PHASE I

Geology, Energy, and Mineral (GEM)
Resource Evaluation of Elkhorn
GRA, Montana, including the Elkhorn
(075-114) Wilderness Study Area
(WSA) and the Black Sage (075-115) WSA

Bureau of Land Management

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

By:

Greg Fernette
William Jones

Contributors:

C.G. Bigelow
R.S. Fredericksen
J. Bressler
D. Blackwell
G. Webster
E.F. Evoy

ANCHORAGE, ALASKA
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WGM INC.
MINING AND GEOLOGICAL CONSULTANTS

EXECUTIVE SUMMARY

The Elkhorn Geology, Energy, Mineral Resource Area (GRA) is located in west-central Montana in the Elkhorn Mountains between Butte and Helena. The GRA contains two BLM Wilderness Study Areas (WSAs), the Elkhorn WSA (075-114) and the Black Sage WSA (075-115). There have been numerous geologic, geochemical, and geophysical studies in the Elkhorn region by governmental agencies, universities, and the private sector; thus, a large amount of data exists upon which to base a resource assessment.

The Elkhorn GRA is within the Montana Thrust belt, a region of extensive thrust faulting, block faulting, and folding. The area is underlain by shelf facies rock units of Precambrian, Paleozoic, and Mesozoic age. The Cretaceous Boulder batholith intrudes these older rocks. A pile of volcanics related to the batholith and in part coevial, the Elkhorn Mountains Volcanics, overlies the older rocks.

A large number of mines, mineral deposits, prospects, occurrences and geochemical anomalies are found within the northern part of the Elkhorn GRA, including the Elkhorn WSA (075-114). The area is well mineralized and has been the scene of considerable past mining activity as well as modern-day exploration. Mineral production has been primarily lead, zinc, copper, gold, and silver. The land classification for the two WSAs is summarized in the accompanying table.

SUMMARY OF GEM RESOURCES LAND

CLASSIFICATION FOR THE ELKHORN GRA

	Elkhorn 075-114	Black Sage 075-115
Locatable Resources:		
a. Metallic Minerals	4D	2C
b. Uranium and Thorium	2C	2C
c. Non-Metallic Minerals	2C	2B
Leaseable Resources:		
a. Oil and Gas	1C	3C
b. Low Temperature Geothermal	1B	2B
High Temperature Geothermal	1B	1B/3B
c. Sodium and Potassium	1D	2C
d. Other	1D	2C
Saleable Resources	2C	2C

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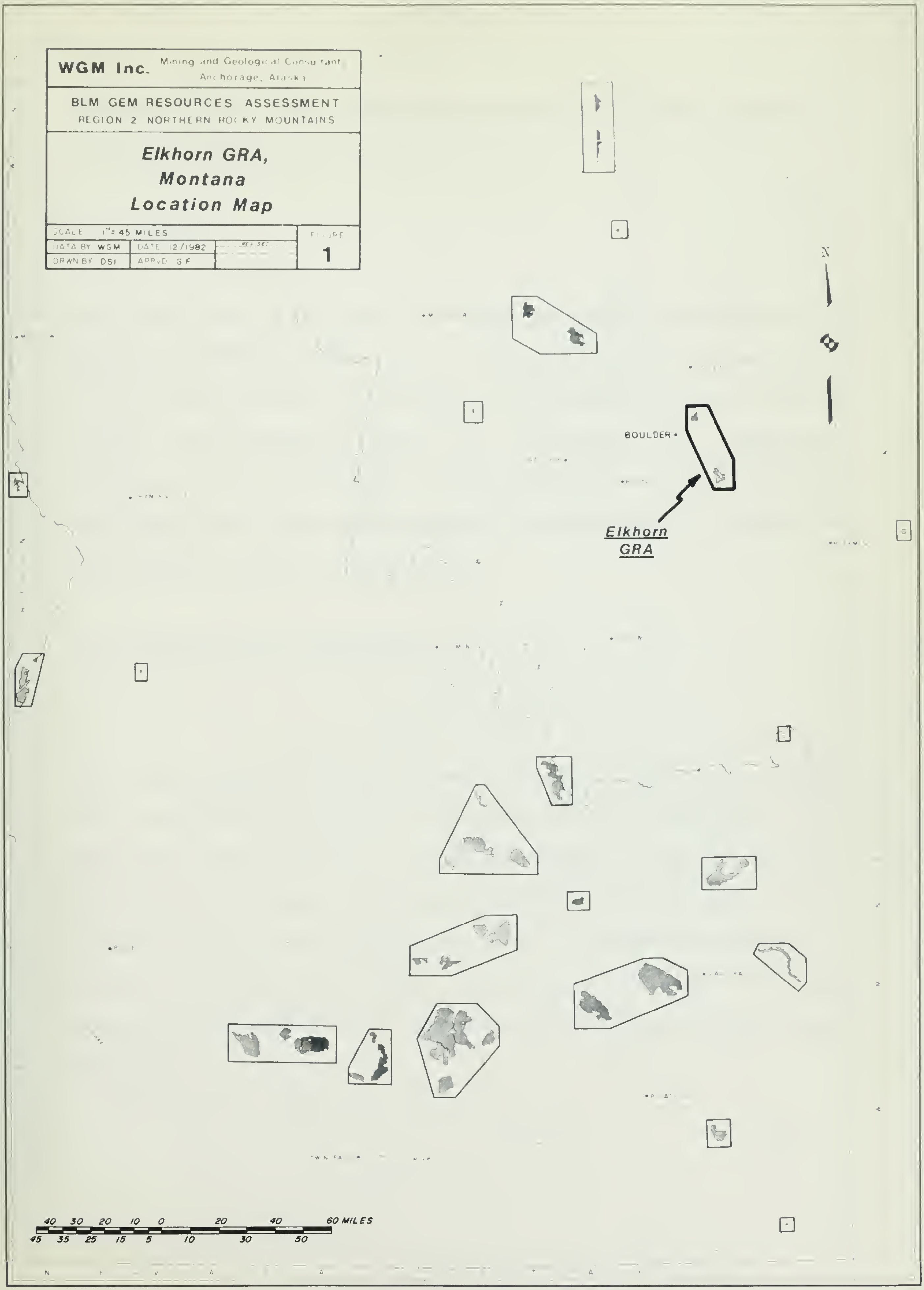
ELKHORN GRA, MONTANA

1.0 INTRODUCTION

The Bureau of Land Management has adopted a two-phase procedure for the integration of geological, energy and minerals (GEM) resources data into the suitable/non-suitable decision-making process for Wilderness Study 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


WGM Inc.
Mining and Geological Consultant
Anchorage, Alaska
BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS
Elkhorn GRA,
Montana
Location Map
SCALE 1"= 45 MILES
DATA BY WGM
DATE 12/1982
DRWN BY DSI
APRVD GF
FIGURE
1
BOULDER
Elkhorn GRA
40 30 20 10 0 20 40 60 MILES
45 35 25 15 5 10 30 50

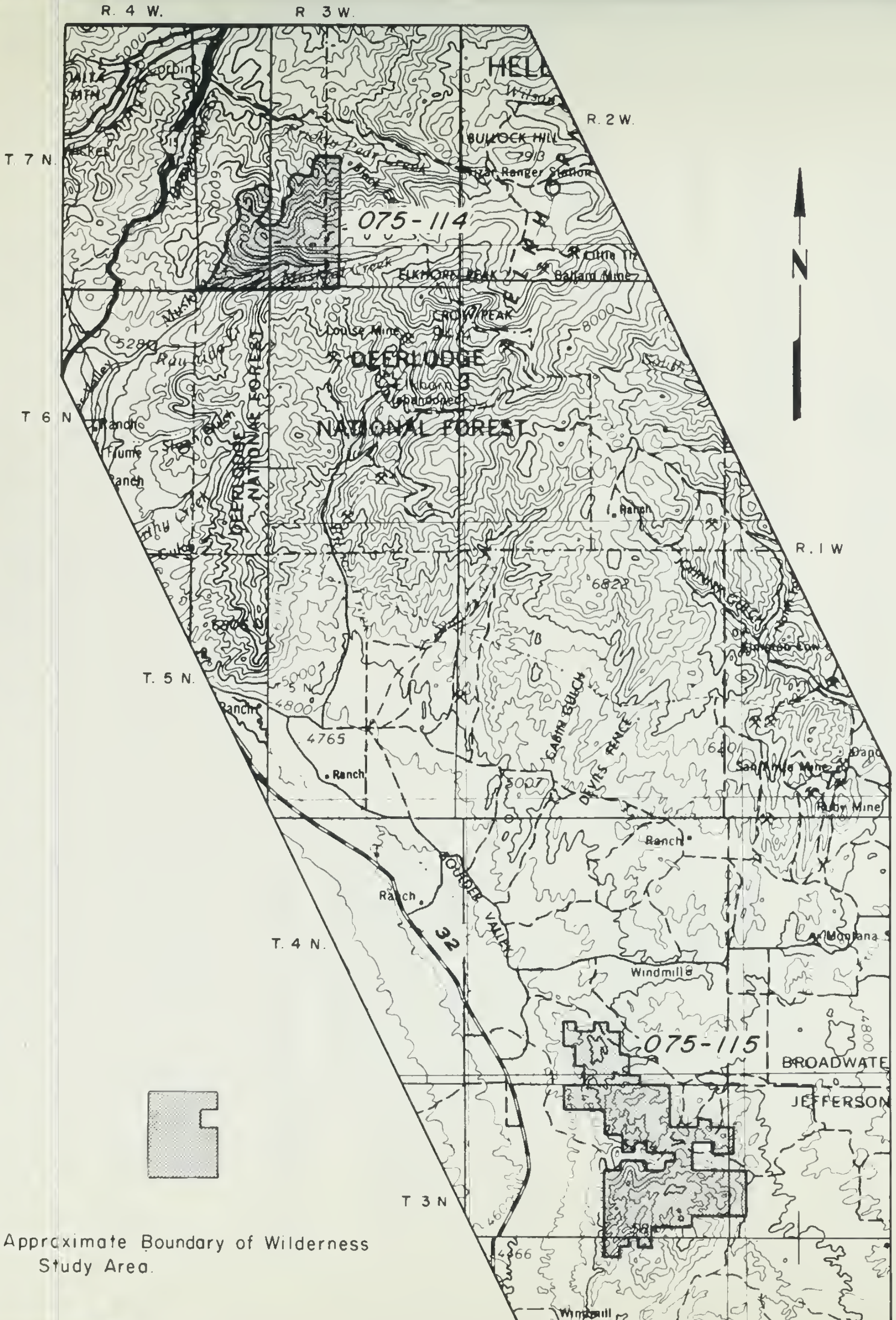
totalling 583,182 acres. The WSA were grouped into 22 GRAs for purposes of the Phase I GEM resources evaluation.

1.1 Location

The Elkhorn GRA is in Jefferson and Broadwater Counties, immediately east of the town of Boulder, Montana (Fig. 1). The area is situated between 49°50' to 46°24' North latitude and 112°60' to 111°45' West longitude in Ts.3-7N., Rs.1-4W. It encompasses an area of more than 241,000 acres. Administratively it is within the Headwaters Resource Area of the Butte BLM district. The Elkhorn GRA includes two Wilderness Study Areas (WSAs): Elkhorn (075-114) and Black Sage (075-115) (Fig. 2).

1.2 Population and Infrastructure

Butte, approximately 25 miles southwest of Boulder, and Helena, approximately 25 miles north of Boulder, are the major cities in the region. The Burlington Northern Railroad and Interstate Highway 15, the major artery between Butte and Helena, pass through the Elkhorn GRA just west of the Elkhorn WSA. The southern portion of the GRA is accessible via Montana Highway 281 North from the Cardwell interchange on Interstate 90. Numerous secondary roads and jeep trails extend into the GRA from these major highways.



Approximate Boundary of Wilderness Study Area.

BLM Wilderness Study Areas Included in the Elkhorn GRA.

WSA	NAME	ACREAGE
075 114	Elkhorn	3,585
075-115	Black Sage	5,976

5 4 3 2 1 0 3 6 Miles

5 4 3 2 1 0 5 10 Kilometers

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BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Elkhorn GRA, Montana

Topographic Map

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

1.3 Basis of the Report

This report is based on a review, compilation and analysis of available published and unpublished data on the geology, energy and mineral resources of the Elkhorn GRA. The area has a long mining history and consequently has been the subject of numerous detailed geologic studies. The Elkhorn WSA is adjacent to a Forest Service WSA which was examined by the U.S. Geological Survey and U.S. Bureau of Mines in 1976 and 1977. Both the Butte and White Sulfur Springs quadrangles are covered by NURE reports. Mining claim and oil and gas lease information were compiled from BLM land records. Information contributed by private industry was particularly valuable in the oil and gas evaluation. Areal photographs and LANDSAT images of the GRA were also reviewed. In addition, a brief field examination was made of the Elkhorn WSA in October 1982 by WGM geologists.

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

1.4 Acknowledgements

We would like to thank 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 discourse on the areas. 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.

In particular, we would like to thank Irvin Kranzler and John Warne, petroleum geologists from Billings, for allowing us use to their report on

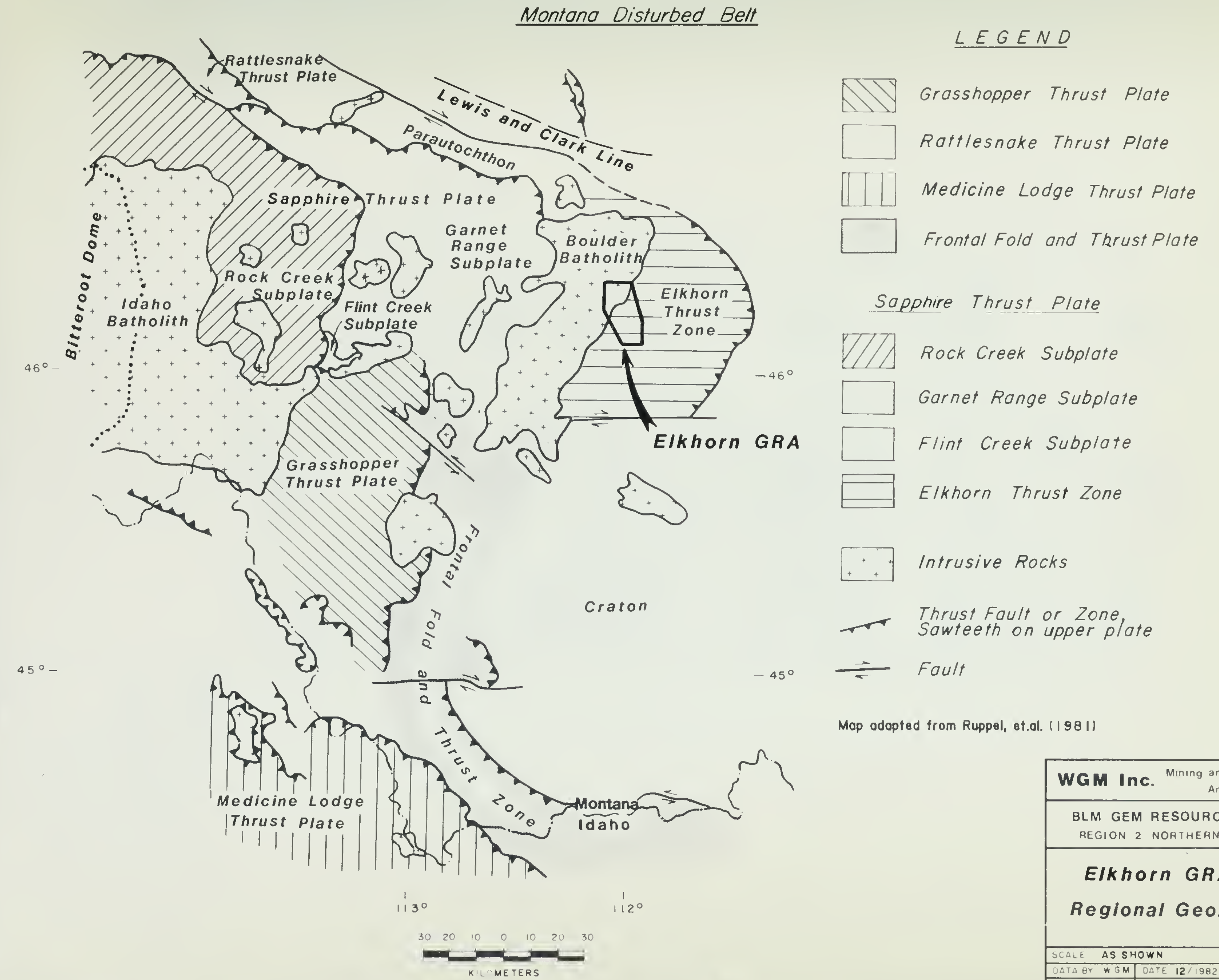
the oil and gas potential of the Devils Fence Anticline in this evaluation. In addition, Mr. Kranzler took the time to discuss the area with WGM personnel. We would also like to thank Mr. Herb Black, geophysicist with SOHIO Petroleum for providing us with seismic data on the area.

2.0 GEOLOGY

2.1 Introduction

The Elkhorn GRA encompasses the western and southern parts of the Elkhorn Mountains. The northern part of the GRA is underlain by granitic rocks of the Boulder batholith and related satellite plutons whereas the southern part of the GRA is underlain by Precambrian (older than 600 m.y.) to Mesozoic (230-65 m.y.) sedimentary rocks and Cretaceous (141-65 m.y.) volcanics (Figs. 4 and 5). Structurally the area is within the eastern margin of the Rocky Mountain Thrust belt (Fig. 3). The area is highly mineralized and has been the scene of considerable past mining activity as well as modern day exploration. The mineral deposits consist of vein, skarn, breccia-pipe and porphyry-type deposits in and associated with the plutonic rocks of the Boulder batholith.

Numerous detailed U.S. Geological Survey investigations, most with geologic mapping at a scale of 1:48,000, cover most of the Elkhorn GRA and much of the surrounding region. Results of these studies have been published by Becraft et al. (1963); Becraft and Pickney (1961); Freeman (1958); Klepper et al. (1957, 1971); Knopf (1963); Pinckney and Becraft (1961); Robinson (1963); Ruppel (1961, 1963): Smedes (1966); and Smedes et al. (1962). The work by Smedes (1966) included a study of the igneous petrology of rocks belonging to the Boulder batholith. Gravity and magnetic data from the Elkhorn region have been published by Kinoshita (1964, 1961) and Geodata International (1979).



Map adapted from Ruppel, et.al. (1981)

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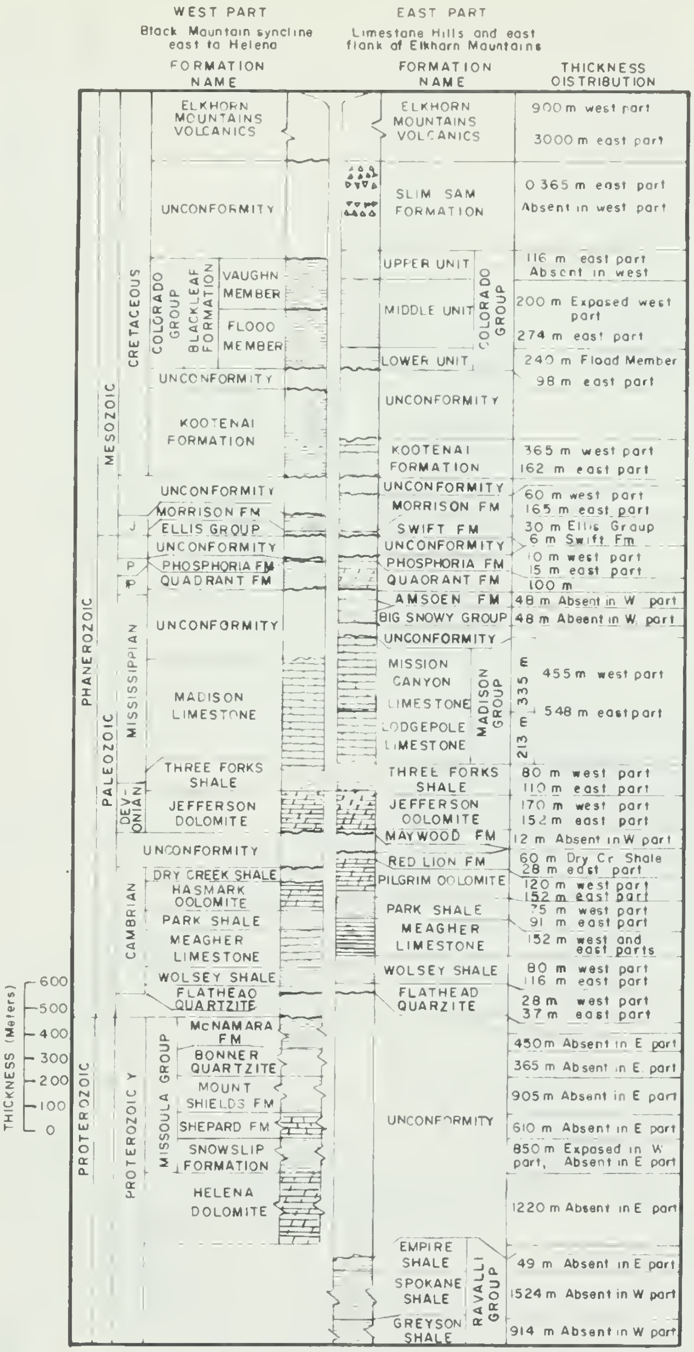
BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Elkhorn GRA, Montana
Regional Geologic Setting

SCALE AS SHOWN			FIGURE 3
DATA BY W G M	DATE 12/1982	REVISED	
DRWN BY DS1	APRVD G.F		



Data by: Ruppel, et. al, 1981

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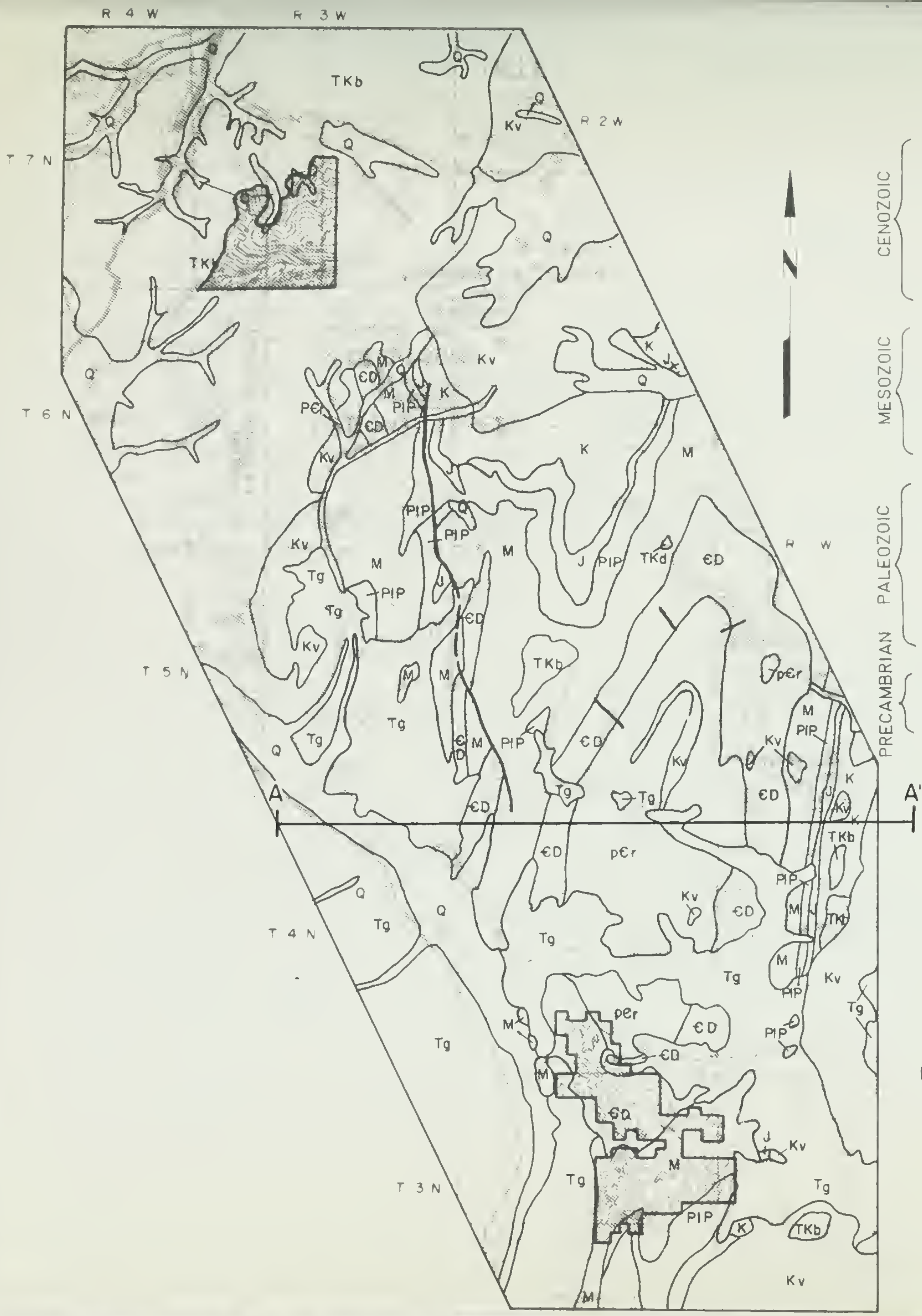
Anchorage, Alaska

BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Elkhorn GRA, Montana

Stratigraphic Column of the Elkhorn Thrust Zone

SCALE			FIGURE
DATA BY	DATE 1/1983	REV. SEC.	4
DRWN BY DSI	APPR. G.F.		



