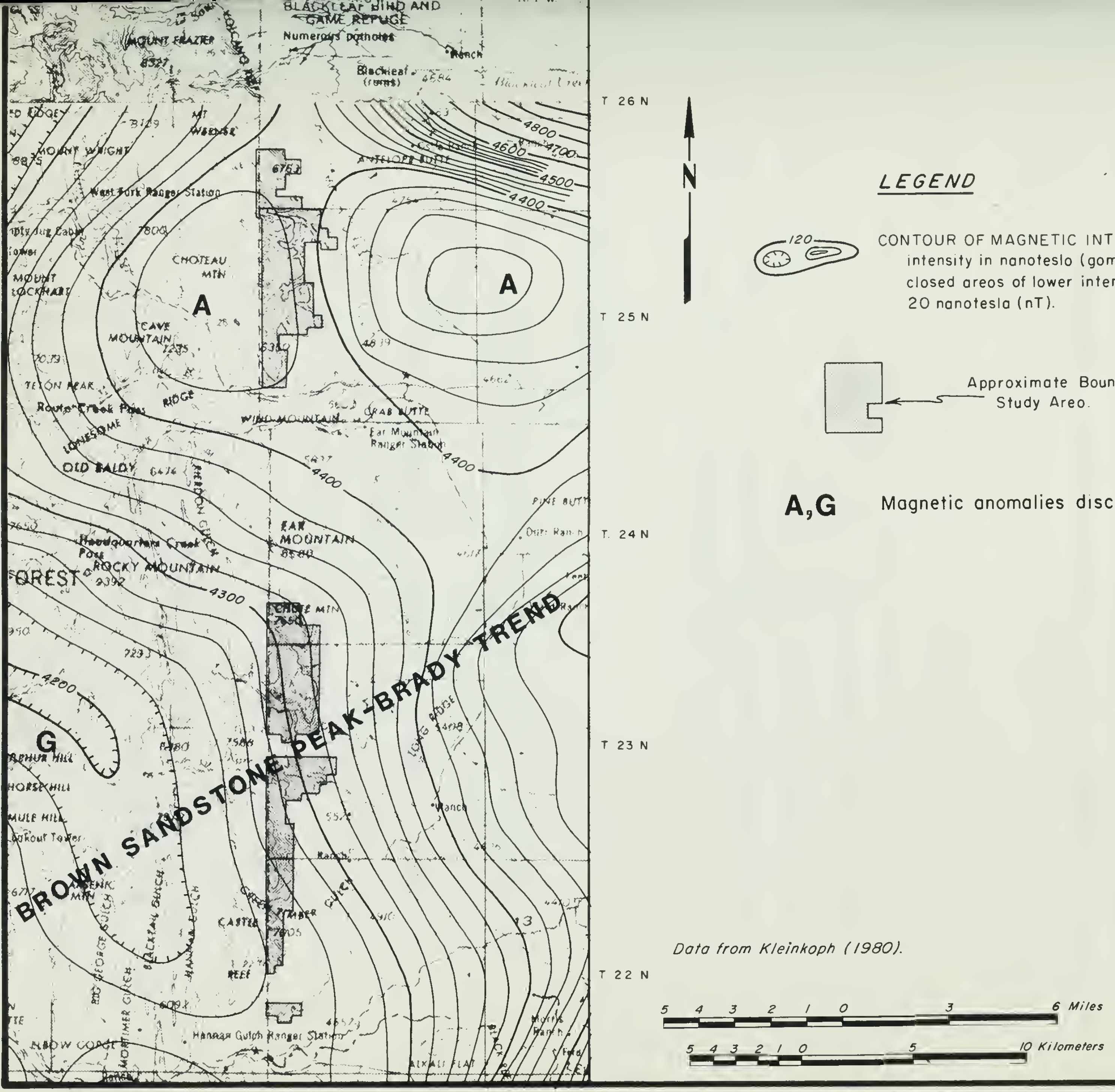
eastern structural province (Mudge, 1972b). The folds are northerly-trending elongate open anticlines and synclines with moderately dipping limbs. The east limbs of some anticlines dip more steeply than the west limbs. Some small thrust and normal faults with minor throw occur near the transition between the eastern and western structural province.

The thrust faulting and deformation took place between Paleocene (65-55 m.y.) and late Eocene (55-38 m.y.) time (Hoffman, et al. 1976). Mudge (1972b) concluded that the sequence of thrusting was from east to west by gravitational movement from an uplifted area to the west. However Reed (1982a, b) has recently restudied the structure of the Sun River Canyon area and concluded that the structures developed from west to east. This change in interpretation could change conceptual models currently used in oil and gas exploration.

Aeromagnetic data (Fig. 6) and lineaments visible on Landsat photos define a northeast-trending feature known as the Brown Sandstone-Brady trend which crosses the Sawtooth GRA near Deep Creek (Kleinkopf, 1980a; Mudge and Earhart, 1978; Weidman, 1982). The data suggest that this structure is a fault in the basement rocks (Alpha, 1955a, b; Dobbin and Erdman, 1955; Kleinkopf, 1980).

2.5 Paleontology

The paleontologic occurrences in much of the Sawtooth GRA are well described because of the extensive stratigraphic work by the U.S. Geological Survey. Mudge (1972a) describes the fauna of the Paleozoic, and most of the Mesozoic



LEGEND

CONTOUR OF MAGNETIC INTENSITY – Showing mognetic intensity in nanoteslo (gommos). Hatchured to indicote closed areos of lower intensity. Contour interval 10 ond 20 nanotesla (nT).

Approximate Boundary of Wilderness Study Areo.

A,G Magnetic anomalies discussed in text.

Data from Kleinkoph (1980).

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Sawtooth GRA, Montana

Aeromagnetic Map

SCALE: 1" = 4 MILES (1:250,000)
DATA BY
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FIGURE
6

formations. His descriptions include summaries of previous work by Deiss (1933, 1938). A very detailed description of the Madison Group faunas is given by Mudge, Sando and Dutro (1962) who have designated the exposures north of Gibson Reservoir as a reference section. Brief descriptions of the fossils in the Upper Cretaceous units are given by Cobban (1955). Hansen (1960), Ore (1959) and Osborne (1963) describe the fossils in the northern part of the GRA, however their descriptions are not as complete as those mentioned above.

Although fossils are common in many units exposed in the Sawtooth GRA, particularly the Mississippian carbonates (Mudge, 1972a), only one exceptional locality is mentioned. This is a good trilobite location north of the Gibson Reservoir in sec. 31, T.22N., R.9W. within the southwest corner of the GRA. A Mississippian reference section is present within the GRA in Sun River Canyon outside of the WSAs (Mudge et al., 1962).

2.6 Historical Geology

The Paleozoic and Mesozoic rocks in the Sawtooth GRA are underlain by Precambrian rocks of the Belt Series. The Belt Series consists of a thick section of quartzites and carbonates deposited in a basin on the edge of the North American craton (Harrison, 1972). These sediments form the basement in the GRA and they correlate with sediments hosting copper deposits to the south and east.

The Paleozoic rocks in the Sawtooth GRA are dominated by shallow water, marine shelf carbonates which generally exhibit a three-stage

transgressive-regressive sequence (Peterson, 1981). The sequence starts with transgressive sandstone and mudstone which are overlain by a deeper water limestone which are in turn overlain by regressive shallow water dolomite and evaporites (Mudge, 1972a). This sequence is especially evident in the Cambrian. The Pagoda Limestone, a deep water carbonate unit, is overlain by the shallow water Steamboat Limestone indicating a regression. This is followed by a transgression during which the Switchback shales and conglomerates were deposited. The uppermost Cambrian unit, the Devils Glenn Dolomite, indicates another regression and local emergence as indicated by shallow water fossils and evaporite solution breccias.

The absence of Ordovician and Silurian rocks in the area and the presence of erosional channels in the top of the Devils Glenn Dolomite indicate a period of emergence and erosion. This and earlier Cambrian uplifts reflect the development of the Sweetgrass Arch as a positive tectonic feature (Mudge, 1970).

In Devonian time the area was a partly emergent shallow marine shelf with local restricted basins developed behind stromatoporoid-coral reefoid banks (Mudge, 1972a). Extensive evaporites were deposited in the back-bank areas and westward refluxion of magnesium from dissolved evaporites led to extensive early formation of dolomites (Peterson, 1981). The carbonate shelf persisted into Mississippian time when the thick carbonate bank of the Madison group was deposited (Mudge, Sando and Dutro, 1962). Evidence from elsewhere in Montana indicates that the epeirogenic-orogenic tempo increased after Madison time. The Sawtooth GRA was part of the Alberta Shelf which

had a stable or relatively neutral (Mississippian history. Post-Mississippian erosion, however, has removed any post-Madison rocks which were deposited (Smith and Gilmour, 1979).

The Mississippian-Jurassic unconformity in the area indicates a period of uplift and erosion. Pennsylvanian, Permian and Triassic rocks are present elsewhere in Montana but they may not have been deposited in the Sawtooth area. The presence of deep channels and weathering profiles indicates that the Mississippian surface was exposed for a considerable length of time (Mudge, 1972a).

The Jurassic marks the beginning of a series of worldwide transgressive-regressive cycles which in North America involved the incursion of boreal seas onto the continent (Peterson, 1981). The Ellis Group records a period of complex gentle uplifts with deposition of clastic debris from a western source area. These uplifts may in part reflect the initial development of the Idaho and Boulder batholiths. Within the Ellis Group the basal conglomerates of the Sawtooth formation indicate a period of erosion of Mississippian carbonates to the west (Mudge, 1972a). These grade to finer, deeper water, clastic sediments in the Rierdon and lower Swift formations. The upper Swift is coarser grained and has numerous fossil ripple marks, burrows, and rain drops indicating renewed uplift and regression. Current directions in conglomerates in the upper Swift formation indicate that the source was a positive area to the northwest (Mudge and Shepard, 1968). The Morrison formation is comprised of terrestrial and fresh water clastics with some limestone and tuffaceous rocks which mark a major period of uplift in western Montana (Mudge, 1970). The Morrison thickens rapidly to the west

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Relatively gentle pulsating uplifts continued through the Cretaceous and into the Tertiary (Mudge, 1970). Truncation of the upper Morrison and the presence of basal conglomerates and channels in the Cretaceous Kootenai

Formation indicate a period of erosion in pre-Kootenai time followed by deposition of lake sediments and shallow brackish water to marine sediments. The Colorado Group sediments give evidence for as many as five transgressive-regressive cycles. Ripple marks, cross bedding, mud cracks and fresh water fossils indicate that the Flood Shale Member of the Blackleaf Formation was deposited in a regression. The Taft Hill Member was deposited in a shallow marine trough with non-marine conditions to the west. The upper Taft Hill records several cycles of regression. A period of non-deposition marks the transition to the overlying Vaughn Member. The Vaughn is terrestrial as indicated by plant fossils and paleo-weathering surfaces. The plant remains indicate a warm moist climate. The shallow water marine sediments of the Marais River Shale indicate another transgression.

In Lower Cretaceous time the emplacement of the Idaho and Boulder batholiths and associated volcanism were major tectonic events as indicated by the presence of numerous bentonite beds in the Vaughn Member of the Blackleaf Formation (Peterson, 1981). Some plutons may have intruded the basement rocks of the Sawtooth GRA, but they have not yet been unroofed (Kleinkopf, 1980). Also during this time there was abundant tectonic transposition of sediments from west to east marking the beginning of the development of the Disturbed Belt (Mudge, 1970).

The Late Cretaceous Montana Group records a period of predominantly non-marine brackish water, and terrestrial sedimentation with a minor transgression when the Horse Thief Sandstone was deposited (Cobban, 1955). Tertiary rocks are absent in the Sawtooth GRA, however a regional withdrawal of the seas from the craton is indicated (Peterson, 1981).

The major tectonic event, development of the Montana Thrust Belt, occurred in Paleocene to late Eocene time (Hoffman, et al. 1976). Mudge (1970) suggests that the thrusts developed by gravity sliding along stratigraphically controlled decollments off of the uplift related to the intrusion of the northern part of the Idaho Batholith. Thrust faulting of the Mississippian carbonates resulted in the formation of traps for hydrocarbons. The thrusting was followed by block faulting which continued into the Quaternary (2 m.y. to present) (Mudge, 1970, 1972a).

3.0 ENERGY AND MINERAL RESOURCES

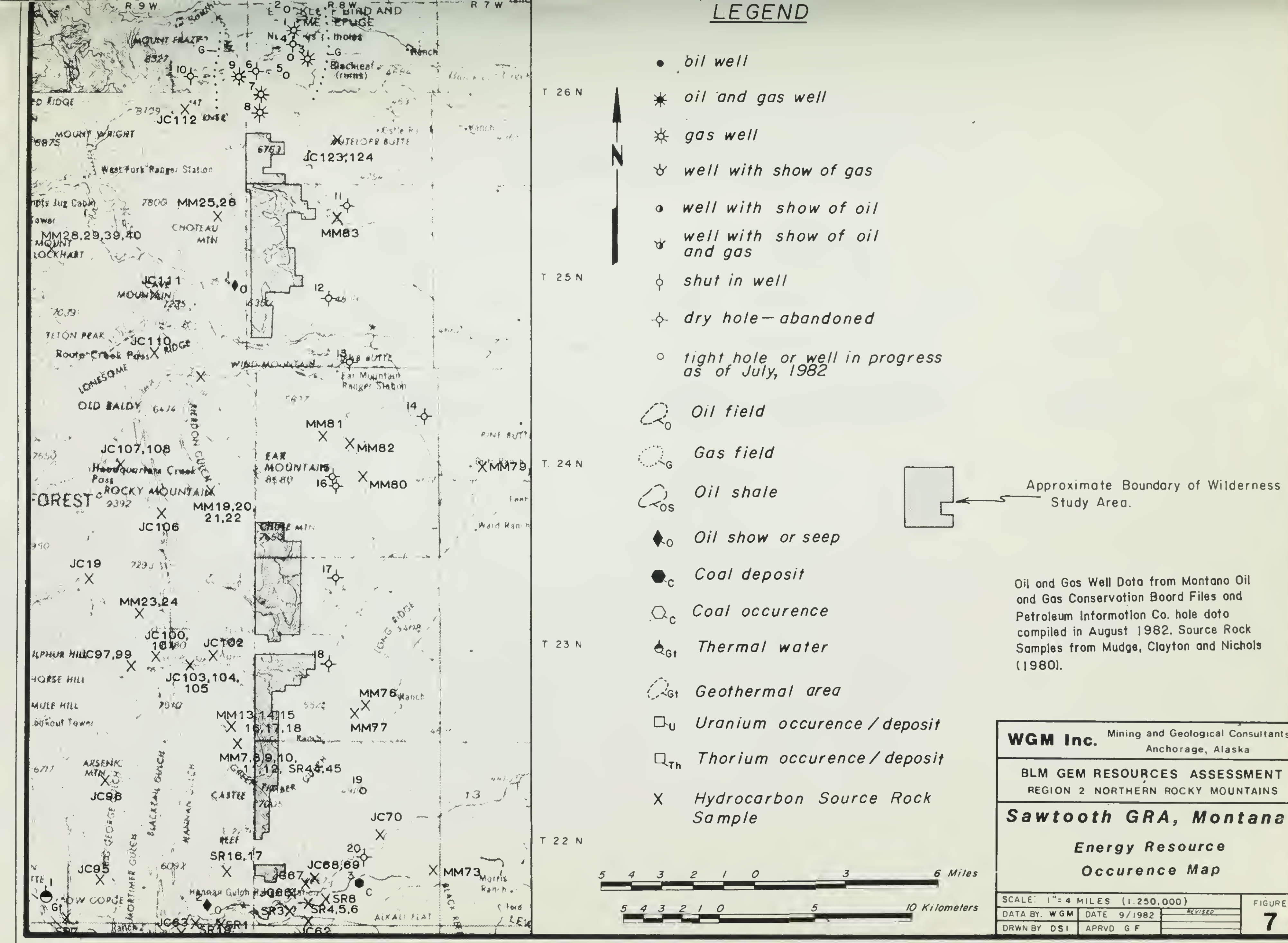
3.1 Known Mineral and Energy Deposits

There are no known mineral deposits in the Sawtooth GRA.

Low rank coal has been mined for local use from the Two Medicine Formation near Sun River (Earhart et al., 1981). There is no quantitative data available on the quality of the coal or the potential reserves, however Mudge (1972) describes the beds as being only a few feet thick. The Two Medicine Formation does not outcrop in any of the WSAs.

The most important energy deposit in the Sawtooth GRA is the Blackleaf Canyon gas field which is located just north of WSA 075-102 (Fig. 7, Table I). This field was discovered in 1958 by Northern Natural Gas Company (Heany, 1961) and is currently being developed by a consortium of Milestone Petroleum, Williams Exploration and Superior Oil Company. No reserve figures have been released. Five wells in the Blackleaf field are capable or producing from 0.9 to 9.9 million cubic feet of gas per day each, with an average of 5.3 million cubic feet per day (Table II). Data from an additional three wells is still confidential. Production from the field commenced in late 1982 (MSR Exploration, 1983).

Production in the Blackleaf field is from the Sun River member of the Mississippian Castle Reef Dolomite. The gas is water driven at a pressure of 800 PSI (Heany, 1961). In the No. 1 Blackleaf Federal A (loc. 9, Table II) the producing zone is 300 feet of tan, finely crystalline, fractured



Oil and Gas Well Data from Montana Oil and Gas Conservation Board Files and Petroleum Information Co. hole data compiled in August 1982. Source Rock Samples from Mudge, Clayton and Nichols (1980).

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Sawtooth GRA, Montana
Energy Resource
Occurence Map

SCALE: 1" = 4 MILES (1:250,000)		FIGURE
DATA BY: WGM	DATE 9/1982	REVISED
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TABLE I

ENERGY RESOURCE OCCURRENCES, SAWTOOTH GRA, MONTANA

Map No.	Type of Occurrence	Location Sec.	T.	R.	Description	Source of Data
1	Oil	25	25N	9W	Oil show in Madison Limestone.	Cavanaugh and Cavanaugh (1982).
2	Oil	35	22N	9W	Dead oil in pores and fractures in Madison Limestone.	Montana Geology Society (1979).
3	Coal	27	22N	8W	Beds of low rank coal in Two Medicine Formation. Mined for local use.	Earhart et al. (1981)
4	Gas	24-26	26N	9W	Natural gas field in Sun River Member of Madison Group. Five wells produce an average of 5.3 million cubic feet per day.	Milestone Petroleum, written comm. (1979).
		19-21, 28-30 31-33	26N	8W		
		5-6	25N	8W		

TABLE II

SAWTOOTH GRA, MONTANA, OIL AND GAS WELLS

Map No.	Location			Well	Company	Year Drilled	Total Depth (ft.)	Production	Status (Aug. 1982)
	Sec.	T.	R.						
1	5	26N	8W	1-5 Blackleaf	Williams Exploration	1981	5,992	9,000 Mcfgpd, Sun River	Shut in
2	5	26N	8W	2-5 Blackleaf	Williams Exploration	1981	5,700	Tight hole	No data
3	8	26N	8W	1-8 Blackleaf	Williams Exploration	1980	6,259	7,100 Mcfgpd, Sun River	Shut in
4	8	26N	8W	1 Teton-Knowlton	Gulf Oil Company	1956	7,853	None	Plugged and abandoned
5	16	26N	8W	1-16 Blackleaf	Williams Exploration	1981	5,600?	Tight hole	No data
6	18	26N	8W	11-18 Blackleaf A	Burlington Northern	1976	6,000	None	Plugged and abanoned
7	19	26N	8W	1-19 Blackleaf	Williams Exploration	1981	6,217	4,074 Mcfgpd	Shut in
8	19	26N	8W	1 Blackleaf Fed B	Northern Natural Gas	1958	5,844	969 Mcfgpd	Shut in
9	13	26N	9W	1 Blackleaf Fed A	Northern Natural Gas	1957-58	6,323	6,293 Mcfgpd	Shut in
10	14	26N	9W	1 Blackleaf	General Petroleum	1947-48	7,571	None	Plugged and abandoned
11	3	25N	8W	Govt. 38-3-G	General Petroleum	1945-46	3,129	None	Plugged and abandoned
12	21	25N	8W	1 Pamburn Fed	Wexpro	1981	6,362	None	Plugged and abandoned

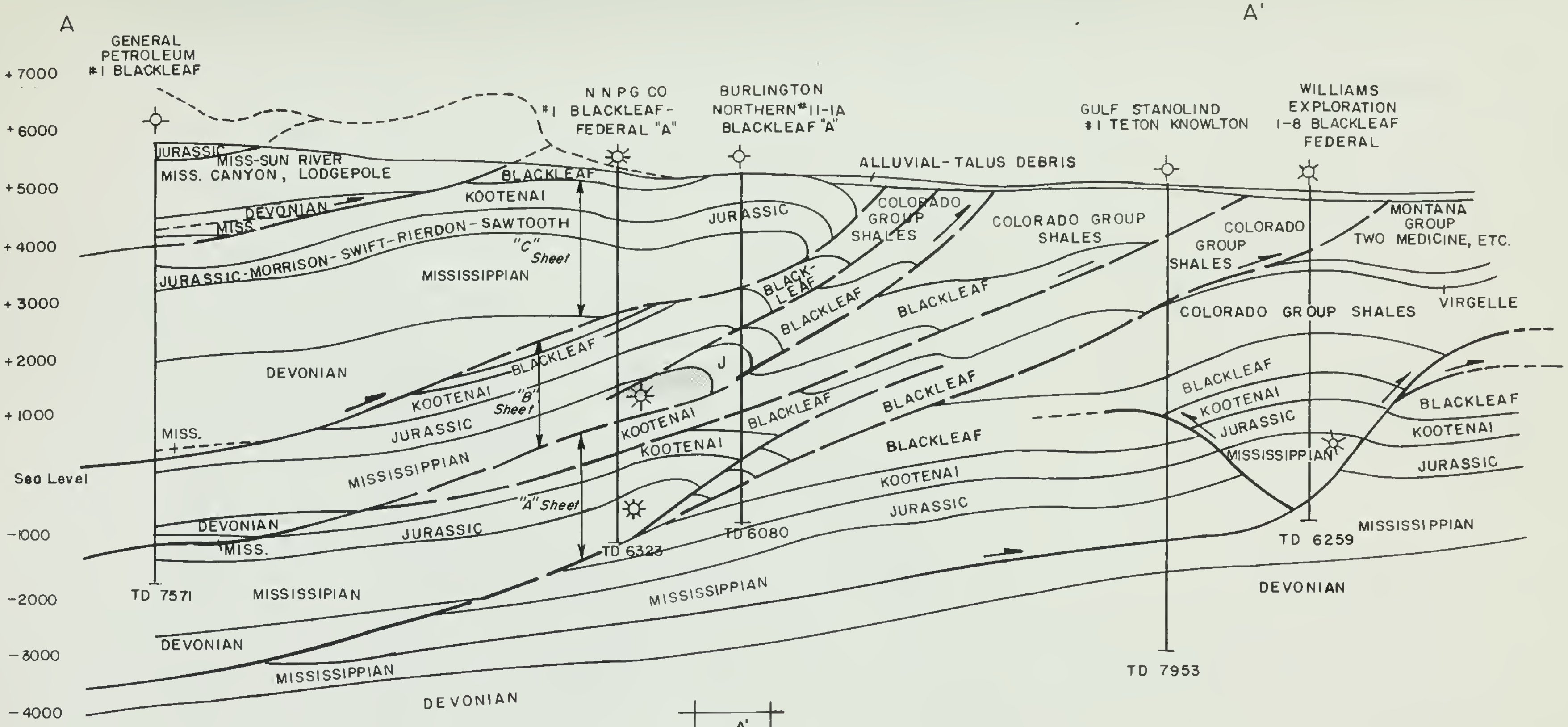
TABLE II (Cont.)

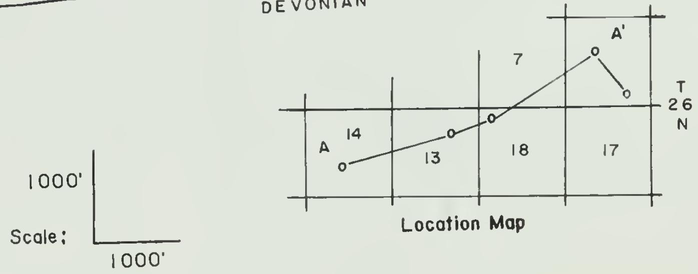
Map No.	Location Sec.	T.	R.	Well	Company	Year Drilled	Total Depth (Ft.)	Production	Status (Aug. 1982)
13	34	25N	8W	14-34 Unit	Shell	1960	4,911	None	Plugged and abandoned
14	12	24N	8W	1 Moore Govt.	Farmers Union Central	1947	3,531	None	Plugged and abandoned
15	21	24N	8W	State No. 1	Trans American Oil	1931	920	None	Plugged and abandoned
16	21	24N	8W	1 Teton Unit	Humble Oil	1969-70	10,090	None	Plugged and abandoned
17	4	23N	8W	Salmond	Rocky Mtn. Oil and Gas Company	????	1,700	None	Plugged and abandoned
18	21	23N	8W	1 Fed 51 Teton	Sinclair	1964	3,000	None	Plugged and abandoned
19	10	22N	8W	Federal 1-10	Williams Exploration	1981-82	?????	Tight hole	No data
20	22	22N	8W	Govt. No. 1	Farl Oil Company	1929-32	3,840	None	Plugged and abandoned

dolomite with a net average of 80 feet of intercrystalline and vuggy porosity (Heany, 1961). The trap is a structural high along the wedge edge of an overthrust slice (Fig. 8 and 9; Hurley, 1959). There are two producing slices, referred to as the "A" (lower) and "B" (upper) (Fig. 8). The producing thrust slices are the deeper, second and third slices. No gas has been found in the uppermost thrust plate to date. The source rock for the gas is believed to be the Eckshaw Shale (J. Cannon, pers. comm., 1982). The operators of the Blackleaf partnership believe that the gas field extends south into WSA 075-102 and have applied for a drilling permit in section 30, T.26N., R.8W. (J. Cannon, pers. comm., 1982).