EXPLANATION

Sedimentary | **Igneous**

		Sedimentary		Igneous		
CENOZOIC	Q	alluvium, colluvium, and glacial deposits			Pleistocene	Quaternary
	Tg	valley fill clastics				Tertiary
			TKb	Baulder batholith and granitic intrusives of similar age		Cretaceous
MESOZOIC	K	Koatenai, Colorado, and Slim Slam Formations	Kv	Elkhorn Mountains volcanics and related rocks		
	J	Morrison and Swift Formations				Jurassic
PALEOZOIC	PIP	Phosphoria, Quadrant and Amsden Formations				Pennsylvanian-Permian
	M	Madison Group and Big Snawy Formation				Mississippian
	ЄD	Jefferson, Maywood, Three Forks, Red Lion, Snowy Range, Pilgrim, Park, Meagher, Wolsey, and Flathead Formations				Cambro-Devonian
PRECAMBRIAN	PЄr	Ravalli Group and equivalent (Belt) including Empire, Spokane and Greyson Formations				Precambrian

Approximate Boundory of Wilderness Study Area

5 4 3 2 1 0 3 6 Miles

5 4 3 2 1 0 5 10 Kilometers

A — A'
Line of Geologic Cross Section

Data by: McClernan, 1980
Robinson, 1963

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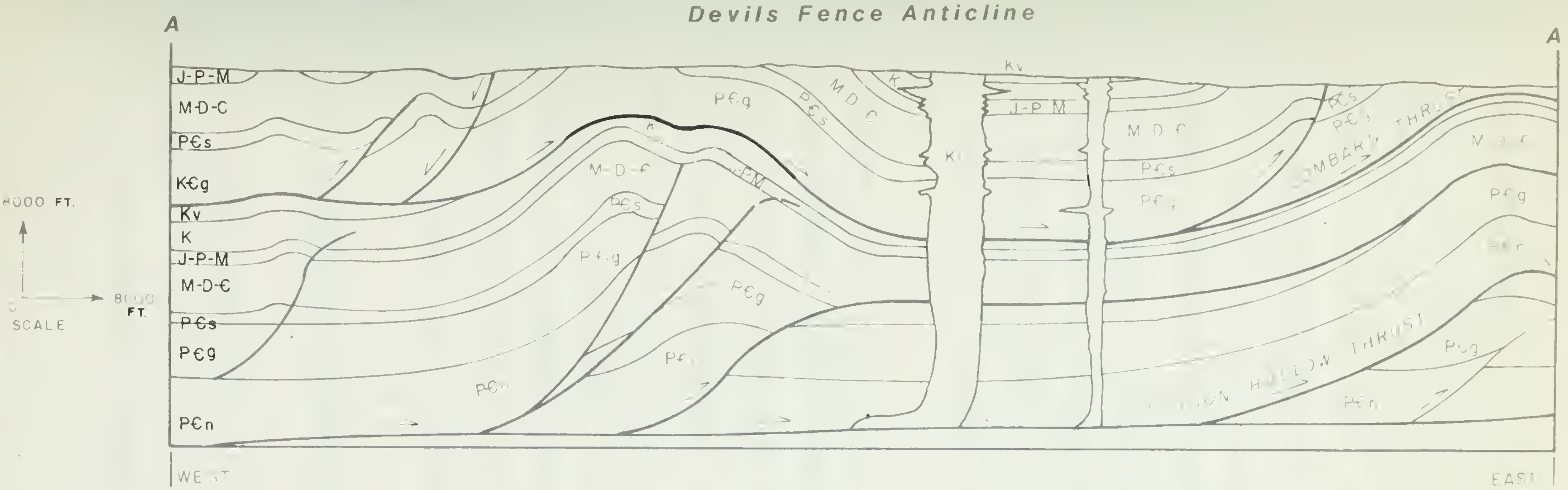
REGION 2 NORTHERN ROCKY MOUNTAINS

Elkhorn GRA, Montana

Geologic Map

SCALE 1:250000
DATE 1/1983
DRAWN BY DSI
G F

5

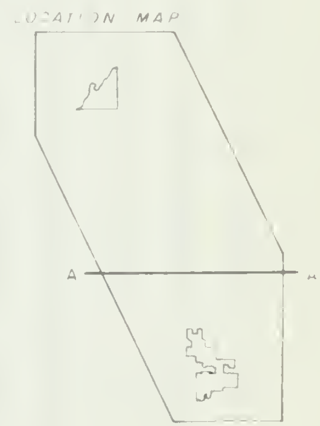


Q-T	Quaternary and Tertiary Sediments
Tv	Tertiary volcanic rocks
K	Cretaceous sediments
Kv	Cretaceous volcanic rocks and sediments rich in volcanic clasts
M-D C	Madison, Devonian, Cambrian
Ki	Cretaceous igneous intrusive rocks

Precambrian Belt Group Sediments

P€m	Missoula
P€s	Spokane
P€g	Greyson
P€n	Newland
P€xln	Crystalline basement

Data by Kranzler and Warne, 1978



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BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Elkhorn GRA, Montana

Geologic Cross Section A - A'

AS SHOWN

6

2.2 Physiography

The Elkhorn GRA is in the Northern Rocky Mountains physiographic province (Hunt, 1974; Alden, 1954). The Elkhorn Mountains are the predominant physiographic and topographic feature in the area. The northern part of the GRA consists of rugged glaciated mountains which diminish southward into low hills. The mountains are bounded by the valleys of Prickly Pear Creek, Beavertown Creek and the Boulder River to the west and by the valley of the Missouri River to the south, east and north. Elevations vary from over 9,400 feet on Crow Peak in the north-central part of the GRA to less than 4,500 feet at the southwest edge of the area in the Boulder Valley (Fig. 2).

Streams in the northern half of the GRA have a crude radial pattern centered around Elkhorn and Crow Peaks. The northeast side of these peaks show evidence of glaciation with well developed cirques centered on the tarns of Hidden and Glenwood Lakes. The drainage pattern in the southern part of the GRA consists of a collection of intermittent streams connecting to a few permanent streams which flow into the Boulder Valley. The low hills of the southern Elkhorn Mountains are underlain by folded sedimentary rocks which produce alternating hills and valleys that coincide with more resistant and less resistant rocks, respectively.

2.3 Rock Units - Lithology and Stratigraphy

The oldest rocks exposed in the Elkhorn GRA belong to the Precambrian Belt Supergroup. The Belt rocks in the GRA comprise a sequence of argillaceous rocks and sandstones belonging to three formations: (1) the Greyson Shale,

(2) the Spokane Shale, and (3) the Empire Shale. The Greyson Shale, the oldest unit, is an alternating sequence of drab mudstone or shale and light-colored sandstone or quartzite with a few thin beds of limestone in the upper part (Klepper et al., 1957). The base of the Greyson is not exposed in the GRA, but it is at least 1,500 feet thick. Thin lenticular limestone beds containing fossil algae occur in the 50 to 200 foot thick transition interval with the overlying Spokane Formation (Fenton and Fenton, 1937). The Spokane is a 1,700 foot-thick sequence of grayish-red mudstone and shale with subordinant beds of sandstone. Locally the rocks are green or greenish-gray colored. The Spokane Shale grades upward into and intertongues with the Empire Shale. The two formations are lithologically distinct but are at least partly equivalent in age (Klepper et al., 1957). The Empire is 800 feet thick on the north end of the Devils Fence Anticline but is absent along the south flanks of the fold. The Empire is composed of gray, greenish-gray and brown distinctly laminated, blocky-fracturing siliceous mudstone or argillite with subordinant interbeds of quartzitic sandstone and shale. The Belt Supergroup is 1020-1135 m.y. old based on potassium-argon and rubidium-strontium age determinations from samples of the upper Spokane and Empire Shales (Obradovich and Peterman, 1968).

The Precambrian Belt Series is unconformably overlain by the Middle Cambrian (542-515 m.y.) Flathead Quartzite which extends over much of Montana and Wyoming. The unconformity between the Cambrian and Precambrian is regional in extent (Deiss, 1935). The Flathead is composed mainly of homogeneous, well-sorted, medium- to thick-cross bedded vitreous quartzite. Thin discontinuous pebble zones are sparsely present throughout the formation,

but are most common near the base. The Flathead forms conspicuous outcrops and is a key marker unit. The average thickness is about 100 feet (Klepper et al., 1957).

The Wolsey Shale conformably overlies the Flathead quartzite. The formation is 360 to 380 feet thick and is composed of two predominant rock types: (1) a lower greenish-gray and drab shale with interbeds of sandstone and impure limestone which is commonly micaceous and occasionally glauconite-bearing, and (2) an upper interbedded argillaceous, crudely laminated gray limestone and calcareous greenish-gray mudstone or shale. The Wolsey weathers recessively and usually occurs in vallies (Klepper et al., 1957). About 8 miles south of the Elkhorn GRA in sec. 11, T.1N., R.1W., many fragments of a characteristic Middle Cambrian trilobite, Ehmania, have been found in a limestone bed about 200 feet below the top of the Wolsey. Twelve miles south of the GRA, (sec. 8, T.1S., R.1W.) another limestone about 30 feet below the top of the Wolsey yielded a definitive Middle Cambrian fauna (Robinson, 1963).

The Meagher Limestone conformably overlies the Wolsey, although the contact is typically poorly exposed. The Meagher is composed of an upper and lower unit of mainly well bedded aphanitic to medium-grained limestone and finely crystalline dolomite separated by a distinctive unit of gray thick-bedded limestone with thin interbeds of siliceous dolomite. In the upper and lower units the limestone is medium-gray in color whereas the dolomite is yellow-brown giving the rocks a characteristic color banding. Thickness ranges from 490 to 570 feet (Klepper et al., 1957). A Middle Cambrian age is well established by fossil collections from several horizons and locales (Robinson, 1963).

The Park Shale conformably overlies the Meagher Limestone. It is a waxy-appearing olive-gray, and gray and light-brown shale with minor amounts of thin-bedded ribbony argillaceous limestone, siltstone and silty fine-grained sandstone. The Park Shale ranges between 200 to 290 feet thick. The formation weathers recessively and outcrops are rare (Klepper et al., 1957). Sparse fossil fauna from neighboring areas indicate a latest Middle Cambrian age for the Park (Robinson, 1963).

The Park Shale is in sharp but conformable contact with the overlying Pilgrim Dolomite. The Pilgrim consists of: (1) a lower unit, 50 feet thick, of mottled light-gray and dark-gray crystalline and oolitic dolomite with sporadic beds of intraformational conglomerate, (2) a middle unit, 175 feet thick, of light- and medium-gray crystalline limestone with irregular ribbons of yellowish-gray silty dolomite, and (3) an upper unit, 150-225 feet thick, of light-gray medium-crystalline to sugary massive to indistinctly bedded dolomite (Klepper et al., 1957). Some oolitic limestone beds in the middle unit contain the trilobites Cedaria and Kormagnostus which are characteristic of the Upper Cambrian (515-500 m.y.).

In southwestern Montana, a sequence of varicolored argillaceous and impure carbonate rocks ranging from 30 feet to about 200 feet in thickness, is present between the Pilgrim Dolomite and the Devonian (395-345 m.y.) Jefferson Dolomite. These rocks were considered by Sloss and Laird (1947) to be wholly Late Cambrian, but they are now known to be partly Late Cambrian and partly Devonian (Klepper et al., 1957). Although these rocks are broken into two units for descriptive purposes, they are not separated

for mapping purposes in the southern Elkhorn Mountains due to poor exposure and lithologic similarity.

The uppermost Cambrian unit present in the Elkhorn GRA is the Red Lion Formation. This unit consists of predominately red and yellowish-brown argillaceous rocks. A distinct gray limestone with conspicuous thin siliceous laminae is present at the top. This lamianted limestone is strikingly similar to the laminated limestone member of the Red Lion Formation in the Philipsburg Quadrangle (Klepper et al., 1957). In the eastern part of the Elkhorn region the clastic Dry Creek Shale replaces the limestone-rich Red Lion (Ruppel et al., 1981). The Red Lion is poorly exposed and ranges in thickness from 30 to 95 feet. In places it has been entirely removed by pre-Devonian erosion. The laminated limestone bed contains the characteristic Upper Cambrian brachiopod, Billingsella (Klepper et al., 1957). An erosional unconformity separates the Cambrian and Devonian systems over all of western Montana (Sloss and Laird, 1947). The unconformity is poorly exposed in the GRA, and it is difficult to recognize where the laminated limestone at the top of the Red Lion has been eroded (Klepper et al., 1957).

The overlying Denovian Maywood Formation consists of silty dolomite with interbeds of shale, limestone, and sandstone. The beds weather to shades of gray and less commonly, shades of red and orange. The Maywood appears to have a uniform thickness of about 40 feet (Klepper et al., 1957). Brachiopod fossils indicate an early Late Devonian (360-345 m.y.) age. The Maywood has been interpreted as an extensive tidal flat deposit based on studies southwest of the Elkhorn GRA (Meyers, 1980).

The Maywood Formation is overlain by the Late Devonian Jefferson Dolomite. The Jefferson Dolomite consists of dark-gray granular-weathering, well-bedded, fetid dolomite. Minor amounts of dark-gray limestone and medium-gray dolomite are present throughout the unit (Klepper et al., 1957). The Jefferson is usually divided into a lower limestone and an upper dolomite member (Sloss and laird, 1947) but the distinction evident in other areas is not present in the Elkhorn GRA (Klepper et al., 1957). Where intruded by igneous rocks the Jefferson is typically bleached and locally converted to marble. The unit ranges from 620 to 735 feet in thickness. Only poorly preserved coral and crinoid fossils are reported from the Jefferson in the GRA, although it is fossiliferous elsewhere (Klepper et al., 1957). The Jefferson Formation is a potential hydrocarbon reservoir rock (Kranzler and Warne, 1981).

The Three Forks Shale overlies the Jefferson Dolomite and spans the time between the Late Devonian and the Mississippian (345-310 m.y.). The formation consists of interbedded silty carbonate and argillaceous rocks. It is 300 to 375 feet thick but has been thickened and thinned by folding. Upper Devonian fauna from limestone beds in the middle part of the unit are found in sec. 31, T.4N., R.1W. (Klepper et al., 1957).

A thick limestone sequence comprising the Madison Group overlies the Three Forks Shale. The Madison Group consists of a lower unit of thin-bedded limestone, the Lodgepole Limestone, grading upward into a thick-bedded limestone, the Mission Canyon Limestone. The Madison Group underlies extensive areas on the north, east and west flanks of the major domal

structure present in the southern Elkhorn Mountains (Klepper et al., 1957; Fig. 5). The Madison Group rocks are potential reservoir rocks for hydrocarbons (Kranzler and Warner, 1981).

The Lodgepole Limestone consists of medium-gray, thin and distinctly bedded, locally dense limestone. In the lower part of the formation beds average 3 to 4 inches in thickness with a range of 1 inch to 1 foot. Fossiliferous limestone, thin interbeds of yellowish, and rarely reddish, calcareous mudstone are common. The fossiliferous beds characteristically have a fetid odor. In the upper part of the Lodgepole, 2 to 3 foot beds are interspersed with horizons of thinner beds. The formation is 500 to 700 feet thick and outcrops are sparse (Klepper et al., 1957).

The Lodgepole Limestone grades upward into the thickly and indistinctly bedded Mission Canyon Limestone over an interval of 100-200 feet. The Mission Canyon is composed of medium-gray to light-gray crystalline to granular limestone with subordinate more thinly bedded darker gray limestone near the top and bottom. Sparse gray chert nodules occur in the upper half of the formation. Discontinuous beds of coarse, angular, intraformational breccia ranging from 10 to 75 feet thick occur in the upper 200 feet of the unit. Klepper et al. (1957) believe that these breccias formed by solution and subsequent collapse in a karst terrain. The contact with the overlying Amsden Formation is poorly exposed but an erosional unconformity is probably present over a considerble distance (Klepper et al., 1957).

The Amsden Formation is typically 200 to 300 feet thick. The lower half (100 to 150 feet) consists of mudstone and shale with lesser amounts of

argillaceous sandstone. This lower section is generally red or grayish-red but many gray, brown, or yellow beds are present. The medial 50 feet of the Amsden is comprised of medium- and dark-gray, thick-bedded dolomite with some argillaceous partings and fossiliferous interbeds. The uppermost 50 feet of the Amsden is lithologically similar to the lower part of the unit (Klepper et al., 1957).

Gradationally overlying the Amsden is the Quadrant Formation consisting of 225 to 325 feet of interbedded light-colored quartzite sandstone and light-gray sandy dolomite. The sandstone is a well-sorted, well-rounded fine- to medium-grained quartz sand cemented by overgrowths of quartz and locally minor amounts of red iron oxide. The sandy dolomite consists of a matrix of crystalline dolomite surrounding about 30% subangular to sub-rounded very fine-grained quartz sand. The proportion of sandstone increases from subordinant amounts near the base of the formation to nearly 75% of the rock in the upper 100 feet of the formation. The Quadrant is Pennsylvanian (310-280 m.y.) based on correlation with similar rocks elsewhere. Replacement type lead-silver and gold mineralization occurs in carbonate beds in the Quadrant adjacent to intrusive bodies in the east part of the Elkhorn GRA (Klepper et al., 1957).

The contact of the Quadrant with the overlying Permian (280-230 m.y.) Phosphoria Formation is gradational. The Phosphoria consists predominantly of chert and quartzitic sandstone with one or two thin interbeds of phosphate rock. The formation ranges from 45 to 125 feet thick. In the southeastern part of the Elkhorn Mountains, the thickest measured phosphatic section consists of four feet of oolitic beds and phosphatic mudstone

(Klepper et al., 1957). Analyses of phosphatic beds (less than one foot thick) exposed a few miles south of Elkhorn and in Johnny Gulch indicate a tri-calcium phosphate content of 25% and 57% respectively (Condit et al., 1928). Both the thickness and the phosphate content of the formation decrease to north and northeast in the southern part of the Elkhorn Mountain. The top of the Phosphoria is marked by a widespread beveled erosion surface (Condit, 1918) which is not strongly evident in the GRA due to a lack of local relief during preJurassic erosion (Klepper et al., 1957). The unconformity is indicated however by the absence of Triassic rocks in the area and the presence of a thin (up to 3 feet thick) chert pebble conglomerate at the base of the overlying Late Jurassic (158-141 m.y.) Swift Formation.

The Swift Formation consists of an inconspicuous unit of marine sandstone 25 to 30 feet thick. It is composed of punky, grayish-brown calcareous sandstone speckled with grains of black chert and scattered grains of limonite. Broken pelycpod shells are common in the lower part of the unit. The unit is too thin to be mapped separately; thus, it is included with the conformably overlying Morrison Formation as a single map unit (Klepper, 1957).

The Morrison Formation is a sequence of varicolored shales, mudstones, and siltstones with sporadic thin beds of aphanitic limestone and fine-grained argillaceous sandstone. Many argillaceous beds are calcareous. It ranges in thickness between 400 and 800 feet. The formation is poorly exposed in the southern Elkhorn Mountains and the details of its stratigraphy are not well known (Klepper et al., 1957).

The boundary between the Late Jurassic Morrison and the overlying Early Cretaceous (141-100 m.y.) Kootenai Formation is an erosional unconformtiy throughout northern Montana (Cobban, 1945; Brown, 1946), but in the southern Elkhorn Mountains, if present, has not been recognized and the boundary is arbitrarily placed at the top of a unit of dark-gray, and sparsely lignitic, shale (Klepper et al., 1957). This shale is probably equivalent to carbonaceous beds at the top of the Morrison farther north (Cobban, 1945). The non-marine Kootenai Formation consists of a basal "pepper-and-salt" sandstone unit, a middle red and green shale and siltstone unit, and a upper gray limestone unit. The lower sandstone unit is 100 to 200 feet thick and consists of cross-bedded, chert-rich sandstone and local thin lenses of pebble conglomerate, and interbedded shale and mudstone. The middle unit is 200 to 300 feet of mixed blocky siltstone and fissile shale with common concretions of very fine-grained, almost lithographic limestone. The upper unit is a 10 to 30 foot-thick bed of fetid fresh water limestone overlain by 5 to 60 feet of drab-colored mudstone and shale. In total, the Kootenai ranges from 400 to 700 feet in thickness (Klepper, 1957).

The Kootenai is overlain, probably with slight erosional unconformity by the Colorado Formation. In the southern Elkhorn Mountains the Colorado is not accorded Group status, but it is subdivided into three mappable members: (1) a lower black shale unit, (2) a middle sandstone and siliceous mudstone unit and (3) an upper black unit (Klepper et al., 1957; Smedes, 1963). Correlation of the Colorado Formation with a reference section for the western U.S. indicates that the Colorado Formation spans Early Cretaceous and Late Cretaceous (100-65 m.y.) time (Klepper et al., 1957).

The lower black shale unit consists of a basal yellowish gray weathering fine-grained quartz sandstone about 15 feet thick. The basal sandstone is correlative with the Fall River Sandstone elsewhere in the western interior U.S. (Klepper et al., 1957). A drab and olive-gray blocky siltstone and very fine-grained sandstone succeeds the basal bed. The siltstone and sandstone are overlain by rusty-weathering very dark-gray or black shale with a few interbeds of siltstone and very fine-grained sandstone, that grades upward into dark-gray carbonaceous, partly limonitic, speckled and slightly mottled fine-grained sandstone with some interbeds of black shale. Total thickness of the lower black shale unit ranges from 215 to 325 feet (Klepper et al., 1957).

The medial siliceous mudstone and sandstone unit is an intertongued nonmarine and marine sandstone, mudstone and siliceous mudstone beds. It is divided into three subunits: (1) a lower olive-gray and gray mudstone and interbedded gray speckled, feldspathic, partly calcareous, locally cross-bedded quartz-chert sandstone which is dominant in the lower half, (2) interbedded hard, blocky, light-gray siliceous mudstones and quartzitic and calcareous chert-rich sandstone beds, and (3) an upper subunit of medium- and fine-grained chert-rich sandstone, conspicuous coarse-grained "salt-and-pepper" sandstone and lesser amounts of shale. The lithologic similarity of the siliceous mudstone in subunit 2 to typical Mowry Shale elsewhere in Montana indicates that the subunit is probably the Mowry equivalent in the southern Elkhorn Mountains. Total thickness of the medial Colorado unit ranges from 610 to 920 feet (Klepper et al., 1957).

The upper black shale unit is almost entirely very dark-gray to black fissile shale that contains sporadic concretions and septarian nodules of brown-weathering dense limestone. In the lower part of the unit, a few interbeds of dark-gray, fine-grained sandstone and siltstone are present. Thickness of the unit ranges from 265 to 390 feet. The ammonite, Inoceramus deformis, is present in the basal sandy and silty beds indicating a time of deposition corresponding to the lowest part of the Niobrara Formation (middle Late Cretaceous) elsehwere in the western interior United States. The succeeding Niobrara fauna is present in the overlying black shale (Klepper et al., 1957).

The Colorado Formation grades upward into the Slim Sam Formation which consists of a 1,200 foot sequence of coarse-clastic and volcaniclastic rocks (Klepper et al., 1957; Robinson, 1963). The lower portion of the sequence is comprised of quartz-chert sandstone with interbedded black shales in the lowest 400 feet, and subordinant sandstone with lenses of crystal-lithic tuff and sedimentary tuff or black shale. Quartz is the predominant mineral in rocks within the lower portion of the Slim Sam. The Slim Sam Formation has a significant volcaniclastic content which becomes more prevalent upward. The uppermost part of the formation consists of fine- to medium-grained crystallithic tuff and sedimentary tuff with at least two units of hard mudstone. Quartz probably constitutes less than 5% of the upper part of the Formation. The lower part of the Slim Sam is uniform throughout the area whereas the upper portion shows numerous lateral variations in lithology. The Slim Sam is present only in the east part of the Elkhorn GRA and has been eroded away prior to deposition of the Elkhorn Volcanics or was never deposited in much of the surrounding region. The volcanic material in

the upper part of the Slim Sam was probably derived from early units of the Elkhorn Mountains Volcanics. The pelecypod, Macta arenaria, has been found as high as 380 feet above the base of the Slim Sam indicating a late Niobrara age (Klepper et al., 1957).

Although not obvious the contact between the Slim Sam Formation and the overlying Elkhorn Mountains Volcanics is an angular unconformity. In the Crow Creek Falls area, about 3 miles east-southeast of the Tizer Ranger Station, the Slim Sam appears to grade upward into the Elkhorn Volcanics, but further south and west, the Elkhorn is unconformable upon successively lower beds. For example, at Radersburg Pass the volcanics overlie the lower black shale unit of the Colorado Formation whereas about 10 miles south of the Elkhorn GRA, the volcanics exhibit angular discordance with the underlying Madison Limestone. Thus, the magnitude of the unconformity increases to the west and south from the Crow Creek Falls area. Within most of the Elkhorn GRA, the pre-Elkhorn Mountains Volcanic units appear to be truncated gradually, thereby indicating that pre-volcanism deformation resulted in broad open-folds (Klepper et al., 1957).

The Elkhorn Mountains Volcanics are a plateau-like remnant of a volcanic field that probably originally covered several thousand square miles (Cadwick, 1981). In the central part of the field the volcanics were originally more than 10,000 feet thick but in the Elkhorn GRA they were probably around 5,000 feet thick. In the GRA the volcanic sequence consists of a lower member of mainly andesitic and rhyodacitic autoclastic breccia and lava; a middle member of rhyolitic welded tuff; and an upper member dominated by erosional debris from the lower two members (Smedes, 1966;

Klepper et al., 1957). The middle member is not present in the southern part of the Elkhorn Mountains (Klepper et al., 1957). On the basis of fossil evidence from units above and below, the Elkhorn Volcanics are Late Cretaceous. Radiometric evidence suggests the Elkhorn Mountains Volcanics were erupted over a 2 to 5 million year period from about 75 to 80 million years ago (Robinson, et al., 1968; Tillings, 1973a, b). They may represent a preliminary phase of Boulder batholithic plutonic rocks (Klepper et al., 1971; Hamilton and Myers, 1974a, b).

The lower member of the Elkhorn Volcanics ranges in thickness from 2,000 to 5,000 feet. It is dominantly pyroclastic and sedimentary debris, auto-brecciated lava, and mudflow deposits. The debris consists of both mono-lithologic and polylithologic tuff, tuff breccia, and breccia of rhyodacitic, andesitic or basaltic composition. The fragmental rocks and lavas range from basaltic to rhyodactic in composition. Water-laid deposits are common in the basal part of the lower member but they occur throughout the unit. Volcanic breccia and conglomerate increase in abundance upwards as part of a generally coarsening trend in the lower member (Smedes, 1966).

The middle member of the Elkhorn Mountains Volcanics ranges between 3,000 and 7,500 feet thick and consists of rhyolitic welded tuff interlayered with andesitic, rhyodacitic and basaltic tuff and lapilli tuff, volcanic breccia, and conglomerate (Smedes, 1966; Klepper et al., 1957). Welded tuff forms nearly half the total volume and occurs in at least seven large ash-flow units. They range in thickness from 3 to 200 feet, but most are between 20 and 60 feet thick. Plagioclase and biotite crystals, rock fragments and pieces of pumice make up the welded tuff. Fragmental rocks are similar to

those in the upper part of the lower member. Rock fragments constitute between 5% and 50% of different flow units and are dominantly trachandesite, basalt and rhyodacite (Klepper et al., 1971).

The upper unit ranges in thickness from 2,000 to about 6,000 feet. It is dominantly composed of water-laid thin- to medium-bedded mudstone; andesitic and basaltic siltstone, sandstone, and conglomerate; and bedded tuff. The upper unit also includes a few thin beds of volcanic breccia. Ripple marks, cross-bedding, channel sandstone and mudcracks are common within the finer-grained rocks. Outcrops of the upper unit mark the crest of the northern Elkhorn Mountains (Smedes, 1966).

Numerous andesitic and basaltic intrusions cut the Elkhorn Mountains Volcanics (Smedes, 1966; Klepper et al., 1957). The similarity in composition and age of the intrusives to that of the volcanics suggests that they are products of the same magmatic events (Klepper et al., 1971).

The northwestern part of the Elkhorn GRA, including WSA 075-114, is underlain by intrusive rocks belonging to the Boulder batholith (Fig. 3), an elongate plutonic body roughly 60 miles long and 22 miles wide (Klepper et al., 1971). Numerous smaller satellite plutons and sills related to the Boulder batholith are present in the southern part of the GRA. The batholith and associated satellite bodies are composite epizonal plutons of four general compositional groups: (1) early mafic rocks, (2) granodiorite, (3) the Butte Quartz Monzonite, and (4) late leucocratic and felsic rocks (Smedes, 1973). The bulk of the batholith is made up of Butte Quartz Monzonite. Older granodiorite and gabbro occur as border masses (Klepper et

al., 1971). Late plutons and small bodies of leucocratic rocks were emplaced along the axis of the batholith (Smedes, 1973). The rocks show a general trend of increasing silica content with decreasing age (Smedes, 1966). Lead and strontium isotope studies suggest that the batholith was derived from two chemically distinct magma series (Doe et al., 1968; Tilling, 1973a, b, 1974a, b). Isotopic dating indicates that the batholith was emplaced 78 to 68 million years ago (Tilling et al., 1968). The nature of the Boulder batholith has been the subject of much discussion in recent years and several schools of thought exist. Klepper et al. (1971, 1974) suggest that the batholith is a thick body with steep outward dipping sides whereas Hamilton and Myers (1967, 1974a, b) conclude that it is a thin, tabular sheet with inward sloping sides. Hyndman et al. (1975) have suggested that the Boulder batholith is a block detached from the Idaho batholith and thrust eastward. The majority of the mineral deposits in the GRA are either in plutonic rocks belonging to the Boulder batholith or are related to them (Klepper, 1973).

2.4 Structural Geology and Tectonics

The Thrust belt in west-central Montana is divided into the Rattlesnake and Sapphire plates and the Elkhorn thrust zone (Fig. 3). These structural units underlie the region bounded approximately by the Lewis and Clark line on the north, the Townsend Valley on the east, and the Bitterroot Range on the west (Ruppel et al., 1981).

The Elkhorn GRA is within the Elkhorn thrust zone, a stratigraphically distinct tectonic unit which lies east of the Sapphire plate. Thrust faults

included in the Elkhorn thrust zone by Ruppel et al. (1981) were previously considered to be part of the Montana Disturbed belt (Robinson, 1963; Klepper et al., 1971). The Elkhorn thrust zone is bounded by an arcuate band of thrust faults that extend from the vicinity of Helena, Montana through Townsend Valley to the vicinity of Three Forks, Montana. On the south the Elkhorn thrust zone may be bounded by the Willow Creek fault zone. The relationship between the Elkhorn zone and the parautochthon to the northeast is not certain. The two units may merge or a zone of thrust faults with small apparent displacement may separate the two terranes (Ruppel et al., 1981).

The structural style of the Elkhorn thrust zone is characterized by: (1) thrust faults that tend to develop along bedding planes; (2) abundant laterally continuous thrust fault strands that extend 7-40 miles along strike; (3) thrust faults that do not form an anastomosing network; (4) large anticlines and synclines located adjacent to thrust faults that generally have axial planes which dip steeply to the west; (5) thrust faults that tend to be widely spaced and individual thrust slabs that are 2-16 miles across; and (6) the apparent stratigraphic separation along major thrust faults that is seldom more than 2-3 miles and usually between 1,600 and 5,000 feet. The absence of imbricate and anastomosing thrust faults, the relatively small separation on most thrusts, along with the absence of isoclinal folds distinguish structures in the Elkhorn zone from those in the adjacent Sapphire plate. The Elkhorn zone is differentiated from the Disturbed belt to the north by thrust faults which are steeper, less continuous along strike, and exhibit less apparent stratigraphic separation (Ruppel et al., 1981).

A structural question of particular importrance to the evaluation of the hydrocarbon potential of the southern part of the Elkhorn GRA is the presence or absence of a basal decollment in the Elkhorn thrust zone. Ruppel et al. (1981) do not believe that a decollment is present. However, Kranzler and Warne (1981) suggest that a decollment is present along the Lombard and Poison Hollow thrusts (Fig. 6). Proprietary seismic data suggests that the decollment is present.

In the northwest portion of the Elkhorn GRA which is underlain by plutonic rocks, the predominate structures are high angle faults which post-date the batholith (Smedes, 1966, 1973). The contact of the batholith with the older sedimentary rocks to the southeast is irregular and shows some evidence of faulting contemporaneous with intrusion (Smedes, 1966; Klepper et al., 1957). All of the pre-Tertiary rocks are deformed by the folds and faults described above. These folds trend roughly north-south and are broad and open (Klepper et al., 1957).

2.5 Paleontology

The Paleozoic and Mesozoic strata which predominant in the south half of the Elkhorn GRA are dominated by shelf facies carbonate and clastic rocks. They are by-and-large moderately fossiliferous. Table I summarizes the fossils reported from each stratigraphic unit. The descriptions of faunas in the GRA generally indicate that fossils are poorly preserved.

TABLE I

FOSSILS REPORTED FROM THE SOUTHERN ELKHORN MOUNTAINS

(from Klepper et al., 1957; Robinson, 1963; and Smedes, 1966)

Age	Unit	Fossils
Precambrian Y	Greyson Shale	Stromatolites-Collenai (fossil algae)
	Spokane Shale	Stromatolites-Collenai (fossil algae)
Middle Cambrian	Wolsey Shale	Ehmania sp., Tonkinella, Kootenai sp. Bolaspis sp. Glyphasis sp.
	Meagher Limestone	Glyphasis sp. Dorypyge sp. Elrathina sp. Ehmania sp. Dictyonina sp. Ptchagnostus atarus Tomagnostus sp. Bathyuriscus Peronopsis Prototreta flabellata
Late Cambrian	Pilgrim Dolomite	Arapahoia polita, Baltagnostus beltensis, Cedaria n.sp., Kormagnostus esterius, Paracedaria montanesis, Semnocephalus centralis, Sysphacheilus dunoriensis, Dicellomos
	Red Lion	Billingsella
Late Devonian	Maywood	Platyrachella Atrypa Allanaria
	Jefferson	Cladopora Amphipora

TABLE I (Cont.)

FOSSILS REPORTED FROM THE SOUTHERN ELKHORN MOUNTAINS

(from Klepper et al., 1957; Robinson, 1963; and Smedes, 1966)

Age	Unit	Fossils
	Three Forks Shale (medial limestone bed)	Paurorhyncha Cyrtospirifer Schizophoria Ambocoelia Camarotoechia Productellia Mucrospirifer Athyris Leiorhynchus Straparollus Lyriopecten Edmondia(?) Raymondiceras Tornoceras Platyclymenia
Mississippian	Lodgepole Limestone	Fenestella sp., Spirifer sp., Spiriferina sp., Platyceras sp. Camarotoechia sp., Chonetes sp., Schuchertella sp., Productus gallatinensis, Dielasma sp., Schizophoria sp., Axiodeaneia sp., Torynifer cooperensis, Composita madsonensis, Linoproductus sp., Leptaena analoga, Orthotetes sp., Straparollus sp.
	Mission Canyon Limestone	Coral (incl. horn), brachiopods
Late Mississippian-Early Pennsylvanian	Amsden Formation (all from middle of unit)	Clieothyridina sp., Dictyoclostus, sp., Echinoconchus sp., Linoproductus sp., Composita sp., Antiquatonia sp., Spirifer increbescens, Punctospirifer sp., Chonetes sp., Linoproductus sp., Rhipidomella sp., Derbya sp., Dictyoclostus inflatus, Straparollus sp.
	Phosphoria Formation	Pseudoschuagerina sp.
Late Jurassic	Swift Formation	Broken shells of: Eumicrotis Ostrea Camptonectes

TABLE I (Cont.)

FOSSILS REPORTED FROM THE SOUTHERN ELKHORN MOUNTAINS

(from Klepper etl al., 1957; Robinson, 1963; and Smedes, 1966)

Early Cretaceous	Kootenai Formation (non-marine)	Gastropods (in 15 foot fresh water limestone bed)
Late Cretace-	Colorado Formation (upper black shale unit)	Inoceramus deformis (ammonite) Scaphites ventricosus Baculites asper Inoceramus umbonatus
	Slim Sam	Mactra arenaria (pelecypod) Scaphites ventricosus Abundant plant remains, esp. twigs and branches
	Elkhorn Volcanics	Dammara sp.
Oliogcene and Miocene(?)	Tuffaceous Sediments	Mammal remains in tuff

2.6 Historical Geology

The Precambrian Belt Basin developed about 1,450 m.y. ago and was an active depositional basin for 600 m.y. (Harrison, 1972). This basin was a major northwest-trending trough which was the site of delatic, shelf and basin sedimentation. Regionally the Wallace and Helena Formations which are not exposed in the Elkhorn GRA, comprise a shelf-slope sequence and a basin-axis facies with the source and shelf located to the west. Rocks belonging to the Mt. Shields Formation, a thick northeasterly prograding delta sequence, indicate a period of renewed subsidence and deposition during later Precambrian time (Ruppel et al., 1981).

The Paleozoic rocks in west-central Montana are dominately shallow water, marine shelf carbonates which generally exhibit a three-stage transgressive-regressive sequence (Peterson, 1981). The sequence starts with transgressive Cambrian sandstone (Flathead Quartzite)-mudstone and limestone (Silver Hill Formation)-dolomite (Hasmark Formation)-deep water limestone. Regression is indicated by the Dry Creek Member of the Red Lion Formation which consists of shallow water dolomite and shale (Mudge, 1972). Laminated argillaceous limestone belonging to the Sage Member of the Red Lion Formation indicates a transgressive depositional environment and marks the last stage of the sequence.

The lack of Ordovician (500-435 m.y.) and Siluram (435-395 m.y.) strata in west-central Montana indicates a protracted period of emergence and erosion. This emergent period and earlier Cambrian uplifts reflect the development of the Sweetgrass Arch as a positive tectonic feature (Mudge, 1970).

During most of Devonian time the area encompassing the Elkhorn GRA was a partly emergent shallow marine shelf at the edge of the Sappington-Cottonwood Basin and Cordilleran miogeosyncline (Smith and Gilmour, 1979). Local restricted basins developed behind stromatoporoid-coral reefoid banks (Meyers, 1980). 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). In very late Devonian time, the initial incursion of the Madison sea from the Cordilleran miogeosyncline occurred resulting in the formation of the Big Snowy Trough across central Montana. This transgression is recorded in Lodgepole strata which was deposited over the existing irregular erosion surface in shallow basins. As the rapid transgression continued, downwarping of the Big Snowy Trough (or the rise in sea level) exceeded rates of sediment influx resulting in deeper water environments. Finally prior to deposition of the Mission Canyon Limestone regression of the Madison seas began. As exposure progressed the shelves became the site of sabkhas and salt pans in which evaporites were deposited. The withdrawal of the Madison sea from most of the Montana craton exposed the Mission Canyon to subaerial weathering and subsequent karst formation as shown by the presence of collapse structures at the Mission Canyon-Amsden unconformity (Smith and Gilmour, 1979; Kauffman, 1963).

Subsequent transgression in Pennsylvanian time (Smith and Gilmour, 1979) resulted in deposition of clastic strata belonging to the Amsden and Quadrant Formations. The clastic debris had a source area to the west or northwest which continued to supply sediment to the basin through the Permian (Kauffman, 1963). The Permian section is a regressive sequence as

indicated by the terrestrial Phosphoria Formation. This was followed by a period of pre-Jurassic erosion (Peterson, 1981).

The Early Jurassic marks the beginning of a series of worldwide transgressive-regressive cycles which in North America involved the incusion 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, 1972). 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 drop impressions 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).

Relatively gentle pulsating uplifts continued through the Cretaceous and into the Tertiary (Mudge, 1970; Gwinn, 1960). Truncation of the upper Morrison and 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 Member of the Blackleaf Formation was deposited in a regressive sea. The presence of volcanic material in the Colorado may indicate early volcanism associated with emplacement of the Boulder batholith (Greenwood et al., 1979).

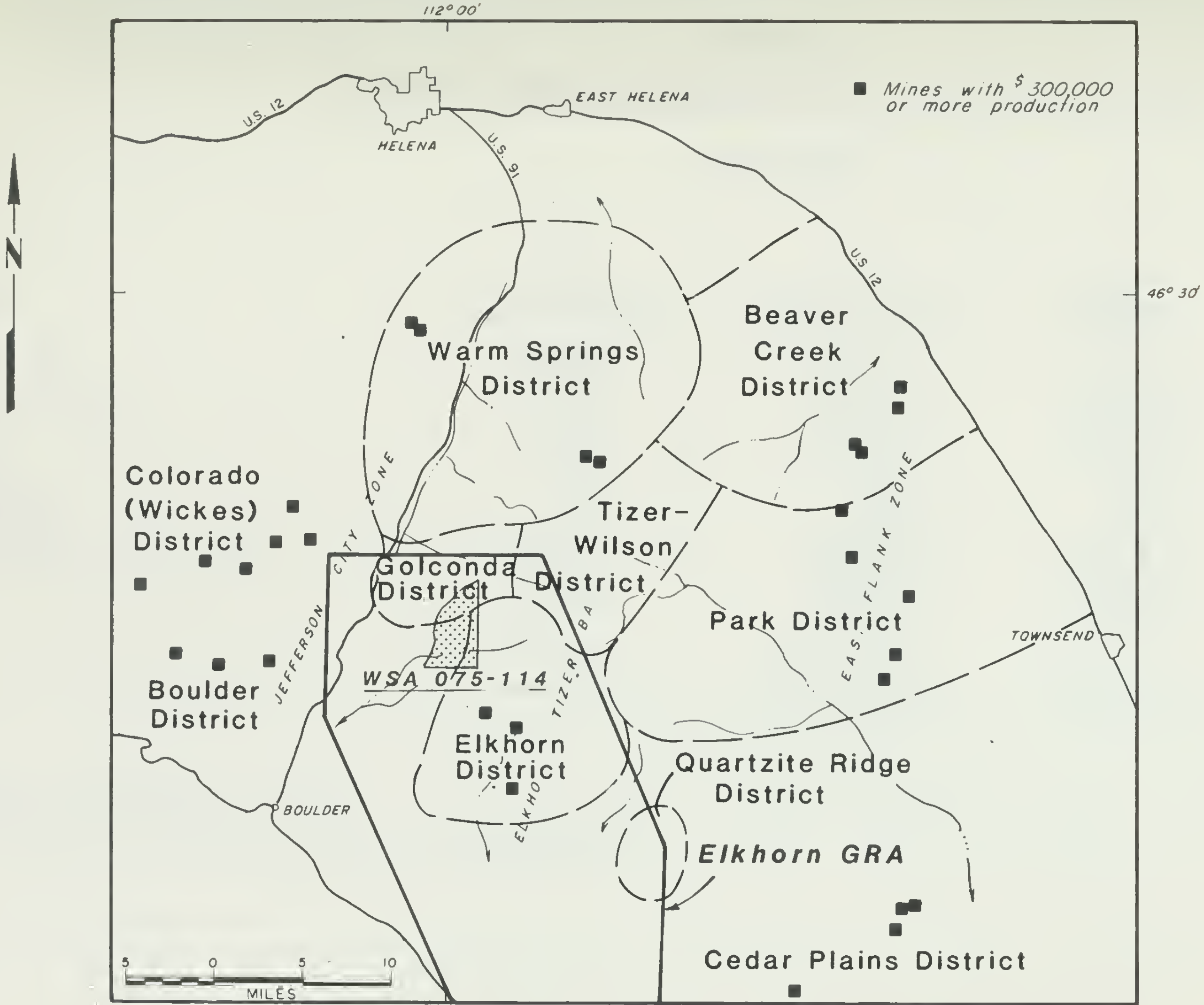
Intrusion of the Boulder batholith beginning about 80 m.y. ago (Robinson et al., 1968) was preceeded by a major episode of folding. The Slim Sam Formation and the thick Elkhorn Mountains volcanic pile represent the volcanic ejecta from the roof of the Boulder batholith (Robinson et al., 1968; Hamilton and Myers, 1974a, b). These rocks are largely unqiue to the Elkhorn thrust zone (Ruppel et al., 1981). Thrusting associated with development of the Montana Thrust belt occurred after extrusion of the middle member of the Elkhorn Mountains Volcanics (Ruppel, 1963) during the late stages of development of the Boulder batholith (Klepper et al., 1973). Folding continued after deposition of the Elkhorn Mountains Volcanics but had largely ceased by the time the youngest plutons were emplaced (Ruppel et al., 1981). High angle faulting continued into the Tertiary (Klepper et al., 1957).

3.0 ENERGY AND MINERAL RESOURCES

3.1 Known Mineral and Energy Deposits

The Elkhorn GRA is within an area containing numerous mines with historical production (Fig. 7). These include the Warm Springs district to the north; the Beaver Creek district to the northeast; the Park district to the east; and the Boulder district immediately southwest of the GRA. The GRA encompasses parts of the Elkhorn, Golconda, Colorado (Wickes), Tizer-Wilson and Quartzite Ridge districts (Greenwood et al., 1978). Production from mining districts in the vicinity of the GRA is shown in Table II. Significant mining properties within the Elkhorn GRA are compiled in Table III and shown on Figure 8.

The Elkhorn district, encompassing most of the north-central part of the Elkhorn GRA is situated on the southwest side of the Elkhorn Mountains near the east contact of the Boulder batholith. It is the largest producing district within the vicinity of the Elkhorn GRA (Table II). The rocks in the Elkhorn district consist of Precambrian and Paleozoic sedimentary units folded into a major-plunging anticline which is truncated on the west by intrusion of the Boulder batholith and associated satellite stocks (Smedes, 1966). The sedimentary rocks are interbedded limestone, dolomite, quartzite and shale. Mineralization occurs as replacement deposits in carbonate rocks, contact metamorphic deposits, and pipe-like breccia deposits (Klepper et al., 1957).