3.2 Known Mineral and Energy Prospects, Occurrences and Mineralized Areas

There are four mineral occurrences reported in the Sawtooth GRA (Fig. 10). None of these occurrences is within a Wilderness Study Area. Three of these are titaniferous magnetite beds in the Virgelle Sandstone (Table III). These deposits are stratiform and occur in the upper part of the formation (Earhart et al., 1981). The beds range from 1 to 20 feet thick and average about 5 feet thick (Mudge, 1972a). The most extensive deposits are located just east of the GRA near Choteau. These were evaluated by the U.S. Bureau of Mines who concluded that the deposits contain 10.29 million tons averaging over 30% iron (Wimmler, 1946). The Virgelle Sandstone does not crop out in any of the WSAs. One of the magnetite occurrences may have associated rare earth minerals (Table III), however no detailed data on the occurrence is available other than a MILS reference.





Location Map

Data from: Milestone Petroleum 1880, modified from Mont. Geol. Soc. Guidebook 1979

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Sawtooth GRA, Montana
Blackleaf Canyon Gas Field
Cross Section

SCALE. AS SHOWN			FIGURE
DATA BY.	DATE 9/1982	REVISED	8
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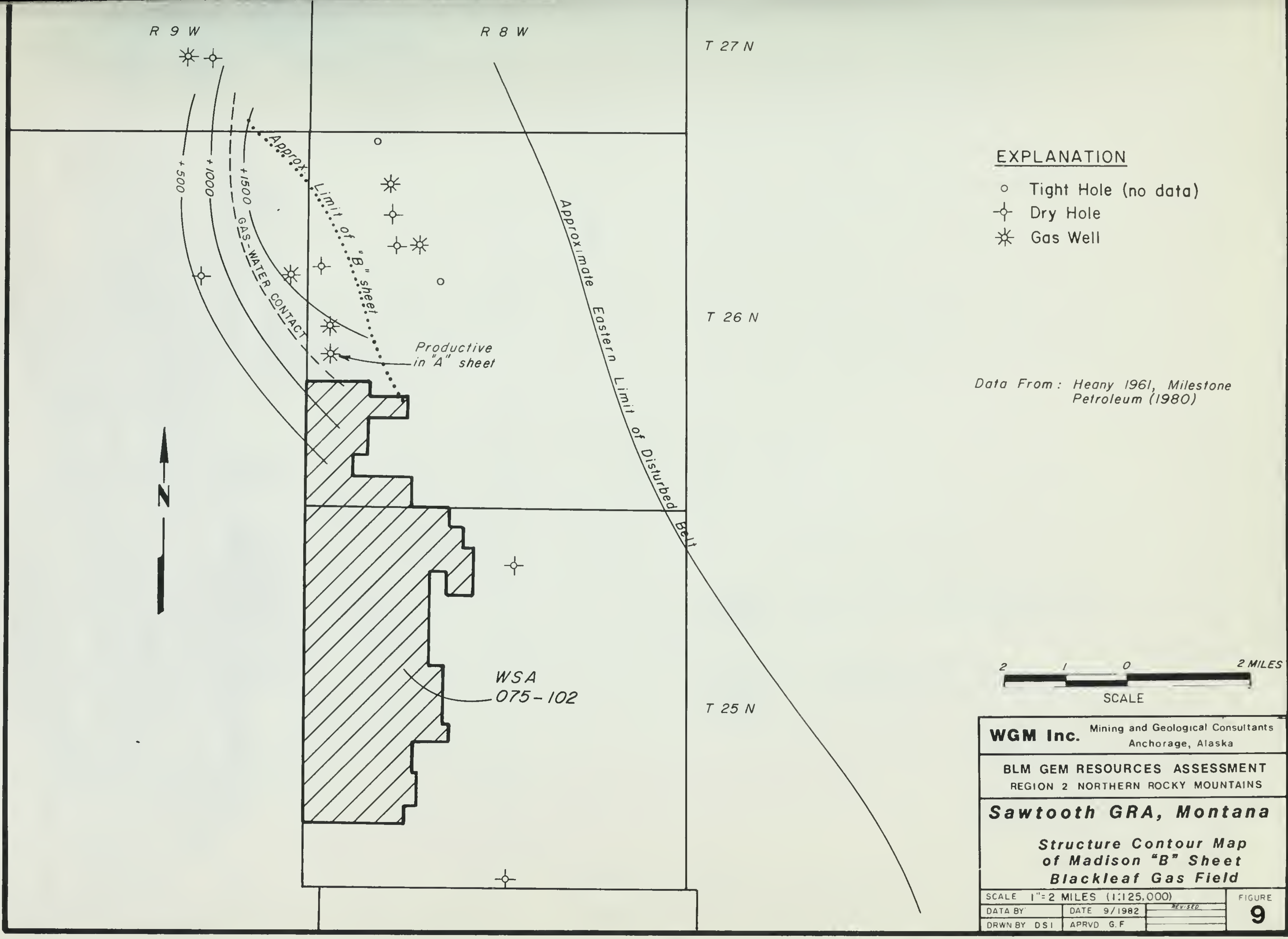

Data From: Heany 1961, Milestone Petroleum (1980)

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REGION 2 NORTHERN ROCKY MOUNTAINS

Sawtooth GRA, Montana

***Structure Contour Map
of Madison "B" Sheet
Blackleaf Gas Field***

SCALE 1"=2 MILES (1:125,000)			FIGURE
DATA BY	DATE 9/1982	REVISED	9
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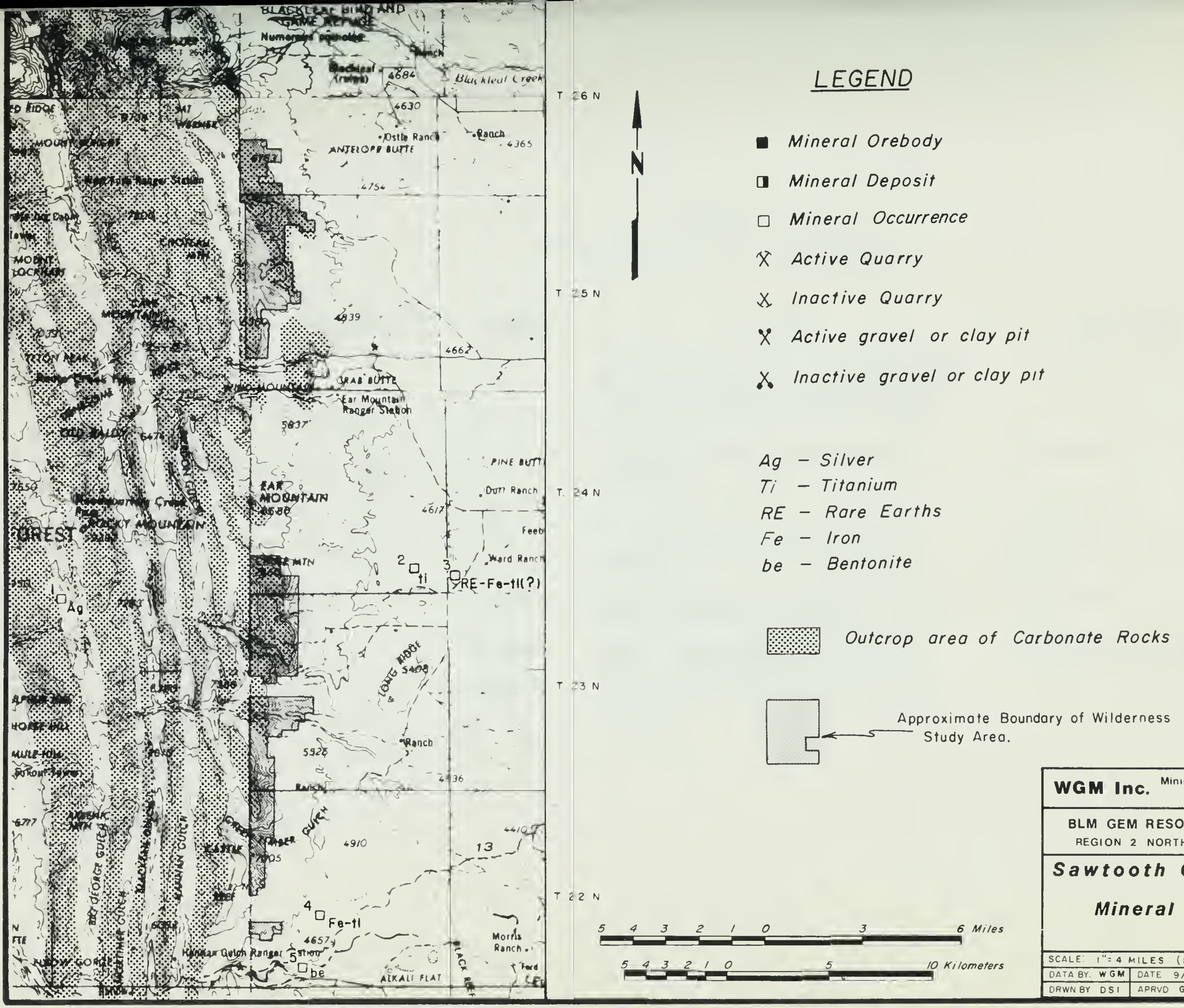

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BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Sawtooth GRA, Montana

Mineral Occurrences

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

TABLE III

MINERAL OCCURRENCES, SAWTOOTH GRA, MONTANA

Map No.	Name	Location			Commodity	Description	Source of Data
		Sec.	T.	R.			
1	Biggs Creek Prospect	31	24N	9W	Ag	Four-foot thick zone of iron-stained carbonaceous shale with local dolomite breccia and chert nodules at unconformity between sandstone shale and underlying dolomite. USBM samples show 0.1 oz/t Ag, 0.12% Zn maximum.	USBM MILS file. Marks (1978).
2	Theboe Lake-Fowler Creek		23N 24N 24N	7W 8W 7W	Fe-Ti	Titaniferous magnetite beds in Mesozoic sandstones.	USBM MILS file.
3	Unnamed	36	24N	8W	RE-Fe-Ti	No description.	USBM MILS file.
4	Unnamed	21	22N	8W	Fe-Ti	Titaniferous magnetite beds in Mesozoic sandstones.	Mudge (1972a), Earhart et al. (1981).
5	Unnamed	32	22N	8W	Bentonite	Bentonite bed up to 7 feet thick in the Cone Member of the Marais River Shale.	Mudge (1972a).
6	Unnamed				Limestone and Dolomite	High Ca limestone reported in the Middle Member of the Allan Mountain Limestone (Miss.). High Mg dolomite reported in the Sun River (Miss.) and Devils Glenn (Camb.) Dolomites.	Mudge et al. (1962), Mudge (1972a), Earhart (1978).

The remaining metallic mineral occurrence is an iron stained zone with very low grade silver-zinc values (Marks, 1978).

There are two non-metallic mineral occurrences within the Sawtooth GRA (Table III). Mudge (1972a) reports beds of bentonite up to seven feet thick in the Cone Member of the Marias River Shale. No data on the quality of the bentonite is available and the host rocks do not crop out in the WSAs.

Carbonate rocks are abundant in the Sawtooth GRA and crop out extensively in all four WSAs, however there are no quarries in the GRA (Chelini, 1965). Sampling by Earhart (1978) and Mudge, Sando and Dutro (1962) indicate that the middle member of the Mississippian Allan Mountain Limestone may average about 96% $CaCO_3$ (Earhart et al., 1981). The Devils Glenn Dolomite and the Sun River Member of the Castle Reef Dolomite both contain intervals with over 40% $MgCO_3$ (Mudge, 1972a). Industrial high calcium limestone must contain over 95% $CaCO_3$ and high purity dolomite must be over 40% $MgCO_3$ (Hubbard and Erickson, 1973; Carr and Rooney, 1975); therefore, some of the units in the GRA have potential for high calcium limestone or high purity dolomite. Available analyses of carbonate rocks in the general area of the Sawtooth GRA are summarized in Table IV.

There are two reported oil shows in the Sawtooth GRA (Table I). In addition, oil stain and oil filled cavities are common in Madison Group units throughout the region (J. Cannon pers. comm., 1982).

There is one thermal spring; Sun River Springs, in the Sawtooth GRA (Fig. 7). The spring has a surface temperature of 30.4°C and an estimated reservoir temperature of 35°C (Table V).

TABLE IV

AVERAGE CALCIUM AND MAGNESIUM CONTENT OF SOME PALEOZOIC CARBONATE ROCKS IN AND NEAR THE BOB MARSHALL WILDERNESS

Cambrian Rocks			
Formation	--	Devils Glenn Dolomite	Damnation Limestone
Thickness	--	154 feet (47 meters)	144 feet (44 meters)
No. Samples	--	4	4
Av. Ca	--	22.3	35.5
Av. $CaCO_3$	--	55.6	63.5
Av. Mg	--	12.9	1.2
Av. $MgCO_3$	--	44.7	3.9

Devonian Rocks			
Formation	--	Maywood (Upper Member)	Jefferson (Lower Member)
Thickness	--	149 feet (45 meters)	577.5 feet (166 meters)
No. Samples	--	6	25
Av. Ca	--	26.0	26.6
Av. $CaCO_3$	--	64.9	66.2
Av. Mg	--	7.8	9.1
Av. $MgCO_3$	--	26.9	31.4

TABLE IV (Cont.)

		Mississippian Rocks	
Formation	--	Allan Mountain Limestone (Middle Member)	Allan Mountain Limestone (Upper Member)
Thickness	--	118 feet (36 meters)	209.6 feet (64 meters)
No. Samples	--	3	7
Av. Ca	--	38.5	36.9
Av. $CaCO_3$	--	95.8	92.2
Av. Mg	--	0.3	1.2
Av. $MgCO_3$	--	1.1	4.2
Formation	--	Castle Reef Dolomite (Lower Member)	(Sun River Member)
Thickness	--	442.7 feet (135 meters)	256 feet (78 meters)
No. Samples	--	14	6
Av. Ca	--	32.9	21.6
Av. $CACO_3$	--	82.1	53.7
Av. Mg	--	4.5	12.9
Av. $MgCO_3$	--	15.4	44.8

Note: Data from Earhart (1978; Table 7, p. 103), however much of the sampling was done by Mudge, Sando and Dutro (1962).

TABLE V

THERMAL SPRINGS IN THE SAWTOOTH GRA, MONTANA

Map No.	Name	Location			Source	Observed Temp (C°)	Estimated Reservoir Temp (C°)	pH	SC[1]	TDS[2]	Source of Data
		Sec.	T.	R.							
1	Sun River Springs	26	22N	10W	Madison Limestone	30.4	35	7.2	1,190	890	Sonderegger and Bergantino (1981).

Notes: 1. Specific conductance.
2. Total dissolved solids.

3.3 Mining Claims, Leases and Material Sites

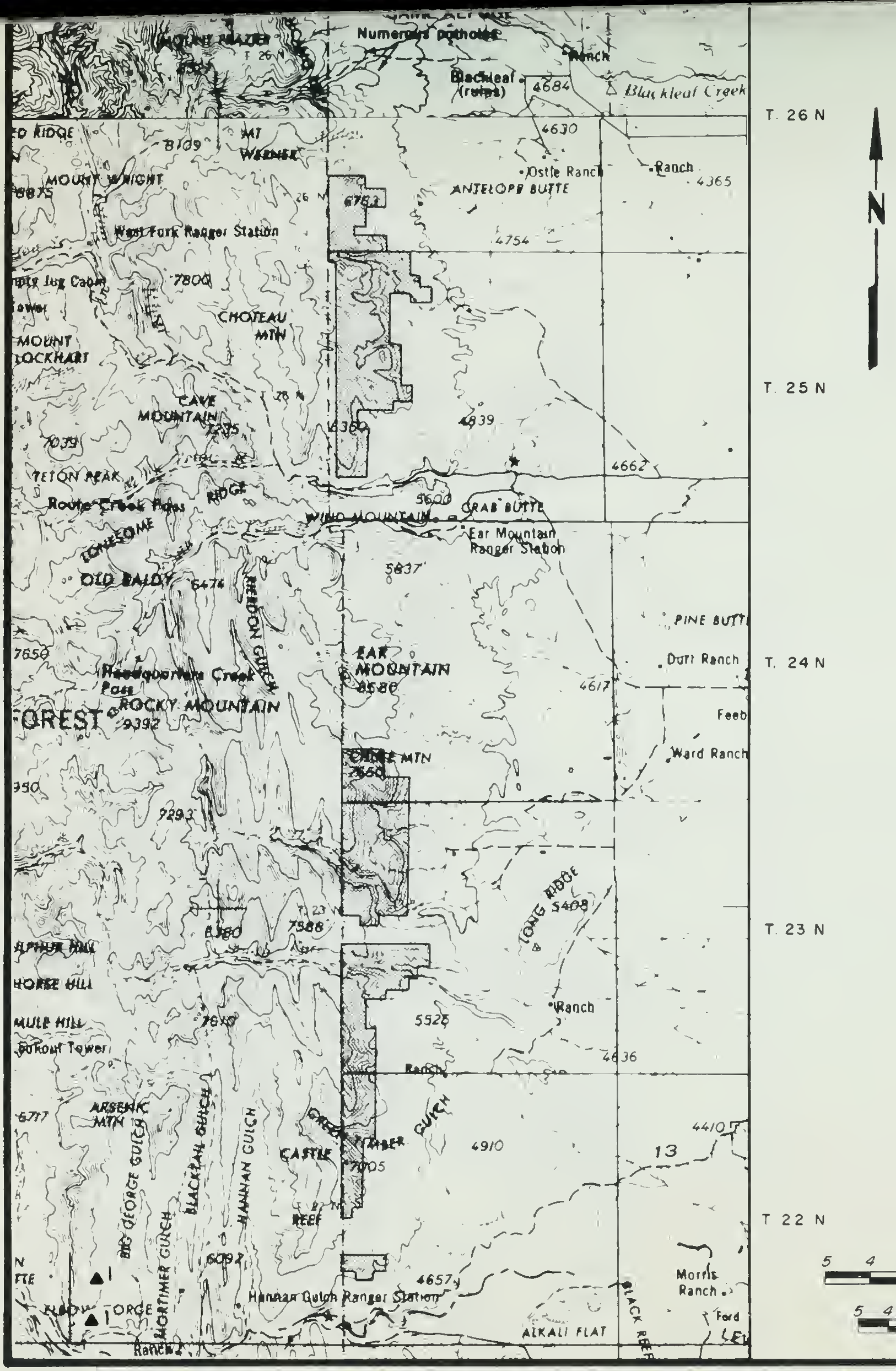
There are no unpatented mining claims in the Sawtooth GRA as of August 4, 1982 according to BLM mining claims records. There are two patented claims located about six miles west of WSA 075-107 (Fig. 11).

Most of the Sawtooth GRA is covered by oil and gas leases or lease applications (Fig. 12). The Wilderness Study Areas in the GRA are covered by 18 oil and gas leases. All of these were issued from 1971 to 1975, pre-dating the WSAs (Table VI).

3.4 Mineral and Energy Deposit Types

Of the known mineral occurrences in the Sawtooth GRA the type most likely to occur in the WSAs is high calcium limestone - high purity dolomite. Since known metallic mineral occurrences are absent in the GRA, its potential for metallic minerals must be evaluated using the extensive geochemical and aeromagnetic data available from the U.S. Geological Survey's CUSMAP program.

Fifty eight stream sediment samples and 104 rock samples were collected in the Sawtooth GRA (Fig. 13, Appendix III and IV) during the CUSMAP program. A review of the data and accompanying evaluations (Grimes and Leinz, 1980a, b; Leinz and Grimes, 1980a, b, c) shows that no geochemical anomalies were detected in any of the WSAs. High zinc-mercury-arsenic-molybdenum values are present in one silt sample and seven widely-spaced rock samples from the upper part of the Deep Creek drainage in the western part of the GRA (Fig.



Area of Search: T 22 N, R 8-9 W
T 23 N, R 8-9 W
T 24 N, R 8-9 W
T 25 N, R 8-9 W
T 26 N, R 8-9 W

Source of Data: 1) BLM Land Status Plats
2) BLM Claims Microfiche

Date: Aug. 30, 1982

x Unpatented Claim
▲ Patented Claim

Approximate Boundary of Wilderness Study Area.

WGM Inc. Mining and Geological Consultants
Anchorage, Alaska

BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Sawtooth GRA, Montana

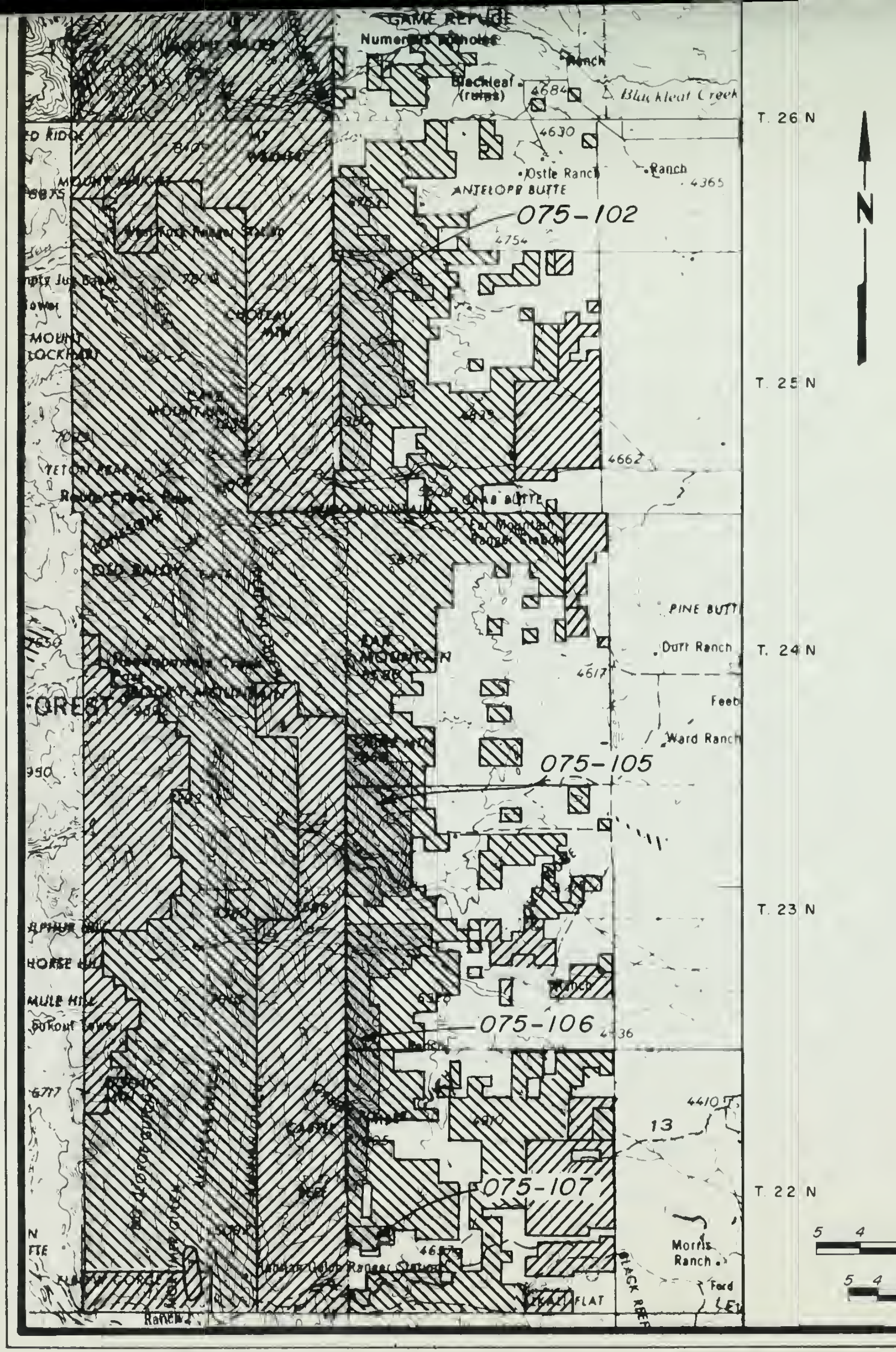
Mining Claim and Mineral Lease Map

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

FIGURE 11

Area of Search: T 22 N, R 8-9 W
T 23 N, R 8-9 W
T 24 N, R 8-9 W
T 25 N, R 8-9 W
T 26 N, R 8-9 W

Source of Data: BLM Land Status Plats
Date: Aug. 4, 1982



▨ Lease Application

▨ Lease

☐ Approximate Boundary of Wilderness Study Area.