Source: Greenwood et. al., 1978

WGM Inc. Mining and Geological Consultants
Anchorage, Alaska

BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Elkhorn GRA, Montana

Major Mines Near the Elkhorn (075-114) WSA

SCALE: AS SHOWN			FIGURE 7
DATA BY WGM	DATE 9/1982	REVISED	
DRWN BY DSI	APPR'D G.F		

TABLE II

PRODUCTION FROM LODE MINING DISTRICTS, ELKHORN GRA VICINITY[1]

(1902-1957)

District	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)
Warm Springs	15,427	118,057	103,753	740,792	12,042
Boulder	3,124	353,712	368,337	1,946,344	411,281
Colorado (Wickes)	30,673	3,472,658	4,880,706	27,254,784	9,717,803
Elkhorn	61,295	6,152,555	1,025,125	12,404,569	3,204,429
Golconda	623	6,585	2,810	72,871	13,743
Tizer-Wilson	6,235	7,938	9,655	78,380	1,500
Beaver Creek	146,400	1,205,000	200,000	10,800,000	1,000,000
Cedar Plains (Radersburg)[2]	402,120	260,000	2,720,000	6,500,000	500,000
Park	41,464	250,000	100,000	4,440,000	2,700,000
TOTAL	757,861	11,826,505	9,410,386	64,237,735	17,560,798

1. Source: Roby et al., 1960.
2. Includes the Quartzite Ridge mining district.

TABLE III

MINERAL DEPOSITS, PROSPECTS, AND OCCURRENCES IN THE ELKHORN GRA

Map No. (Fig. 7)	Property	Sec.	Tp.	Rg.	Commodities	Comments	References
1	Monte Cristo	3	7	4	Zn, Pb	No production.	Becraft et al., 1963 (p. 78)
2	Rarus mine	3	7	4	Zn, Pb, Cu, Ag	Produced 531 oz. Ag; 1,278 lb. Cu; 2,298 lb. Pb; and 14,438 lb. Zn.	Becraft et al., 1963 (p. 81) Roby et al., 1960 (p. 110)
3	Atomizer	1	7	4	U	No production. Chalcedonic quartz vein.	CRIB Files
4	Bertha mine (Bertha and Corbin)	3	7	4	Cu, Pb, Ag, Au	Produced 162,043 oz. Ag; 2,423,143 lb. Cu; 26,730 lb. Pb; 279 oz Au.	Becraft et al., 1963 (p. 78) Roby et al., 1960 (p. 108)
5	Winston Bros. placer	6	7	3	Au	Prickley Pear Creek produced over 49,000 ozs. of Au.	Becraft et al., 1963 (p. 52) Roby et al., 1960 (p. 13)
6	Madison	5	7	3	Pb, Ag, Au	Several tunnels and pits.	Pardee and Schrader, 1933 (p. 241)
7	Alta mine	10	7	4	Ag, Pb, Zn, Cu, Au	Most productive in Jefferson City Quadrangle. Production was over 1½ million tons of ore. Producing flux for East Helena smelter in 1956.	Becraft et al., 1963 (p. 70-71) Roby et al., 1960 (p. 107)
8	Polaris mine	11	7	4	Pb, Cu, Zn, Mo	Two adits, 300 feet apart.	Becraft et al., 1963 (p. 81)
9	Comet Creek placer	11	7	4	Au	Small placer operation	Roby et al., 1960 (p. 15)
10	Helena-Jefferson mine	13	7	4	Ag, Zn, Pb, Cu	Produced 113 oz. Ag; 6,216 lb. Zn; 5,231 lb. Pb; and 159 lb. Cu in 1928.	Becraft et al., 1963 (pp. 81-82) Roby et al., 1960 (p. 51)
11	Mastodon Lodes	17,18	7	2	Ag	No reported production, patented after 1926.	Greenwood et al., 1978 (p. 303)
12	West Ridge-Zalinski	18,19	7	2	Ag, Pb, Zn	No reported production.	Greenwood et al., 1978 (pp. 311-312)
13	Big Chief mine	17	7	3	Pb, Zn, Ag	Produced 23,800 lb. Pb; 11,922 lb. Zn, 875 lb. Cu; 722 oz. Ag; 30 oz. Au.	Becraft et al., 1963 (p. 82-83) Roby et al., 1960 (p. 65 and 113)
14	Wickes-Corbin mine	22	7	3	Pb, Zn, Cu	No reported production.	CRIB Roby et al., 1960 (p. 53)
15	Copper Nugget placer	23	7	4	Native copper nuggets	No production. Copper precipitated in bog. Est. 77,000 yd^3 avg. 8.7 lbs. Cu/yd^3.	Roby et al., 1960 (p. 66-67) Forrester, 1942 (p. 133-135)
16	Beaverton Ranch	24	7	4	Metatorbernite (Cu, U)	Narrow vein in quartz monzonite. No production.	Roby et al., 1960 (pp. 46-47) Sahinen, 1956 (p. 7).
17	Golconda mine (Golden Assets)	29	7	3	Zn, Pb, Ag	Produced 20,200 oz. Ag; 120 oz. Au; 5,200 lb. Cu; 10,400 lb. Pb; 2,800 lb. Zn.	Becraft et al., 1963 (p. 81) Roby et al., 1960 (p. 67)
18	Robert Emmett mine	27	7	4	Cu, Pb, Zn	Produced 7,356 lb. Zn; 5,897 lb. Pb; 2,711 lb. Cu; 1,151 oz. Ag.	Becraft et al., 1963 (p. 95) Roby et al., 1960 (p. 22)
19	Anderson Gulch	27	7	3	Cu, Ag	No production.	Greenwood et al., 1978 (pp. 273-274)
20	Solar Silver mine	29	7	2	Ag, Pb	Under development.	MILS Lawson, 1978 (p. 10)
21	Bob Ingersol mine	27,28	7	4	Pb	No production.	Roby et al., 1960 (p. 21)
22	Elkhorn Peak iron deposits	36	7	3	Fe, Cu, Au, Ag	Magnetite and chalcopyrite in lenses at andesite-limestone contact. Mined in late 19th century as smelter flux.	Roby et al., 1960 (pp. 58-59) Klepper et al., 1957 (p. 72)
23	Blackjack	32	7	2		Pyrite and tourmaline in brecciated andesite pipe.	Klepper et al., 1957 (p. 72)
24	Center Reef (Ballard)	32	7	2	Au, Ag, Pb, Cu	Produced 2,725 oz. Au; 7,173 oz. Ag; 9,753 lb. Pb; 133 lb. Cu.	Klepper et al., 1957 (p. 73) Roby et al., 1960 (p. 79)

TABLE III (Cont.)

MINERAL DEPOSITS, PROSPECTS, AND OCCURENCES IN THE ELKHORN GRA

Map No. (Fig. 7)	Property	Sec.	Tp.	Rg.	Commodities	Comments	References
25	Ann Kinzer mine	2	6	2	Ag, Pb, Zn	Produced 11 tons ore containing 2,500 lb. Pb; 400 lb. Zn; 100 lb. Cu; 83 oz. Ag and 1 oz. Au between 1942 and 1968.	Greenwood et al., 1978 (p. 212-213)
26	Union	11	6	3	Ag, Pb, Cu	Produced 13,439 oz. Ag; 11 oz. Au; 75,870 lb.; 1,062 lb. Cu.	Klepper et al., 1957 (p. 69) Roby et al., 1960 (p. 65)
27	C and O (Boulder-Belle) (Louise)	11	6	3	Ag, Pb, Au, Cu	Produced 7,748 oz. Ag; 641 oz. Au; 90,770 lb. Pb; 769 lb. Cu.	Klepper et al., 1957 (p. 69) Roby et al., 1960 (p. 110)
28	Silver Tip mine (Reddings)	8	7	3	Ag, Pb, Zn	Produced about $10,000 worth of ore.	Becraft et al., 1963 (p. 82) Roby et al., 1960 (p. 67)
29	Skyline mine	8	6	2	Ag, Pb, Zn	No production reported. Brecciated pipe.	Klepper et al., 1957 (pp. 70-71) Roby et al., 1960 (p. 63)
30	Last Chance lode	11,14	6	2	Au, Ag	Shear zone.	CRIB
31	Muskrat Creek	14	6	4	Au	Placer. Tested but not worked.	Roby et al., 1960 (pp. 14-15)
32	Hard Cash (Dolcoath)	11	6	3	Cu, Au, Ag, Pb	Produced 12,863 lb. Cu: 809 oz. Au; 392 oz. Ag; 391 lb. Pb.	Klepper et al., 1957 (p. 69) Roby et al., 1960 (p. 61-62)
33	Klondyke mine (including the Dunstone)	11	6	3	Cu, Au, Ag, Pb	Produced 8,640 lb. Cu; 539 oz. Au; 309 oz. Ag; 567 lb. Pb. Dunstone is just east of the Klondyke.	Klepper et al., 1957 (p. 69) Roby et al., 1960 (pp. 58, 62-63)
34	Heagan	11-14	6	3	Au, Ag, Cu, Pb	Produced 191 oz. Au, 294 oz. Ag: 241 lb. Cu; 710 lb. Pb.	Roby et al., 1960 (p. 62)
35	Carmody-Papesh (Jack lode)	14	6	3	Au, Ag	Deposit in thermally metamorphosed Wolsey Shale. Cyanide test indicated avg. recoverable gold is 0.14 oz/ton.	Klepper et al., 1957 (p. 70) Roby et al., 1960 (p. 58)
35	Swissmont and Pittsmont	14	6	3	Au, Ag	Produced 16,200 oz. Au; 3,200 oz. Ag.	Klepper et al., 1957 (p. 69)
36	Keene	11	6	3	Au, Pb	Production estimated at 500 tons high grade Au-Pb ore. 650 feet north of Elkhorn mine.	Klepper et al., 1957 (p. 68)
36	Elkhorn mine (Holter)	14	6	3	Ag, Au, Pb, Zn, Cu	Produced 5,860,000 oz. Ag; 11,500 oz. Au; 10,000,000 lb. Pb; 2,800,000 lb. Zn; 150,000 lb. Cu.	Klepper et al., 1957 (pp. 67-68) Roby et al., 1960 (p. 59)
37	Luxemburgh	14	6	3	Cu, Pb, Ag	Produced 7,860 lb. Cu; 192 oz. Ag; 6 oz. Au.	Roby et al., 1960 (p. 63)
38	Blackbird	12	6	3	Pb, Ag, Au	No production reported. Subsurface potential.	Greenwood et al., 1978 (p. 169)
39	Big and Little Goldy	13? or 24?	6	4	Au, Ag, Pb	Produced 227 oz. Ag; 75 oz. Au; 2,476 lb. Pb; 276 lb. Cu.	MILS Roby et al., 1960 (p. 110 and 112)
40	Tourmaline Queen (New Gold Era)	22	6	3	Au, Ag	Recently active. Reserves are 300,000 tons of low grade material on the order of 0.02 oz/ton Au and 0.5 oz/ton Ag. No production.	CRIB Klepper et al., 1957 (p. 70) Roby et al., 1960 (p. 64-65)
41	Bulwer mine (Bulware, Bouloware)	23	6	3	Cu	Produced 53.6 tons Cu 1913-1920.	Klepper et al., 1957 (p. 70) Roby et al., 1960 (p. 58)
42	Passover	25	5	3	Ag, Pb, Zn, Cu	Produced 3,096 oz. Au; 69,498 lb. Pb; 532 lb. Zn; 383 lb. Cu; 1 oz. Au. Small breccia pipe.	Roby et al., 1960 (p. 63) Klepper et al., 1957 (p. 74)
43	Tacoma	34	6	3	Au, Ag, Pb	Produced 694 oz. Ag; 26 oz. Au; 15,091 lb. Pb.	Roby et al., 1960 (p. 64) Klepper et al., 1957 (p. 72)

TABLE III (Cont.)

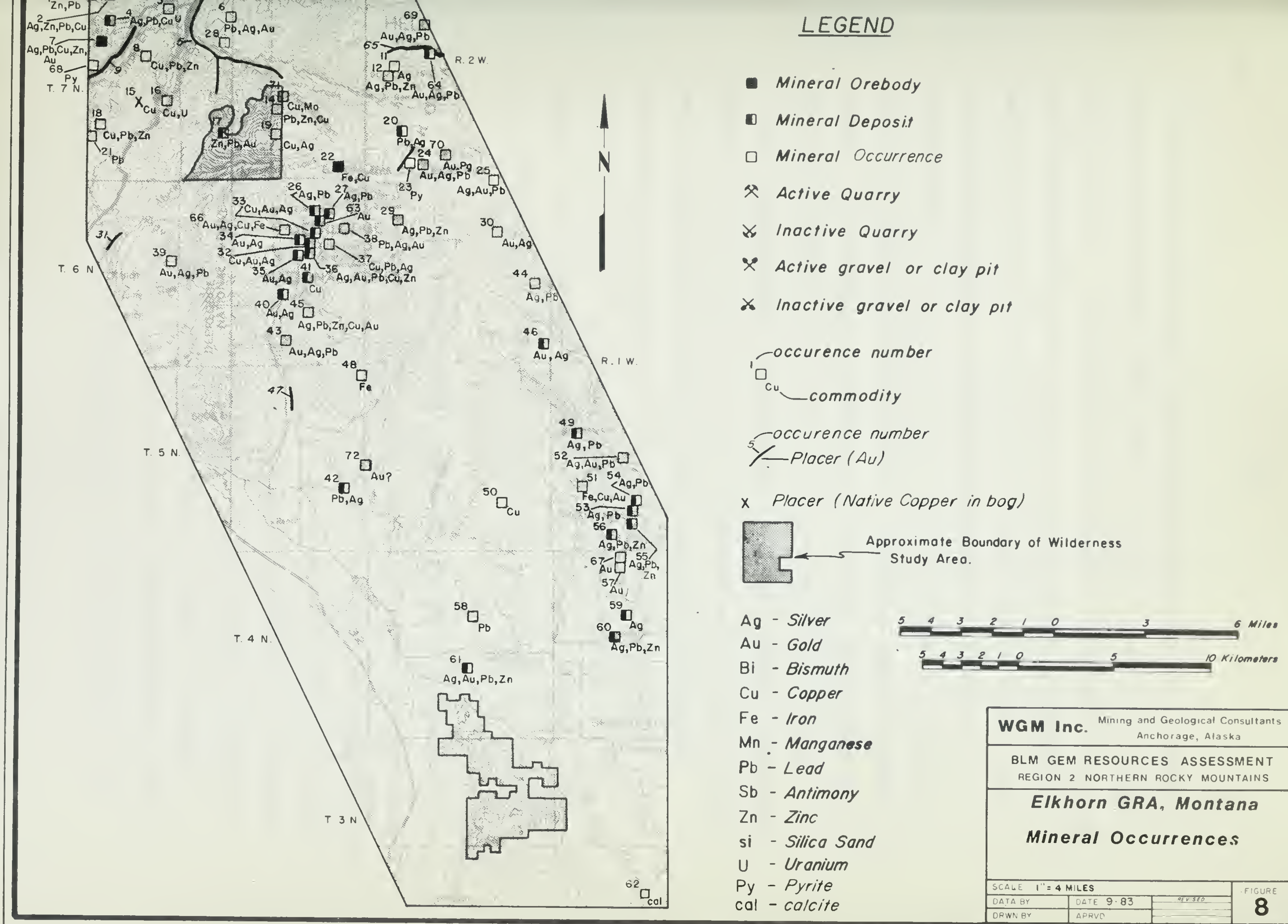
MINERAL DEPOSITS, PROSPECTS, AND OCCURRENCES IN THE ELKHORN GRA

Map No. (Fig. 7)	Property	Sec.	Tp.	Rg.	Commodities	Comments	References
44	Bonanza	24	6	2	Ag, Pb	No production reported.	Klepper et al., 1957 (p. 74) Roby et al., 1960 (p. 55, 57)
45	Elkhorn Queen	26	6	3	Ag, Pb, Zn, Cu, Au	Produced 150,000 oz. Ag; 4,900,000 lb. Pb; 356,000 lb. Zn; 13,000 lb. Cu; 1,850 oz. Au.	Klepper et al., 1957 (p. 70, 72) Roby et al., 1960 (p. 61, 111)
46	Spar	36	6	2	Ag, Au	Produced 63,700 oz. Ag; 110 oz. Au; 3 tons Zn; 1 ton each Cu and Pb.	Klepper et al., 1957 (p. 74-75) Roby et al., 1960 (p. 63-64)
47	Elkhorn Creek	3	5	3	Au	Placer gold mined in 1940 from a 3,000 ft. by 200 ft. area in an abandoned channel of Elkhorn Creek. 678 oz. Au recovered.	Roby et al., 1960 (p. 16) Klepper et al., 1957 (p. 72)
48	Boulder	1	5	3	Fe	Several hundred tons of hematite produced at shale-limestone contact.	Roby et al., 1960 (p. 57-58)
49	Parker Group (Silver Belle, Ned, Globe)	18	5	1	Ag, Pb	Produced 1,000 tons of ore.	Klepper et al., 1957 (p. 77)
50	Katiedid	26	5	2	Cu	No production recorded.	Klepper et al., 1957 (p. 74) Roby et al., 1960 (p. 62)
51	Rothfus	19	5	1	Fe, Cu, Au	Magnetite, hematite and malachite in thermally metamorphosed limestone. Mined as smelter flux. Traces Au.	Klepper et al., 1957 (p. 77)
52	North Home	16	5	1	Ag, Pb, Au	Produced 4,000 tons ore averaging 2.3% Pb, 17.4 oz/ton Ag, 0.06 oz/ton Au.	Klepper et al., 1971 (p. 48)
53	Jo Dandy	28	5	1	Ag, Pb	Produced 9,300 tons ore averaging 34% Pb, 11.9 oz/ton Ag	Klepper et al., 1971 (p. 46)
54	Jo Jo	28	5	1	Ag, Pb	Past producer.	MILS
55	Santa Anita mine	33	5	1	Ag, Pb, Au	Produced 1,600 tons ore averaging 23% Pb, 5.7 oz/ton Ag, 0.02 oz/ton Au.	Klepper et al., 1971 (p. 46)
56	Ruby (Ruby Silver) mine	33	5	1	Ag, Pb, Zn	Produced 4,000 tons ore averaging 4.4% Pb, 8.8% Zn, 5 oz/ton Ag.	Klepper et al., 1971 (p. 47-48)
57	Buckhorn mine	4	4	1	Au	Free gold in porous iron oxide. Production unknown.	Klepper et al., 1971 (p. 38)
58	J and F no. 1 (Valley View, Silver Hill)	15	4	2	Pb	No production.	Klepper et al., 1957 (p. 74)
59	Silver Star	16	4	1	Ag	Producer.	MILS
60	Summit	17	4	1	Ag, Pb, Zn	Past production not known.	MILS
61	Ida	22	4	2	Ag, Au, Pb, Zn, Cu	Produced 20,800 oz. Ag; 100 oz. Au; 89 tons Pb; 24 tons An; 1 ton Cu.	Klepper et al., 1957 (p. 76-77) Roby et al., 1960 (p. 62)
62	Dunbar	33	3	1	Calcite	Three veins with optical-calcite. No production.	Roby et al., 1960 (p. 85)
63	Golden Moss	11	6	3	Au	Reported to average 1 oz/ton.	Roby et al., 1960 (p. 61) Klepper et al., 1957 (p. 69)
64	Belle	15	7	2	Au, Ag, Pb	Ore averaged 0.77 oz/ton Au, 17 oz/ton Ag, 17% Pb. Total value of production was $16,000.	Klepper et al., 1957 (p. 73)
65	Wilson and Crow Creek	23	7	2	Au	Placer gold production unknown.	Klepper et al., 1957 (p. 73) Roby et al., 1960 (p. 16)
66	Golden Curry (Sourdough, Jacquemin)	10	6	3	Au, Ag, Cu, Fe	Produced 23,900 oz. Au; 11,500 oz. Ag; 650,500 lb. Cu. Ore averaged 35 to 40% Fe. Mined as smelter flux prior to 1911.	Roby et al., 1960 (p. 61) Klepper et al., 1957 (p. 72)

TABLE III (Cont.)

MINERAL DEPOSITS, PROSPECTS, AND OCCURRENCES IN THE ELKHORN GRA

Map No. (Fig. 7)	Property	Sec.	Tp.	Rg.	Commodities	Comments	References
67	Nada	4	4	1	Au	Free gold in porous iron oxide. Production unknown.	Klepper et al., 1971 (p. 38)
68	David Copperfield	15	7	4		Sericite, pyrite siliceous alteration zone. No known production.	Becraft et al., 1963 (p. 78)
69	Moonlight	9	7	2	Au, Ag, Pb	Pyrite in silicified breccia. Grab samples showed traces Au, several oz/ton Ag, several percent Pb.	Greenwood et al., 1978 (p. 304-305)
70	Little Tizer-Wildcat mine	33	7	2	Au, Ag	Produced 54 tons ore.	Greenwood et al., 1978 (p. 297-303)
71	Andy	14-17 20-23 26-28	7	3	Cu, Mo	Porphyry copper-molybdenum target. Exxon has drilled. No information on results.	Greenwood et al., 1978 (p. 274-275)
72	Unnamed	24	5	3	Au?	Pit in limestone unit of Three Forks Shale. May be old gold prospect.	Klepper et al., 1957 (p. 65)



LEGEND
Mineral Orebody
Mineral Deposit
Mineral Occurrence
Active Quarry
Inactive Quarry
Active gravel or clay pit
Inactive gravel or clay pit
occurence number
commodity
occurence number
Placer (Au)
x Placer (Native Copper in bog)
Approximate Boundary of Wilderness Study Area.
Ag - Silver
Au - Gold
Bi - Bismuth
Cu - Copper
Fe - Iron
Mn - Manganese
Pb - Lead
Sb - Antimony
Zn - Zinc
si - Silica Sand
U - Uranium
Py - Pyrite
cal - calcite
6 Miles
10 Kilometers
N
R. 2 W.
R. 1 W.
T. 7 N.
T. 6 N
T. 5 N.
T. 4 N.
T 3 N
WGM Inc.
Mining and Geological Consultants
Anchorage, Alaska
BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS
Elkhorn GRA, Montana
Mineral Occurrences
SCALE 1" = 4 MILES
DATA BY
DATE 9·83
DRWN BY
APRVD
REVISED
FIGURE
8

Mineralization most commonly occurs as replacement deposits in carbonate rocks, particularly the Pilgrim Dolomite, Meagher Limestone and Madison Group carbonates. The majority of the production in the district has come from the Elkhorn mine (loc. 36, Fig. 8, Table III) where replacement deposits of argentiferous galena occur in the Pilgrim Dolomite. The argentiferous galena is associated with small amounts of pyrite and sphalerite as well as sproadic occurrences of chalcopyrite, tetrahedrite, bourhonite, argentite and quartz gangue. Two general types of orebodies are present: (1) siliceous ore that typically occurs in the uppermost beds of the Pilgrim Dolomite and (2) non-siliceous ore that forms pods and irregular-shaped bodies in stratigraphically lower portions of the Pilgrim Dolomite. The "siliceous ore" and to a lesser extent the "non-siliceous ore" are localized in the crests of small anticlinal folds beneath silicified shale or argillite of the Red Lion Formation. Smaller mines classed as carbonate replacement deposits include the Keene mine (loc. 36, Fig. 8), the C and D mine (loc. 27, Fig. 8), the Union mine (loc. 26, Fig. 8), the Swissmont and Pittsmont (loc. 35, Fig. 8) (Klepper et al., 1957).

Skarn replacement bodies of high-temperature silicate minerals containing magnetite, specularite, pyrite or chalcopyrite, or combinations of these minerals, are common in carbonate rocks near the margins of intrusive bodies in the Elkhorn district. In the Elkhorn Peak area (loc. 22, Fig. 8, Table III) and at the Rothfus (loc. 51) and Golden Curry mines (loc. 66) skarns with a high iron content were exploited for smelter flux. The skarns at Elkhorn Peak consist of magnetite intergrown with andradite, epidote, calcite, quartz, actinolite, axinite, pyrite, specular hematite and chalcopyrite in thermally metamorphosed impure calcareous sediments. The

iron-rich skarns often contain a few hundredths of an ounce of gold per ton (Klepper et al., 1957). Greenwood et al. (1978) estimate that 4.2 million tons of rock containing 0.03 ounce of gold per ton, 0.02 ounce of silver per ton, 0.15% copper, and 28.7% iron are present in the Elkhorn Peak area. The Hard Cash (loc. 32, Fig. 8), Klondyke (loc. 33), Golden Moss (loc. 63), and Carmody-Papesh (loc. 35) mines exploited copper-rich skarns which also contain significant gold contents. The Hard Cash orebody consists of intergrown garnet, diopside, calcite, and epidote, with small amounts of bismuthinite, tetradymite and chalcopyrite which replaced a thin bed of impure limestone in the Park Shale. Gold-bearing telluride minerals are present at both the Hard Cash and Klondyke mines. Cyanide tests on ore mined in 1935 or 1936 from the Carmody-Papesh property indicated an average recoverable gold content of about 0.14 ounces per ton (Klepper et al., 1957).

Breccia pipe deposits in the Elkhorn district consist of brecciated rock cemented by quartz, tourmaline and sulfide minerals. Appreciable amounts of gold and silver as well as lead and zinc are present. At the Elkhorn Queen mine (loc. 45, Fig. 8, Table III), a steeply plunging pipe-like orebody cuts across granodiorite porphyry and thermally metamorphosed Three Forks Shale. Ore consists of brecciated porphyry or hornfels cemented by quartz, black tourmaline, galena, pyrite, sphalerite, and sparse arsenopyrite. The upper part of the orebody was thoroughly oxidized and yielded a substantial amount of high grade gold-lead-silver ore. Another breccia pipe occurs in gently dipping andesite at the Skyline property (loc. 29, Fig. 8, Table III). This deposit has been glaciated; thus, it is only slightly oxidized (Klepper et al., 1957).