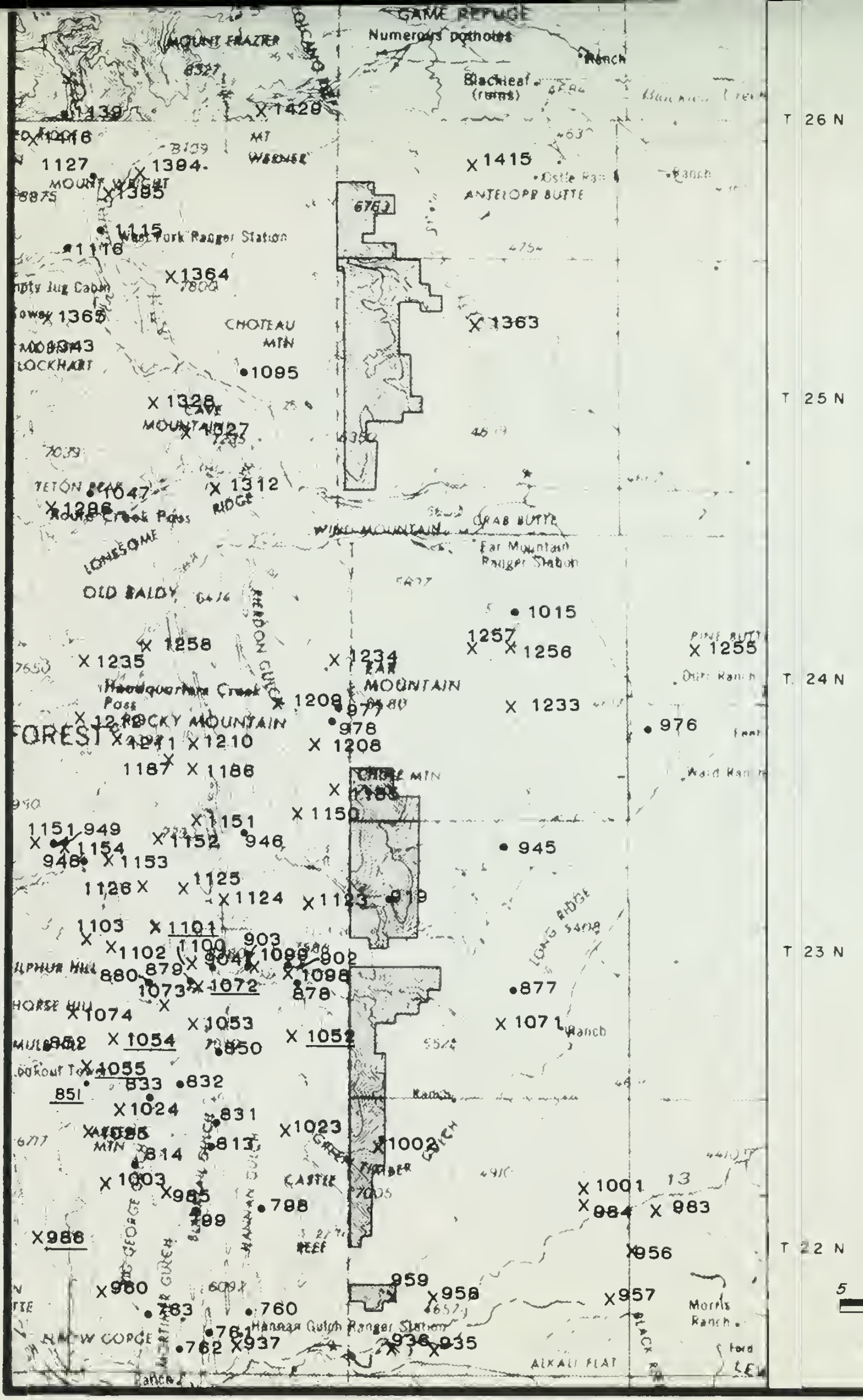
WGM Inc. Mining and Geological Consultants
Anchorage, Alaska

BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Sawtooth GRA, Montana

Oil and Gas Lease Map

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



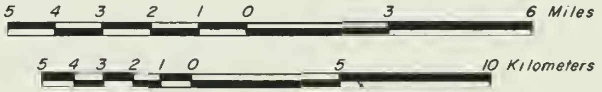
X Rock Sample

• Stream Sediment Sample

Note: Anomolous samples are underlined.

Approximate Boundary of Wilderness Study Area.

Data by: Grimes, Leinz and Hopkins, 1980



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Anchorage, Alaska

BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Sawtooth GRA, Montana

U. S. Geological Survey
Geochemical Sample Locations

SCALE 1"= 4 MILES (1:250,000)			FIGURE
DATA BY	DATE 9/1982	REVISED	13
DRWN BY DSI	APRVD G.F		

TABLE VI

OIL AND GAS LEASES IN WSAs IN THE SAWTOOTH GRA, MONTANA

WSA	Lease No.	Owner of Record	Date Issued
075-102	M 19133	Mountain Fuel Supply Co. P.O. Box 11368 Salt Lake City, Utah 84139	09-01-71
	M 19134	" "	09-01-71
	M 19135	" "	09-01-71
	M 22178	Burlington Northern Railroad Co. 902 First Northwestern Bank Center Billings, Montana 59103 Rainbow Resources, Inc. No. 10 Lakeside Lane Burlington Northern Railroad Co. 4707 Harlem Denver, Colorado 80215 The Superior Oil Co. Box 1521 Houston, Texas 77001	09-01-72
	M 21902	Mountain Fuel Supply Co.	07-01-72
	M 24615	Burlington Northern Rainbow Resources The Superior Oil Co.	04-01-73
	M 24616	" "	04-01-73
	M 31690	?	?
	M 48938	Mountain Fuel Supply Co.	07-01-72
075-105	M 24723	Mobil Oil Corporation P.O. Box 5444, Terminal Annex Denver, Colorado 80217	09-01-74
	M 23984	" "	01-01-73
	M 23988	" "	09-01-73

TABLE VI (Cont.)

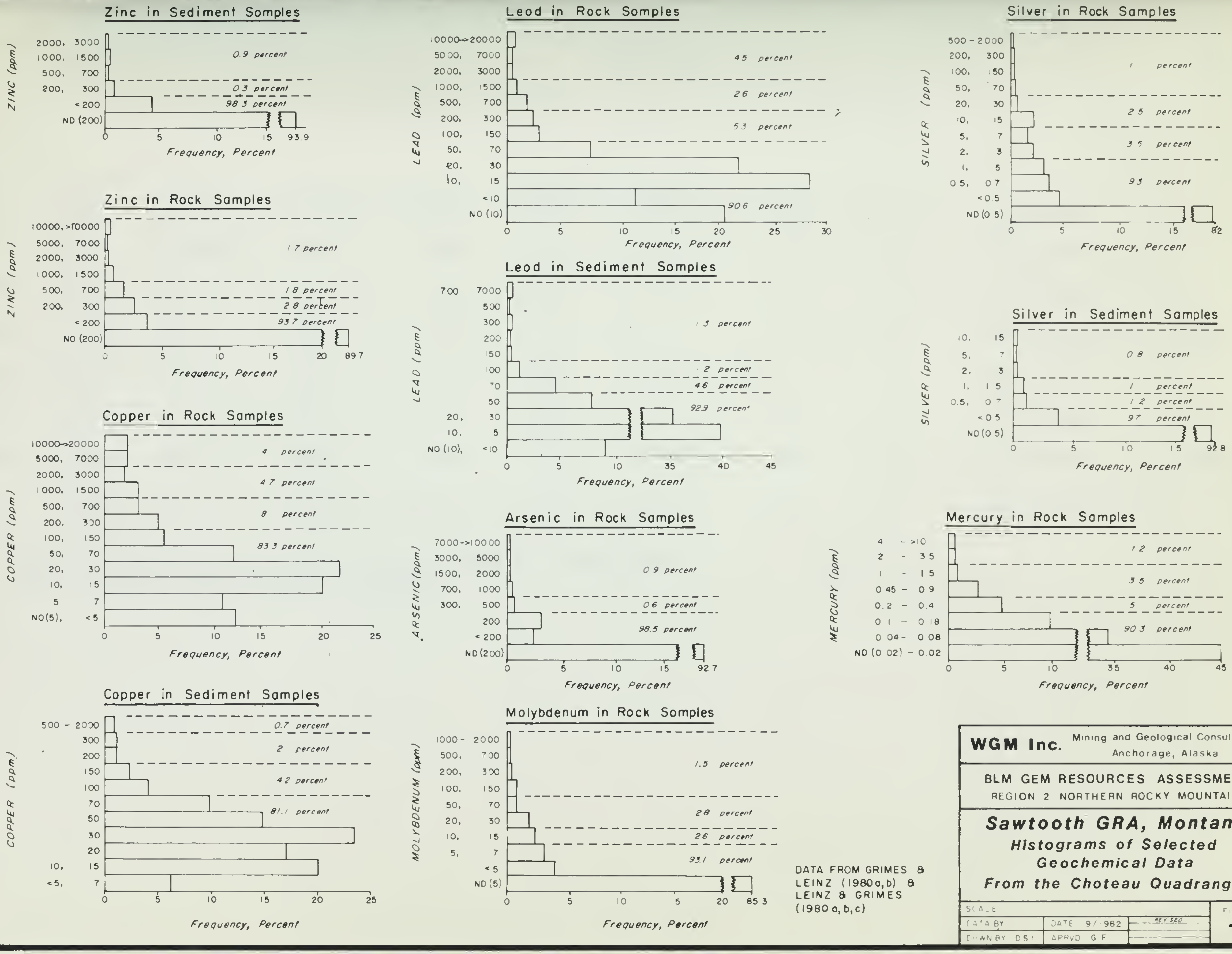
075-106	M 24043	Mobil Oil Corporation	01-01-73
	M 24043A	" "	03-23-73
	M 24613	Burlington Northern Rainbow Resources, Inc. The Superior Oil Co.	04-01-73
	M 24614	" "	04-01-73
	M 24722	Mobil Oil Corporation	09-01-74
075-107	M 30950	" "	03-01-75

13, Table VII). The anomalous values are weak when compared to anomalous samples elsewhere in the Choteau Quadrangle (Fig. 14). The anomalous rock samples are Paleozoic limestones containing limonite in nodules and on fracture surfaces (Leinz and Grimes, 1980b, c; Grimes and Leinz, 1980c). The anomaly is interpreted to reflect hydromorphic transport of metals along fracture systems from a subsurface source, perhaps a buried intrusive (Leinz and Grimes, 1980b).

Additional geochemical results are available from the Department of Energy's NURE Program (Arendt, 1981; Zinkl et al., 1982) in the Choteau Quadrangle. Approximately 85 samples were collected in the Sawtooth GRA during this program. Uranium content of these samples ranges from 1 to 6 ppm which is not considered to be anomalous (Zinkl et al., 1982. The uranium potential of the Sawtooth GRA can be farther assessed by comparing it to known uranium producing areas.

Most uranium is from felsic igneous rocks such as granite, syenite, pegmatite, and rhyolite. Because of its large ion size, uranium does not enter the ordinary rock-forming minerals except as inclusions; hence, in the formation of granitic masses, it forms its own minerals, forms an intergranular film, enters some accessory minerals such as zircon, sphene, or biotite, or it concentrates in late magmatic differentiates; hence, its occurrence in veins and pegmatites.

The average uranium content of the earth's crust is about 2 ppm, and that of granite is about 4 ppm. Felsitic volcanic rocks generally contain more uranium than their plutonic equivalents, perhaps as much as 50% more. To be



DATA FROM GRIMES & LEINZ (1980a,b) & LEINZ & GRIMES (1980 a,b,c)

WGM Inc. Mining and Geological Consultants
Anchorage, Alaska

BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Sawtooth GRA, Montana
Histograms of Selected
Geochemical Data
From the Choteau Quadrangle

SCALE			FIGURE
DATA BY	DATE 9/1982	REV SED	14
DRAWN BY DSI	APPVD G F		

TABLE VII

ANOMALOUS GEOCHEMICAL SAMPLES FROM THE SAWTOOTH GRA[1]

Map No.	USGS Sample No.	Type	ANALYTICAL DATA[2] Zn (ppm)	Cu (ppm)	Pb (ppm)	Ag (ppm)	Mo (ppm)	Hg (ppm)	Description
851	CH 181	Sediment	3,000	50	50	0.5	30	----	Silt sample, -80 mesh
986	HS 780	Rock	-----	<5	<10	ND	100	0.08	Iron-stained limestone
1052	HS 833	Rock	<200	20	15	<0.5	100	2	Iron-stained conglomerate
1054	HS 819	Rock	1,500	70	200	<0.5	300	----	Iron nodule
1055	CH 181	Rock	3,000	50	50	ND	30	0.28	Iron nodule
1072	CH 164	Rock	1,000	30	50	ND	20	0.55	Iron-stained calcite vugs
1101	HS 828	Rock	3,000	200	70	5	100	1.5	Iron-stained vugs

---

1. Data from Leinz and Grimes (1980b, c) and Grimes and Leinz (1980c).
2. Semi-quantitative spectrographic analyses.

commercially exploitable, a uranium deposit must be ordinarily contain at least 1,000 ppm or one kilogram per ton. Thus, concentration by later geologic processes is usually necessary to form an economic uranium deposit. The uranium minerals in igneous rocks are mostly in the tetravalent state and oxidize readily to provide hexavalent uranium. Hexavalent uranium is soluble in ground waters. During transport by ground water, uranium may be: (1) partially absorbed by clay or carbonaceous matter, (2) precipitated in a chemically hospitable environment by reduction or evaporation, or (3) combine with another element to form a mineral stable in the oxidized state. If carried to the ocean, it tends to: (1) precipitate with phosphatic sediments, or (2) be absorbed by organisms and/or carbonaceous mud. The uranium-bearing accessory minerals, being resistant to erosion, are more likely to weather out of the igneous host as detritus and become dispersed in detrital sediments or, more rarely, concentrated into placers.

Three ore environments, in about equal amounts, host 90% of the free world uranium reserves. These are:

1. early Precambrian quartz-pebble conglomerates,
2. sandstone hosted roll-front deposits, mainly in post carboniferous continental sandstones, and
3. unconformity vein deposits, thus far known only in Proterozoic rocks.

The sandstone deposits account for about 95% of United States uranium reserves. The hosts are river-borne arkosic sandstone deposits, commonly intercalated with acidic tuff and clay beds. The tuffs and/or nearby

granitic uplifts, and the arkose itself, are thought to be the source rocks. The uranium is dissolved from the source rocks by meteoric water. The course of these uranium-bearing meteoric waters is directed by clay beds or old channel scours, and the precipitating medium for the uranium is believed to be organic matter. Somewhat surprisingly, therefore, lignite deposits rarely have associated ore, though they may be quite anomalous in uranium. Deposits are individually small (with exceptions) with grade ranging from 3 to 8 pounds per ton. Uranium in peneconcordant sandstone deposits is accompanied by iron (as pyrite if the ore is unoxidized) and in many cases by copper, molybdenum, selenium, and vanadium.

From the above discussion of uranium deposits it can be seen that the Cretaceous clastic units which underlie portions of the eastern half of the Sawtooth GRA may constitute favorable host rocks for sandstone uranium deposits. The distribution of coal-bearing beds in the Cretaceous units suggests that the environment is marginal marine and possibly continental. Some of the NURE stream sediment data is anomalous in vanadium, but the uranium results are not exciting. Thus, on the basis of apparent stratigraphic relationship the eastern part of the GRA warrants farther evaluation for uranium potential. The marine carbonate rocks which underly most of the four WSAs are not favorable host rocks for uranium deposits.

Aeromagnetic data for the Sawtooth GRA (Kleinkopf, 1980) shows four anomalies (Fig. 6). Two negative magnetic anomalies (labeled A) at the northern end of the GRA probably indicate magnetic sources within the basement, possibly gabbroic bodies (Kleinkopf and Mudge, 1972). One of these is beneath WSA 075-102. An irregular isolated magnetic low (labled G)

underlies the area where the anomalous geochemical samples previously described were collected. The magnetic anomaly may reflect a shallow pluton (Kleinkopf, 1980). A 40 nanotesla positive anomaly located in the Gibson Reservoir area at the southern edge of the GRA suggests that a stock, similar to the one underlying anomaly G, is present (Kleinkopf, 1980).

The aeromagnetic data indicates that there are probably buried plutons within the Sawtooth GRA. These plutons may have associated metallic mineralization. The mineralization would most likely be vein and replacement type deposits in the country rocks, or porphyry copper-molybdenum mineralization similar to that in the Heddleston district (Miller et al., 1973). The aeromagnetic data indicate a minimum depth of 3,500 feet to the pluton below Gibson Reservoir and an even greater depth for the one causing Anomaly G (Kleinkopf, 1980).

The most significant resource potential in the Sawtooth GRA is for oil and gas production. The GRA is located in the east-central part of the Disturbed Belt and along the western edge of the southern part of the Sweetgrass Arch. The stratigraphy of the area (Fig. 4) was defined by Mudge (1972a) and Mudge and Stebinger (1979). Several units, known to produce oil and/or gas along the Sweetgrass Arch, are prsent in the subsurface of the GRA. These units are the Cretaceous Blackleaf Formation, the Jurassic Swift and Sawtooth Formations and the Mississippian Sun River Member of the Castle Reef Dolomite. In addition, the Cutbank Sandstone Member of the Mt. Pablo Formation, a producer in the Cut Bank Field, probably occurs a few miles east of the Sawtooth GRA (Mudge et al., 1980) and although unlikely, might extend into the subsurface of the GRA.

The complex structure of the Disturbed Belt has been difficult to interpret in the past but detailed surface mapping (Mudge, 1968, 1972a; Mudge and Earhart, 1979a, b; Mudge, Earhart and Rice, 1977b) coupled with modern seismic studies (most of which are presently confidential) permit good definition of subsurface structures (McCaslin, 1981; Cavanaugh and Cavanaugh, 1982). The discovery of the Blackleaf Field showed that multiple thrust slices of Mississippian carbonates are present along the Disturbed Belt east of the mountain front (Hurley, 1959; Heany, 1961; Milestone Petroleum, 1981). Production is found in the lower plates and may be from more than one plate. It is highly probable that some of these structures extend into the WSAs and that other similar favorable structures are present in the WSAs (Fig. 5 and 9).

Hydrocarbon exploration of the Disturbed Belt is summarized by Darrow (1955) and the Montana Geological Society (1979). Exploration has been rather slow because major discoveries were made during days of low prices or no market and seismic techniques were inadequate to properly interpret the subsurface structures (Hurley, 1959). Interest in the area has been sporadic but its potential has been advocated by several individuals over the years (Hurley, 1959: Cannon, 1971; Woodward, 1981; McCaslin, 1981; among others). The interest has continued because the area is proximal to major oil and gas fields along the Sweetgrass Arch and oil seeps are known just west of WSA 075-102 and southwest of WSA 175-107 (Fig. 7). Recent discovery of gas in the Two Medicine and Knowlton Fields within the Disturbed Belt north of the Sawtooth GRA and the discovery of several major oil and gas fields in the Thrust Belt of western Wyoming and northeastern Utah have intensified the interest all along the Thrust Belt from Canada to Arizona.

The Cut Bank Field, located on the western flank of the Sweetgrass Arch some 30 to 70 miles northeast of the Sawtooth GRA, was included by Halbouty (1970) as a giant American oil field. This definition is applied when field will produce over 100 million barrels of oil or one trillion cubic feet of gas. Discovered in 1915, the Cut Bank Field had produced nearly 500 billion cubic feet of natural gas by 1968 (Nordquist and Leskela, 1969) from eight stratigraphic units. By 1978 the Cut Bank Field had produced 147.8 million barrels of oil and it was estimated that it would ultimately produce 162.5 million barrels (Estelle and Miller, 1978). Other significant oil and gas reservoirs occur in the Gypsy Basin, Pondera and other associated fields 4 to 16 miles east-northeast of the Sawtooth GRA. The Pondera Field is estimated to have an ultimate recovery of 25 million barrels of oil (Estelle and Miller, 1978).

Hydrocarbon source beds and potential reservoir beds within the Disturbed Belt including the Sawtooth GRA (Table VIII) were summarized by Rice (1977) and Mudge (1980). The samples from Mudge (1980) which are within the Sawtooth GRA are reproduced in this report as Tables IX and X. Their analyses include 118 surface and core samples, many of which were taken within the Sawtooth GRA, from stratigraphic units (Table X) which extend into the WSAs. In addition Mudge et al. (1980) ran geothermal analyses on these samples and results of these tests indicated that temperatures had been sufficient to generate hydrocarbons and that any commercial hydrocarbon deposits present along the mountain front will most likely be natural gas.

TABLE VIII

HYDROCARBON POTENTIAL OF SOME SEDIMENTARY ROCK UNITS IN THE CHOTEAU QUADRANGLE, MONTANA

[(S), potential source rocks; (R), potential reservoir rocks; (NE), not evaluated; (NP), no potential source of reservoir rock]

Tertiary	Siltstone, sandstone, conglomerate, and minor coal		(NP)
	St. Mary River Formation		(NE)
	Horsethief Sandstone		(NE)
	Two Medicine Formation		(NE)
Upper Cretaceous	Virgelle Sandstone		(NE)
	Telegraph Creek Formation		(NE)
	Marias River Shale	Kevin Member	(S)
		Ferdig Member	(R) (S)
		Cone Member	(S)
		Floweree Member	(S)
Lower Cretaceous	Blackleaf Formation	Vaughn Member	
		Taft Hill Member	(S)
		Flood Member	(R) (S)
	Kootenai Formation		(R)
	Mount Pablo Formation	Upper and middle parts	(R)
		Cut Bank Sandstone Member	(R)
Upper Jurassic	Morrison Formation		
Upper and Middle Jurassic	Swift Formation	Sandstone Member	(R)
		Shale Member	(S)
Middle Jurassic	Rierdon Formation		(R)
	Sawtooth Formation	Siltstone Member	(NP)
		Shale Member	(S)
		Sandstone Member	(R)
Upper Mississippian	Castle Reef Dolomite	Sun River Member	(R)
		Lower Member	(R)
Lower Mississippian	Allan Mountain Limestone	Upper Member	(R)
		Middle Member	(NE)
		Lower Member	(S)

TABLE VIII (Cont.)

Upper Devonian	Three Forks Formation		(R) (S)
	Jefferson Formation	Birdbear Member	(R)
		Lower Member	(NE)
Middle and Lower Devonian	Maywood Formation	Upper Member	(NE)
		Lower Member	

Data by Mudge et al. (1981).

TABLE IX

SAWTOOTH GRA, HYDROCARBON SOURCE ROCK ANALYSES[1,2]

Sample No.	Organic Carbon (Wt. %)	Bitumen (ppm)	Saturated Hydrocarbons (ppm)	Aromatic Hydrocarbons (ppm)	Asphaltic Compounds (ppm)	Total Hydrocarbons (ppm)	Hydrocarbons Organic Carbon (%)	Formation	Age
JC 123	0.70	1,428	619	231	632	850	12.1	Marias River Kevin Member	Upper Cretaceous
MM 82	0.76	545	211	88	247	299	3.9	"	"
JC 96	1.93	631	300	137	194	437	2.26	Blackleaf	Lower Cretaceous
JC 101	1.52	303	160	74	69	234	1.5	Swift	Upper and Mid Jurassic
JC 105	0.84	139	89	27	23	116	1.4	Swift	"
JC 97	8.79	1,265	348	700	217	1,048	1.2	Threeforks	Devonian

---

[1] Analyses by solvent extraction and elution chromatography.

[2] Data by Mudge, M.M., Clayton, J.L. and Nichols, K.M. (1980), Table 3.

TABLE X

SAWTOOTH GRA, ANALYSES OF HYDROCARBON SOURCE ROCK SAMPLES[1,2]

Sample No.	Sample Interval (ft.)	Organic Carbon (%)	Pyrolitic Hydrocarbon Yield (%)	Volatile Hydrocarbon Content (ppm)	Pyrolitic Hydrocarbon Organic Carbon (%)	Temperature of Maximum Pyrolysis Yield (in °C)	Formation	Age
MM 79	Grab	0.44	0.02	28	4.9	510	Horsethief Sandstone	Upper Cretaceous
JC 70	Grab	1.49	0.45	211	30.4	492	Virgelle Sandstone	Upper Cretaceous
JC 69	Grab	0.84	0.12	218	14.3	512	Telegrah Creek	Upper Cretaceous
MM 82	Grab	0.76	0.08	147	11.0	497	Marias River Shale, Kevin Member	Upper Cretaceous
MM 83	Grab	1.60	0.06	193	3.7	498	Marias River Shale, Kevin Member	Upper Cretaceous
JC 123	Grab	0.70	0.23	172	32.3	496	Marias River Shale, Kevin Member	Upper Cretaceous
MM 77	Grab	1.65	0.15	318	9.2	516	Marias River Shale, Kevin Member	Upper Cretaceous
JC 68	Grab	1.11	0.08	124	7.6	502	Marias River Shale, Kevin Member	Upper Cretaceous
MM 80	Grab	1.18	0.12	112	10.4	523	Marias River Shale, Ferdig Member	Upper Cretaceous
JC 124	Grab	0.99	0.26	185	26.4	484	Marias River Shale, Ferdig Member	Upper Cretaceous
MM 76	Grab	1.05	0.56	95	5.4	520	Marias River Shale, Ferdig Member	Upper Cretaceous
JC 62	Grab	1.13	0.04	17	3.2	504	Marias River Shale, Ferdig Member	Upper Cretaceous
SR 6	Lower 20	1.03	0.08	127	7.8	507	Marias River Shale, Ferdig Member	Upper Cretaceous
JC 67	Grab	2.91	0.38	349	13.1	500	Marias River Shale, Cone Member	Upper Cretaceous
SR 4	Upper 15	0.4-0.49	0.026	43	6.7	480	Marias River Shale, Cone Member	Upper Cretaceous
SR 5	Lower 85	2.35-2.92	0.18	152	7.9	490	Marias River Shale, Cone Member	Upper Cretaceous
MM 17	15	0.96	0.026	39	2.8	512	Blackleaf, Taft Hill Member	Lower Cretaceous
MM 16	50	0.93	0.027	55	3.0	---	Blackleaf, Taft Hill Member	Lower Cretaceous
JC 65	Grab	0.80	0.06	95	7.9	510	Blackleaf, Taft Hill Member	Lower Cretaceous
SR 2	Grab	0.87	0.046	46	5.3	514	Blackleaf, Taft Hill Member	Lower Cretaceous
SR 1	Grab	0.68-0.86	0.062	57	7.3	508	Blackleaf, Taft Hill Member	Lower Cretaceous
MM 81	Grab	0.60	0.02	72	3.5	520	Blackleaf, Flood Member	Lower Cretaceous
JC 102	Grab	0.76	0.04	87	4.6	544	Blackleaf, Flood Member	Lower Cretaceous
MM 15	15	0.33	0.022	41	6.7	502	Blackleaf, Flood Member	Lower Cretaceous
MM 14	65	0.95	0.036	73	3.9	504	Blackleaf, Flood Member	Lower Cretaceous
MM 13	40	1.16	0.045	93	3.9	504	Blackleaf, Flood Member	Lower Cretaceous
JC 96	Grab	1.93	30	76	15.8	485	Blackleaf, Flood Member	Lower Cretaceous
JC 65	Grab	1.17	0.06	116	5.2	506	Blackleaf, Flood Member	Lower Cretaceous
SR 3	Grab	1.43	0.083	104	5.8	506	Blackleaf, Flood Member	Lower Cretaceous
SR 10	Grab	1.19	0.087	42	7.3	490	Blackleaf, Flood Member	Lower Cretaceous
JC 63	Grab	1.25	0.04	36	3.1	490	Blackleaf, Flood Member	Lower Cretaceous

TABLE X (Cont.)

Sample No.	Sample Interval (ft.)	Organic Carbon (%)	Pyrolitic Hydrocarbon Yield (%)	Volatile Hydrocarbon Content (ppm)	Pyrolitic Hydrocarbon Organic Carbon (%)	Temperature of Maximum Pyrolysis Yield (in °C)	Formation	Age
MM 18	Grab	0.55	0.023	34	4.3	508	Kootenai	Lower Cretaceous
MM 22	40	0.69	0.023	28	3.4	540	Swift	Upper and Middle Jurassic
JC 101	Grab	1.52	0.11	108	7.6	517	Swift	Upper and Middle Jurassic
JC 103	Grab	0.67	0.02	46	3.8	520	Swift	Upper and Middle Jurassic
JC 104	Grab	0.56	0.02	27	2.8	550	Swift	Upper and Middle Jurassic
JC 105	Grab	0.84	0.01	27	1.1	560	Swift	Upper and Middle Jurassic
MM 10	40	0.80	0.54	69	6.8	506	Swift	Upper and Middle Jurassic
JC 112	Grab	0.21	0.01	25	6.0	528	Riderdon	Middle Jurassic
MM 26	113	0.31	0.010	14	6.2	506	Riderdon	Middle Jurassic
JC 110	Grab	0.28	0.02	42	6.2	522	Riderdon	Middle Jurassic
JC 19	Grab	0.27	0.01	14	4.8	500	Riderdon	Middle Jurassic
JC 106	Grab	0.37	0.01	28	3.3	520	Riderdon	Middle Jurassic
MM 21	Entire Fm.	0.22	0.011	26	5.3	520	Riderdon	Middle Jurassic
JC 100	Grab	0.41	0.04	74	8.8	499	Riderdon	Middle Jurassic
MM 8	Lower 55	0.32	0.013	29	4.4	509	Riderdon	Middle Jurassic
MM 9	Upper 55	0.23	0.017	40	7.7	504	Riderdon	Middle Jurassic
JC 95	Grab	0.27	0.01	28	5.0	500	Riderdon	Middle Jurassic
MM 25	57	0.41	0.020	38	4.9	492	Sawtooth	Middle Jurassic
JC 111	Grab	0.27	0.01	26	4.0	530	Sawtooth	Middle Jurassic
MM 19	Lower 50	0.61	0.017	39	2.9	520	Sawtooth	Middle Jurassic
MM 20	Upper 10	0.39	0.022	71	5.8	500	Sawtooth	Middle Jurassic
MM 7	Entire Mbr.	0.31	0.021	43	7.3	502	Sawtooth	Middle Jurassic
SR 7	50	0.18-0.45	0.028	65	6.3	502	Allan Mountain	Lower Mississippian
MM 23	Lower 50	1.08	0.019	24	1.8	558	Allan Mountain	Lower Mississippian
JC 96	Grab	1.93	30	76	15.8	485	Three Forks	Devonian
JC 108	Grab	0.87	0.01	30	---	---	Three Forks	Devonian
JC 97	Grab	1.03	0.02	31	2.1	600	Three Forks	Devonian
JC 99	Grab	0.01	0.01	25	99.3	420	Three Forks	Devonian
JC 107	Grab	0.33	0.01	28	3.8	560	Three Forks	Devonian

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1. Organic carbon by combustion and pyrolitic hydrocarbon yield by thermal analysis.
2. Data from Mudge, M.M., Clayton, J.L. and Nichols, K.M. (1980), Table 2.

The reservoir rock at the Blackleaf Field is the Sun River Member of the Castle Reef Dolomite (Heany, 1961). This unit is a porous crinoidal grainstone which has undergone secondary eogenetic dolomitization, probably in late Mississippian time (Nichols, 1980). The grainstone is underlain by dense packstone-wackstone facies and has been largely removed by erosion in the southern part of the Sawtooth GRA (Nichols, 1980; Mudge, 1972a). Nichols (1980) suggests that the distribution of this grainstone unit may be a significant factor in formation of the gas reservoirs. In contrast, Hurley (1959) states that the permeability at the Blackleaf Field is caused by fracturing. This coupled with the structural nature of the traps suggests that the intensity of fraturing may be a more important factor in determining reservoir quality. The lack of success in wells drilled in the southern part of the GRA is probably due to their failure to penetrate structurally lower Mississippian thrust slices (J. Cannon pers., comm., 1982).

Hydrocarbon exploration in the Sawtooth GRA has resulted in the drilling of 19 wells including the discovery well for the Blackleaf Field (Table II). Five of the wells are gas wells each capable of producing between 0.9 and 9.9 million cubic feet per day (averaging at least 5.3 million cubic feet per day) and data from three others is confidential. Gas production commenced from the Blackleaf Field in December 1982 at the rate of six million cubic feet per day. The gas is sold to a gas plant 15 miles northeast of the Blind Horse Creek WSA (MSR Exploration, 1983). The remaining 11 wells were plugged and abandoned as dry holes. The five gas wells and two of the confidential holes are located within 3.5 miles of the northern end

of the Blind Horse WSA (075-102); the other confidential hole is approximately three miles east of WSA 075-106 (Fig. 7). Wells drilled in the area have all been shallow holes, with only three deeper than 7,000 feet, one of which bottomed at 10,090 feet. No wells have penetrated the total Paleozoic stratigraphic section and deeper structures remain untested. Milestone Petroleum (1981) has expressed continued interest in the Blackleaf Canyon area for exploration. James L. Cannon who has worked in the area for over 20 years, expressed the belief that there is excellent potential for gas and good potential for oil in the Sawtooth GRA (pers. comm., 1982). His belief is strengthened by possession of outcrop samples of Madison Limestone (Sun River Member) containing petroleum. Furthermore, Mr. Cannon stated that there is evidence that oil can occur in the Greenhorn Shale (Marias River Shale).

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 (over 150°C) hydrothermal convection systems

b. Intermediate temperature (90-150°C) hydrothermal convection systems

4. Low temperature (less than 90°C) hydrothermal convection systems
5. Geo-pressured geothermal energy systems

For the purposes of this mineral assessment these classes can be reduced to two: (1) high temperature (greater than 150°C) hydrothermal convection

systems, and (2) low/intermediate temperature (40-150°C) hydrothermal convection systems. Geo-pressured geothermal energy systems do not exist in the areas discussed. Theoretically geothermal resources exist everywhere because the temperature of the earth's crust everywhere increases with depth; thus, high temperatures are reached at some depth below any given point on the earth's surface. At the present time, and in the foreseeable future, a naturally occurring hot fluid coupled with sufficiently porous and permeable rocks to allow fluid migration, are prerequisites for practical use of geothermal energy; thus conduction-dominated and "magma-tap" geothermal systems are not included in this evaluation. Also, for the purposes of this report the resources are classified in terms of observed or expected system temperature. It is not possible to evaluate the geothermal resources within the Sawtooth GRA based on actual drilling and production testing.

Most geothermal exploitation to the present time has involved areas with surface manifestations. There are geothermal systems which have no surface manifestations and are therefore "blind". An example of this sort of system in central Montana, the Marysville mining district, (Blackwell et al., 1975; Blackwell and Morgan, 1976) is near the Continental Divide. The bedrock is contact metamorphosed Precambrian Belt Series rocks underlain by Cretaceous and Cenozoic intrusive rocks. An area of approximately 50 square miles has a heat flow well above the regional background and at least half that area is underlain by a geothermal system with temperatures of approximately 100°C. Other blind systems are also known and the possibility of the existence of such systems cannot be ruled out without site-specific geothermal exploration data.

There are many exploration techniques used in the exploration for, and evaluation of, geothermal systems. The most practical techniques, in order of cost and recommended application, are: geologic mapping; spring and well geochemical analysis for "reservoir" temperature determination (Ellis and Mahon, 1977); and temperature gradient/heat flow determination in existing wells and drill holes. Other geophysical techniques such as electrical resistivity, gravity, seismic studies, etc., are not specific to geothermal resources and may generate anomalies which have little or no relationship to geothermal systems. However, in specific geothermal areas, all of these techniques are often used in exploration. Ball et al. (1979) present a brief discussion of exploration and reservoir assessment techniques and costs.

Western Montana and southern Idaho are included in the Cordilleran Mountain Belt of western North America. Volcanic and tectonic processes have been active in these areas within the past few millions of years and there are extensive manifestations at the surface of geothermal resources. However, within this area there are quite significant geographic variations. The area within GEM Region 2 can be divided into six provinces of different geothermal significance as follows:

TABLE XI

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 Sawtooth GRA is in the Montana Thrust Belt/Foothills province which is bounded on the west by the Montana Basin and Range province and on the east by the Great Plains province.

Heat flow values in the Great Plains geothermal province are normal at approximately 40-60 milliwatts per square meter (Blackwell, 1969). Because the heat flow is normal, gradients are generally fairly low in typical rocks in this province (20-40°C/km, 1.1-2.2°F/100 ft.). However, there are many artesian aquifers in the sedimentary section. Some of these aquifers are quite deep, and thus have quite warm water due to the burial depth. The Madison Limestone, one of the deeper major aquifers, underlies much of eastern and central Montana. Average geothermal gradients from the surface to the Madison Limestone have been calculated by Balster (1975) and, given the depth of the Madison, these gradients can be used to estimate the temperature in the Madison. In most cases the depths are too great for exploitation except in cases where deep holes may already be drilled for hydrocarbon exploration which, if unproductive, can be turned into geothermal wells. Temperatures and gradients in this province are such that only the occurrence of low and intermediate temperature geothermal resources can be expected.

The Montana Foothills/Thrust Belt province probably has a similar geothermal setting to the Great Plains province. However, virtually nothing is known about the hydrologic or geothermal character of the Thrust Belt/Foothills region because of lack of drilling and the complicated geology. It is likely that recharge for some of the aquifers in the Great Plains might take place through rocks exposed at high elevations in the Thrust Belt/Foothills province; therefore, temperature gradients may be depressed in this region. On the other hand, there is a transition within the Thrust Belt/Foothills province to higher heat flows which are characteristic of the Montana Basin and Range province to the west. Thus, along the western edge of the Thrust Belt/Foothills province the background conductive heat flows might be higher than observed in the Great Plains province where maximum aquifer temperatures at a depth of about 3,000 feet or less are generally less 50°C.

The Sawtooth GRA is underlain by thrust-faulted Paleozoic carbonate rocks. The age of the thrust faulting is late Mesozoic and very early Cenozoic. There has been no nearby Cenozoic volcanic activity and the area is east of the Intermountain Seismic Belt (Smith, 1978) and the westernmost normal faults in the Montana Basin and Range province. The geothermal setting of the area is between the normal heat flow and geothermal gradient region of the Great Plains province to the east (indicated by data at the Kevin-Sunburst oil field) and the high heat flow regime characteristic of the Montana Basin and Range province to the south and west. Hydrologically most of the GRA is probably in a recharge region as most of the area is at quite high elevation. Water may be expected to percolate downwards through solution channels in the carbonate rocks. If circulation is deep enough then warm springs may occur in discharge areas. Such a spring, Sun River

Springs, is within the Sawtooth GRA (Fig. 7). The outlet of Sun River Springs is at an elevation of less than 5,000 feet in the Sun River valley. The estimated reservoir temperature of the spring is only 35°C, 5°C above the actual measured temperature (Table V). Although no detailed analysis is available, the TDS of the spring is only 890 g/ml not typical of a very warm or high temperature geothermal fluid (Sonderegger and Bergantino, 1981). Observed geothermal gradients based on bottom hole temperature measurements in petroleum exploration holes, 10 miles east of the WSAs, (Fig. 7) are only 18-30°C/km (1.0-1.6°F/100 ft., Balster, 1975).

3.5 Mineral and Energy Economics

The principal resources which could be produced at the present time from within any of the four WSAs in the Sawtooth GRA are limestone and natural gas.

Limestone and dolomite have a variety of uses including aggregate, cement, lime, building stone, fluxes, glass raw material, refractories fillers, abrasives, soil conditioners and many others (Chelini, 1965). The generally low unit value of most limestone and dolomite dictates that production and transportation cost be low (Carr and Rooney, 1975); thus, distance to market is a major factor affecting the economic viability of these deposits. The relatively undeveloped character of the Sawtooth GRA and the distance to major population centers probably prohibit development of common varieties of limestone and dolomite in the GRA. Use is a major factor in determining how far limestone and dolomite can be shipped. High calcium limestone (95% $CaCO_3$) and high purity dolomite (40% $MgCO_3$) have a variety of uses in the

chemical and metallurgical industries and are less common; thus, they have a higher unit value than common grades of limestone and dolomite (Brobst and Pratt, 1973). There is potential for both high calcium limestone and high purity dolomite in Cambrian, Devonian and Mississippian carbonate rocks in WSAs 075-102, 105, 106 and 107 (Mudge, 1972a; Chelini, 1965; Earhart, 1978; and Earhart et al., 1981). The general lack of chemical and metallurgical industries in northern Montana and abundant local sources near smelters in the southwestern part of the state suggest that very high quality limestone and dolomite would be needed to provide impetus for development.

The early wells in the Blackleaf Canyon gas field were shut in until December 1982, due to a lack of a market for the gas (Heany, 1961). With the recent deregulation of natural gas prices and current federal policy to encourage domestic energy production and reduce U.S. reliance on imported energy, development of the reserves at Blackleaf Canyon and at other locations in the Montana Disturbed Belt is now economically attractive. A pipeline, connecting the Blackleaf Canyon field to a gas plant located about 15 miles northeast, improves the economic viability of any natural gas reserves present in the Sawtooth GRA. This conclusion is strengthened by the continued exploration of the region by private industry. For example the consortium operated by Williams Petroleum, which is developing the Blackleaf Canyon field, has spent over $14,000,000 on exploration in the Disturbed Belt during the last four years (James Cannon pers. comm. 1982). Additional exploration in the region is being done by Shell Oil Company, Mobil Oil Company, Wexpro, Sun Oil Company and Hunt Oil Company.

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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 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 on the order of 10-20°C 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 than approximately 40-60°C is considered an economic cutoff for a geothermal resource. Another important economic factor affecting the viability of a geothermal resource is the distance from the source to the point of consumption. At lower temperatures it is not feasible to consider long-distance transportation of geothermal energy whereas for electrical grade resources long transportation distances are of course feasible. Of course many of the warm springs in the western United States have been used for recreational purposes regardless of location.

4.0 LAND CLASSIFICATION FOR GEM RESOURCES POTENTIAL

4.1 Explanation of Classification Scheme

In the following section the land in the four WSAs within the Sawtooth GRA is classified for geology, energy and mineral (GEM) resources potential. The classification scheme used is shown in Table XII. 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).

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 Sawtooth GRA.

TABLE XII

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.

TABLE XII

BUREAU OF LAND MANAGEMENT GEM RESOURCES LAND CLASSIFICATION SYSTEM

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 minéral 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 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.

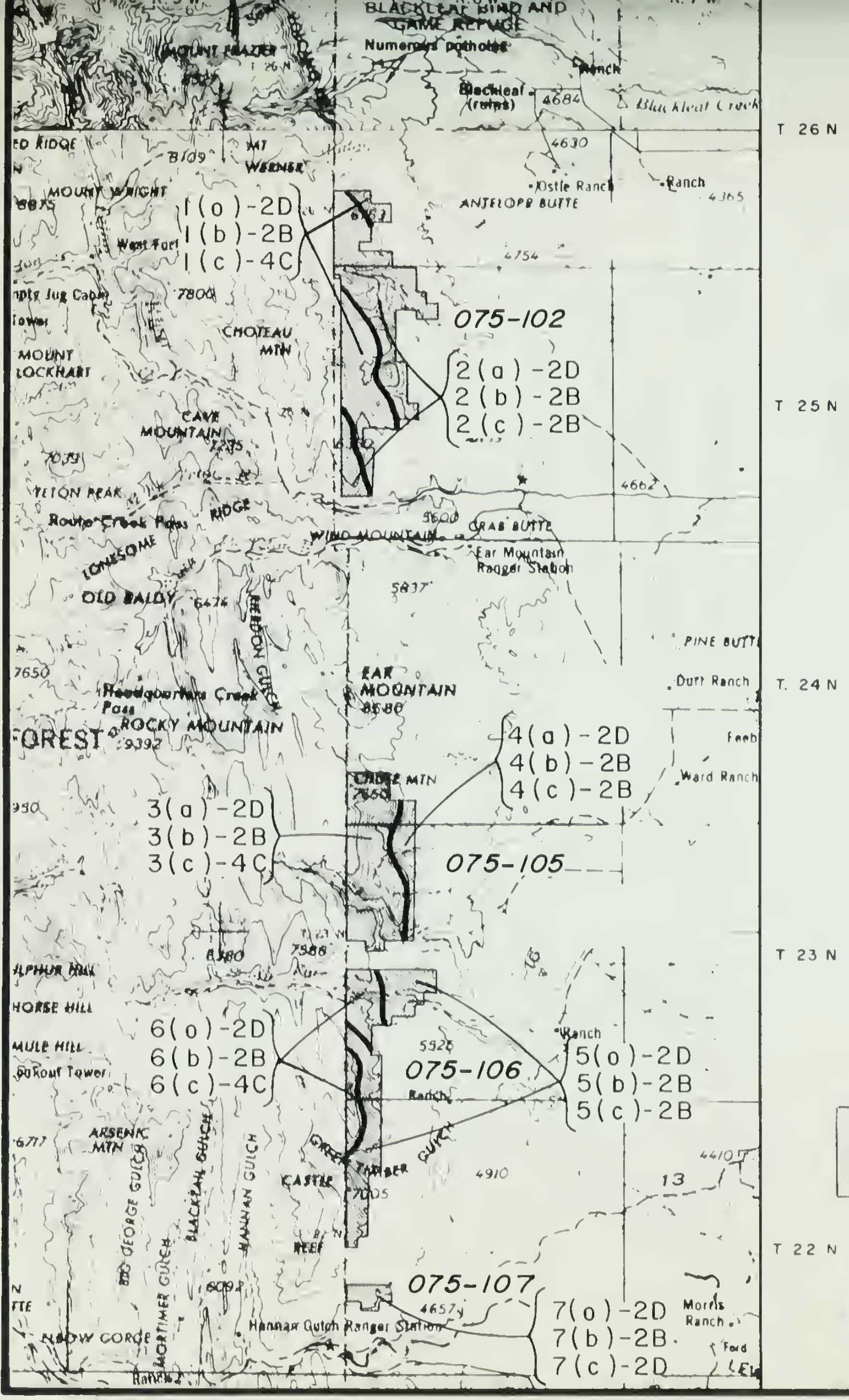
4.2 Classification of the Blind Horse Creek Wilderness Study Area (WSA 075-102)

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, pumicite, clay, magnesite, silica sand, etc. (Maley, 1983).

4.2.1a Metallic Minerals. The entire area of WSA 075-102 (Area 1a and 2a, Fig. 15) is classified as having low favorability for metallic mineral resources based on direct evidence (2D). This classification is based on the lack of known occurrences, lack of geochemical and geophysical anomalies, and absence of mineral deposits in similar environments in the region.

4.2.1b Uranium and Thorium. The entire area of WSA 075-102 (Areas 1b and 2b, Fig. 15) is classified as having low favorability for uranium and thorium based on indirect evidence (2B). This classification is based on a review of NURE data for the area, lack of known occurrences and geochemical anomalies, and the low favorability of the geologic environment as compared to known uranium-thorium producing environments. Cretaceous non-marine clastic sedimentary rocks which underlie the eastern part of the Sawtooth



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
Area I.D. Number
Commodity
Classification
Level of Confidence

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

Approximate Boundary of Wilderness Study Area.

5 4 3 2 1 0 3 6 Miles
5 4 3 2 1 0 5 10 Kilometers

WGM Inc. Mining and Geological Consultants
Anchorage, Alaska

BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Sawtooth GRA, Montana

Wilderness Study Area
Land Classification
Locatable Resources

SCALE 1" : 4 MILES (1:250,000)			FIGURE
DATA BY WGM	DATE 9/1982		15
DRWN BY DSI	APRVD GF		

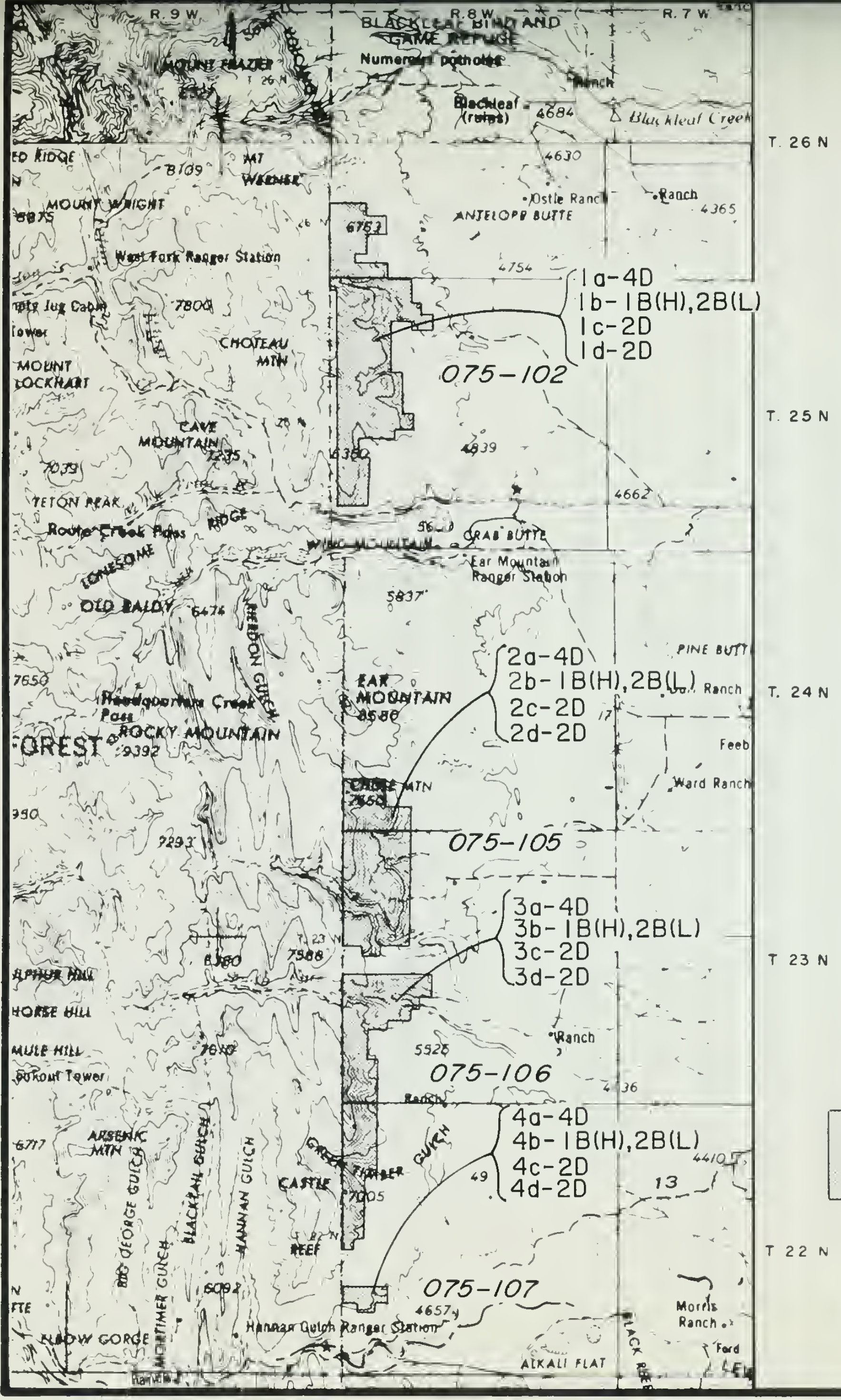
GRA constitute a favorable environment for sandstone-hosted uranium mineralization. These rocks occur in the subsurface of the WSA, but there is no evidence that uranium mineralization is present in them.