The second most productive area overlapping the Elkhorn GRA is the Colorado (Wickes) district which encompasses the northern part of the GRA including the seldom-recognized Golconda district. Butte Quartz Monzonite and late-stage rocks belonging to the Boulder batholith underlie most of the northern and eastern parts of the Colorado district, and Elkhorn Mountains Volcanics underlie much of the central, western and southwestern parts. In the central part of the district, tuffaceous rocks belonging to the Lowland Creek Volcanics overlies the Elkhorn Mountain Volcanics and both are cut by steeply dipping dikes and irregular bodies of quartz latite (Becraft et al., 1963).

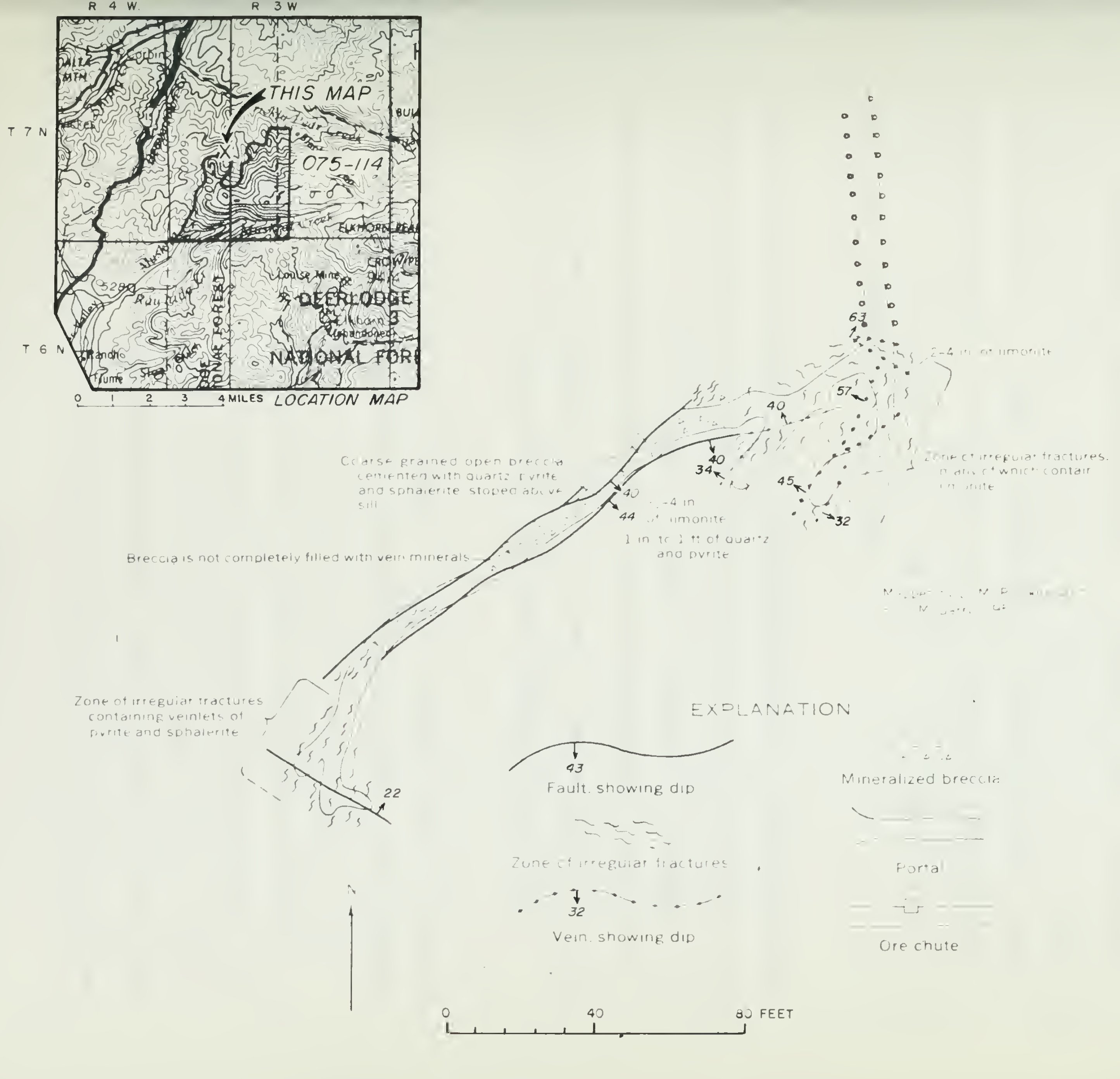
Almost all of the ore in the Colorado district has come from quartz veins. The most productive veins occupy well-defined, steeply dipping, nearly east-trending shear structures, and they contain silver-lead orebodies largely composed of galena, sphalerite, pyrite, and quartz. East of Alta Mountain, the quartz veins trend northeast and their dominant mineral assemblage is quartz, pyrite and chalcopyrite. The latter veins are generally narrow and have produced little ore (Becraft et al., 1963).

The most productive mine in the Colorado district, the Alta mine (loc. 7, Fig. 8, Table III), produced 1¼ million tons of ore from a east-trending shear zone in fractured Elkhorn Mountains Volcanics. Records on the ore tenor are incomplete but smelter returns indicate that crude ore averaged 0.10 ounce gold per ton, 20 to 50 ounces silver per ton and 18 to 35% lead. Significant quantities of zinc were often present. The shear zone hosting the orebodies is almost entirely in Elkhorn Mountains Volcanics and near the contact with batholithic rocks. The volcanics adjacent to the shear zone

are intensely altered for widths of 150 to 200 feet. The shear zone dips 30°-60°N in the upper levels of the mine and 60°-70°N in the lower levels (Becraft et al., 1963).

The Alta orebody is 1,600 feet long and has been mined to a depth of 1,400 feet below the outcrop. The orebody consists of large, overlapping lenses, veins, and replacement bodies consisting dominately of galena, pyrite, tetrahedrite, and minor sphalerite. Three major shoots, 250 to 400 feet long, separated by lean unmined zones, 100 to 150 feet long, are present (Becraft et al., 1963).

The northern half of the Elkhorn WSA is within the Golconda district which is often included in the Colorado mining district. The best producer in the Golconda area, the Golconda (Golden Assets) mine located within the WSA (loc. 17, Fig. 8, Table III), produced 116 ounces of gold; 20,189 ounces of silver; 5,218 pounds of copper; 10,397 pounds of lead; and 2,800 pounds of zinc (Roby et al., 1960). The Golconda workings are apparently in a mineralized fault breccia cemented with sulfide minerals and bounded by strong gouge strands (Becraft et al., 1963). Roby et al. (1960) describe a mineralized stockwork in soft, altered, and bleached granite in the area surrounding the fault breccia and the fracturing described by Becraft et al. (1963) in the hangingwall of the middle adit could be a stockwork system (Fig. 9). Roby et al. (1960) describe individual bodies, up to 150 feet long and 35 feet wide, of mineable grade gold ore within the stockwork. These orebodies strike N60°W and dip about 35°N. The gold is in small reticulated veinlets principally containing iron-stained quartz with minor



Data from: Becraft, et. al (1963)

WGM Inc. Mining and Geological Consultant
Anchorage, Alaska

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REGION 2 NORTHERN ROCKY MOUNTAINS

Elkhorn GRA, Montana

Geologic Map of the Middle Adit, Golconda Mine

1" = 40 ft

1/1983

DSI | GF

9

amounts of manganese oxide. The bleached granite extends for at least another 2,000 feet to the southeast (Roby et al., 1960).

The other major producer in the Golconda mining district, the Big Chief mine located immediately adjacent to the Elkhorn WSA (loc. 13, Fig. 8, Table III), has yielded 30 ounces of gold; 772 ounces of silver; 875 pounds of copper; 23,800 pounds of lead; and 11,922 pounds of zinc over an eight-year period (Roby et al., 1960). The deposit is in an east-trending, steeply dipping vein within a 40-foot wide zone of bleached and altered quartz monzonite. The vein contains black sphalerite, galena, pyrite, and a little chalcopyrite (Becraft et al., 1963).

The Tizer-Wilson mining district encompasses the part of the northeastern Elkhorn GRA which is drained by Tizer and Wilson Creeks. The central part of the basin is covered by glacial deposits, but andesitic fragmental rocks and flows cut by intrusive rocks similar in composition to the extusives crop out around the margins of the Tizer basin. The margin of the Boulder batholith is 2 to 3 miles west of the basin (Klepper et al., 1957).

Production amounting to 9,000 ounces of gold, 20,000 ounces of silver, and 100 tons of lead is credited to the Tizer-Wilson district. The orebodies were in veins occupying narrow shear zones in altered andesite. When unoxidized, the veins contain pyrite, galena, sphalerite, chalcopyrite, and rare specks of gold and tetrahedrite. Production is almost entirely from the oxidized portion of veins which principally consist of soft limonitic material with some vuggy quartz and gold. The Center Reef (Ballard) mine (loc. 24, Fig. 8, Table III) and the Callahan mines (outside the GRA) were

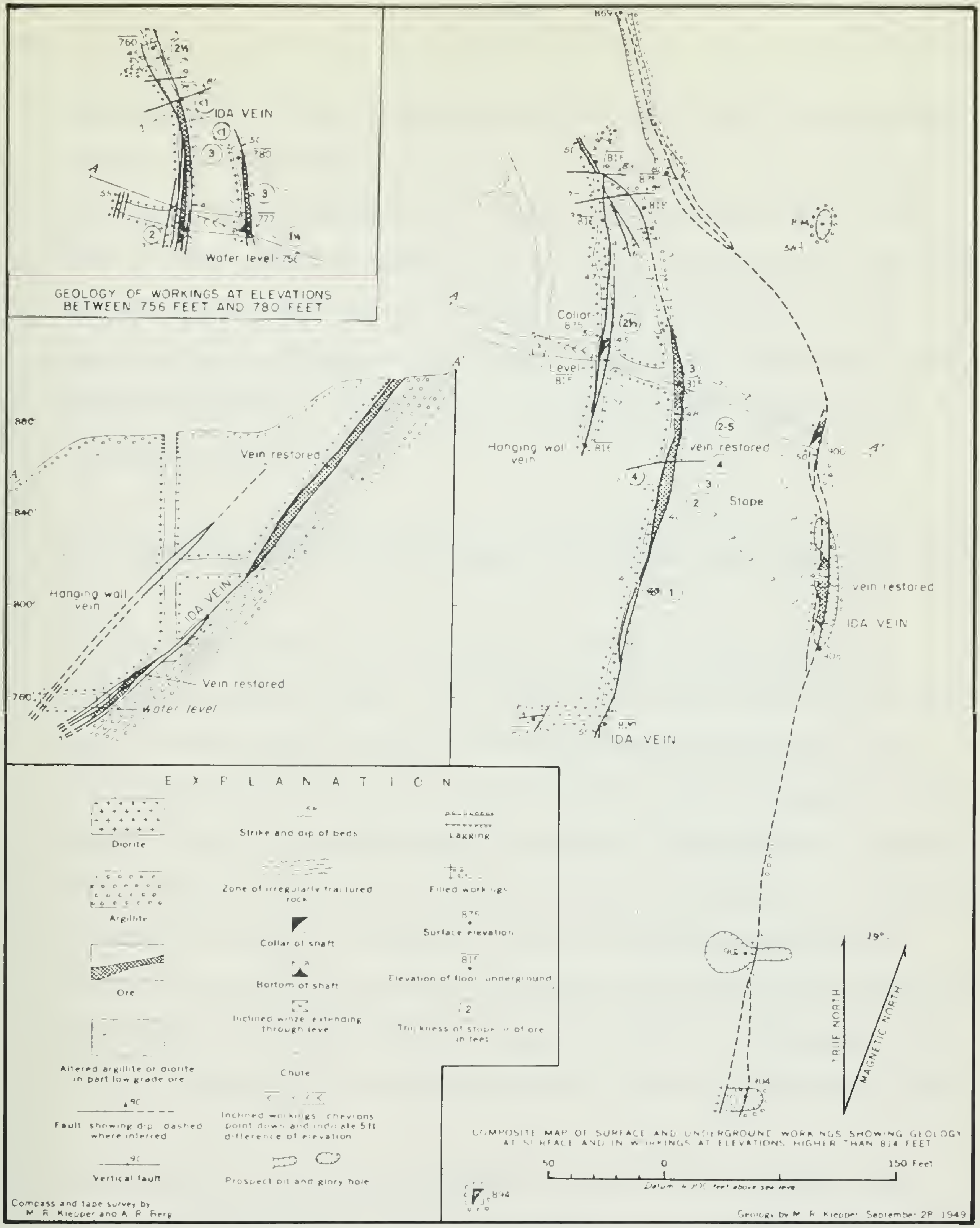
the chief producers in the district (Klepper et al., 1957). Greenwood et al. (1978) report that about 280,000 tons of rock averaging 0.10 ounce of gold per ton are present on the Center Reef (Ballard) and Little Tizer-Wildcat (loc. 70, Fig. 8, Table III) properties.

In the Quartzite Ridge mining district (T.5N., R.1W., Fig. 7), pipe-like and lenticular bodies of silver-lead-zinc ore have replaced favorable beds adjacent to steeply dipping, east-trending faults. Most of the orebodies are in thin dolomites interbedded with quartzite belonging to the Quadrant Formation, but at least two of them occur in the Mission Canyon Limestone. One of the orebodies in the Mission Canyon is localized in a collapse breccia. The ore consists of galena, sphalerite, and pyrite, or their oxidized equivalents in a gangue of chalcedony, jasper, and calcite or dolomite. The most productive mine in the area, the Jo Dandy (loc. 53, Fig. 8, Table III) produced 9,300 tons of ore averaging 34% lead and 11.9 ounces of silver per ton. Five pipe-like replacement bodies were mined at the Jo Dandy. These replacement bodies were localized at intersections of east-trending, nearly vertical fractures and north-trending dolomite beds in the Quadrant Formation. The largest orebody was mined from the surface to the 600 foot level. In cross section it ranged from 2 to 16 feet along the fracture and from 4 to 15 feet along bedding. Other mines in this district which are within the Elkhorn GRA are the North Home mine (loc. 52, Fig. 8, Table III), the Ruby mine (loc.56), and the Santa Anita mine (loc. 55). These mines produced an additional 9,600 tons of high grade lead-zinc-silver ore. Two other mines in the Quartzite Ridge area, the Nada (loc. 67) and the Buckhorn (loc. 57) are located in the Quadrant Formation. The control and habit of the ore at these mines is similar to the lead-zinc-silver

replacement deposits except that the ore is porous iron oxide that contains free gold and little or no silver, lead and zinc (Klepper et al., 1971).

The southern part of the Elkhorn GRA appears to be sparsely mineralized compared to the northern part of the GRA. The Ida mine (loc. 61, Fig. 8, Table III) located north of the Black Sage WSA, has been sproadically productive from 1915 to 1951. During this time 1,332 tons of ore were produced yielding 107 ounces of gold; 22,191 ounces of silver; 1,619 pounds of copper; 171,000 pounds of lead; and 40,889 pounds of zinc. The mineralization occurs in a vein that follows the footwall contact between a diorite sill and the Greyson Shale (Fig. 10). The sill parallels and is adjacent to the contact of the Greyson Shale with the Spokane Shale, probably reflecting some control by this stratigraphic horizon. The principal vein averages 2½ feet in thickness and can be traced on the surface for over 500 feet. Ore minerals consist of pyrite, galena, and sphalerite which occur in association with quartz and silicified argillite and fault gouge (Roby et al., 1960).

Placer gold deposits were mined within the Elkhorn GRA on Prickly Pear Creek, Spring Creek, Tizer Creek, Wilson Creek and Elkhorn Creek (Fig. 8). The most prolific gravels were in the Prickley Pear drainage which produced an estimated 49,020 ounces of gold (Lyden, 1948). A Yuba connected-bucket floating dredge was installed in 1938 on Prickley Pear Creek about 3 3/4 miles downstream of Jefferson City. This dredge worked upstream to the confluence of Beavertown Creek (loc. 5, Fig. 8, Table III) recovering about $1.5 million of gold from a strip of placer ground four miles long and 1,000 feet wide (Becraft et al., 1963). In 1940, an attempt was made to mine a



Data by: Klepper et. al., (1957)
Location SW 1/4 Sec. 22 T 4 N, R 2 W.

WGM Inc. Mining and Geological Consultants
Anchorage, Alaska

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Elkhorn GRA, Montana

Geologic Map of the Ida Mine

SCALE AS SHOWN			FIGURE
DATA BY	DATE 9/1982	REV. SEC.	10
DRWN BY DSI	APRVD G.F.		

short section of Elkhorn Creek (loc. 47) utilizing a dragline dredge, but only 678 ounces of gold was recovered. An abundance of large boulders contributed to the shutdown of the Elkhorn Creek operation (Roby et al., 1960). Placer mining on Spring (loc. 9), Tizer, and Wilson (loc. 65) Creeks was sporadic and small-scale. Sluicing or dry-land dredging were the general methods employed on these creeks. Roby et al. (1960) report that Muskrat Creek (loc. 31) was tested for dredging ground, but it was not subsequently worked.

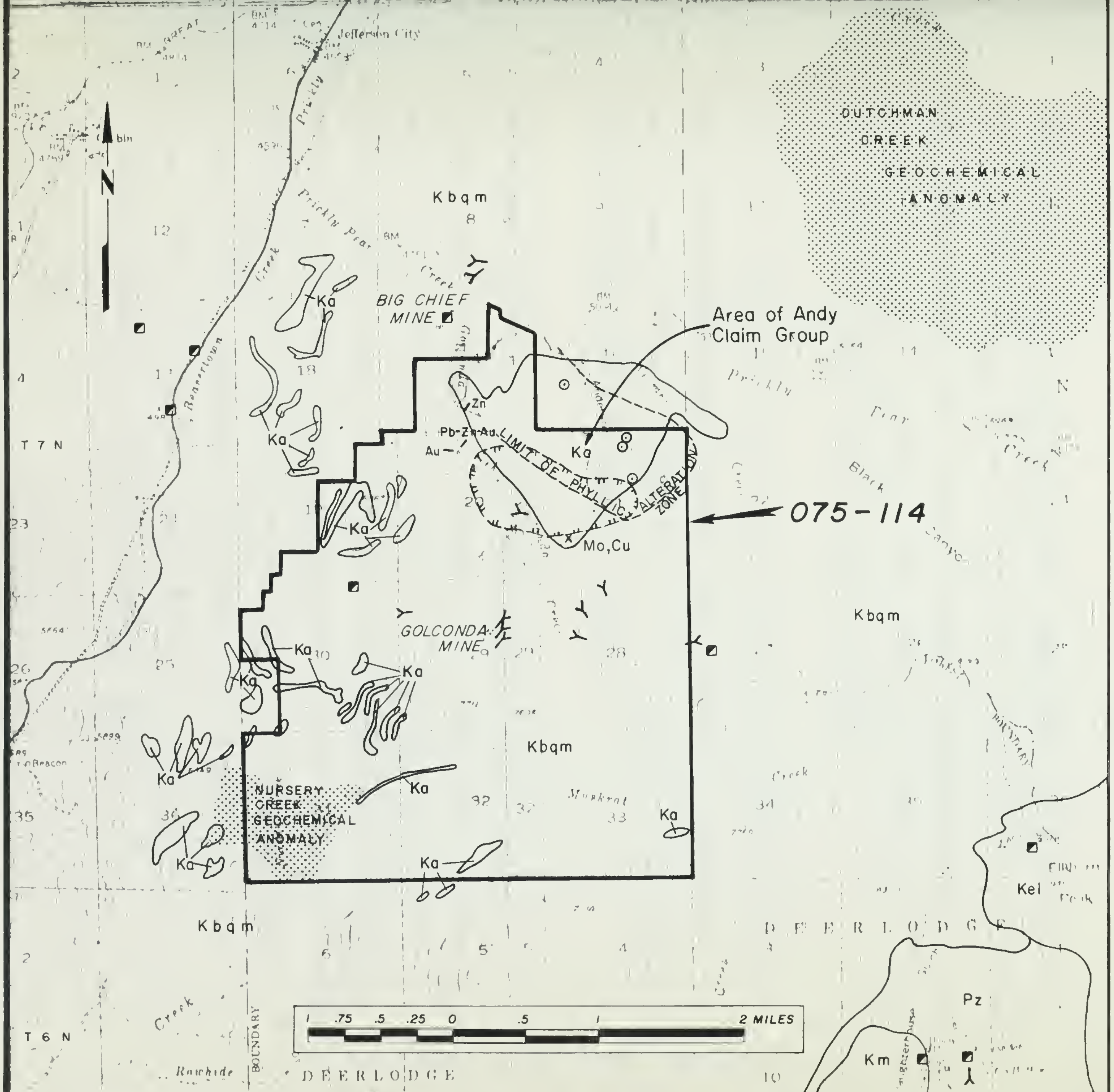
3.2 Known Mineral and Energy Prospects, Occurrences, and Mineralized Areas

A number of gold-silver-lead-zinc-copper prospects, occurrences, and mineralized areas are known in the northern two-thirds of the Elkhorn GRA. Most of these consist of either vein or replacement mineralization and exhibit the same style of mineralization as the deposits discussed in the previous section; thus, additional discussion of these prospects is unnecessary. The more significant of these occurrences are tabulated in Table III and shown on Figure 8. In addition, there are numerous prospect pits, shafts, and adits shown the detailed geologic maps which provide evidence of past prospecting activity for these types of deposits. Undoubtedly, there is some evidence of mineralization at many of these old prospecting sites.

Two prospects in the Elkhorn GRA indicate potential for porphyry copper-molybdenum mineralization. The two prospects are the Turnley Ridge prospect (Bulwer mine area - loc. 41, Fig. 8, Table III) and the Andy claim group (loc. 71) in the Golconda area.

The Turnley Ridge prospect was investigated during 1973 and 1974 by U.S. Borax. The program included two drill holes (Greenwood et al., 1978). An assemblage of potassic, phyllic and propylitic alteration is developed near the center of the Turnley Ridge stock, a quartz monzonite porphyry. The stock is a satellitic pluton of the Boulder batholith. Sulfide development is generally weak, but molybdenum and minor copper sulfides occur in quartz veins within the potassic and phyllic zones. The best mineralized intercept reported consists of 0.079% molybdenum over 10 feet (Senter, 1975). Senter (1975) concluded that the Turnley Ridge mineralization represents a single phase, relatively weak porphyry system.

The Andy claim group (Fig. 11) is predominantly underlain Butte Quartz Monzonite exhibiting a variable composition and texture (Greenwood et al., 1978). The prospect is centered on a body of equigranular aplite which hosts the copper-molydenum mineralization and is co-extensive with a well developed phyllic alteration assemblage. This assemblage is characterized by quartz and sericite which have almost completely replaced the original feldspar, the absence of biotite, and numerous (1-5%) disseminations and veinlets of pyrite. Strong copper and molybdenum rock geochemical anomalies are also present over the prospect. An area about 1,500 feet in diameter (NE¼, sec. 21 and SE¼, sec. 16, T.7N., R.3W.) is highly anomalous in copper and molybdenum. Some molybdenum values are over 300 ppm and some copper values exceed 1,000 ppm. The central anomaly is surrounded by a fringing anomaly roughly 7,000 feet by 4,000 feet with molybdenum values ranging from 50 to 200 ppm and copper values ranging from 100 to 1,000 ppm. Exxon Corporation drilled four diamond core holes during 1977, but the drill results are not known. The Andy porphyry prospect has many of the important



LEGEND

Kbqm	Butte Quartz Monzonite
Km	Maffic Intrusive Rocks
Ka	Aplite
Kel	Lower Member of Elkhorn Mountain Volcanics
Pz	Poleozoic Sedimentary Rocks

Adit
Shaft
Drill Hole
Area of U.S. Geological Survey Geochemical Anomaly
Aeromagnetic Anomaly
WGM Sample Location showing anomalous elements,
/ = Silt Sample
X = Rock Sample

Compiled from:

Greenwood et al, 1978
Becraft et. al., 1963
Smedes, 1966

WGM Inc. Mining and Geological Consultant, Anchorage, Alaska

BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Elkhorn GRA, Montana

**Geology, Geochemistry, and Geophysics
Elkhorn WSA (075-114)**

1" = 1 MILE, 1:62,500
WGM 1/983
DSI GF

11

features of a porphyry copper-molybdenum system, including well developed phyllic alteration, a strong geochemical expression, and an assemblage of quartz-pyrite veinlets. In the context of the well established Lowell and Guilbert (1970) porphyry deposit model these features are indicative of the fringing or overlying phyllic assemblage adjacent to the ore zone (Greenwood et al., 1978).

Klepper et al. (1957) report that spradic limonitized replacement bodies as much as 75 feet long and 15 feet thick occur in a limestone bed in the Three Forks Shale belt that crops out along the range line between R.2W. and R.3W. in T.5N. These bodies reportedly contain some gold. A pit shown on his map (loc. 72, Fig. 8) may be in one of these occurrences.

Roby et al. (1960) report that several hundred tons of hematite have been mined from the Boulder mine (loc. 48, Fig. 8, Table III). The deposit measures about 100 feet in length and 15 feet in length. It is localized along a vertical contact of shale and limestone.

An unusual occurrence of copper is reported at Copper Gulch (loc. 15, Fig. 8, Table III), a tributary to Beavertown Creek. Copper occurs in the metallic form and as oxide in a peat bog. The principal concentration of metallic copper is mixed with sand layers and pockets near bedrock whereas copper oxide is found with the peat (Roby et al., 1960). Apparently, copper leached from nearby chalcopyrite-bearing quartz veins was precipitated in the bog by either carbonaceous peat or iron oxide. Exploration by the U.S. Bureau of Mines indicates that about 77,000 cubic yards of material averages 8.7 pounds of copper per cubic yard (Forrester, 1942).

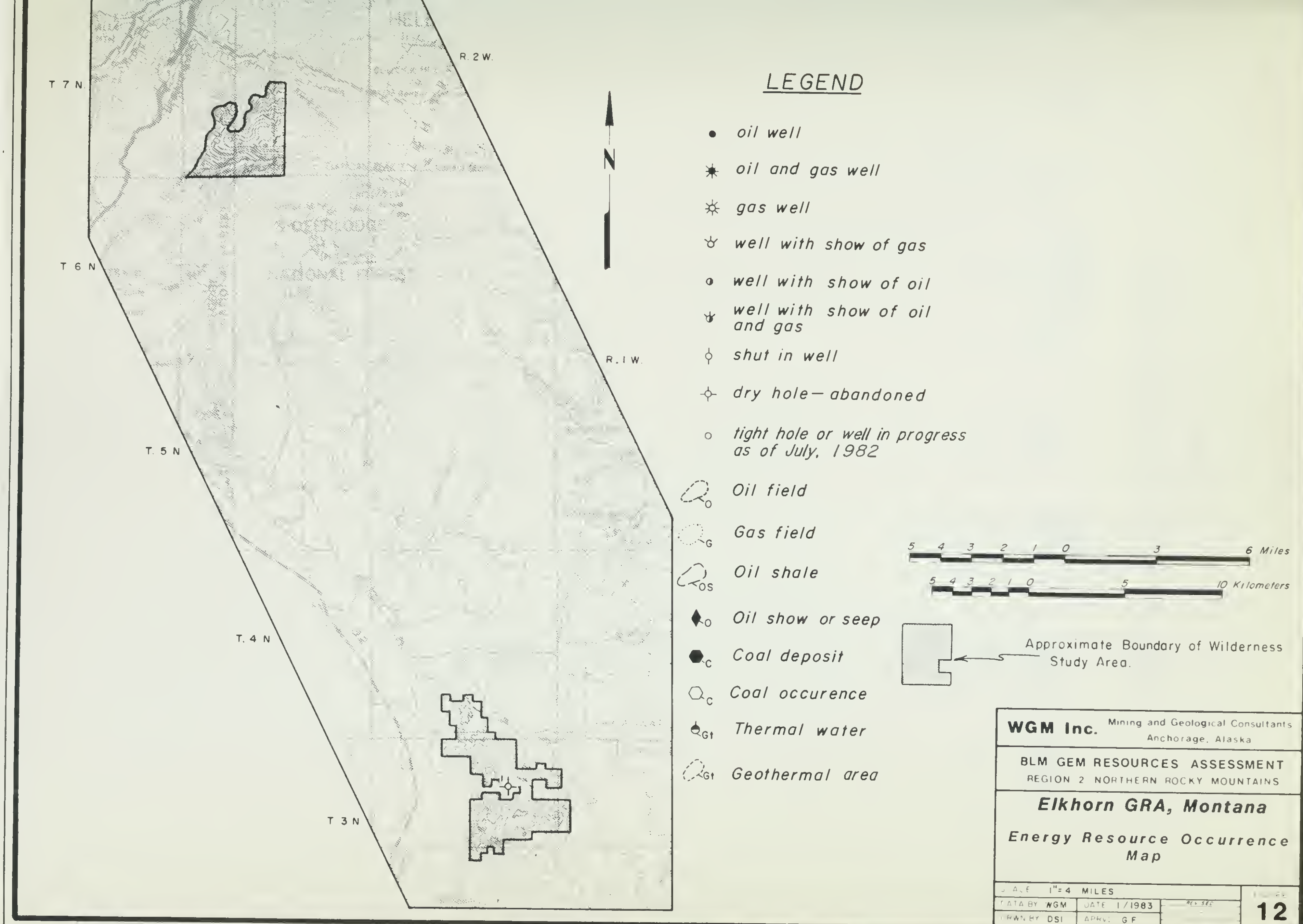
Two small uranium occurrences, the Atomizer (loc. 3, Fig. 8, Table III) and the Beaverton Ranch prospect (loc. 16, Fig. 8, Table III), are known in the Elkhorn GRA. At the Atomizer, uranium occurs in a chalcedonic quartz vein (CRIB files) and at the Beaverton Ranch, metatorbernite (a copper-uranium mineral) occurs in a narrow vein in quartz monzonite. Grade is approximately 0.05% uranium (Sahinen, 1956).

Three veins of optical grade calcite occur at the Dunbar calcite property (loc. 62, Fig. 8, Table III). The veins range from 4 to 6 feet in width and are in andesite. They have been exposed by shallow surface cuts for a length of about 500 feet, but no production is recorded (Roby et al., 1960).

There has not been any oil or gas production from the Elkhorn GRA. Three shallow dry holes have been drilled in the region and two had reported oil shows. One of these was drilled in sec. 11, T.3N., R.2W. and is in or immediately adjacent to the Black Sage WSA (Fig. 12). This well was 1,000 feet deep (Table IV).

3.3 Mining Claims, Leases and Material Sites

A review of BLM records current to August 30, 1982 shows that there are approximately 764 unpatented and 255 patented mining claims within the Elkhorn GRA (Fig. 13). There are approximately 27 unpatented and 7 patented mining claims, both lode and placer, in or immediately adjacent to the Elkhorn WSA. No mining claims are within the Black Sage WSA.

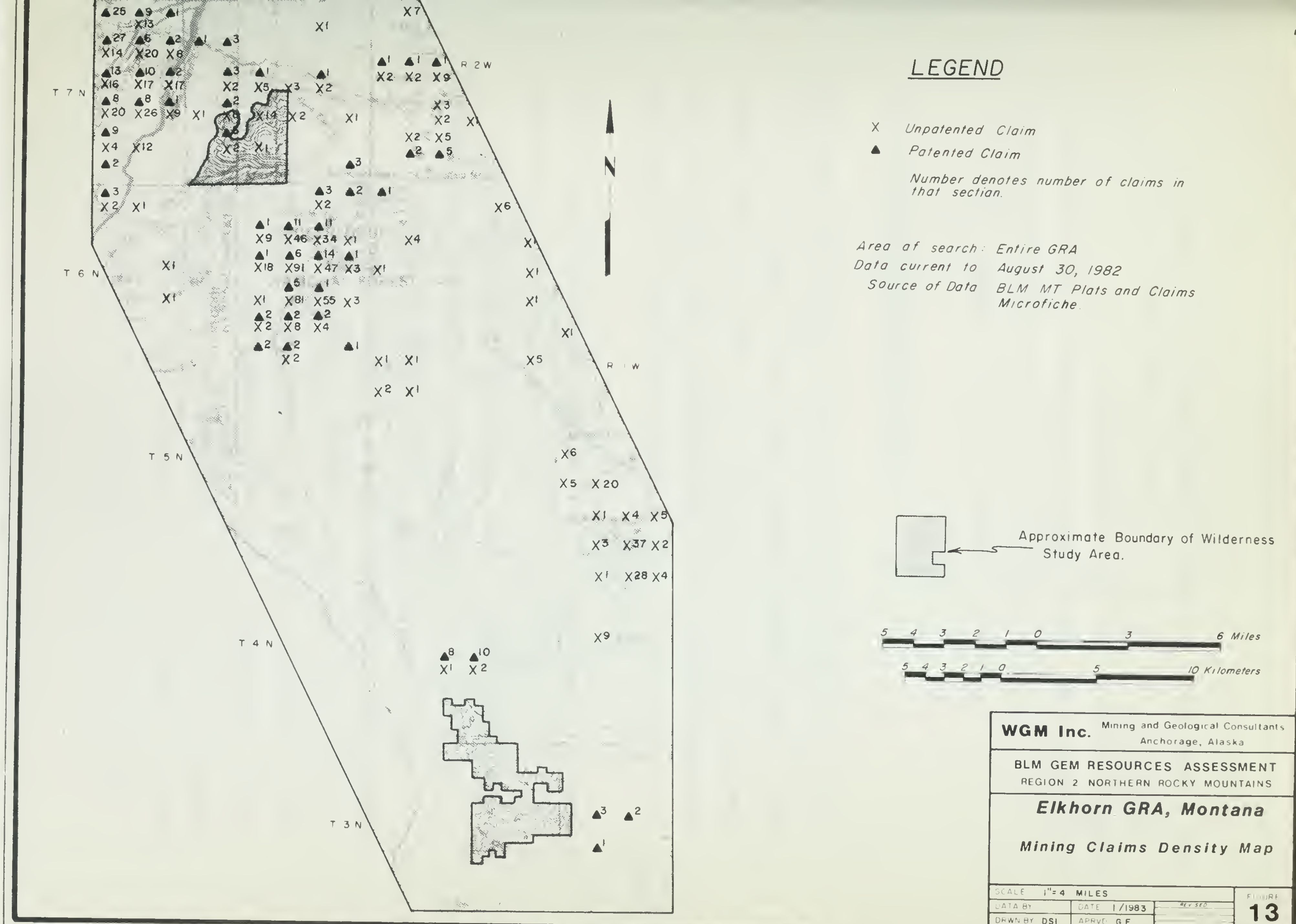


R. 2 W.
R. 1 W.
T 7 N.
T 6 N
T. 5 N
T. 4 N
T 3 N
N
LEGEND
oil well
oil and gas well
gas well
well with show of gas
well with show of oil
well with show of oil and gas
shut in well
dry hole — abandoned
tight hole or well in progress as of July, 1982
Oil field
Gas field
Oil shale
Oil show or seep
Coal deposit
Coal occurence
Thermal water
Geothermal area
5 4 3 2 1 0 3 6 Miles
5 4 3 2 1 0 5 10 Kilometers
Approximate Boundary of Wilderness Study Area.
WGM Inc. Mining and Geological Consultants Anchorage, Alaska
BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS
Elkhorn GRA, Montana
Energy Resource Occurrence Map
1" = 4 MILES
WGM
DATE 1/1983
DSI
G F
12

TABLE IV

OIL AND GAS WELL IN THE ELKHORN GRA, MONTANA

Map No.	Location Sec.	T.	R.	Name	Total Depth	Date	Results
1	11	3N	2W	No. 1	1,000 ft.	1969	Show of oil



LEGEND
X Unpatented Claim
▲ Patented Claim
Number denotes number of claims in that section.
Area of search: Entire GRA
Data current to August 30, 1982
Source of Data BLM MT Plats and Claims Microfiche.
Approximate Boundary of Wilderness Study Area.
5 4 3 2 1 0 3 6 Miles
5 4 3 2 1 0 5 10 Kilometers
N
T 7 N
T 6 N
T 5 N
T 4 N
T 3 N
R 2 W
R 1 W
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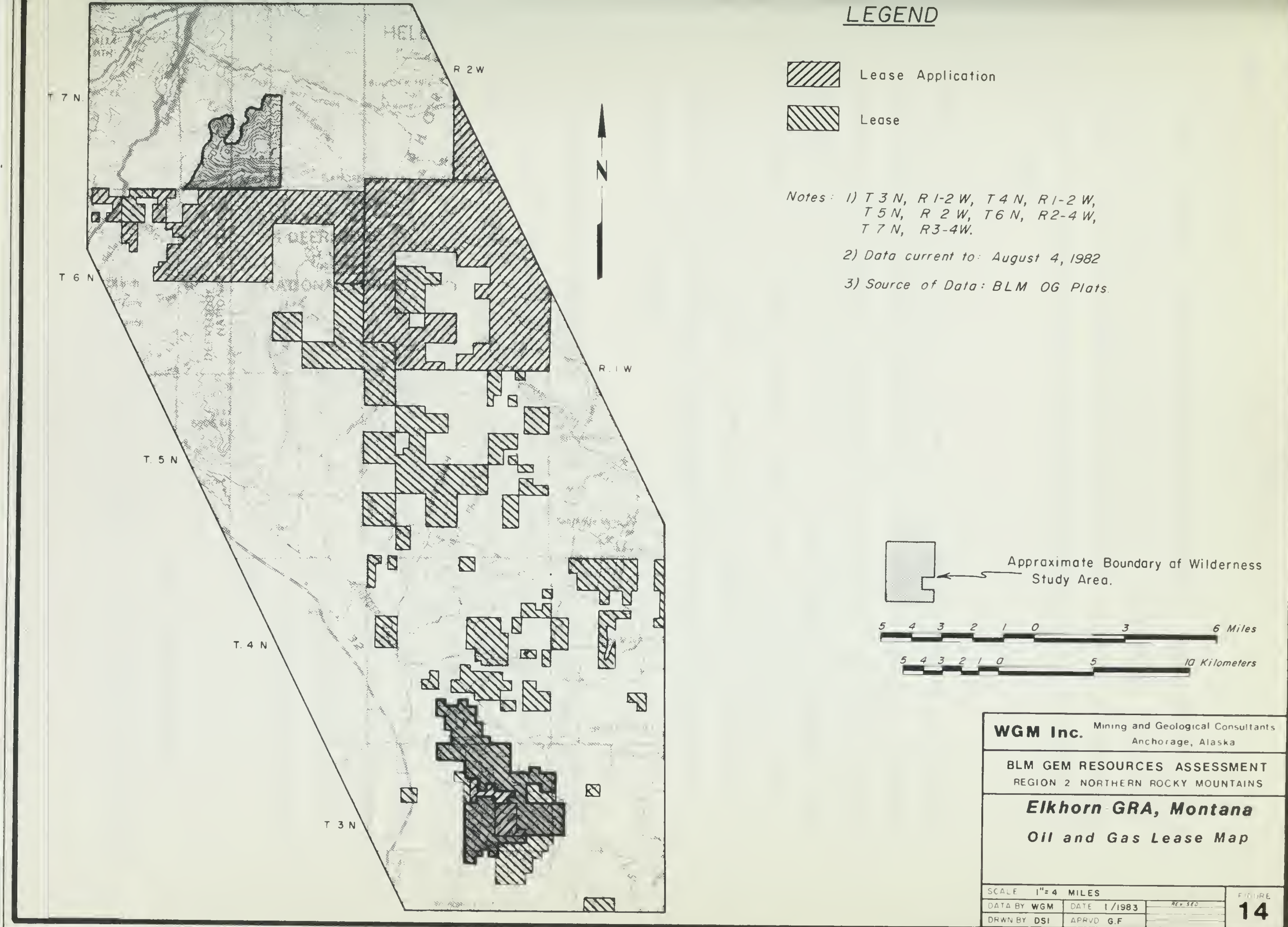
Elkhorn GRA, Montana
Mining Claims Density Map
SCALE 1"=4 MILES
DATA BY
DATE 1/1983
DRWN BY DSI
APRVD G.F
REVISED
FIGURE 13

Oil and gas lease plats current to August 4, 1982 were also reviewed. About 25 to 30% of the Elkhorn GRA is covered by oil and gas leases or applications (Fig. 14). All of the Black Sage WSA except for one parcel, about one square mile in area, is covered by oil and gas leases. The remainder of the Black Sage WSA is covered by an oil and gas lease application. None of the Elkhorn WSA is covered by oil and gas leases or applications.

3.4 Mineral and Energy Deposit Types

The Elkhorn GRA encompasses a diversified geologic environment that has potential for several different types of metallic mineral deposits. These include base/precious metal veins, skarn deposits, carbonate replacement deposits, porphyry copper-molybdenum deposits, bulk tonnage disseminated gold deposits, and placer gold deposits.

Veins in the Elkhorn Mountains region have been categorized on the basis of their mineralogical content into quartz and chalcedony veins (Becraft et al., 1963; Smedes, 1966; Klepper et al., 1971). The quartz veins are tabular bodies, predominately of coarsely crystalline quartz, in zones of sheared and intensely altered batholithic and pre-batholithic rocks. Some of these veins exhibit simple structures while others are complex networks. They contain varying amounts of sulfides and parts of a quartz vein may contain little or no quartz gangue. When tourmaline is present in large amounts, it is generally intergrown with quartz and some pyrite. Chalcedony is not unknown, but it is a minor constituent and definitely younger than the quartz and sulfides. Chacedony veins consist mainly of chalcedony and microcrystalline quartz, but characteristically are low in sulfide



T 7 N.
T 6 N
T. 5 N
T. 4 N
T 3 N
R 2 W
R. I W
N
LEGEND
Lease Application
Lease
Notes: 1) T 3 N, R 1-2 W, T 4 N, R 1-2 W, T 5 N, R 2 W, T 6 N, R 2-4 W, T 7 N, R 3-4 W.
2) Data current to: August 4, 1982
3) Source of Data: BLM OG Plats.
Appraximate Boundary af 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
Elkhorn GRA, Montana
Oil and Gas Lease Map
SCALE 1"= 4 MILES
DATA BY WGM
DATE 1/1983
DRWN BY DSI
APRVD G.F
FIGURE
14

mineral content. They occur singly or in groups in batholithic rocks that have been repeatedly brecciated and silicified along steep fractures. Commonly they have prominent reef-like outcrops. Some of the chalcedony veins are radioactive and a few actually produced uranium ore (Becraft et al., 1963).

Skarn or contact metamorphic bodies of high-temperature silicate minerals that contain magnetite, specularite, pyrite, or chalcopyrite, or combinations of these minerals, are common near the margins of intrusive bodies. The skarns are localized in Paleozoic carbonate rocks or in impure limestone units in the Wolsey and Park Shales and in the lower part of the Elkhorn Mountains Volcanics. Many of these deposits carry significant amounts of gold and some have been exploited for use as a smelter flux (Klepper et al., 1957).

Silver-lead-zinc replacement deposits occur in the Pilgrim Dolomite (the most prolific horizon), the Meagher Limestone, the Mission Canyon Limestone, and in the limestone and dolomite beds belonging to the Quadrant Formation. Argentiferous galena, accompanied by at least a small amount of pyrite and sphalerite, is apparently common to all of these deposits. Chalcopyrite, tetrahedrite, bournonite, argentite, and quartz gangue are also present in some deposits. Most ores contain both silver and gold, but the ratios of these two metals varies widely among deposits. The near-surface portions of these deposits are oxidized (Klepper et al., 1957).

The varied spectrum of ore deposits that are often associated with a porphyry system are present within or adjacent to the Elkhorn GRA (Greenwood

et al., 1978). Skarn and limestone replacement deposits are well developed in the Elkhorn district and to the east in the Radersburg district (Weed, 1901; Smedes, 1966). In addition, a breccia pipe cemented by tourmaline, quartz, and sulfide minerals is present at the Skyline mine (loc. 29, Fig. 8) and may overlie a buried porphyry copper-molybdenum system. Indications of porphyry copper-molybdenum mineralization are present at the Turnley Ridge prospect (loc. 41, Fig. 8) in the Elkhorn district as well as within the Boulder batholith around Golconda Creek (Senter, 1975; Greenwood et al., 1978). The porphyry mineralization is developed in association with aplitic phases of the Boulder batholith and with satellite stocks (Greenwood et al., 1978).

In recent years low grade (often less than 0.1 ounces of gold per ton) but large tonnage gold orebodies have been exploited. These deposits consist of disseminations or stockworks in igneous plugs, stocks, dikes and sills; altered zones within volcanic flows principally of Tertiary and Mesozoic age; and in various types of sedimentary rocks. The principal economic element in these deposits is gold with small amounts of silver although a few deposits yield base metals (Boyle, 1979). The gold in these deposits often occurs as microscopic or sub-microscopic grains (Elevatorski, 1981). Potential for this type of deposit may exist at the following prospects and occurrences:

1. The stockwork system surrounding the Golconda (Golden Assets) mine (loc. 17, Fig. 8). According to Roby et al. (1960), individual bodies of high grade gold ore are present and alteration of the host granite

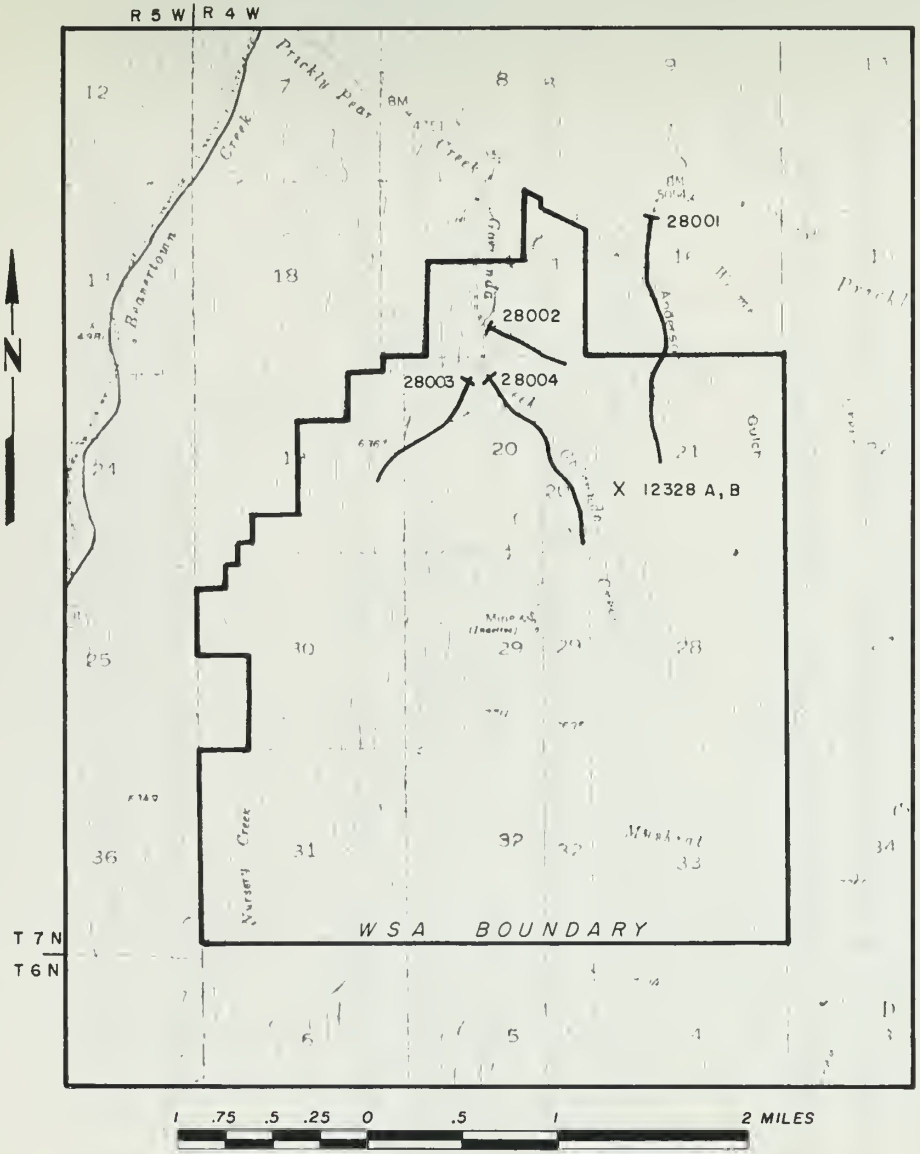
extends southeast for at least 2,000 feet. Within the altered area, significant tonnages of lower grade material might exist. Two stream silt samples collected from streams draining the area contained significant gold values, 0.30 and 0.24 ppm (nos. 38003 and 28004, Fig. 15).