4.1.1c Non-Metallic Minerals. The area of WSA 075-102 which is underlain by carbonate rocks (Area 1c, Fig. 15) is classifed as having high favorability for uncommon varieties of limestone and dolomite, i.e. high calcium limestone and high magnesium dolomite based on limited direct evidence (4C). The WSA is largely underlain by carbonate rocks which are known to contain stratigraphic intervals of high calcium limestone and high magnesium dolomite elsewhere in the region, but the lack of site-specific sample data precludes a complete evaluation of this resource potential. The remainder of the WSA (Area 2c, Fig. 15) is classified as having low favorability for locatable non-metallic minerals based on direct evidence or 2D.

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 of 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, 1980).

4.2.2a Oil and Gas. The entire area of WSA 075-102 (1a, Fig. 16) is classified as highly favorable for the occurrence of oil and gas based on



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
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), No specific commodity designation indicates that the rating applies to all of the above.

Approximate Boundary of Wilderness Study Area.

5 4 3 2 1 0 3 6 Miles

5 4 3 2 1 0 5 10 Kilometers

WGM Inc. Mining and Geological Consultants
Anchorage, Alaska

BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Sawtooth GRA, Montana

Wilderness Study Area
Land Classification
Leasable Resources

SCALE 1" = 4 MILES (1 250,000)			FIGURE
DATA BY WGM	DATE 9/1982	REVISED	16
DRWN BY DSI	APRVD G.F		

direct evidence (4D). Known oil seeps are present in the Sawtooth GRA and proven reserves of natural gas are present in the Blackleaf Canyon gas field immediately adjacent to the WSA. The same reservoir rocks as well as the same stratigraphic and structural conditions present in nearby areas with proven reserves extend into the WSA. Moreover, published geochemical analyses indicate that hydrocarbon source beds are present in the area. Geothermal studies indicate that not only has hydrocarbon generation occurred but temperatures were not so severe that hydrocarbons were driven out.

4.2.2b Geothermal. All of the area of WSA 075-102 (1b, Fig. 16) is classified as unfavorable for the occurrence of high temperature geothermal resources based on indirect evidence (1B) and as having low favorability for low to intermediate temperature geothermal resources based on indirect evidence (2B). The basis of this evaluation is the data and conclusions presented in the geothermal discussion in section 3.4. The most negative evidence is the discouraging bore hole temperature data from the area east of the WSA. Data from future deep drill holes in the area for hydrocarbons might cause a modification of the 2B ranking with respect to the possibility of low to intermediate temperature geothermal resources.

4.2.2c Sodium and Potassium. The entire area of WSA 075-102 (1c, Fig. 16) is classified as having low favorability for carbonates, borates, silicates, sulfates and nitrates of sodium and potassium based on direct evidence (2D). This classification is based on the general unfavorability of the geologic

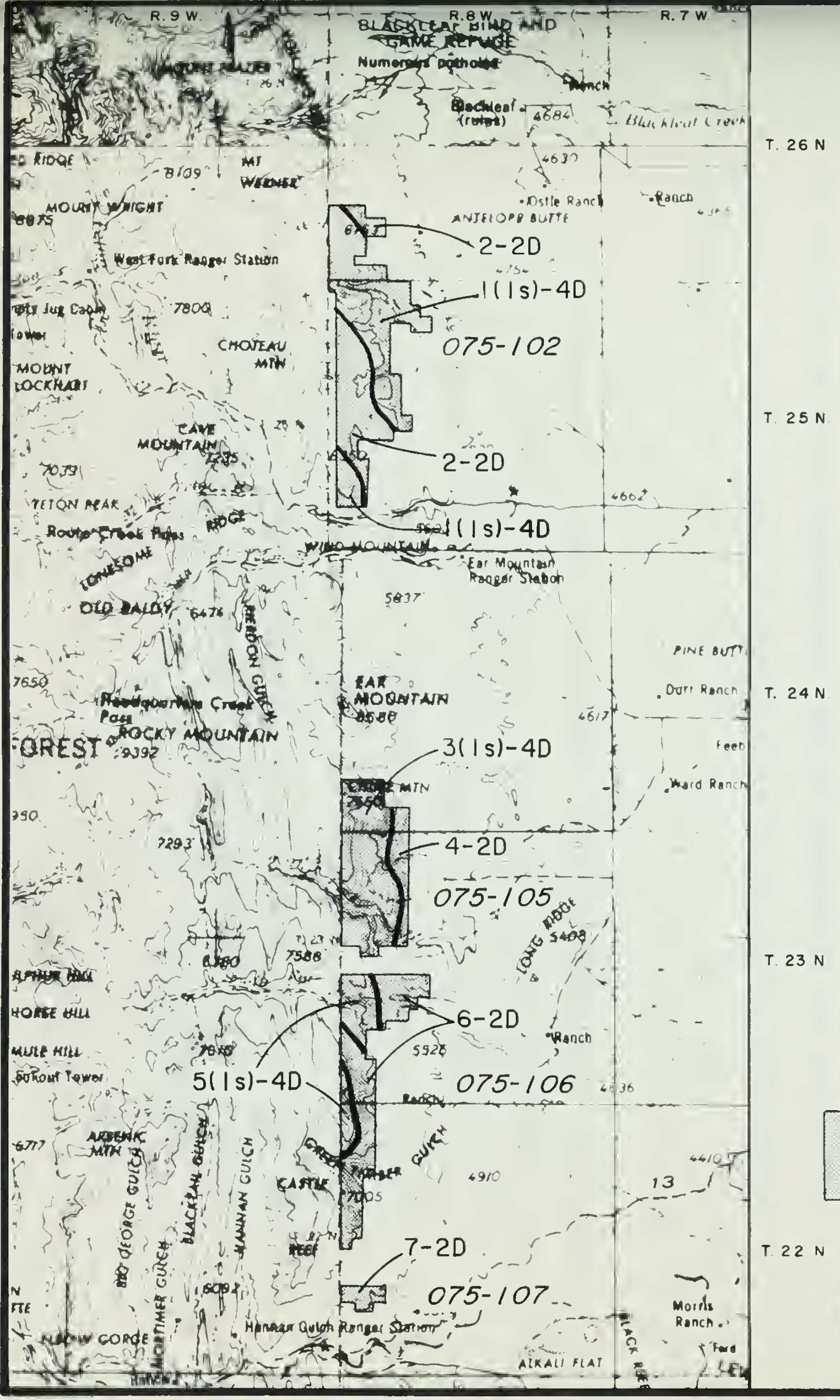
environment, the age of the rock units, and the lack of occurrences in the region.

4.2.2d Other. The entire area of WSA 075-102 (1d, Fig. 16) is classified as having low potential for the occurrence of asphalt, bitumen, coal, oil shale, and phosphate based on direct evidence (2D). This classification is based on the absence of the Phosporia Formation (phosphate) and lack of reported occurrences of oil shale. Thin beds of coal could be present in Mesozoic rocks in the subsurface but no occurrences are known. Although oil seeps occur in the region, no occurrences of asphalt or bitumen are reported.

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 portions of WSA 075-102 which are underlain by carbonate rocks (1, Fig. 17) are classified as having high favorability for common varieties of limestone and dolomite based on direct evidence (4D). The remaining area of the WSA (2, Fig. 17) is classified as having low favorability for saleable resources based on direct evidence (2D).



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(1s)- 4D

Area I.D. Number
Commodity
Classification
Level of Confidence

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

▨ Approximate Boundary of Wilderness Study Area.

5 4 3 2 1 0 3 6 Miles

5 4 3 2 1 0 5 10 Kilometers

WGM Inc. Mining and Geological Consultants
Anchorage, Alaska

BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Sawtooth GRA, Montana

Wilderness Study Area
Land Classification
Saleable Resources

SCALE: 1" = 4 MILES (1:250,000)			FIGURE
DATA BY WGM	DATE 9/1982	REVISED	17
DRWN BY DSI	APRVD G.F.		

4.3 Classification ot the Chute Mountain Wilderness Study Area (WSA 075-105)

4.3.1 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, nonmetallic minerals such as asbestos, barite, zeolites, grpahite, uncommon varieties of sand, gravel, building stone, limestone, dolomite, pumice, pumicite, clay, magnesite, silica sand, etc. (Maley, 1983).

4.3.1a Metallic Minerals. All of WSA 075-105 (Areas 3a-4a, Fig. 15) is classified as having low favorability for metallic mineral resource potential based on direct evidence (2D). This classification is based on the the lack of known occurrences, lack of geochemical and geophysical anomalies, and the absence of mineral deposits in similar environments in the region.

4.3.1b Uranium and Thorium. The entire area of WSA 075-105 (Areas 3a-4a, Fig. 15) is classified as having low potential for uranium and thorium based on indirect evidence (2B). This conclusion is based on a review of NURE data for the area, the lack of known occurrences and geochemical anomalies, and the unfavorability of the geologic environment as compared to known uranium-thorium producing environments. There may be some uranium potential in the Cretaceous non-marine clastic sedimentary rocks which occur in the

subsurface of the WSA, but no mineralization is known to occur in these rocks.

4.3.1c Non-Metallic Minerals. The area of WSA 075-105 which is underlain by carbonate rocks (Area 3c, Fig. 15) is classified as having high favorability for uncommon varieties of limestone and dolomite, i.e. high calcium limestone and high magnesium dolomite based on limited direct evidence (4C). The WSA is largely underlain by carbonate rocks which are known to contain stratigraphic intervals of high calcium limestone and high magnesium dolomite elsewhere in the region. The lack of site-specific sample data precludes a complete evaluation of this resource potential. The remainder of the WSA is classified as having low favorability for locatable non-metallic resources based on direct evidence (2D).

4.3.2 Leasable Resources

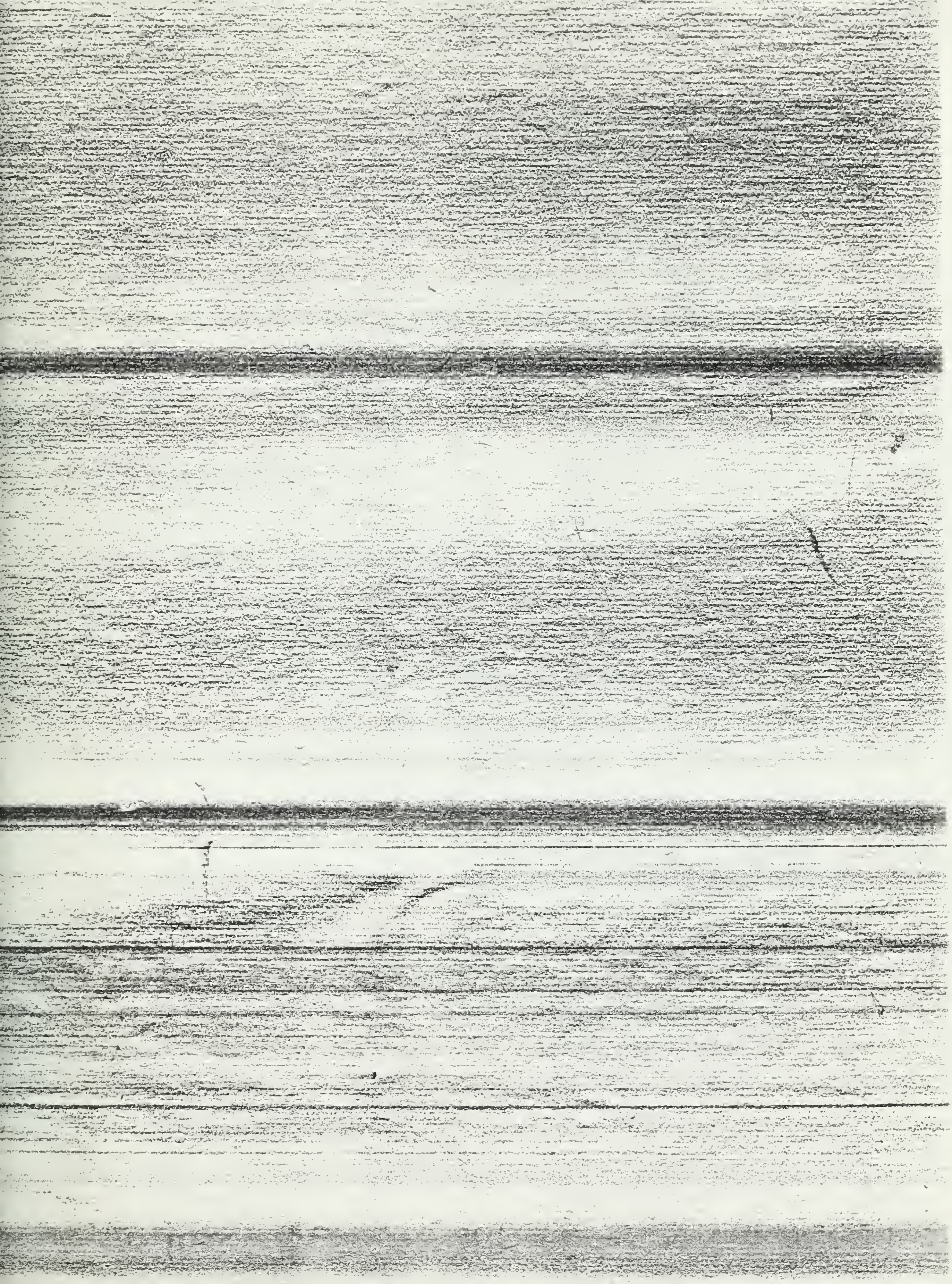
Leasable resources include those which may be acquired under the Mineral Leasing Act of 1920 as amended by the Acts of 1927, 1953, 1970, and 1976. Materials covered under this Act include: asphalt, bitumen, borates of sodium and potassium, carbonates of sodium and potassium, coal, natural gas, nitrates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

4.3.2a Oil and Gas. The entire area of WSA 075-105 (2a, Fig. 16) is classified as having high favorability for the occurrence of oil and gas based on direct evidence (4D). Known oil seeps are present in the Sawtooth

GRA and proven reserves of natural gas are present in the Blackleaf Canyon gas field 15 miles north of the WSA. The same reservoir rocks as well as the same stratigraphic and structural conditions present in the nearby areas with proven reserves are likely to be found in the WSA also. Moreover, published geochemical analyses indicate that hydrocarbon source beds are present in the area. Geothermal studies indicate that hydrocarbon generation has occured and that temperatures were not so severe that hydrocarbons have been driven out.

4.3.2b Geothermal. All of the area of WSA 075-105 (2b, Fig. 16) is classified as unfavorable for the occurrence of high temperature geothermal resources based on indirect evidence (1B) and as having low favorability for low and intermediate temperature geothermal resources based on indirect evidence (2B). The basis of this conclusion is presented in the discussion of the geothermal setting in section 3.4. The most negative evidence is the discouraging bore hole temperature data from the area east of the WSA. Data from future deep drill holes in the area for hydrocarbons might cause a modification of the 2B ranking with respect to the possibility of low to intermediate temperature geothermal resources.

4.3.2c Sodium and Potassium. All of WSA 075-105 (2c, Fig. 16) is classified as having low favorability for carbonates, borates, silicates, sulfates and nitrates of sodium and potassium based on direct evidence (2D) including the general unfavorability of the geologic environment, the age of the rock units, and the lack of occurrences in the region.



4.3.2d Other. The entire area of WSA 075-105 (2d, Fig. 16) is classified as having low potential for the occurrence of asphalt, bitumen, coal, oil shale, and phosphate based on direct evidence (2D). This classification is based on the absence of the Phosphoria Formation (phosphate) and lack of reported occurrences of oil shale. Thin beds of coal could be present in Mesozoic rocks in the subsurface, but no occurrences are known. Although oil seeps occur in the region, no occurrences of asphalt or bitumen are reported.

4.3.3 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).

Areas of WSA 075-105 underlain by carbonate rocks (3, Fig. 17) is classified as having high favorability for common varieties of limestone and dolomite based on direct evidence (4D). The remaining portion of the WSA (4, Fig. 17) is classified as having low favorability for saleable resources based on direct evidence (2D).

4.4 Classification of the Deep Creek/Battle Creek Wilderness Study Area (WSA 075-106)

4.4.1 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, pumicite, clay, magnesite, silica sand, etc. (Maley, 1983).

4.4.1a Metallic Minerals. The entire area of WSA 075-106 (Areas 5a and 6a, Fig. 15) is classified as having low favorability for metallic mineral resource potential based on direct evidence (2D). This classification is based on the lack of known occurrences, lack of geochemical and geophysical anomalies, and absence of mineral deposits in similar environments elsewhere in the region as outlined in previous sections of this report.

4.4.1b Uranium and Thorium. All of WSA 075-106 (Areas 5b-6b, Fig.15) is classified as having low potential for uranium and thorium based on indirect evidence (2B). This conclusion is based on a review of NURE data for the area, the lack of known occurrences and geochemical anomalies, and the unfavorable geologic environment as compared to known uranium-thorium producing provinces. The Cretaceous non-marine clastic sedimentary rocks which underlie the WSA could constitute a favorable environment for sandstone-hosted uranium mineralization but no uranium occurrences are known.

4.4.1c Non-Metallic Minerals. The entire area of WSA 075-106 which is underlain by carbonate rocks (Area 6c, Fig. 15) is classified as having high favorability for uncommon varieties of limestone and dolomite (i.e. high calcium limestone and high magnesium dolomite) based on limited direct evidence (4C). The WSA is largely underlain by carbonate rocks which are known to contain stratigraphic intervals of high calcium limestone and high magnesium dolomite elsewhere in the region, but lack of site-specific sample data preclude a complete evaluation of this resource potential. The remainder of the WSA (Area 5c, Fig. 15) is classified as having low favorability for locatable non-metallic minerals based on direct evidence (2D).

4.4.2 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 of 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).

4.4.2a Oil and Gas. All of WSA 075-106 (3a, Fig. 16) is classified as highly favorable for the occurrence of oil and gas based on direct evidence (4D). Known oil seeps are present in the Sawtooth GRA and proven reserves of natural gas are present in the Blackleaf Canyon gas field 20 miles north of the WSA. The same reservoir rocks as well as the same stratigraphic and

structural conditions present in nearby areas with proven reserves are likely to be found in the WSA also. Furthermore, published geochemical analyses indicate that hydrocarbon source beds are present in the area. Geothermal studies indicate that hydrocarbon generation has occurred and that temperatures were not so severe that hydrocarbons have been driven out.

4.4.2b Geothermal. All of WSA 075-106 (3b, Fig. 16) is classified as unfavorable for the occurrence of high temperature geothermal resources based on indirect evidence (1B) and as having low favorability for low and intermediate temperature geothermal resources based on indirect evidence (2B). The basis of this evaluation is presented in the discussion of the geothermal setting in section 3.4. The most negative evidence is the discouraging bore hole temperature data from the area east of the WSA. Data from future deep drill holes in the area for hydrocarbons might cause a modification of the 2B ranking with respect to the possibility of low to intermediate temperature geothermal resources.

4.4.2c Sodium and Potassium. All of WSA 075-106 (3c, Fig. 16) is classified as having low favorability for carbonates, borates, silicates, sulfates and nitrates of sodium and potassium based on direct evidence (2D) including the general unfavorability of the geologic environment, the age of the rock units, and the lack of occurrences in the region.

4.4.2d Other. The entire area of WSA 075-106 (3d, Fig. 16) is classified as having low potential for the occurrence of asphalt, bitumen, coal, oil shale, and phosphate based on direct evidence (2D). This classification is based on the absence of the Phosphoria Formation (phosphate) and a lack of

reported oil shale occurrences. Thin beds of coal may occur in Mesozoic rocks in the subsurface, but none are known to exist. Oil seeps occur in the region but no occurrences of asphalt or bitumen are reported.

4.4.3 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).

Areas of WSA 075-106 underlain by carbonate rocks (5, Fig. 17) are classified as having high favorability for common varieties of limestone and dolomite based on direct evidence (4D). The remainder of the WSA (6, Fig. 17) is classified as having low favorability for saleable resources based on direct evidence (2D).

4.5 Classification of the North Fork Sun River Wilderness Study Area (WSA 075-107)

4.5.1 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, pumicite, clay, magnesite, silica sand, etc. (Maley, 1983).

4.5.1a Metallic Minerals. The entire area of WSA 075-107 (Area 7a, Fig. 15) is classified as having low favorability for metallic mineral resources based on direct evidence (2D). This classification is based on the the lack of known occurrences, lack of geochemical and geophysical anomalies, and absence of mineral deposits in similar environments elsewhere in the region.

4.5.1b Uranium and Thorium. All of WSA 075-107 (Area 7b, Fig. 15) is classified as having low favorability for uranium and thorium based on indirect evidence (2B). This classification is based on a review of NURE data for the area, the lack of known occurrences and geochemical anomalies, and the low favorability of the geologic environment as compared to known uranium-thorium producing provinces. The Cretaceous non-marine clastic sedimentary rocks which occur in the subsurface of the WSA have potential for uranium mineralization, but no uranium occurrences are reported.

4.5.1c Non-Metallic Minerals. All of WSA 075-107 (7c, Fig. 15) is classified as having low favorability for locatable non-metallic minerals based on direct evidence (2D).

4.5.2 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 of

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).

4.5.2a Oil and Gas. All of WSA 075-107 (4a, Fig. 16) is classified as having high favorability for the occurrence of oil and gas based on direct evidence (4D). This classification is based on the favorable geologic environment, the presence of known oil seeps in the Sawtooth GRA and the presence of proven reserves of natural gas in the Blackleaf Canyon gas field 25 miles north of the WSA. The same reservoir rocks as well as the same stratigraphic and structural conditions present in nearby areas with proven reserves are likely to be found in the WSA also. Published geochemical analyses indicate that hydrocarbon source beds are present in the area. Moreoever, geothermal studies indicate that hydrocarbon generation has occurred and that temperatures were not so severe that hydrocarbons have been driven out.

4.5.2b Geothermal. All of WSA 075-107 (4b, Fig. 16) classified as unfavorable for the occurrence of high temperature geothermal resources based on indirect evidence (1B) and as having low favorability for low and intermediate temperature geothermal resources based on indirect evidence (2B). The basis of this evaluation is presented in the discussion of the geothermal setting in section 3.4. The most negative evidence is the discouraging bore hole temperature data from the area east of the WSA. Data from future deep drill holes in the area for hydrocarbons might cause a

modification of the 2B ranking with respect to the possibility of low temperature geothermal resources.

4.5.2c Sodium and Potassium. The entire area of WSA 075-107 (4c, Fig. 16) is classified as having low favorability for carbonates, borates, silicates, sulfates and nitrates of sodium and potassium based on direct evidence (2D). This classification is based on the general unfavorability of the geologic environment, the age of the rock units, and the lack of occurrences in the region.

4.5.2d Other. All of WSA 075-107 (4d, Fig. 16) is classified as having low favorability for the occurrence of asphalt, bitumen, coal, oil shale, and phosphate based on direct evidence (2D). This classification is based on the absence of the Phosphoria Formation (phosphate) and a lack of reported occurrences of oil shale. Thin beds of coal may occur in Mesozoic rocks in the subsurface, but none are reported. Although oil seeps occur in the region, no occurrences of asphalt or bitumen are known.

4.5.3 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 075-107 (7, Fig. 17) is classified as having low favorability for saleable resources based on direct evidence (2D).

5.0 RECOMMENDATIONS FOR FURTHER WORK

A large number of geochemical samples have been collected in the Sawtooth GRA as part of investigations by the U.S. Geological Survey and by the Department of Energy. While the number of samples and the sample density are sufficient for a regional evaluation there are few samples in the Wilderness Study Areas. In order to provide a complete site-specific data base stream sediment samples should be collected from all of the streams and gullies draining the WSAs. A sample density of one or two per square mile is recommended. The samples should be analyzed for 30 elements by spectrograph and for base and precious metals by atomic absorbtion. The NURE data for the GRA should be examined more closely. Specifically, exact sample locations and values for uranium and vandadium need to be plotted on detailed maps. The existing NURE reports provide only a general analysis of the data.

The potential for high calcium limestone and high purity dolomite in the three northernmost WSAs should be evaluated. Mr. Melvin Mudge of the U.S. Geological Survey should be contacted to obtain copies of his detailed field maps of these WSAs. Once the locations of the favorable units are plotted, each facies of favorable units should be mapped and sampled in detail. Samples should be tested by a lab familiar with ASTM requirements for industrial minerals.

Given the high potential for oil and gas in the WSAs detailed seismic data should be obtained. If detailed seismic data is not available for the four WSAs then it should be run, so that a proper interpretation of the sub-

surface structures could be developed for each WSA. This can be done by industry should exploration of the WSAs be allowed. Good seismic data would also allow the determination of the extent and potential reserves of the Blackleaf Canyon field. Although a preliminary calculation of the reserves of the upper (second thrust plate) horizon in the Blackleaf field could be made at this time the extent and reserves of the lower (third thrust plate) horizon cannot be determined from available data. It is highly probable that one or both of the producing horizons in the Blackleaf field are also present in WSA 075-102.

The general unfavorability of the geothermal setting of the WSAs is such that much expenditure for evaluation is not justified. Collection of water samples from springs within the area would be useful. Shallow heat flow holes in this hydrological setting would probably not be very definitive. If future deep hydrocarbon tests are drilled in the area then temperature data should be collected from these holes. Deep drilling for hydrocarbons might reveal warm artesian aquifers in areas that would not be drilled on the basis of their geothermal potential.

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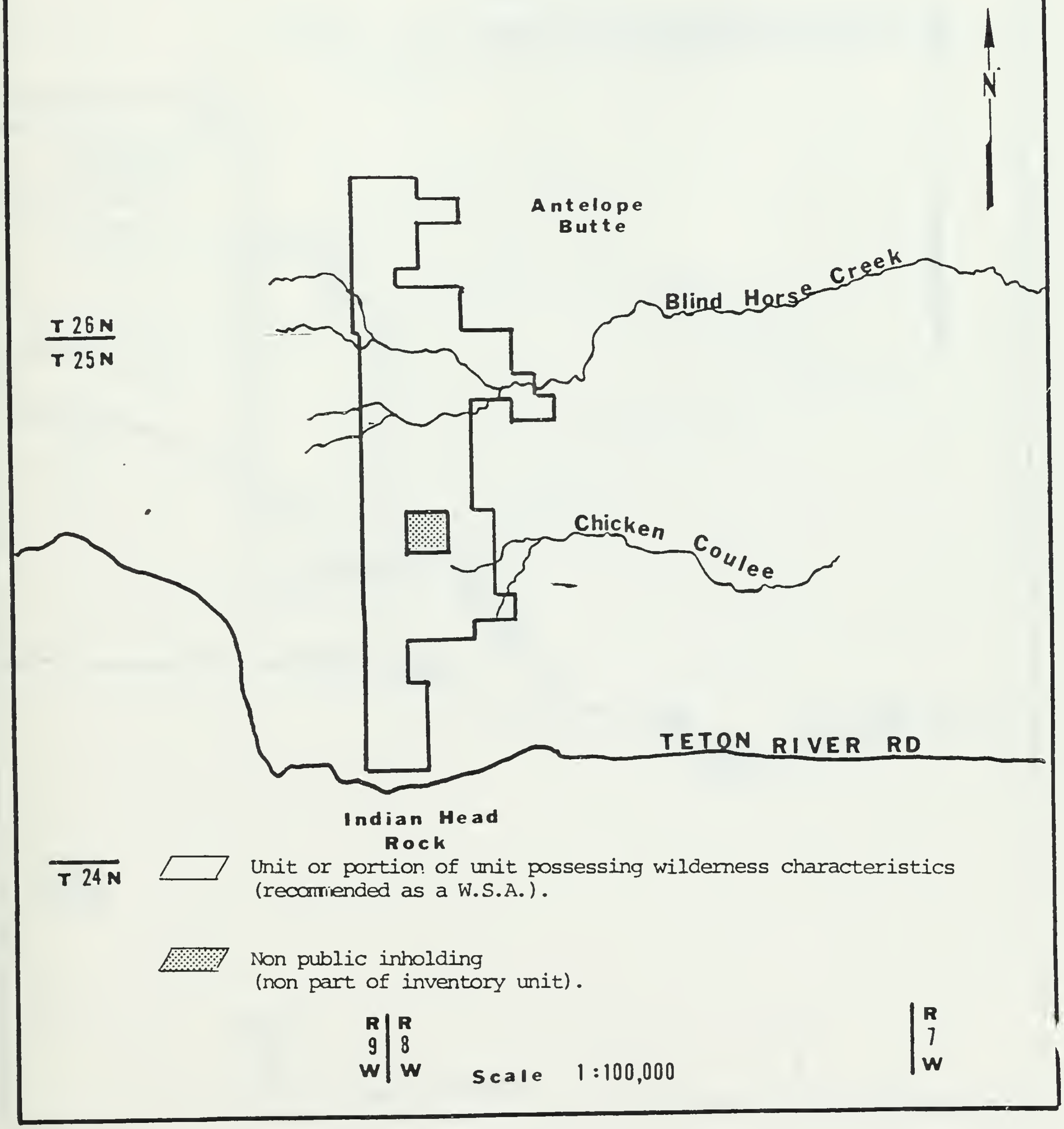
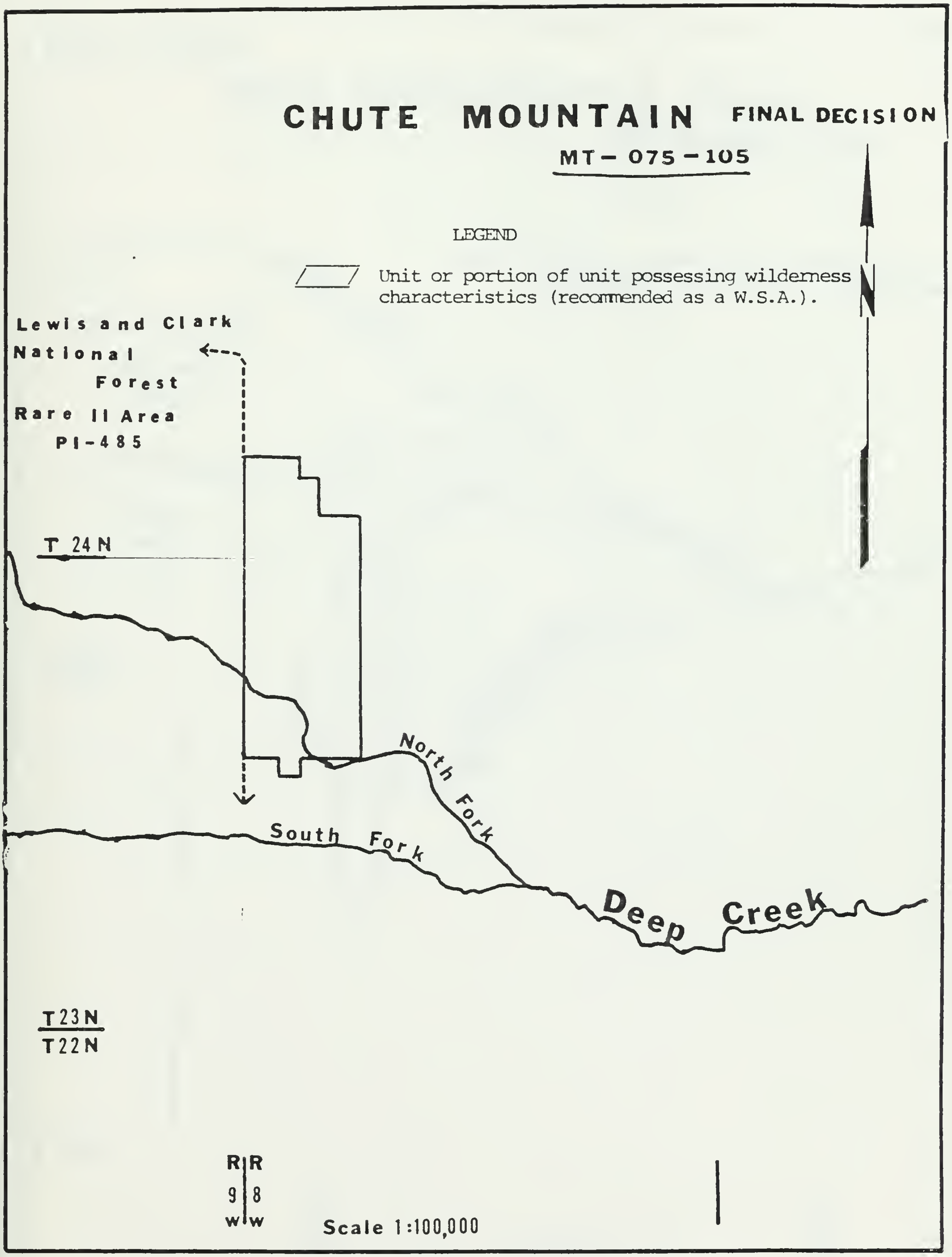
APPENDIX I

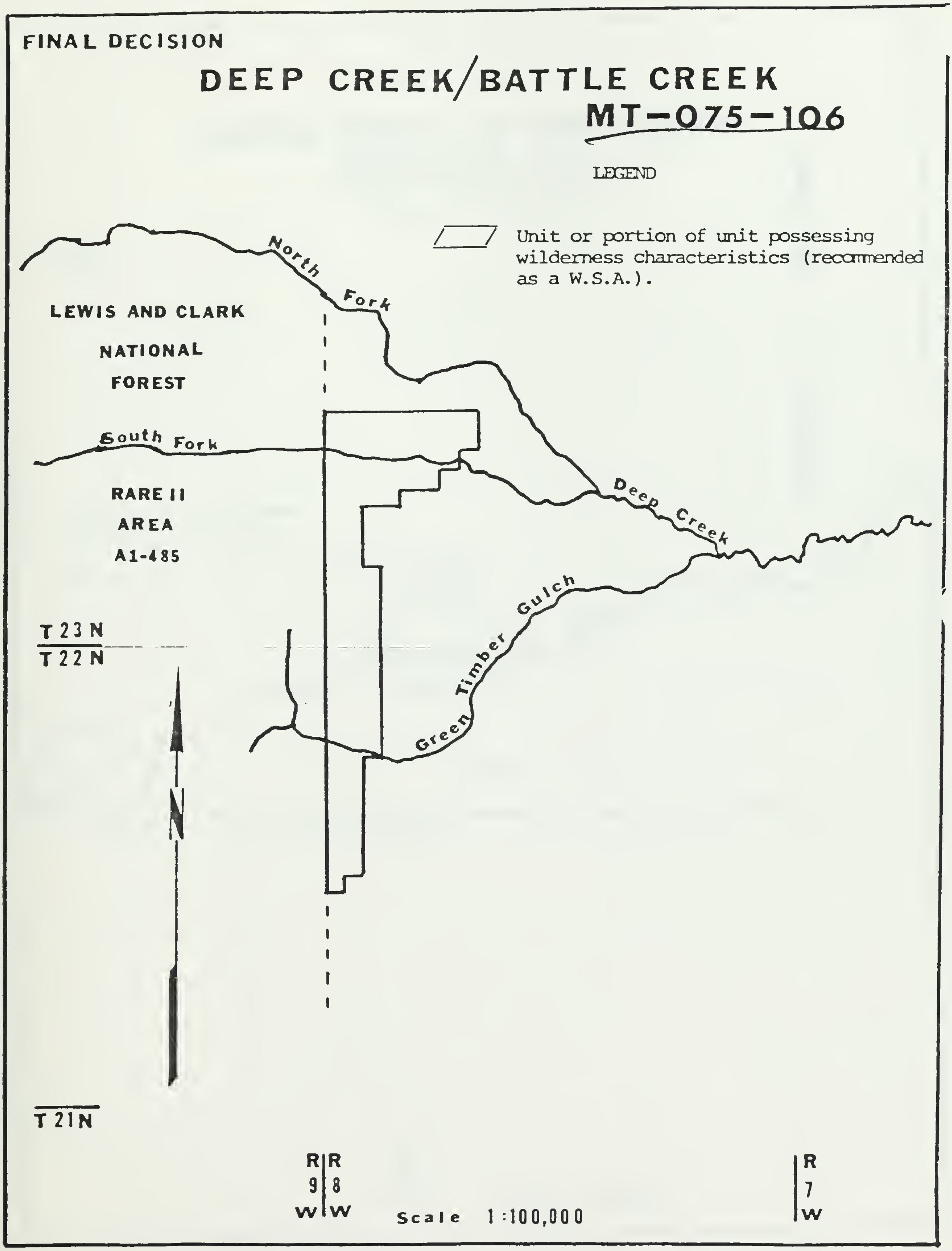
WILDERNESS STUDY AREA MAPS

BLIND HORSE CREEK FINAL DECISION

MT-075-102




CHUTE MOUNTAIN FINAL DECISION
MT-075-105
LEGEND
Unit or portion of unit possessing wilderness characteristics (recommended as a W.S.A.).
N
Lewis and Clark National Forest Rare II Area PI-485
T 24 N
North Fork
South Fork
Deep Creek
T23N
T22N
R 9 W
R 8 W
Scale 1:100,000



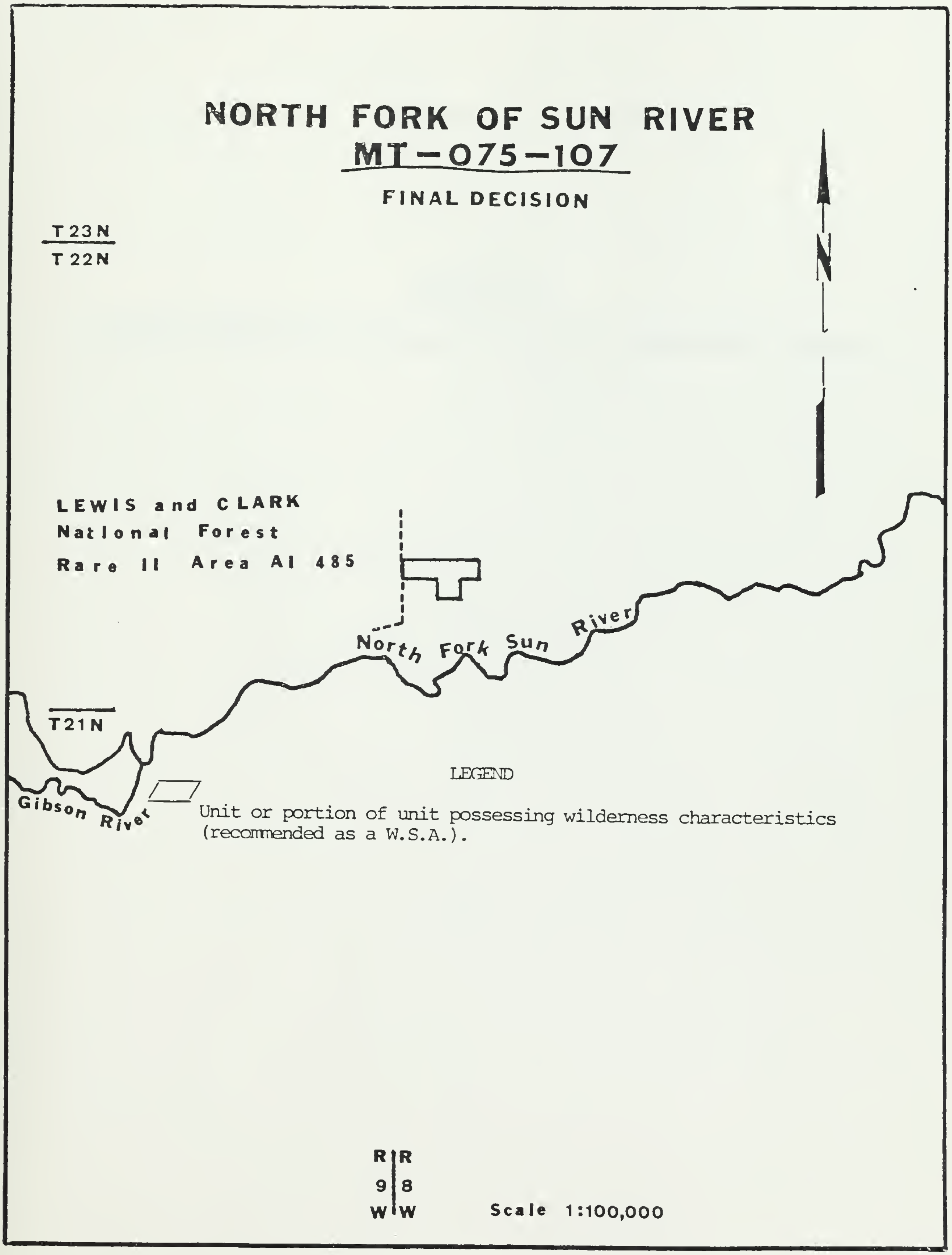
FINAL DECISION

DEEP CREEK/BATTLE CREEK

MT-075-106

LEGEND

▱ Unit or portion of unit possessing wilderness characteristics (recommended as a W.S.A.).



NORTH FORK OF SUN RIVER
MT-075-107
FINAL DECISION

APPENDIX II

SUMMARY SHEETS FOR OIL AND GAS WELLS IN THE SAWTOOTH GRA, MONTANA

GEM PROJECT - OIL AND GAS WELL SUMMARY SHEET

GRA Sawtooth, Montana

Well: No. 2-5 Blackleaf Unit

Company: Williams Exploration

Location: Sec. 5 T. 26N. R. 8W.

Date Drilled: 1981

Elevation: 4,963 feet

Status: Data Confidential

Total Depth: 5,700 feet

Production:

Notes:

No file at M.O.G.C.C.

Log:

Source of Data:

M.O.G.C.C./Billings

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

GEM PROJECT - OIL AND GAS WELL SUMMARY SHEET

GRA Sawtooth, Montana

Well: Sun River Federal 1-10

Company: Williams Exploration

Location: Sec. 10 T. 22N. R. 8W.

Date Drilled: 10/81

Elevation: 4,867 feet

Status: Plugged and abandoned

Total Depth: 8,000 feet

Production: None

Notes:

Log:

Surface	- 2,423	Colorado Shale
2,423	- 2,470	Kone
2,470	- 2,562	Blackleaf Shale
2,922	- 3,588	Fault-Two Medicine
3,588	- 3,756	Virgelle
3,756	- 3,972	Telegraph Creek
3,972	- 4,254	Telegraph Creek
4,254	- 4,405	Fault-Two Medicine
4,405	- 5,750	Two Medicine Volcanics
5,750	- 6,082	Virgelle
6,082	- 6,250	Telegraph Creek
6,250	- 6,592	Colorado Shale
6,592	- 6,766	Fault-Two Medicine
6,766	- 8,000	Two Medicine

Source of Data:

M.O.G.C.C./Billings

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

GEM PROJECT - OIL AND GAS WELL SUMMARY SHEET

GRA Sawtooth, Montana

Well: Blackleaf Unit 1-16

Company: Williams Exploration and Rainbow Resources

Location: Sec. 16 T. 26N. R. 8W.

Date Drilled: 7/2/81-8/3/81

Elevation: 4,957 feet

Status: Temporarily shut in

Total Depth: 5,700 feet

Production: None

Notes:

- Letter from Milestone Petroleum to BLM 8-31-81 shows well as WOCR.
- Recovered 63 feet of high gravity crude oil in D.S.T. from 5,392 to 5,450 feet. The upper Sun River plate contained dead oil stained vugs and fractures. There was less oil stain in the lower Sun River.

Source of Data:

M.O.G.C.C./Billings
Milestone Petroleum

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

Log:

Formation Tops (ft.):

Cone	3,660
Floweree	3,690
Blackleaf	3,770
Flood	4,345
Kootenai	4,435
Swift	5,143
Rierdon	5,254
Sawtooth	5,347
Sun River	5,387
MSR 7JR	5,430
Sawtooth	5,506
Sun River	5,550

GEM PROJECT - OIL AND GAS WELL SUMMARY SHEET

GRA Sawtooth, Montana

Well:	No. 1-5 Blackleaf Canyon Unit	**Company:**	Williams Exploration
Location:	**Sec.** 5 **T.** 26N. **R.** 8W.	**Date Drilled:**	1/27/82-4/30/81
Elevation:	4,973 feet	**Status:**	Shut in
Total Depth:	5,992 feet		
Production:	IPF 9,000 Mcfgpd, FTP 678, 48/64" CK		

Notes:

- Productive zone 5,142-5,228 feet Sun River.
- Letter from Milestone Petroleum to BLM 8-31-83 shows 9,000 Mcfpd.
- Second productive zone in Mission Canyon 5,538-5,550 (drill summary in M.O.G.C.C. files).

Source of Data:

M.O.G.C.C./Billings
Petroleum Information Company

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

Log:

Formation Tops (ft.):

Two Medicine	1,549
Virgielle	1,826
Colorado	2,178
Forelle	3,374
Blackleaf	3,430
Flood	4,007
Kootenai	4,092
Swift	4,702
Rierdon	4,824
Sawtooth	4,966
Sun River	5,019
Mission Canyon	5,457

GEM PROJECT - OIL AND GAS WELL SUMMARY SHEET

GRA Sawtooth, Montana

Well: 1-8 Blackleaf Federal

Company: Williams Exploration and Rainbow Resources

Location: Sec. 8 T. 26N. R. 8W.

Date Drilled: 8/14/80-12/8/80

Elevation: 5,005 feet

Status: Shut in

Total Depth: 6,259 feet

Production: IPF 7,100 Mcfgpd Sun River

Notes:

- P.B. 5800
- Production given in letter to BLM from Milestone Petroleum 8-31-81 as 7,100 Mcfgpd Sun River.
- Productive zone Sun River, 5,256-5,412 (gross).

Source of Data:

M.L.G.C.C./Billings
Milestone Petroleum
Petroleum Information Company

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

Log:

Formation Tops (ft.):

Colorado	Surf.
Thrust Fault	1,468
Two Medicine	1,468
Virgelle	1,787
Cone	3,360
Blackleaf	3,510
Flood	4,054
Kootenai	4,142
Morrison	4,555
Swift	4,752
Rierdon	4,875
Sawtooth	4,950
Sun River	4,993

GEM PROJECT - OIL AND GAS WELL SUMMARY SHEET

GRA Sawtooth, Montana

Well: No. 1 Teton-Knowlton

Company: Gulf

Location: Sec. 8 T. 26N. R. 8W.

Date Drilled: 5/10/56-7/26/56

Elevation: 5,026 feet

Status: Plugged and abandoned

Total Depth: 7,853 feet

Production: None reported

Notes:

- Some gas showing in DST at 5,500-5,560 feet in Sun River.

Source of Data:

M.O.G.C.C./Billings
Petroleum Information Company

Log:

Formation Tops (ft.):

Virgelle	2,020
Colorado	2,486
Blackleaf	3,640
Kootenai	4,583
Morrison	4,983
Swift	5,245
Rierdon	5,368
Sawtooth	5,468
Sun River	5,527
Devonian	6,740

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

GEM PROJECT - OIL AND GAS WELL SUMMARY SHEET

GRA Sawtooth, Montana

Well: No. 11-18 Blackleaf A.

Company: Burlington Northern

Location: Sec. 18 T. 26N. R. 8W.

Date Drilled: 7/24/76-9/30/76

Elevation: 5,258 feet

Status: Dry and abandoned

Total Depth: 6,000 feet

Production: None reported

Notes:

Log:

Formation Tops (ft.):

Morrison	493
Swift	808
Rierdon	910
Sawtooth	1,035
Sun River	1,152
Mission Canyon	1,434
Lodgepole	1,910
Kootenai	2,121
Morrison	3,185
Rierdon	3,597
Blackleaf	5,380
Kootenai	5,740

Source of Data:

M.O.G.C.C./Billings
Petroleum Information Company

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

GEM PROJECT - OIL AND GAS WELL SUMMARY SHEET

GRA Sawtooth, Montana

Well: No. 1-19 Blackleaf Unit

Company: Williams Exploration

Location: Sec. 19 T. 26N. R. 8W.

Date Drilled: 4/14/81-10/3/81

Elevation: 5,869 feet

Status: Shut in(?)

Total Depth: 6,217 feet

Production: IPF 4,074 Mcfgpd, 75 Bwpd, 64/64" CK

Notes:

No file available.

Productive zone Sun River 4,374-4,454 feet.

Log:

Formation Tops (ft.):

Kootenai	798
Swift	1,477
Rierdon	1,595
Sawtooth	1,700
Mission Canyon	2,086
Lodgepole	2,650
Blackleaf	2,834
Morrison	3,500
Sun River	4,360

Source of Data:

M.O.G.C.C./Billings
Petroleum Information Company

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

GEM PROJECT - OIL AND GAS WELL SUMMARY SHEET

GRA Sawtooth, Montana

Well: 1 Blackleaf Federal B

Company: Northern Natural Gas

Location: Sec. 19 T. 26N. R. 8W.

Date Drilled: 7/28/58-11/24/58

Elevation: 5,178 feet

Status: Shut in

Total Depth: 5,844 feet

Production: IPF 969 Mcfgpd, 104 BWD Madison

Notes:

- Productive Zone Madison 5,280-5,300.
- Hurley (1959, BGS) well produced a maximum of 2 mmcfg/d from lower Madison sheet in fall of 1958 before being shut down by weather.

Log:

Formation Tops (ft.):

Colorado Shale	60
Kootenai	100
Morrison	586
Swift	802
Rierdon	934
Sawtooth	1,047
First Madison	1,132
Fault	2,141
Blackleaf	2,156
Kootenai	2,685(?)
Morrison	3,134
Swift	3,400
Rierdon	3,544
Sawtooth	3,670
Second Madison	3,733
Fault	3,822
Blackleaf	3,884
Kootenai	4,366(?)
Morrison	4,779
Swift	5,010
Rierdon	5,132
Sawtooth	5,228
Third Madison	5,274

Source of Data:

M.L.G.C.C./Billings
Petroleum Information Company
Hurly (1959)

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

GEM PROJECT - OIL AND GAS WELL SUMMARY SHEET

GRA Sawtooth, Montana

Well: 1 Blackleaf Federal A

Company: Northern Natural Gas

Location: Sec. 13 T. 26N. R. 9W.