2. An intensely fractured, and sericitized zone at least 2,000 feet in one direction is described by Becraft et al. (1963) at the David Copperfield adit (loc. 68, Fig. 8, Table III). Pyrite and quartz are scattered through the altered rock, but no precious metal assays are reported in the literature.

3. The Iron mine at Elkhorn Peak (loc. 22, Fig. 8) contains a possibel 4.2 million tons of rock containing 0.03 ounce of gold per ton, 0.2 ounce of silver per ton, and 0.15% copper (Greenwood et al., 1978). The mineralization is localized in lenses along bedding and fractures in andesite.

As far as is known, the above areas have not been evaluated in detail for bulk tonnage disseminated/stockwork gold deposits.

Most of the favorable areas amenable to large-scale placer mining have probably been worked out. Those remaining contain large boulders which prohibit the use of high production equipment. However, smaller undiscovered pockets of gold-bearing gravels are probably present along the Wilson, Tizer, and upper Prickley Pear drainages. Some of these could probably be profitably worked by small-scale placer operators.



Analytical Data

SAMPLE NUMBER	SAMPLE TYPE	Cu (PPM)	Pb (PPM)	Zn (PPM)	Au (PPM)	Ag (PPM)	Mo (PPM)
28001	SILT	45	30	130	0.04	1.2	5
28002	SILT	<u>190</u>	<u>65</u>	<u>1000</u>	0.02	0.4	2
28003	SILT	40	50	180	<u>0.30</u>	0.4	6
28004	SILT	80	<u>1000</u>	<u>470</u>	<u>0.24</u>	<u>5.0</u>	5
12328 A	ROCK	<u>240</u>	15	20	0.02	1.4	<u>40</u>
12328 B	ROCK	140	20	100	0.02	0.6	5

Sample Descriptions

12328 A – *Fine grained Aplitic Quartz Monzonite, bleached with 30% Limonite after dessimeminated pyrite.*

12328 B – *Medium grained Biotite Quartz Monzonite with chloritized (?) biotite, abundant hematite and limonite stained fractures.*

Note: 1) Anomalous values are underlined.
2) Samples collected by G. Fernette and W. Jones, Oct., 1982
3) Atomic Absorption Analyses.

Stream Sediment Sample

X *Rock sample*

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Anchorage, Alaska

BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Elkhorn GRA, Montana

Geochemical Sample Locations and Data for the Elkhorn WSA (075-114)

SCALE 1 MILE (1/62,500)		FIGURE
DATA BY WGM	DATE 9/ 982	15
DRWN BY	APRVD G F	

Greenwood et al. (1978) collected approximately 200 rocks, panned concentrate and stream sediment samples in the northern part of the Elkhorn GRA. Approximately 50 of these samples are within the Elkhorn WSA (075-114). The samples were analyzed for 30 elements by semi-quantitative spectrographic methods (Mootka et al., 1978). These data delineate several molybdenum-tungsten-tin anomalies and a precious metal anomaly.

The Elkhorn WSA is located astride a northeasterly-trending alignment of molybdenum-tungsten geochemical anomalies that transects its center (Fig. 11). Three strong molybdenum-tungsten anomalies are present in the Elkhorn GRA along this trend (southwest to northeast): (1) the Nursey Creek anomaly (sec. 31, T.7N., R.4W.), (2) the previously described anomaly over the Andy claims (secs. 16 and 22, T.7N., R.3W.), and (3) the Dutchman Creek anomaly (secs. 2, 11 and 12, T.7N., R.3W.). The geochemical trend of anomalies has been defined over a distance of 18 miles and parallels the eastern contact of the Boulder batholith located a few miles to the east (Greenwood et al., 1978).

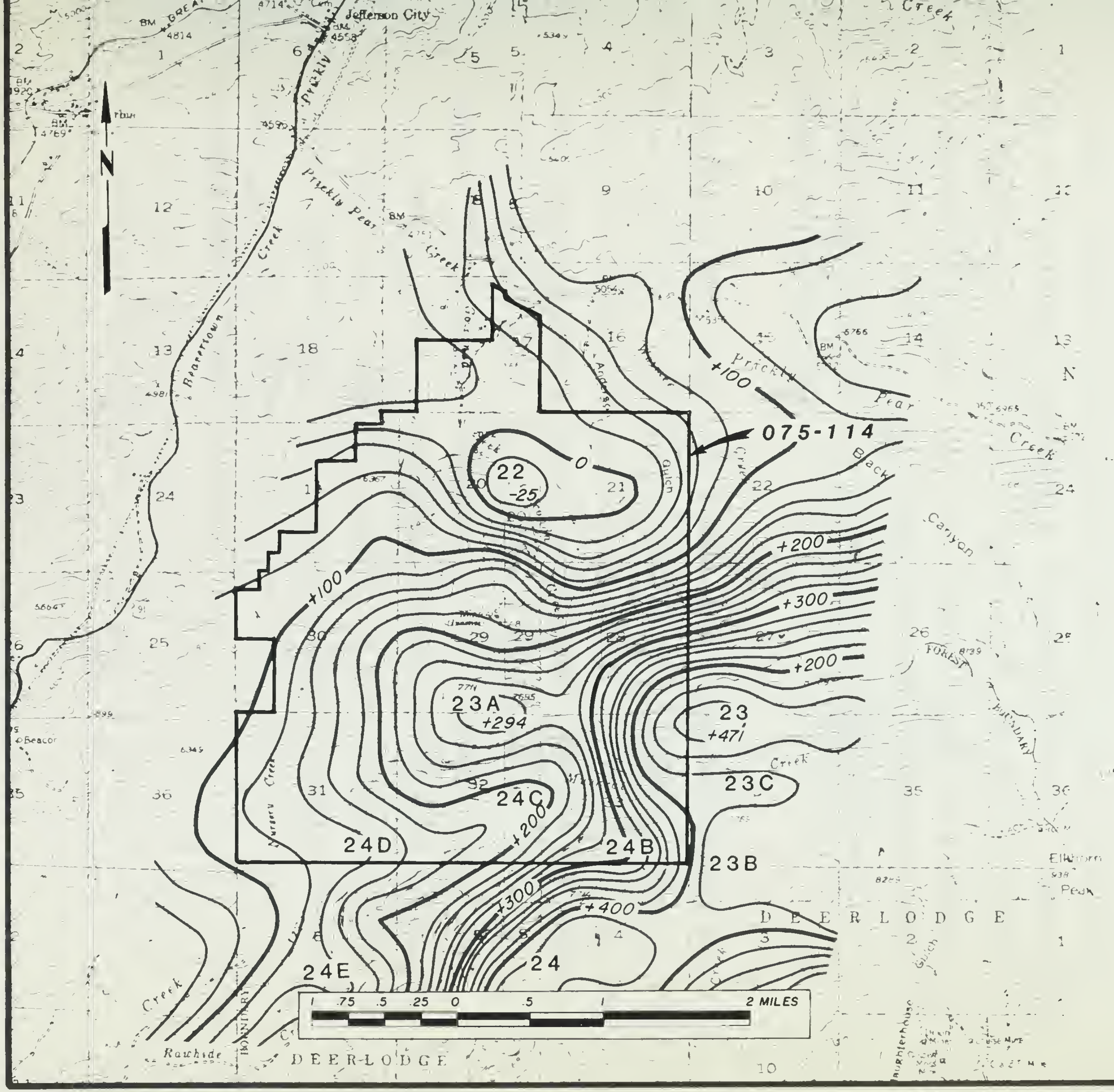
A tin-molybdenum anomaly is present at Hidden Lake (SW¼, NW¼, sec. 6, T.6N., R.3W.). Brecciated andesite cemented by magnetite and stained by copper carbonates occurs in the area. Greenwood et al. (1978) suggest that the presence of copper-rich breccias coupled with the molybdenum-tin anomaly indicate the existence of a breccia pipe deposit similar to that at the Skyline mine.

Panned concentrate samples from six streams draining a ridge near the head of Staubach Creek (secs. 2 and 11, T.6N., R.3W.) are anomalous in gold,

silver, arsenic, bismuth, niobium and thorium. These anomalous samples are unexplained and may reflect undiscovered mineral deposits (Greenwood et al., 1978).

A detailed magnetic survey of the Elkhorn WSA detected two prominent magnetic anomalies (Fig. 16). One of the anomalies, a magnetic low coincides with the tungsten-molybdenum anomaly present on the Andy claims. The second anomaly, a magnetic high, is part of an east-west trending anomaly which transects the southern third of the WSA. This anomaly is interpreted to coincide with highly elevated plutonic rocks (Greenwood et al., 1978).

The Boulder batholith is anomalous in uranium and thorium. Rocks of the batholith typically contain 10 ppm uranium (Tilling and Gottfried, 1969). Thorium is normally associated with uranium in igneous rocks and its crustal abundance is three to four times greater than that of uranium. From 1949 to 1956 the area underlain by the Boulder batholith was intensely prospected for uranium (Smedes, 1966). The uranium occurrences located were associated with chalcedony veins. Both primary and secondary uranium minerals have been identified. Roberts and Gude (1953) suggested that the close spatial association of primary and secondary uranium minerals indicates that little or no migration of uranium has occurred. They concluded that the primary uranium was deposited by ascending epithermal solutions during silicification. Most of these uranium deposits are too small to be mined economically (Becraft et al., 1966). However, minor production was obtained from the W. Wilson property and the Lone Eagle mine (both outside the Elkhorn GRA). The



Note: Contours represent total intensity residual magnetic field in gammas.

Data by: Greenwood et al.,(1978)

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Elkhorn GRA, Montana

Aeromagnetic Map of the Elkhorn WSA (075-114)

SCALE 1" = 1 MILE			FIGURE
DATA BY WGM	DATE 9/1982	REV SEC	16
DRWN BY DSI	APRVD G.F		

small production obtained from the Boulder batholith despite intensive prospecting suggests that the chances of discovering larger uranium deposits is small (Becraft, 1963; Smedes, 1966).

The Elkhorn WSA lies entirely within the Boulder batholith which was intruded into the section during and after folding and thrusting (Ruppel et al. 1981). Although igneous rocks may form an oil and gas reservoir when they are fractured and buried beneath sedimentary source beds, igneous rocks are exposed on the surface within the Elkhorn WSA. There is no possibility that hydrocarbon resources are present in the WSA unless it is part of a thrust plate. Then hydrocarbon bearing traps might be present in underlying plates. Based on present knowledge and geologic interpretation this possibility appears unlikely.

The remainder of the Elkhorn GRA is part of the west-central portion of the Montana Thrust belt. The nearest production to the GRA is approximately 125 miles east in the Mud Creek gas field and 130 miles north in the oil and gas fields on the southern part of the Sweetgrass Arch. Commercial production in the Thrust belt is known in southwestern Wyoming and near Glacier, Montana. The Sweetgrass Arch and Wyoming Thrust belt are recognized as major petroleum provinces. Several authors have considered the Montana Thrust belt to have considerable potential for hydrocarbon production (McCaslin, 1981b; Woodward, 1981a, b; Cannon, 1971). Although relatively few tests have been drilled in the Montana Thrust belt, drilling has increased recently (McCaslin, 1981a).

Both hydrocarbon source beds and reservoir beds are recognized in the western Montana Thrust belt (Woodward, 1981a, b). A hydrocarbon prospectus by Kranzler and Warne (1981) presented source rock and thermal maturity analyses on samples taken in the vicinity of the Elkhorn GRA from the Precambrian, Devonian, Mississippian, Pennsylvanian and Cretaceous sediments (Table V). The results indicated that the dark shales sampled could all be considered potential source beds. Hydrocarbon generation ranges from very good to excellent oil and associated "wet" gas to good "dry" methane gas source character. Potential reservoir beds in the region include Precambrian, Cambrian, Devonian, Pennsylvanian, Jurassic and Cretaceous sandstones (Kranzler and Warne, 1981; Woodward, 1981a, b; Table VI). The Devonian and Mississippian carbonates and Pennsylvanian and Cretaceous sandstones are producing formations in central and eastern Montana.

Four conditions which must be present for hydrocarbon accumulation to result are:

1. The presence of Source beds within the area of migration of petroleum from nearby beds.
2. The occurrence of reservoir beds.
3. The occurrence sufficient temperature and time to allow hydrocarbon generation.
4. The presence of a trap in the reservoir beds.

The first three conditions are recognized within the southern part of the Elkhorn GRA and structures capable of forming traps have been mapped within the Elkhorn GRA; thus hydrocarbon potential is good. Until deep tests are

TABLE V

ORGANIC CARBON AND VISUAL KEROGEN ANALYSES OF SOURCE ROCK

SAMPLES FROM THE ELKHORN GRA, MONTANA

Location	Formation	Percent Organic Carbon	VISUAL KEROGEN: Organic Matter Type	VISUAL KEROGEN: Alteration (1-5 Scale)	Hydrocarbon Source Character at Present Level of Thermal Maturity
36-2N-3W	Belt	0.51	Am (Al);-;-	4- to 4	Severely altered, fair to good "dry" methane gas source character.
2-1S-2W	Jefferson	0.14		--	Too organically "lean" to be considered a prospective source.
2-1S-2W	Bakken	3.96	Am (Al);-;-	2- to 2	Moderately mature, very good to excellent oil and associated "wet" gas source character.
5-4N-3E	Heath	2.34	H;-;W	3- to 3	Mature, very good oil and associated "wet" gas source character.
22-5N-1W	Lower Colorado	1.14	H;W-I;-	3+ to 4-	Very mature to severely altered, good "dry" gas source character.
5-6N-1W	Upper Colorado	0.83; 0.84R	I;H*;-	4- to 4	Severely altered, fair "dry" methane gas source character.
16-6N-1W	Slim Sam	2.27	I;H*;-	4- to 4	Severely altered, very good "dry" methane gas source character.

R = Repeat Analysis

Kerogen Key		
Predominant: 60-100%	Secondary: 20-40%	Trace: 1-20%

Al = Algal
Am = Amorphous-Sapropel
H = Herbaceous-Spore/Cuticle
H* = Degraded Herbaceous
W = Woody
C = Coaly
U = Unidentified Material

Data by: Kranzler and Warne (1981).

TABLE VI

POTENTIAL HYDROCARBON RESERVOIR UNITS IN THE ELKHORN GRA, MONTANA

Formation	Age	Potential Net Pay
Primary Potential Hydrocarbon Reservoirs		
Madison (Mission Canyon) Limestone	Mississippian	80-150 feet
Jefferson Dolomite	Devonian	80-150 feet
Secondary Potential Hydrocarbon Reservoirs		
Colorado (Bow Island and Frontier Sandstones)	Cretaceous	20- 50 feet
Flood (Dakota) Sandstone	Cretaceous	10- 30 feet
Kootenai Gastropod Limestone	Cretaceous	10- 25 feet
Kootenai Basal (Lakota or Cut Bank) Sandstone	Cretaceous	30- 50 feet
Swift Sandstone	Jurassic	20- 35 feet
Quadrant (Tensleep) Sandstone	Pennsylvanian	50-150 feet
Lodgepole (Madison) Limestone	Mississippian	50-200 feet
Pilgrim Limestone	Cambrian	25-100 feet
Meagher Limestone	Cambrian	25-100 feet
Flathead Quartzite	Cambrian	50-150 feet
Belt Limestone and Clastic Beds	Precambrian	100- ? feet

Data by: Kranzler and Warne (1981).

made within the area, however, it will remain unknown if commercial hydrocarbons are present.

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 study the above classes can be reduced to two: (1) high temperature (over 150°C) hydrothermal convection systems, and (2) low/intermediate temperature (40-150°C) hydrothermal convection systems.

The area of western Montana and Idaho containing the Wilderness Study Areas (WSAs) evaluated during this project can be divided into six provinces of different geothermal significance:

TABLE VII

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 Elkhorn GRA is in the Montana Basin and Range province. Although western Montana is classed physiographically as part of the Northern Rocky Mountains, the Cenozoic (65 m.y. to present) structural geology is similar to the Basin and Range province of the southwestern United States in that western Montana consists of northwest-trending ranges separated by valleys which are controlled by horst and graben structures. The normal fault systems have been active in the Pliocene (6-2 m.y.)-Pleistocene (Pardee, 1950), and they currently from one of the major seismic zones in the western United States. This zone, the Intermountain Seismic Belt (Smith, 1978), more or less marks the eastern boundary of the Montana Basin and Range province. Typical heat flow values in this province are 75 to 90 milliwatts per square meter (Blackwell, 1969; Blackwell and Robertson, 1973). Typical geothermal gradients range from 15 to 40°C/km and the data are reasonably complete on a reconnaissance basis for this province.

There are numerous hot springs in southwestern Montana. These have been discussed in some detail by Robertson et al. (1976) and are shown on the resource map by Sonderegger and Bergantino (1981). Geochemical reservoir temperatures and measured surface temperatures of these systems generally indicate maximum temperatures between 75 and 150°C. Typically these hot springs are associated with major fracture zones in granitic plutons or with major fracture/fault zones such as the range-bounding faults (especially when major cross structures intersect these zones). The available data suggest that the likelihood of electrical grade temperatures (over 150°C) resources in this province is small. On the other hand, on a relative basis, the low/moderate temperature geothermal resources in the area are significant based on the many known hot and warm springs.

The bedrock in the northern part of the Elkhorn GRA is predominantly the Boulder batholith, its metamorphosed country rocks, and mid-Cenozoic silicic volcanic rocks. The Elkhorn WSA is very near the N17°E alignment of hot springs described by Robertson et al. (1976). This trend includes the Alhambra Hot Spring (about 10 miles north) and Boulder Hot Spring (10 miles to the south). Both springs are controlled by fractures in the granitic rocks of the Boulder batholith. The flow rate at Alhambra Hot Springs is 380 l/min. of 56°C water with an estimated maximum reservoir temperature of 96°C. The flow rate at Boulder Hot Springs is 1,900 l/min. of 76°C water with an estimated maximum reservoir temperature of 136°C. A site in granitic rocks six miles west of Alhambra Springs gave a heat flow value of 80 milliwatts per square meter and a gradient of 26°C/km (1.4°F/100 ft.), a typical value for the Montana Basin and Range province (Blackwell and Robertson, 1973). Gradient measurements from an area two miles southwest of Wicks, Montana, and another area three miles west-northwest from the Elkhorn WSA are normal for the region (21°C/km, 1.2°F/100 ft., Blackwell and Robertson, 1973).

The Black Sage WSA and the southern portion of the Elkhorn GRA are underlain by Precambrian and Paleozoic rocks. The WSA is located on the south end of a doublely-plunging anticline. The Boulder Valley, located to the west, and the Radersburg basin, located to the east, have been rated as having high geothermal potential (Sonderegger and Bergantino, 1981). No geothermal gradient data are available from near the WSA.

3.5 Mineral and Energy Economics

The rise in the price of gold in the past decade has spurred massive exploration efforts and led to the development of many depostis which were previously uneconomic. It is forecast that domestic mine production will supply only about one-third of United States demand for primary gold through the year 2000, with about two-thirds of mined gold coming from gold deposits and the remainder produced as by-products of base metal mining (Butterman, 1980). The consequent demand for gold and present high price levels make development of domestic gold deposits attractive.

Many fine-grained or low grade gold ores which are not amenable or economical to process through a conventional mill can now be processed by cyanide heap-leaching. This process is used to recover gold and silver from ores assaying 0.03 to 0.09 ounces of gold per ton and involves spraying dilute cyanide solutions over crushed ore on impervious pads. The pregnant solutions are recovered after percolating through the ore heap. The precious metals are recovered from the solutions using carbon-absorption or zinc dust precipitation (Elevatorski, 1981). The world's largest heap-leaching operation is in north-central Montana within the Little Rocky Mountains where 65,000 ounces of gold and 140,000 ounces of silver are produced annually from 3.8 million tons of ore averaging 0.033 ounces of gold per ton and 0.285 ounces of silver per ton (Rogers and Enders, 1982).

The price of silver has also increased dramatically in recent years and the United States currently imports over 50% of its silver. Current import

levels are expected to continue if future supply-demand relationships follow present trends (Drake, 1980; Rosta, 1982).

With the increase in the price of imported oil in the past decade, the deregulation of domestic natural gas prices, and increasing government emphasis on energy self sufficiency, exploration and development of domestic oil and gas resources has proceeded at an accelerated pace. Natural gas reserves discovered in the late 1950s and 1960s in Montana were often not developed because of a lack of market. However, under present conditions development drilling is taking place with an eye to near-term production.

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 evaluation, a lower temperature than 40°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.

4.0 LAND CLASSIFICATION FOR GEM RESOURCES POTENTIAL

4.1 Explanation of Classification Scheme

In the following section the land in the two WSAs in the Elkhorn GRA is classified for geology, energy and mineral (GEM) resources potential. The classification system used is shown in Table VIII. 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 system has been accomplished 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 of 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. Some field work was conducted in the Elkhorn WSA.

TABLE VIII

BUREAU OF LAND MANAGEMENT GEM RESOURCES LAND CLASSIFICATION SYSTEM

CLASSIFICATION SCHEME	LEVELS OF CONFIDENCE
1. The geologic environment and the inferred geologic processes do not indicate favorability for accumulation of mineral resources.	A. The available data are either insufficient and/or cannot be considered as direct evidence to support or refute the possible existence of mineral resources within the respective area.
2. The geologic environment and the inferred geologic processes indicate low favorability for accumulation of mineral resources.	B. The available data provide indirect evidence to support or refute the possible existence of mineral resources.
3. The geologic environment, the inferred geologic processes, and the reported mineral occurrences indicate moderate favorability for accumulation of mineral resources.	C. The available data provide direct evidence, but are quantitatively minimal to support or refute the possible existence of mineral resources.
4. The geologic environment, the inferred geologic processes, the reported mineral occurrences, and the known mines or deposits indicate high favorability for accumulation of mineral resources.	D. The available data provide abundant direct and indirect evidence to support or refute the possible existence of mineral resources.

4.2 Classification of the Elkhorn Wilderness Study Area (WSA 075-114)

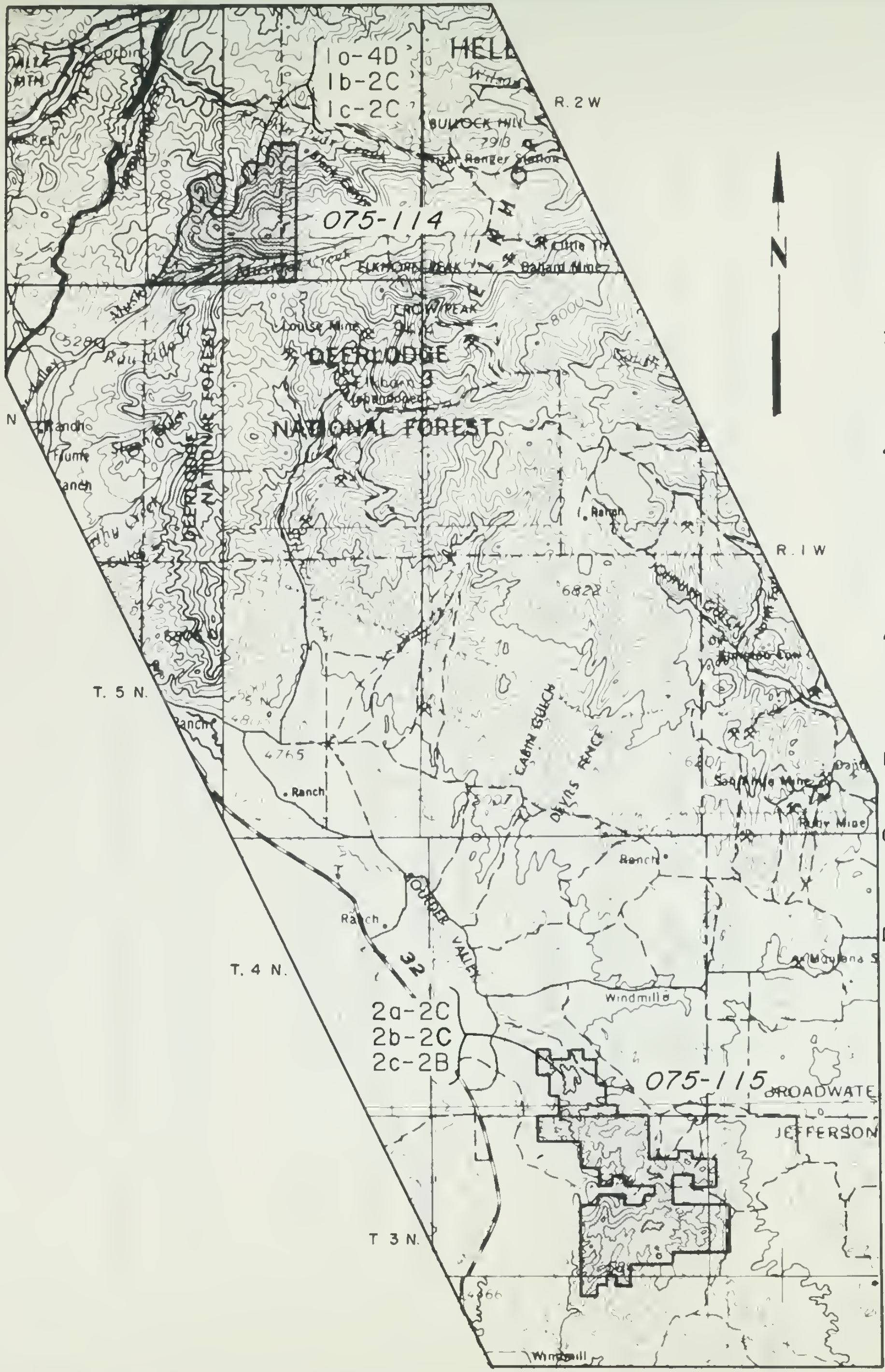
4.2.1 Locatable Minerals

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, and silica sand, etc. (Maley, 1980).