Date Drilled: 12/25/57-6/6/58

Elevation: 5,340 feet

Status: Shut in

Total Depth: 6,323 feet

Production: IPF 6,293 Mcfgpd, 518" CK

Notes:

- PB: 4350.
- Productive zone 3,794-3,830 Madison.
- Hurley (1959, BGS) perforation in top 80 feet of second miss. slice. Sheet has net porosity of 135 feet between 3,800 and 4,100. Porosity analysis 2.9 to 11.6%. Permeability caused by fracturing, range <0.1 to 37 millidarcies. Porosity intercrystalline some vugs. Also had porosity and permeability log.
- Discovery well for Blackleaf Canyon field.

Log:

Formation Tops (ft.):

Blackleaf Shale	90
Kootenai	250
Morrison	700(?)
Swift	1,033
Rierdon	1,124
Sawtooth Zone	1,230
Mississippian	1,322
Major Fault Zone	2,495
Kootenai Drag Slice	2,495
Minor Fault Zone	2,528
Blackleaf Shale	2,528
Kootenai	2,574
Morrison	3,200(?)
Swift	3,460
Rierdon	3,594
Sawtooth Zone	3,712
Mississippian	3,792
Major Fault Zone	4,342
Kootenai Drag Slice	4,342
Minor Fault Zone	4,435
Blackleaf Shale	4,435
Kootenai	4,530
Morrison	5,215
Swift	5,472
Rierdon	5,587
Sawtooth	5,692
Mississippian	5,748

Source of Data:

M.O.G.C.C./Billings
Petroleum Information Company
Hurley (1959)

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

GEM PROJECT - OIL AND GAS WELL SUMMARY SHEET

GRA Sawtooth, Montana

Well: No. 1 Blackleaf

Company: General Petroleum Corporation

Location: **Sec.** 14 **T.** 26N. **R.** 9W.

Date Drilled: 7/31/47-7/20/48

Elevation: 5,846 feet

Status: Plugged and abandoned

Total Depth: 7,571 feet

Production: None reported

Notes:

No file available at M.O.G.C.C.

Source of Data:

M.O.G.C.C./Billings
Petroleum Information Company

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

Log:

Formation Tops (ft.):

Madison	220
Devonian	1,610
Kootenai	1,745
Morrison	2,030
Ellis	2,230
Madison	2,545
Devonian	3,745
Madison	5,310
Madison	7,085

GEM PROJECT - OIL AND GAS WELL SUMMARY SHEET

GRA Sawtooth, Montana

Well: Government No. 38-3-G

Company: General Petroleum Company

Location: Sec. 3 T. 25N. R. 8W.

Date Drilled: 9/3/45-5/15/46

Elevation: 4,935 feet

Status: Abandoned

Total Depth: 3,129 feet

Production: None reported

Notes:

Strip log in file.

Log:

Formation Tops (ft.):

Blackleaf Sandy Member	1,300
Eagle Sandstone	1,946
Colorado Shale	2,300

Source of Data:

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

GEM PROJECT - OIL AND GAS WELL SUMMARY SHEET

GRA Sawtooth, Montana

Well: No. 14-34 Unit

Company: Shell Oil Company

Location: Sec. 34 T. 25N. R. 8W.

Date Drilled: 8/7/60-9/30/60

Elevation: 4,895 feet

Status: Dry and abandoned

Total Depth: 4,911 feet

Production: None reported

Notes:

Traces of oil stain and traces of bleeding gas.

Source of Data:

M.O.G.C.C./Billings
Petroleum Information Company

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

Log:

Formation Tops (ft.):

Morrison	3,690
Swift	3,800
Rierdon	3,935
Madison	4,055

GEM PROJECT - OIL AND GAS WELL SUMMARY SHEET

GRA Sawtooth, Montana

Well: No. 1 Moore Government

Company: Farmers Union Central Exchange

Location: Sec. 12 T. 24N. R. 8W.

Date Drilled: 7/26/47-11/20/47

Elevation: 4,650 feet

Status: Plugged and abandoned

Total Depth: 3,531 feet

Production: Non reported

Notes:

Log:

Formation Tops (ft.):

Colorado Shale to	2,180
Madison	2,180
Eagle	2,925
Colorado/Eagle Transition	3,020
Colorado Shale	3,055

Source of Data:

M.O.G.C.C./Billings
Petroleum Information Company

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

GEM PROJECT - OIL AND GAS WELL SUMMARY SHEET

GRA Sawtooth, Montana

Well: State No. 1	**Company:** Trans-American Oil Company
Location: Sec. 21 T. 24N. R. 8W.	**Date Drilled:** 1931
Elevation: 5,350 feet	**Status:** Abandoned
Total Depth: 920 feet	

Production: No reported

Notes:

No file available.

Log:

Source of Data:

M.O.G.C.C./Billings

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

GEM PROJECT - OIL AND GAS WELL SUMMARY SHEET

GRA Sawtooth, Montana

Well: No. 1 Teton Unit

Company: Humble Oil and Refining

Location: Sec. 21 T. 24N. R. 8W.

Date Drilled: 8/21/69-2/12/70

Elevation: 5,489 feet

Status: Dry and abandoned

Total Depth: 10,080 feet

Production: None reported

Notes:

PB: 6881

Log:

Formation Tops (ft.):

Cretaceous	3,204
Rierdon	6,220
Madison	6,332
Jurassic	6,940
Rierdon	7,153
Madison	7,301
Bakken	8,546
Devonian	8,587

Source of Data:

M.O.G.C.C./Billings
Petroleum Information Company

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

GEM PROJECT - OIL AND GAS WELL SUMMARY SHEET

GRA Sawtooth, Montana

Well: Salmond

Company: Rocky Mountain Oil & Gas Company

Location: Sec. 4 T. 23N. R. 8W.

Date Drilled: ?

Elevation: 5,292 feet

Status: Abandoned

Total Depth: 1,700 feet

Production: None reported

Notes:

No file present 8/4/82.

Log:

None.

Source of Data:

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

GEM PROJECT - OIL AND GAS WELL SUMMARY SHEET

GRA Sawtooth, Montana

Well: No. 1 Federal 51 Teton

Company: Sinclair Oil and Gas

Location: Sec. 21 T. 23N. R. 8W.

Date Drilled: 8/27/64-9/25/64

Elevation: 5,036 feet

Status: Dry and abandoned

Total Depth: 3,000 feet

Production: None reported

Notes:

Log:

Formation Tops (ft.):

Dakota	1,245
Kootenai	1,283
Swift	1,917
Rierdon	2,010
Mission Canyon	2,165
Mission Canyon Limestone	2,508

Source of Data:

M.O.G.C.C./Billings
Petroleum Information Company

Date Checked: 8-4-82

By: GF/JPF

GEM PROJECT - OIL AND GAS WELL SUMMARY SHEET

GRA Sawtooth, Montana

Well:	No. 1 Pamburn Unit-Federal	**Company:**	Wexpro Company
Location:	**Sec.** 21 **T.** 25N. **R.** 8W.	**Date Drilled:**	8/22/81-11/4/81
Elevation:	5,827 feet	**Status:**	Dry and abandoned
Total Depth:	6,362 feet		
Production:	None reported		

Notes:

No file available.

Log:

Formation Tops (ft.):

Kootenai	Surf.
Sun River	367
Mission Canyon	456
Lodgepole	1,728
Bakken	1,942
Threeforks	1,950
Potlatch	1,985
Fault	2,077
Kootenai	2,077
Blackleaf	2,962
Bow Island	3,282
Dakota	3,888
Kootenai	4,002
Sunburst	4,442
Morrison	4,550
Swift	4,693
Rierdon	4,810
Sawtooth	4,870
Sun River	4,902
Mission Canyon	5,226
Lodgepole	5,884
Fault	6,088
Kootenai	6,088
Sunburst	6,303

Source of Data:

M.O.G.C.C./Billings
Petroleum Information Company

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

APPENDIX III

U.S. GEOLOGICAL SURVEY STREAM SEDIMENT SAMPLE DATA FOR THE SAWTOOTH GRA

Notes:
1. Data from: Grimes, Leinz and Hopkins (1980).
2. All elements except gold and mercury by emission spectrograph. Gold by atomic absorption. Mercury by vapor detector.
3. --: Not determined
   N: Not detected
   G: Greater than
   L: Less than

Map No.	USGS Sample No.	Fe %	Mg %	Ca %	Ti %	Mn (ppm)	As (ppm)	B (ppm)	Be (ppm)	Bi (ppm)	Cd (ppm)	Co (ppm)
744	CH144	3.0	2.00	5.00	0.500	500	G200	100	1.0	G10	G20	10
745	CH100	7.0	2.00	3.00	0.700	2,000	G200	30	G1.0	G10	G20	5
760	CH44	1.0	3.00	10.00	0.200	300	500	30	1.0	G10	G20	10
761	CH47	2.0	2.00	2.00	0.300	1,000	1,000	70	2.0	G10	G20	20
762	CH51	2.0	2.00	15.00	0.150	300	G200	70	1.0	G10	G20	5
763	CH52	2.0	5.00	20.00	0.100	300	G200	50	G1.0	G10	G20	7
798	795SS	-	-	10.00	-	300	N	-	N	N	N	-
799	CH134	1.0	1.00	5.00	0.300	500	G200	20	G1.0	G10	G20	5
812	792SS	-	-	-	-	200	N	-	N	N	N	-
"	793SS	-	-	-	-	200	N	-	N	N	N	-
"	794SS	-	-	-	-	300	N	-	N	N	N	-
813	CH143	5.0	2.00	5.00	0.500	1,000	G200	20	1.0	G10	G20	5
814	1328	2.0	3.00	5.00	0.200	300	N	50	1.5	N	N	5
831	CH142	3.0	3.00	7.00	0.300	700	G200	50	1.0	G10	G20	5
832	CH137	1.5	2.00	7.00	0.500	500	G200	50	1.0	G10	G20	5
833	CH139	1.5	2.00	7.00	0.500	300	G200	50	G1.0	G10	G20	5
850	CH135	1.0	2.00	10.00	0.150	300	G200	20	G1.0	G10	G20	G5
851	CH181	20.0	0.10	0.20	0.010	20	G200	G10	G1.0	G10	G20	5
852	459	2.0	1.50	2.00	0.150	300	N	70	1.0	N	N	10
"	470	1.0	5.00	7.00	0.050	70	N	G10	N	N	N	G5
"	471	3.0	1.50	3.00	0.150	200	N	50	1.5	N	N	10
877	AMS871	-	-	-	-	500	-	-	-	-	-	N
878	1300	3.0	2.00	3.00	0.300	300	N	70	1.5	N	N	7
879	1303	0.7	10.00	10.00	0.050	70	N	30	G1.0	N	N	N
880	CH170	3.0	2.00	5.00	0.300	300	G200	70	1.0	G10	G20	15
902	1301	3.0	2.00	7.00	0.200	300	N	70	1.0	N	N	5
"	1302	3.0	3.00	5.00	0.300	500	N	50	1.5	N	N	5
903	1304	3.0	2.00	5.00	0.300	500	N	70	1.5	N	N	5
904	CH168	2.0	2.00	7.00	0.200	300	G200	30	1.0	G10	G20	10
"	1305	5.0	2.00	5.00	0.300	700	N	70	1.5	N	N	7
"	1306	3.0	1.50	3.00	0.300	500	N	70	2.0	N	N	5
919	1327	3.0	2.00	5.00	0.300	300	N	500	1.5	N	N	7
945	AMS870	-	-	-	-	500	-	-	-	-	-	15
946	1311	5.0	1.50	3.00	0.300	700	N	70	2.0	N	N	7
"	1312	5.0	2.00	5.00	0.300	700	N	70	1.5	N	N	7
"	1313	5.0	1.50	3.00	0.500	500	N	70	2.0	N	N	7
947	1309	5.0	2.00	3.00	0.300	700	N	100	2.0	N	N	7
"	1310	5.0	2.00	3.00	0.300	700	N	70	2.0	N	N	10

Map No.	USGS Sample No.	Cu (ppm)	Pb (ppm)	Zn (ppm)	Mo (ppm)	Ag (ppm)	Au (ppm)	Au (ppm)[1]	W (ppm)	Sn (ppm)	Hg (ppm)[2]	Ba (ppm)
744	CH144	10	10	G200	G5.0	G0.5	-	-	G50	G10	-	200
745	CH100	30	15	G200	G5.0	G0.5	-	-	G50	G10	-	1,500
760	CH44	10	N	N	N	N	-	-	G50	N	-	500
761	CH47	15	70	G200	G5.0	G0.5	-	-	G50	G10	-	1,000
762	CH51	10	G10	N	N	N	-	-	G50	N	-	500
763	CH52	10	G10	G200	G5.0	G0.5	-	-	G50	G10	-	300
798	795SS	10	15	N	N	N	N	N	N	N	-	-
799	CH134	5	20	G200	G5.0	G0.5	-	-	G50	G10	-	700
812	792SS	10	30	N	N	N	N	N	N	N	-	-
"	793SS	15	30	N	N	N	N	N	N	N	-	-
"	794SS	7	30	N	N	N	N	N	N	N	-	-
813	CH143	30	20	G200	G5.0	G0.5	-	-	G50	G10	-	20
814	1328	15	G10	N	N	N	N	N	N	N	0.02	200
831	CH142	30	20	G200	G5.0	G0.5	-	-	G50	G10	-	300
832	CH137	5	10	G200	G5.0	G0.5	-	-	G50	G10	-	700
833	CH139	5	15	G200	G5.0	G0.5	-	-	G50	G10	-	300
850	CH135	7	10	G200	G5.0	G0.5	-	-	G50	G10	-	500
851	CH181	50	50	3,000	30.0	G0.5	-	-	G50	G10	-	50
852	469	G10	G10	N	N	N	N	N	N	N	0.08	150
"	470	10	G10	N	N	N	N	N	N	N	0.16	20
"	471	20	10	N	N	N	N	N	N	N	0.11	150
877	AMS871	20	15	N	N	N	-	-	-	N	-	300
878	1300	30	30	N	N	N	N	N	N	N	0.06	500
879	1303	10	20	N	N	N	N	N	N	N	0.04	50
880	CH170	20	30	G200	G5.0	G0.5	-	-	G50	G10	-	300
902	1301	30	20	N	N	N	N	N	N	N	0.02	300
"	1302	30	20	N	N	N	N	N	N	N	0.02	500
903	1304	30	15	N	N	N	N	N	N	N	0.04	700
904	CH168	20	20	G200	5.0	G0.5	-	-	G50	G10	-	200
"	1305	30	15	N	N	N	N	N	N	N	0.02	700
"	1306	20	10	N	N	N	N	N	N	N	0.02	700
919	1327	30	10	N	N	N	N	N	N	N	0.06	200
945	AMS870	30	20	N	N	N	-	-	-	N	-	500
946	1311	50	20	N	N	N	N	N	N	N	0.04	500
"	1312	50	20	N	N	N	N	N	N	N	0.02	1,500
"	1313	30	20	N	N	N	N	N	N	N	0.02	500
947	1309	50	20	N	N	N	N	N	N	N	0.02	500
"	1310	50	20	N	N	N	N	N	N	N	0.02	500

Map No.	USGS Sample No.	Cr (ppm)	La (ppm)	Nb (ppm)	Ni (ppm)	Sb (ppm)	Sc (ppm)	Sr (ppm)	V (ppm)	Y (ppm)	Zr (ppm)
744	CH144	70	50	-	30	G100	G5	200	150	10	100
745	CH100	70	G20	-	50	G100	7	300	300	30	300
760	CH44	70	G20	-	20	G100	5	200	100	G10	200
761	CH47	100	100	-	30	G100	10	150	100	7	300
762	CH51	30	G20	-	15	G100	7	1,000	70	10	100
763	CH52	30	G20	-	15	G100	7	700	50	5	70
798	795SS	70	-	-	-	N	-	-	70	20	-
799	CH134	50	30	-	7	G100	5	200	70	10	300
812	792SS	70	-	-	-	N	-	-	70	30	-
"	793SS	200	-	-	-	N	-	-	70	50	-
"	794SS	70	-	-	-	N	-	-	70	30	-
813	CH143	70	20	-	30	G100	10	300	200	10	150
814	1328	50	20	N	20	N	10	G100	70	15	70
831	CH142	50	20	-	30	G100	10	200	150	10	150
832	CH137	50	30	-	15	G100	5	200	100	5	70
833	CH139	70	30	-	10	G100	5	200	70	10	50
850	CH135	50	20	-	7	G100	5	200	70	5	50
851	CH181	G10	G20	-	50	G100	G5	G100	100	10	G10
852	469	50	30	N	20	N	10	N	30	15	30
"	470	10	G20	N	7	N	G5	N	N	G10	20
"	471	50	30	N	30	N	7	G100	50	20	100
877	AMS871	70	-	-	20	-	-	-	200	10	-
878	1300	70	30	N	30	N	10	100	100	20	150
879	1303	30	N	N	10	N	G5	G100	15	G10	15
880	CH170	70	50	-	20	G100	5	200	70	10	200
902	1301	70	20	N	20	N	7	150	70	20	100
"	1302	50	30	N	30	N	7	150	100	20	100
903	1304	70	30	N	30	N	10	150	100	20	150
904	CH168	50	20	-	30	G100	5	100	70	10	150
"	1305	70	30	N	30	N	10	150	100	20	200
"	1306	50	30	N	30	N	10	150	100	20	150
919	1327	70	30	N	30	N	10	100	100	20	100
945	AMS870	150	-	-	30	-	-	-	300	15	-
946	1311	100	30	N	30	N	15	100	150	20	150
"	1312	100	30	N	30	N	15	100	100	20	150
"	1313	70	30	N	30	N	15	100	150	30	200
947	1309	100	30	N	30	N	15	150	150	20	200
"	1310	70	30	N	50	N	15	100	150	20	150

Map No.	USGS Sample No.	Fe %	Mg %	Ca %	Ti %	Mn (ppm)	As (ppm)	B (ppm)	Be (ppm)	Bi (ppm)	Cd (ppm)	Co (ppm)
948	138	2.0	1.50	5.00	0.300	300	N	100	1.0	N	N	20
949	137	1.0	3.00	15.00	0.150	200	N	50	G1.0	N	N	5
"	439	1.0	7.00	10.00	0.050	70	N	15	N	N	N	N
976	AMS869	-	-	-	-	500	-	-	-	-	-	N
977	1325	3.0	1.50	3.00	0.300	300	N	70	1.5	N	N	7
978	1326	5.0	1.50	2.00	0.500	500	N	70	2.0	N	N	7
995	140	3.0	3.00	5.00	0.300	300	N	50	1.0	N	N	20
1016	143	2.0	3.00	10.00	0.200	300	N	50	G1.0	N	N	15
1028	AMS882	-	-	-	-	300	-	-	-	-	-	5
1047	1444	2.0	2.00	7.00	0.300	300	N	100	2.0	N	N	10
"	1445	3.0	3.00	5.00	0.500	500	N	100	1.5	N	N	15
1095	1415	1.5	3.00	15.00	0.150	300	N	50	1.5	N	N	7
1115	1293	2.0	5.00	15.00	0.150	300	N	30	1.5	N	N	10
"	1446	1.5	3.00	7.00	0.150	500	N	30	1.0	N	N	5
"	1447	2.0	5.00	15.00	0.150	500	N	100	1.5	N	N	10
1116	1296	3.0	3.00	7.00	0.200	300	N	50	1.5	N	N	15
"	1297	3.0	3.00	7.00	0.200	300	N	50	1.5	N	N	15
1127	1227	1.5	3.00	7.00	0.100	200	N	30	1.0	N	N	10
"	1228	2.0	3.00	15.00	0.150	300	N	70	1.5	N	N	10
1139	1225	3.0	2.00	5.00	0.200	300	N	30	2.0	N	N	15

Map No.	USGS Sample No.	Cu (ppm)	Pb (ppm)	Zn (ppm)	Mo (ppm)	Ag (ppm)	Au (ppm)	Au (ppm)[1]	W (ppm)	Sn (ppm)	Hg (ppm)[2]	Ba (ppm)
948	138	20	20	N	N	N	N	-	N	N	0.03	500
949	137	15	15	N	N	N	N	-	N	N	0.03	100
"	439	20	10	N	N	N	N	N	N	N	0.05	20
976	AMS869	10	10	N	N	N	-	-	-	N	-	500
977	1325	20	10	N	N	N	N	N	N	N	0.02	200
978	1326	30	15	N	N	N	N	N	N	N	0.04	300
995	140	20	15	N	N	N	N	-	N	N	0.04	700
1016	143	20	20	N	N	N	N	-	N	N	0.05	500
1028	AMS882	7	20	N	N	N	-	-	-	N	-	500
1047	1444	15	10	N	N	N	N	-	N	N	-	500
"	1445	15	10	N	N	N	N	-	N	N	-	500
1095	1415	15	10	N	N	N	N	-	N	N	-	200
1115	1293	30	20	N	N	N	N	N	N	N	0.04	300
"	1446	15	10	N	N	N	N	-	N	N	-	200
"	1447	15	10	N	N	N	N	-	N	N	-	150
1116	1296	30	10	N	N	N	N	N	N	N	0.05	300
"	1297	20	15	N	N	N	N	N	N	N	0.05	300
1127	1227	30	20	N	N	N	N	-	N	N	0.05	200
"	1228	30	30	N	N	N	N	N	N	N	0.06	150
1139	1225	30	20	N	N	N	N	N	N	N	0.06	500

Map No.	USGS Sample No.	Cr (ppm)	La (ppm)	Nb (ppm)	Ni (ppm)	Sb (ppm)	Sc (ppm)	Sr (ppm)	V (ppm)	Y (ppm)	Zr (ppm)
948	138	100	70	10	50	N	20	150	100	30	150
949	137	30	20	G10	15	N	5	300	30	15	150
"	439	10	N	N	10	N	N	G100	15	G10	15
976	AMS869	50	-	-	20	-	-	-	150	10	-
977	1325	70	30	N	30	N	15	100	100	20	150
978	1326	100	30	N	30	N	15	G100	100	20	200
995	140	70	70	10	50	N	15	150	100	30	150
1016	143	70	30	G10	30	N	10	150	70	30	70
1028	AMS882	30	-	-	10	-	-	-	70	10	-
1047	1444	70	30	N	30	N	10	100	100	15	100
"	1445	70	30	N	30	N	10	100	150	15	70
1095	1415	100	20	N	30	N	7	100	70	15	150
1115	1293	70	20	N	20	N	7	150	100	20	100
"	1446	100	30	N	30	N	7	100	50	15	70
1116	1447	100	30	N	30	N	7	100	50	15	70
"	1296	70	30	N	30	N	10	G100	150	15	70
1127	1297	50	30	N	30	N	10	100	150	20	150
"	1227	50	20	N	30	N	7	150	150	20	150
	1228	70	30	N	20	N	7	150	70	15	70
1139	1225	70	30	N	30	N	15	150	150	30	150

APPENDIX IV

U.S. GEOLOGICAL SURVEY ROCK SAMPLE DATA FOR THE SAWTOOTH GRA, MONTANA

Notes:
1. Data from Grimes, Leinz and Hopkins (1980).
2. All elements except gold and mercury by emission spectrograph. Gold by atomic absorption. Mercury by vapor detector.
3. --: Not determined
   N: Not detected
   G: Greater than
   L: Less than