4.2.1a Metallic Minerals. WSA 075-114 (1a, Fig. 17) is classified as highly favorable for metallic mineral deposits based on abundant direct evidence (4D). The basis for the classification are the abundant known deposits, and the favorable geologic, geochemical and geophysical data reviewed in Section 3.0.

4.2.1b Uranium and Thorium. WSA 075-114 (1b, Fig. 17) is classified as having low favorability for the occurrence of uranium and thorium based on limited direct evidence (2C). Intensive past prospecting failed to locate significant deposits and recent geochemical data is not encouraging.

4.1.1c Non-Metallic Minerals. All of WSA 075-114 (1c, Fig. 17) is classified as having low favorability for non-metallic mineral deposits based on limited direct evidence (2C). There is a lack of known occurrences.



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

Area I.D. Number

1(a) - 4D

Commodity — Classification — Level of Confidence

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

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Anchorage, Alaska

BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Elkhorn GRA, Montana

Wilderness Study Area
Land Classification
Locatable Resources

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

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).

4.4.2a Oil and Gas. The entire area of WSA 075-114 (1a, Fig. 18) is classified as unfavorable for oil and gas resources based on limited direct evidence (1C). This classification is based on the fact that the entire WSA is underlain by plutonic rocks.

4.2.2b Geothermal. All of WSA 075-114 (1b, Fig. 18) is classified as unfavorable for both low to intermediate and high temperature geothermal resources based on indirect evidence (1B). This classification is based on nearby geothermal gradient data and the geologic setting.

4.2.2c Sodium and Potassium. The entire area of WSA 075-114 (1c, Fig. 18) is classified as unfavorable for sodium and potassium based on abundant direct evidence (1D). The WSA is entirely underlain by intrusive rocks.

4.2.2d Other. All of WSA 075-114 (1d, Fig. 18) is classified as unfavorable for the occurrence of asphalt, bitumen, coal, oil shale and phosphate

based on abundant direct evidence (1D). The WSA is entirely underlain by intrusive rocks.

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, 1980).

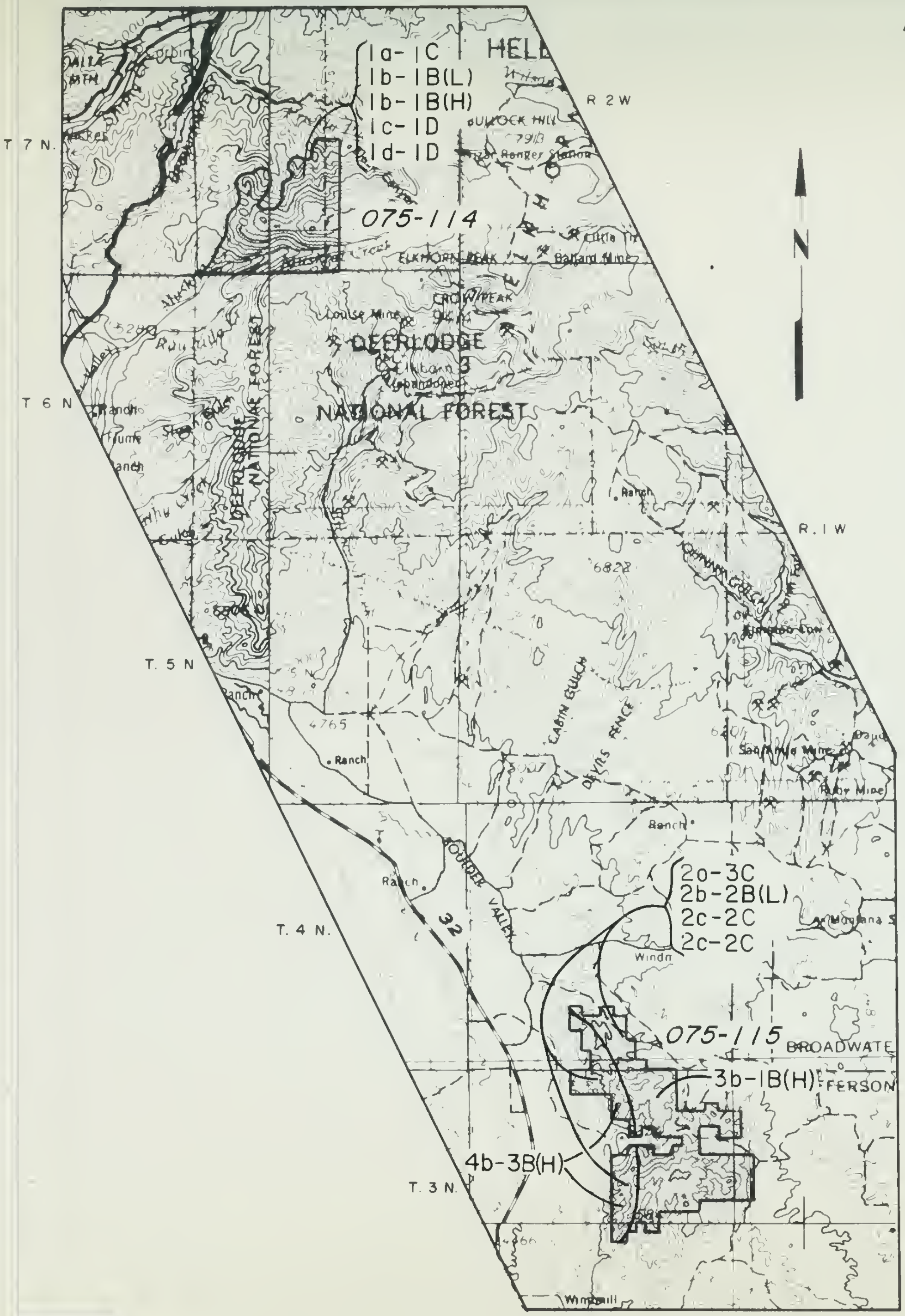
All of WSA 075-114 (1, Fig. 19) is classified as having low favorability for saleable resources based on limited direct evidence (2C).

4.3 Classification of the Black Sage Wilderness Study Area (WSA 075-115)

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, 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, 1980).

4.3.1a Metallic Minerals. All of WSA 075-115 (2a, Fig. 17) is classified as having low favorability for metallic mineral resources based on limited



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

Area I.D. Number

1(a) - 4D

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.

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BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Elkhorn GRA, Montana

Wilderness Study Area Land Classification Leasable Resources

SCALE 1" = 4 MILES (1 250,000)			FIGURE
DATA BY. WGM	DATE 9/1982	REVISED	18
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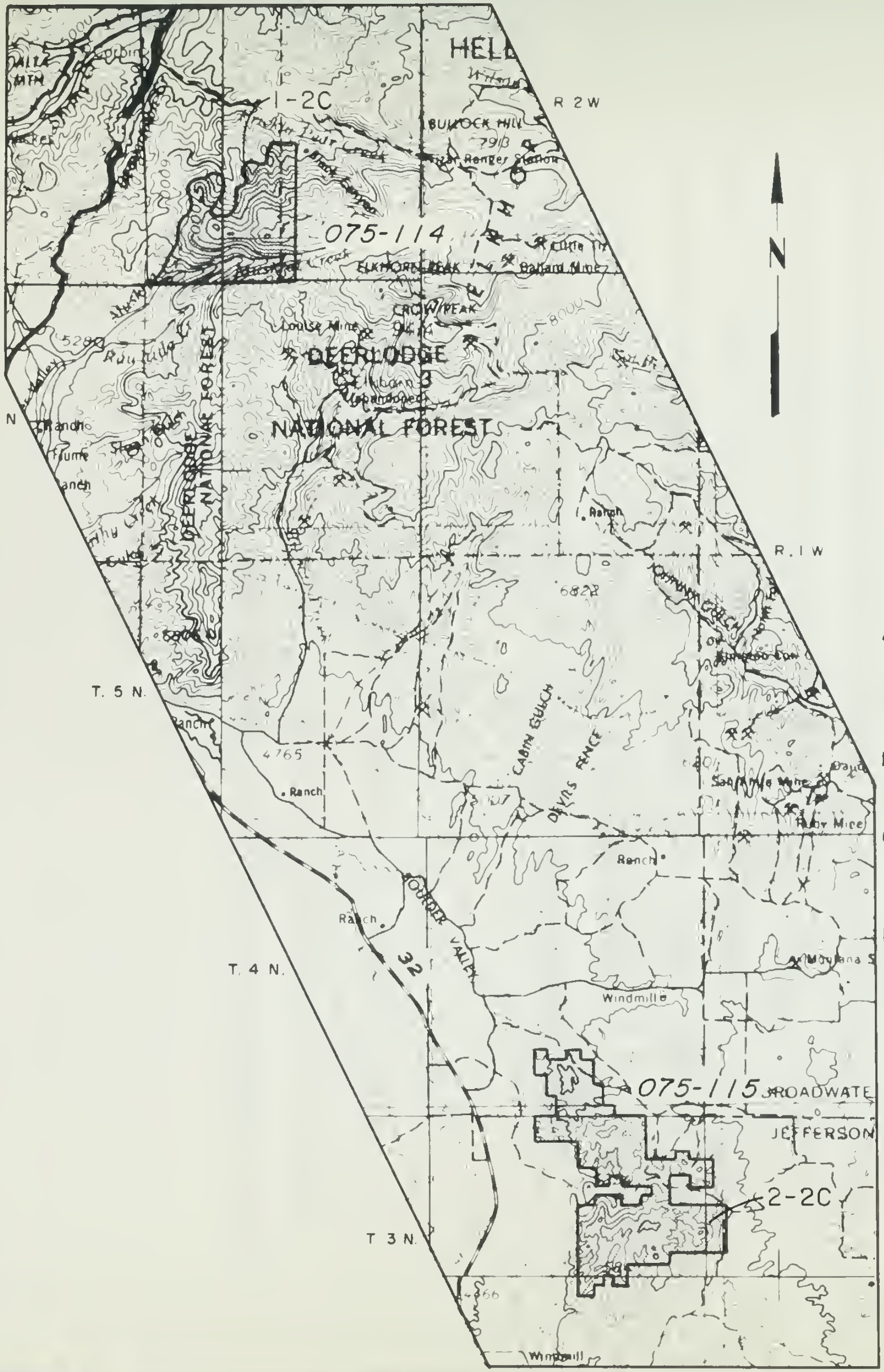

BLM LAND CLASSIFICATION SYSTEM FOR GEM RESOURCES

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

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

s	Sand
g	Grovel
st	Stone
c	Cinders
p	Pumice
pt	Pumicite
cl	Cloy
Ls	Limestone
dl	Dolomite
P	Peot
pw	Petrified wood

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BLM GEM RESOURCES ASSESSMENT
REGION 2 NORTHERN ROCKY MOUNTAINS

Elkhorn GRA, Montana

Wilderness Study Area
Land Classification
Saleable Resources

SCALE 1" = 4 MILES (1:250,000)		FIGURE 19
DATA BY WGM	DATE 9/1982	REVISED
DRWN BY DSI	APRVD G.F	

direct evidence (2C). This classification is based on the lack of known occurrences or geophysical anomalies.

4.3.1b Uranuim and Thorium. WSA 075-115 (2b, Fig. 17) is classified as having low favorability for uranium and thorium based on limited direct evidence (2C). The NURE sampling in the area was not encouraging.

4.3.1c Non-Metallic Minerals. All of WSA 075-115 (2c, Fig. 17) is classified as having low favorability for non-metallic mineral resources based on indirect evidence (2B). There are no known occurrences in the WSA.

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, 1980).

4.3.2a Oil and Gas. All of WSA 075-115 (2a, Fig. 18) is classified as moderately favorable for the occurrence of oil and gas based on limited direct evidence (3C). The classification is based on the geologic environment and the data reviewed in Section 3.4.

4.3.2b Geothermal. All of WSA 075-115 (2b, Fig. 18) is classified as having low favorability for the occurrence of low-intermediate temperature geothermal resources based on indirect evidence (2B). The area adjacent to Boulder Valley (4b(H), Fig. 18) is classified as moderately favorable for high temperature geothermal resources based on indirect evidence (3B). The area is adjacent to the Boulder Valley which is identified as a potential high geothermal province (Sonderegger and Bergantino, 1981). The remainder of the WSA (3b, Fig. 18) is classified as unfavorable for high temperature geothermal resources based on indirect evidence (1B). It is at a relatively high elevation (implying hydrologic recharge is likely).

4.3.2c Sodium and Potassium. All of WSA 075-115 (2c, Fig. 18) is classified as having low favorability for carbonates, borates, silicates, sulfates and nitrates of sodium and potassium based on limited direct evidence (2C). This classification is based on the general unfavorability of the geologic environment, and the lack of occurrences in the region.

4.3.2d Other. WSA 075-115 (2d, Fig. 18) is classified as having low favorability for the occurrence of asphalt, bitumen, coal, oil shale, and phosphate based on limited direct evidence (2C). This classification is based on the narrow thickness of phosphate-rich beds present in the Phosphoria Formation within the WSA.

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, 1980).

The entire area of WSA 075-115 (2, Fig. 20) is classified as having low favorability for saleable resources based on limited direct evidence (2C).

5.0 RECOMMENDATIONS FOR FURTHER WORK

The geologic mapping within the Elkhorn WSA is reasonably detailed. In addition, reasonably detailed geochemical and geophysical data exists for the WSA. This data indicates that it is very likely that mineral deposits are present in the WSA. In particular the altered quartz monzonite around the Golconda (Golden Assets) mine should be mapped, soil sampled and rock sampled in detail to determine if a disseminated/stockwork gold deposit is present.

Data is not so abundant for the Black Sage WSA. A stream silt geochemical survey would raise the confidence level of the rankings for metallic minerals, uranium, and thorium.

Seismic studies should be made of the Black Sage WSA. These studies would permit the interpretation of subsurface structures in the area. Also, they would permit the comparison of subsurface and surface structures for continuity. Seismic studies would also help determine the most favorable drill sites. Such studies would undoubtedly be made by industrial sources prior to drilling deep tests in the area.

The areas of possible geothermal resources is small; thus, a brief geochemical/geologic study with one to two 500 foot drill holes in the western part of the Black Sage WSA would suffice to evaluate the area classed as 3B. If this study is done, the Muskrat Creek drainage should also be included.

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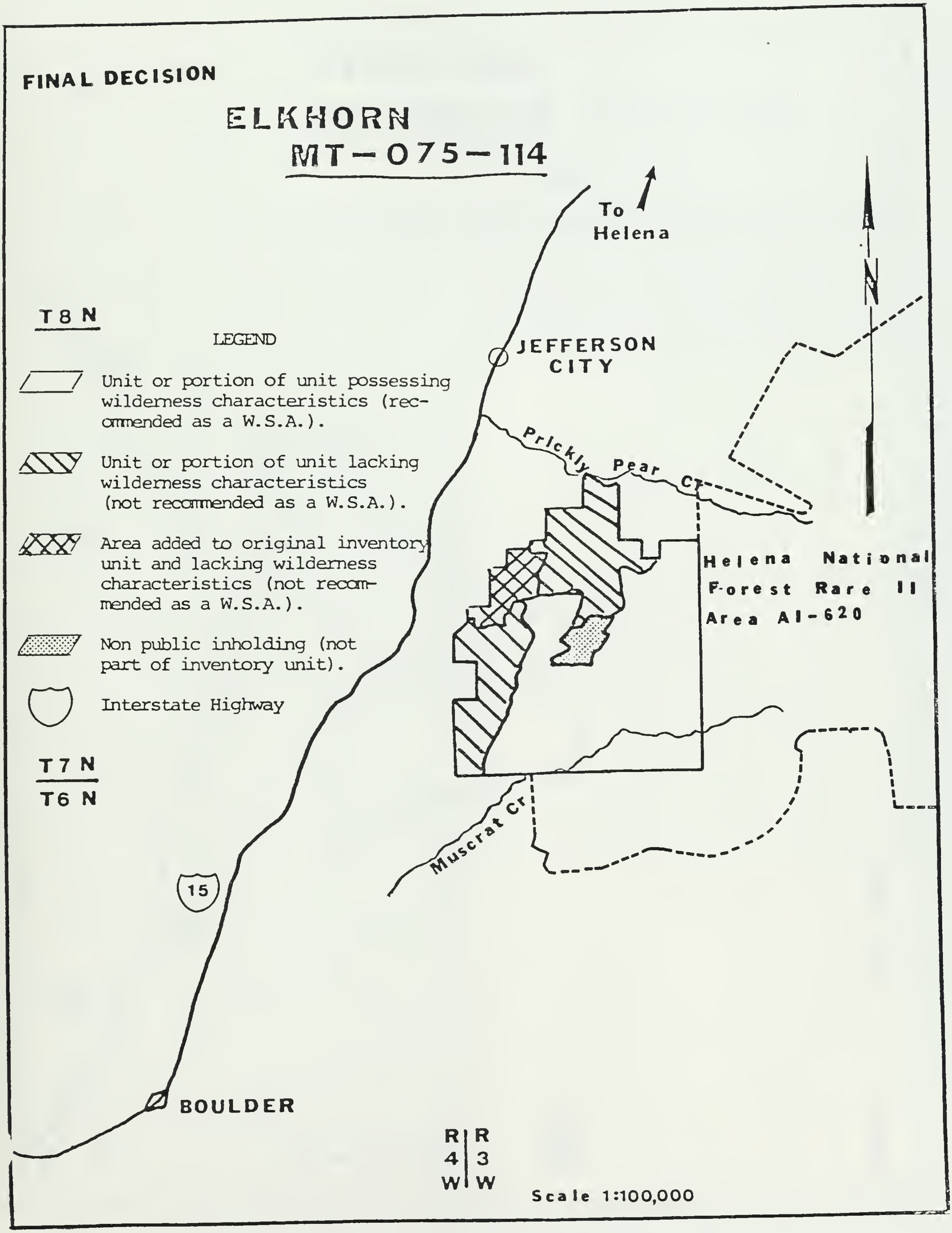
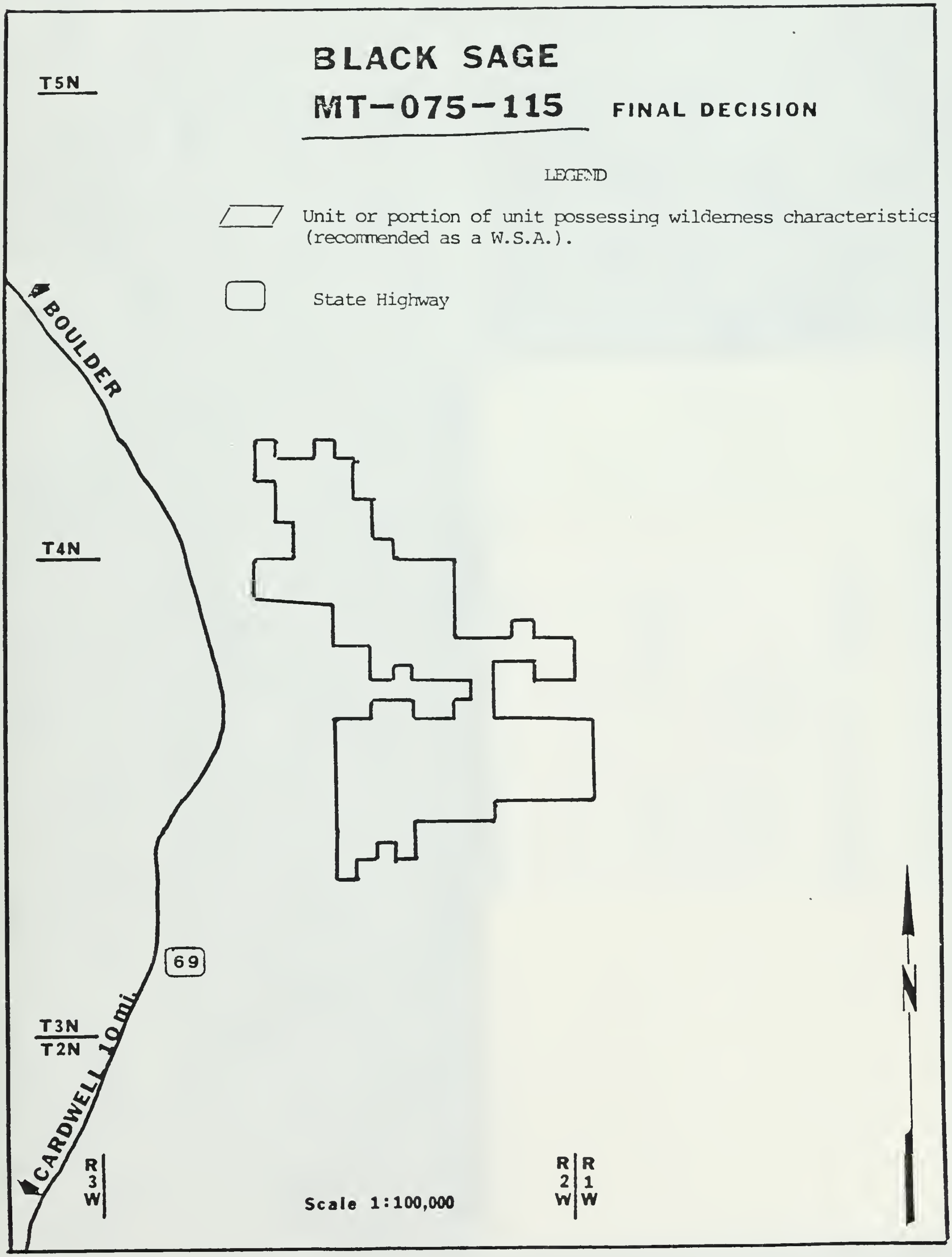
APPENDIX I

WILDERNESS STUDY AREA MAPS


FINAL DECISION
ELKHORN
MT-075-114
To Helena
T8 N
LEGEND
Unit or portion of unit possessing wilderness characteristics (recommended as a W.S.A.).
Unit or portion of unit lacking wilderness characteristics (not recommended as a W.S.A.).
Area added to original inventory unit and lacking wilderness characteristics (not recommended as a W.S.A.).
Non public inholding (not part of inventory unit).
Interstate Highway
JEFFERSON CITY
Prickly Pear Cr
Helena National Forest Rare II Area AI-620
T7 N
T6 N
Muscrat Cr
15
BOULDER
R 4 W
R 3 W
Scale 1:100,000


BLACK SAGE
MT-075-115
FINAL DECISION
LEGEND
Unit or portion of unit possessing wilderness characteristics (recommended as a W.S.A.).
State Highway
T5N
T4N
T3N
T2N
BOULDER
CARDWELL 10 mi.
69
R 3 W
R 2 W
R 1 W
Scale 1:100,000
N