Map No.	USGS Sample No.	Fe %	Mg %	Ca %	Ti %	Mn (ppm)	As (ppm)	B (ppm)	Be (ppm)	Bi (ppm)	Cd (ppm)	Co (ppm)
911	AMS901	15.00	0.30	2.00	-	10	N	-	-	-	-	6
912	HS90	1.50	0.20	0.50	0.100	300	G200	20	1.0	G10	G20	G5
935	EFB295	3.00	0.70	0.30	0.500	50	N	200	5.0	N	N	5
936	EFB297	2.00	1.50	1.50	0.300	300	N	70	5.0	N	N	10
937	AMS900	15.00	0.70	3.00	-	G5,000	N	-	-	-	-	10
"	EFB296	3.00	0.30	0.20	0.700	700	N	70	5.0	N	N	10
956	AMS899	5.00	1.00	1.50	-	150	N	-	-	-	-	10
957	EFB334	3.00	1.50	2.00	0.300	300	N	100	5.0	N	N	10
958	EFB299	1.50	0.50	7.00	0.150	300	N	100	5.0	N	N	10
"	EFB300	3.00	1.50	1.00	0.500	300	N	200	5.0	N	N	15
"	EFB301	2.00	1.50	3.00	0.200	300	N	100	5.0	N	N	7
959	EFB298	3.00	0.70	0.30	0.500	300	N	100	5.0	N	N	15
960	EFB311	3.00	1.50	2.00	0.300	200	N	300	5.0	N	N	15
983	AMS898	15.00	0.20	1.00	-	1,000	N	-	-	-	-	70
984	AMS896	1.00	0.70	0.20	-	10	N	-	-	-	-	N
985	HS277	1.00	0.70	0.70	0.300	50	G200	150	G1.0	G10	G20	G5
986	HS780	1.00	0.05	0.20	0.050	100	N	G10	1.5	N	N	N
1001	AMS897	10.00	0.70	1.50	-	500	N	-	-	-	-	10
1002	792AR	10.00	-	5.00	-	G5,000	N	30	-	N	N	5
"	792BR	1.50	-	3.00	-	1,500	N	50	-	N	N	G5
"	792CR	3.00	-	0.20	-	500	N	70	-	N	N	5
"	794AR	3.00	-	5.00	-	500	N	100	-	N	N	10
"	794BR	1.50	-	5.00	-	1,500	200	20	-	N	N	7
1003	HS774	G20.00	0.05	0.50	0.050	50	G200	30	G1.0	G10	G20	G5
1023	HS539	G0.50	0.20	0.70	0.002	70	N	N	N	N	N	N
1024	HS785	2.00	0.70	1.50	0.150	700	N	G10	1.5	N	N	7
"	HS786	3.00	0.15	0.05	0.500	100	N	30	1.5	N	N	7
1025	EFB312	3.00	0.70	0.30	0.300	150	N	200	5.0	N	N	10
"	HS775	0.50	7.00	0.10	0.050	70	G5	10	1.0	G10	G20	G5
1052	HS833	5.00	1.00	0.50	0.300	700	G200	G10	G1.0	-	G20	G5
1053	HS792	3.00	0.70	0.70	0.300	1,000	G200	10	G1.0	G10	G20	5
1054	HS790	1.50	0.20	1.50	0.150	1,500	N	10	1.0	N	N	N
"	HS791	0.30	0.02	0.70	0.100	200	G200	20	1.0	G10	G20	G5
"	HS819	G20.00	0.50	0.30	0.020	100	G200	100	3.0	G10	G20	G5
1055	CH181	20.00	0.10	0.20	0.010	20	N	G10	G1.0	G10	G20	G5

Map No.	USGS Sample No.	Cu (ppm)	Pb (ppm)	Zn (ppm)	Mo (ppm)	Ag (ppm)	Au (ppm)	Au (ppm)[1]	W (ppm)	Sn (ppm)	Hg (ppm)[2]	Ba (ppm)
911	AMS901	7	50	200	30	N	-	-	N	10	-	300
912	HS90	7	10	G200	G5	G0.5	-	-	G50	G10	-	200
935	EFB295	20	30	N	N	N	N	-	N	N	0.04	1,000
936	EFB297	20	20	N	N	G0.5	N	-	N	N	0.02	1,000
937	AMS900	7	G10	N	N	2.0	-	-	N	N	-	150
"	EFB296	20	20	N	N	N	N	-	N	N	0.02	700
956	AMS899	10	10	N	G5	N	-	-	N	N	-	700
957	EFB334	20	30	N	N	N	N	-	N	N	0.02	700
958	EFB299	50	20	N	10	0.7	N	-	N	N	0.10	700
"	EFB300	30	20	N	N	G0.5	N	-	N	N	0.14	1,000
"	EFB301	15	20	N	N	G0.5	N	-	N	N	0.04	700
959	EFB298	30	30	N	N	0.5	N	-	N	N	0.02	700
960	EFB311	20	15	N	N	N	N	-	N	N	G0.02	300
983	AMS898	30	N	500	10	N	-	-	N	N	-	100
984	AMS896	15	20	N	G5	N	-	-	N	N	-	700
985	HS277	70	70	G200	30	2.0	-	-	G50	G10	-	1,000
986	HS780	G5	G10	N	100	N	N	N	N	N	0.08	150
1001	AMS897	20	N	200	5	N	-	-	N	10	-	100
1002	792AR	7	30	N	15	N	N	-	N	N	G0.02	200
"	792BR	G5	20	N	N	N	N	-	N	N	0.02	200
"	792CR	7	30	N	G5	N	N	-	N	N	N	300
"	794AR	20	20	N	N	N	N	-	N	N	0.02	1,000
"	794BR	5	20	N	7	1.0	N	N	N	N	0.12	300
1003	HS774	10	20	200	10	G0.5	-	-	G50	G10	-	200
1023	HS539	N	N	N	N	N	N	N	N	N	0.06	N
1024	HS785	10	10	N	N	N	N	N	N	N	0.04	2,000
"	HS786	5	G10	N	N	N	N	N	N	N	0.04	150
1025	EFB312	50	30	N	N	N	N	-	N	N	0.06	700
"	HS775	5	10	G200	G5	G0.5	-	-	G50	G10	-	20
1052	HS883	20	15	G200	100	G0.5	-	-	G50	G10	-	200
1053	HS792	5	15	G200	G5	G0.5	-	-	G50	G10	-	1,000
1054	HS790	G5	N	N	N	N	N	N	N	N	0.04	100
"	HS791	5	10	G200	G5	G0.5	-	-	G50	20	-	100
"	HS819	70	200	1,500	300	G0.5	-	-	G50	G10	-	300
1055	CH181	50	50	3,000	30	N	-	-	N	N	-	50

Map No.	USGS Sample No.	Cr (ppm)	La (ppm)	Nb (ppm)	Ni (ppm)	Sb (ppm)	Sc (ppm)	Sr (ppm)	V (ppm)	Y (ppm)	Zr (ppm)
911	AMS901	50	-	-	100	-	-	-	30	10	-
912	HS90	10	20	-	5	G100	G5	500	50	G10	70
935	EFB295	100	-	N	20	N	15	150	200	20	150
936	EFB297	70	-	N	30	N	7	100	100	20	150
937	AMS900	10	-	-	10	-	-	-	10	N	-
"	EFB296	70	-	N	30	N	10	G100	100	50	200
956	AMS899	10	-	-	15	-	-	-	200	10	-
957	EFB334	70	-	N	30	N	10	150	100	20	100
958	EFB299	70	-	N	50	N	7	300	150	15	70
"	EFB300	150	-	N	70	N	15	200	300	20	150
"	EFB301	50	-	N	20	N	5	150	100	15	100
959	EFB298	100	-	N	70	N	15	100	150	30	150
960	EFB311	100	-	N	70	N	15	100	100	20	100
983	AMS898	1,000	-	-	50	-	-	-	1,000	20	-
984	AMS896	50	-	-	5	-	-	-	100	20	-
985	HS277	100	50	-	200	G100	10	700	700	10	100
986	HS780	N	20	N	10	N	10	N	50	N	70
1001	AMS897	200	-	-	10	-	-	-	300	50	-
1002	792AR	30	-	-	7	N	-	-	50	-	-
"	792BR	50	-	-	10	N	-	-	50	-	-
"	792CR	20	-	-	15	N	-	-	50	-	-
"	794AR	100	-	-	30	N	-	-	100	-	-
"	794BR	15	-	-	15	N	-	-	30	-	-
1003	HS774	G10	G20	-	G5	G100	G5	100	10	5	20
1023	HS539	N	20	N	N	N	N	N	N	N	N
1024	HS785	N	G20	N	15	N	7	700	70	10	50
"	HS786	N	30	N	15	N	7	N	30	30	1,000
1025	EFB312	70	-	N	70	N	10	100	150	20	100
"	HS775	20	G20	-	G5	G100	G5	150	30	5	10
1052	HS833	50	20	-	20	G100	10	200	200	10	70
1053	HS792	50	20	-	5	G100	10	700	150	G10	70
1054	HS790	N	30	N	N	N	N	N	30	10	500
"	HS791	10	20	-	G5	G100	G5	150	15	5	100
"	HS819	50	G20	-	300	G100	G5	500	200	70	G10
1055	CH181	N	G20	-	50	G100	G5	G100	100	10	G10

Map No.	USGS Sample No.	Fe %	Mg %	Ca %	Ti %	Mn (ppm)	As (ppm)	B (ppm)	Be (ppm)	Bi (ppm)	Cd (ppm)	Co (ppm)
1071	EFB337	3.00	0.70	0.20	0.500	50	N	200	5.0	N	N	5
"	EFB338	3.00	0.70	0.30	0.500	150	N	200	1.0	N	N	7
1072	CH164	15.00	0.50	10.00	0.030	100	N	30	1.0	G10	G20	N
1073	CH165	20.00	0.30	0.50	0.010	100	N	20	G1.0	G10	G20	N
1074	M021	2.00	1.00	20.00	0.015	100	G200	G10	G1.0	G10	G20	G5
1098	EFB316	5.00	0.50	0.30	0.700	500	N	100	5.0	N	N	15
1099	EFB317	3.00	1.50	7.00	0.300	700	N	300	5.0	N	N	10
"	EFB318	3.00	0.30	0.10	0.500	150	N	200	5.0	N	N	10
"	EFB319	7.00	0.70	0.20	0.300	100	N	500	5.0	N	N	7
1100	EFB314	2.00	1.50	5.00	0.300	500	N	200	5.0	N	N	15
"	EFB315	1.50	1.50	1.00	0.500	200	N	100	5.0	N	N	7
"	HS829	15.00	1.00	1.00	G1.000	1,500	G200	30	G1.0	-	G20	30
1101	AMS894	7.00	0.50	15.00	-	100	N	-	-	-	-	N
"	AMS895	G20.00	0.20	0.70	-	200	N	-	-	-	-	7
"	EFB313	2.00	3.00	5.00	0.300	700	N	300	5.0	N	N	10
"	HS828	15.00	0.10	5.00	0.070	700	700	50	1.0	G10	G20	100
1102	HS796	2.00	3.00	1.50	0.200	1,000	G200	10	1.0	G10	G20	5
"	HS798	0.30	0.15	0.20	0.300	G50	G200	10	G1.0	G10	G20	G5
1103	HS795	1.00	0.02	0.10	0.300	70	G200	30	1.0	G10	G20	G5
"	HS799	0.15	1.50	20.00	0.015	G10	N	N	N	N	N	N
1123	M962	0.05	10.00	10.00	0.003	20	N	N	N	N	N	N
1124	M964	2.00	1.50	15.00	0.100	300	N	70	1.0	N	N	G5
1125	M965	0.07	10.00	10.00	0.007	15	N	N	N	N	N	N
1126	M83	0.05	0.30	20.00	0.010	50	N	N	N	N	N	N
1150	M963	0.07	10.00	15.00	0.005	20	N	N	N	N	N	N
1151	M966	0.70	0.30	0.10	0.200	700	N	30	G1.0	N	N	N
1152	M85	G0.05	7.00	15.00	0.007	500	N	N	N	N	N	N
1153	EFB269	1.50	1.00	0.70	0.300	150	N	150	5.0	N	N	10
1154	M93	N	7.00	10.00	0.002	50	N	N	N	N	N	N
1155	M94	N	0.50	20.00	0.010	N	N	N	N	N	N	N
1185	M961	0.07	10.00	15.00	0.007	50	N	N	N	N	N	N
1186	B849	5.00	1.00	0.50	0.300	1,500	N	20	1.0	N	N	7
"	B850	5.00	0.70	0.50	0.300	700	N	20	N	N	N	G5
1187	B848	0.30	7.00	7.00	0.005	50	N	N	N	N	N	N
"	M84	G0.05	7.00	15.00	0.003	20	N	N	N	N	N	N
1208	M960	0.20	0.20	G0.05	0.200	50	N	20	G1.0	N	N	N

Map No.	USGS Sample No.	Cu (ppm)	Pb (ppm)	Zn (ppm)	Mo (ppm)	Ag (ppm)	Au (ppm)	Au (ppm)[1]	W (ppm)	Sn (ppm)	Hg (ppm)[2]	Ba (ppm)
1071	EFB337	20	30	N	G5	N	N	-	N	N	0.04	1,000
"	EFB338	20	30	G200	N	G0.5	N	-	N	N	0.06	1,000
1072	CH164	30	50	1,000	20	N	-	-	N	N	-	50
1073	CH165	10	50	300	100	N	-	-	N	N	-	50
1074	M021	10	50	G200	G5	G0.5	-	-	G50	G10	-	50
1098	EFB316	50	30	N	N	G0.5	N	-	N	N	0.02	700
1099	EFB317	20	20	N	N	N	N	-	N	N	G0.02	700
"	EFB318	50	50	N	G5	N	N	-	N	N	0.02	500
"	EFB319	70	30	N	N	N	N	-	N	N	0.06	700
1100	EFB314	30	20	N	N	N	N	-	N	N	0.02	500
"	EFB315	30	15	N	N	0.5	N	-	N	N	0.04	500
"	HS829	30	G10	700	5	G0.5	-	-	G50	G10	-	200
1101	AMS894	30	10	700	5	N	-	-	N	N	-	10
"	AMS895	5	N	500	30	N	-	-	N	N	-	70
"	EFB313	15	20	N	N	N	N	-	N	N	0.02	300
"	HS828	200	70	3,000	100	5.0	-	-	G50	G10	-	100
1102	HS796	30	15	G200	G5	G0.5	-	-	G50	G10	-	700
"	HS798	G5	20	G200	G5	G0.5	N	N	G50	G10	0.02	500
1103	HS795	G5	15	G200	G5	G0.5	-	-	G50	G10	-	200
"	HS799	N	N	N	N	N	N	N	N	N	0.02	N
1123	M962	N	N	N	N	N	N	N	N	N	G0.02	N
1124	M964	30	10	N	N	N	N	N	N	N	0.10	150
1125	M965	N	N	N	N	N	N	N	N	N	0.04	N
1126	M83	N	N	N	N	N	N	N	N	N	0.02	N
1150	M963	N	N	N	N	N	N	N	N	N	G0.02	G20
1151	M966	7	G10	N	N	N	N	N	N	N	0.04	150
1152	M85	G5	N	N	N	N	N	N	N	N	N	N
1153	EFB269	50	50	N	N	N	N	-	N	N	G0.02	700
1154	M93	N	N	N	N	N	N	N	N	N	0.04	N
1155	M94	N	N	N	N	N	N	N	N	N	N	N
1185	M961	G5	N	N	N	N	N	N	N	N	G0.02	N
1186	B849	20	G10	N	N	N	N	N	N	N	0.08	700
"	B850	10	20	N	N	N	N	N	N	N	0.12	1,000
1187	B848	N	G10	N	N	N	N	N	N	N	0.06	G20
"	M84	20	N	N	N	N	N	N	N	N	0.09	N
1208	M960	5	G10	N	N	N	N	N	N	N	0.04	200

Map No.	USGS Sample No.	Cr (ppm)	La (ppm)	Nb (ppm)	Ni (ppm)	Sb (ppm)	Sc (ppm)	Sr (ppm)	V (ppm)	Y (ppm)	Zr (ppm)
1071	EFB337	150	-	N	30	N	15	200	300	20	200
"	EFB338	100	-	N	70	N	10	100	300	20	150
1072	CH164	30	20	-	200	G100	G5	G100	100	10	5
1073	CH165	20	G20	-	30	G100	G5	500	50	10	G10
1074	M021	10	G20	-	10	G100	G5	G100	20	G10	G10
1098	EFB316	100	-	N	70	N	20	100	150	30	150
1099	EFB317	100	-	N	70	N	10	200	100	15	70
"	EBF318	100	-	N	50	N	7	100	100	15	200
"	EFB319	200	-	N	20	N	10	700	100	15	150
1100	EFB314	70	-	N	30	N	10	150	70	20	70
"	EFB315	100	-	N	30	N	10	100	100	20	100
"	HS829	150	300	-	50	G100	10	200	500	20	500
1101	AMS894	50	-	-	100	-	-	-	100	20	-
"	AMS895	20	-	-	70	-	-	-	50	20	-
"	EFB313	100	-	N	50	N	10	200	70	15	70
"	HS828	50	500	-	3,000	70	G5	3,000	200	G200	150
1102	HS796	50	20	-	7	G100	G5	G100	100	10	70
"	HS798	30	50	N	G5	G100	G5	G100	70	20	500
1103	HS795	20	30	-	G5	G100	G5	G100	30	15	300
"	HS799	N	N	N	N	N	N	200	N	N	N
1123	M962	30	N	N	5	N	N	N	G10	G10	N
1124	M964	70	20	N	10	N	10	300	30	15	30
1125	M965	10	G20	N	N	N	N	N	10	G10	N
1126	M83	N	N	N	N	N	N	200	N	N	N
1150	M963	15	N	N	G5	N	N	N	G10	G10	N
1151	M966	20	30	N	G5	N	7	N	70	15	G1,000
1152	M85	N	N	N	N	N	N	G100	N	N	N
1153	EFB269	150	-	N	50	N	7	100	100	20	150
1154	M93	N	N	N	N	N	N	G100	N	N	N
1155	M94	N	N	N	N	N	N	700	N	N	N
1185	M961	30	N	N	10	N	N	N	10	G10	N
1186	B849	30	20	N	30	N	10	300	100	10	70
"	B850	30	70	N	G5	N	10	G100	100	G10	200
1187	B848	15	N	N	N	N	N	N	G10	N	N
"	M84	N	N	N	N	N	N	G100	N	N	N
1208	M960	30	30	N	G5	N	5	N	150	10	500

Map No.	USGS Sample No.	Fe %	Mg %	Ca %	Ti %	Mn (ppm)	As (ppm)	B (ppm)	Be (ppm)	Bi (ppm)	Cd (ppm)	Co (ppm)
1209	M957	7.00	2.00	G20.00	0.500	1,000	N	200	1.5	N	N	7
1210	EFB320	3.00	1.00	1.00	0.500	300	N	200	5.0	N	N	15
"	B844	1.00	0.50	5.00	0.100	500	N	50	N	N	N	N
"	B845	2.00	1.50	20.00	0.100	G5,000	N	N	N	N	N	G5
"	B846	1.50	0.50	5.00	0.150	1,000	N	20	G1.0	N	N	G5
1211	M87	G0.05	0.50	20.00	0.010	N	N	N	N	N	N	N
"	M88	N	0.50	20.00	0.007	N	N	N	N	N	N	N
1212	M86	15.00	7.00	15.00	0.300	150	N	G10	2.0	N	N	N
"	M89	10.00	7.00	15.00	0.100	500	N	15	5.0	N	N	G5
1213	M90	2.00	1.00	15.00	0.150	500	N	30	1.5	N	N	G5
"	M91	1.50	5.00	20.00	0.150	100	N	30	G1.0	N	N	7
"	M92	G0.05	7.00	20.00	0.010	N	N	N	N	N	N	N
1233	EFB340	1.50	0.30	0.05	0.500	15	N	200	5.0	N	N	G5
1234	M958	0.50	2.00	20.00	0.030	200	N	N	N	N	N	N
"	M959	5.00	1.00	1.00	0.300	700	N	15	G1.0	N	N	10
1235	M98	N	10.00	20.00	0.200	500	N	G10	5.0	N	N	20
1255	EFB339	2.00	2.00	3.00	0.300	300	N	70	5.0	N	N	7
1256	EFB342	2.00	1.00	0.50	0.500	200	N	150	5.0	N	N	10
1257	EFB341	5.00	0.70	0.30	0.700	1,000	N	100	5.0	N	N	20
1258	EFB321	0.20	10.00	10.00	0.030	100	N	30	5.0	N	N	N
"	EFB322	0.07	0.70	20.00	0.010	50	N	G10	5.0	N	N	N
1278	M100	20.00	10.00	20.00	0.150	50	N	50	2.0	N	N	15
1296	M99	0.15	0.50	L20.00	0.015	300	N	N	N	N	N	N
1312	EFB323	3.00	1.50	15.00	0.300	1,000	N	100	5.0	N	N	10
1327	EFB324	5.00	1.00	0.30	0.700	500	N	200	5.0	N	N	20
1328	B834	2.00	1.00	3.00	0.200	1,000	N	20	1.0	N	N	10
3143	B836	3.00	1.00	15.00	0.100	G5,000	N	10	G1.0	N	N	7
1394	B843	G0.05	0.50	20.00	0.010	30	N	N	N	N	N	N
1395	M943	0.70	2.00	G20.00	0.030	1,000	N	N	N	N	N	N
1415	EFB326	3.00	0.50	G0.05	0.500	100	N	200	5.0	N	N	10
"	EFB327	1.50	0.70	G0.05	0.500	30	N	200	5.0	N	N	5
1416	B841	0.70	0.15	0.30	0.500	100	N	50	G1.0	N	N	N
1429	EFB325	3.00	1.00	0.50	0.500	300	N	200	5.0	N	N	20

Map No.	USGS Sample No.	Cu (ppm)	Pb (ppm)	Zn (ppm)	Mo (ppm)	Ag (ppm)	Au (ppm)	Au (ppm)[1]	W (ppm)	Sn (ppm)	Hg (ppm)[2]	Ba (ppm)
1209	MF957	30	G10	N	N	N	N	N	N	N	0.08	1,500
1210	EFB320	20	30	N	N	N	N	-	N	N	G0.02	500
"	B844	G5	N	N	N	N	N	N	N	N	0.04	100
"	B845	15	10	N	N	N	N	N	N	N	0.10	1,000
"	B846	7	10	N	N	N	N	N	N	N	0.06	150
1211	M87	5	N	N	N	N	N	N	N	N	0.02	N
"	M88	5	N	N	N	N	N	N	N	N	0.02	N
1212	M86	30	N	N	N	N	N	N	N	N	0.13	1,500
"	M89	50	G10	G200	15	N	N	N	N	N	0.35	200
1213	M90	20	G10	N	N	N	N	N	N	N	0.06	100
"	M91	20	N	N	N	N	N	N	N	N	0.14	70
"	M92	N	N	N	N	N	N	N	N	N	G0.02	N
1233	ERB340	15	20	N	N	N	N	-	N	N	0.12	700
1234	M958	5	N	N	N	N	N	N	N	N	0.04	200
"	M959	15	G10	N	N	N	N	N	N	N	0.10	700
1235	M98	30	30	300	N	N	N	N	N	N	0.12	300
1255	EFB339	20	20	N	N	N	N	-	N	N	0.02	700
1256	EFB342	20	20	N	N	N	N	-	N	N	0.10	700
1257	EFB341	50	30	N	N	N	N	-	N	N	0.04	700
1258	EFB321	5	N	N	N	N	N	-	N	N	N	20
"	EFB322	7	N	N	N	N	N	-	N	N	0.02	G20
1278	M100	150	50	500	20	7.0	N	N	N	N	0.50	5,000
1296	M99	N	N	N	N	N	N	N	N	N	0.04	N
1312	EFB323	20	15	N	N	N	N	-	N	N	N	500
1327	EFB324	30	20	N	N	N	N	-	N	N	0.04	500
1328	B834	70	10	N	N	N	N	N	N	N	0.02	300
1343	B836	30	15	N	N	N	N	N	N	N	0.02	300
1394	B843	5	N	N	N	N	N	N	N	N	0.02	N
1395	M943	5	10	N	N	N	N	N	N	N	0.05	50
1415	EFB326	30	30	N	G5	0.5	N	-	N	N	0.12	1,000
"	EFB327	20	20	N	N	N	N	-	N	N	0.02	700
1416	B841	50	N	N	N	N	N	N	N	N	0.04	150
1429	EFB325	30	30	N	N	N	N	-	N	N	G0.02	500

Map No.	USGS Sample No.	Cr (ppm)	La (ppm)	Nb (ppm)	Ni (ppm)	Sb (ppm)	Sc (ppm)	Sr (ppm)	V (ppm)	Y (ppm)	Zr (ppm)
1209	M957	50	G20	N	20	N	N	G300	70	15	200
1210	EFB320	150	-	N	70	N	15	100	100	20	100
"	B844	20	N	N	7	N	G5	100	50	10	70
"	B845	30	30	N	15	N	5	500	30	20	30
"	B846	20	G20	N	15	N	G5	100	50	10	50
1211	M87	N	N	N	N	N	N	1,000	N	N	N
"	M88	N	N	N	N	N	N	700	N	N	N
1212	M86	200	N	N	N	N	N	G100	150	20	N
"	M89	100	N	N	70	N	G5	N	150	100	N
1213	M90	70	G20	N	10	N	5	G150	70	20	300
"	M91	30	G20	N	30	N	G5	200	30	N	N
"	M92	N	N	N	N	N	N	N	N	N	N
1233	EFB340	100	-	N	7	N	10	200	200	15	100
1234	M958	15	N	N	G5	N	G5	G10	G10	G10	20
"	M959	30	20	N	20	N	10	100	100	10	100
1235	M98	300	150	N	50	N	N	300	300	100	G200
1255	EFB339	50	-	N	20	N	7	200	100	15	100
1256	EFB342	100	-	N	50	N	7	100	200	20	150
1257	EFB341	150	-	N	70	N	20	150	200	30	150
1258	EFB321	10	-	N	5	N	N	100	15	G10	G10
"	EFB322	50	-	N	7	N	N	500	10	10	N
1278	M100	150	100	N	300	N	G10	700	50	100	N
1296	M99	N	N	N	N	N	N	100	N	N	N
1312	EFB323	70	-	N	20	N	7	200	50	20	70
1327	EFB324	200	-	N	70	N	15	100	150	20	70
1328	B834	30	G20	N	30	N	15	300	100	15	70
1343	B836	50	N	N	20	N	7	N	100	15	50
1394	B843	N	N	N	N	N	N	300	30	10	N
1395	M943	N	N	N	G5	N	N	300	30	N	N
1415	EFB326	100	-	N	50	N	15	100	200	20	150
"	EFB327	100	-	N	30	N	15	100	200	15	100
1416	B841	70	30	N	5	N	7	N	50	30	100
1429	EFB325	200	-	N	70	N	10	100	150	20	100