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STATE OF MONTANA
Tim Babcock, *Governor*

BUREAU OF MINES AND GEOLOGY
E. G. Koch, *Director*

Bulletin 64
January, 1968

GEOLOGY AND ORE DEPOSITS of the CASTLE MOUNTAIN MINING DISTRICT MEAGHER COUNTY, MONTANA

By Allen S. Winters

STATE OF MONTANA
BUREAU OF MINES AND GEOLOGY
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Allen S. Winters

MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY
Butte, Montana
January 1968

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GEOLOGY AND ORE DEPOSITS OF THE CASTLE MOUNTAIN MINING DISTRICT, MEAGHER COUNTY, MONTANA

by

Allen S. Winters*

ABSTRACT

The Castle Mountain mining district is a mountainous area on the southeastern flank of the Castle stock, which rises to an altitude of 8,606 feet above sea level. Sedimentary rocks ranging from Precambrian to Cretaceous have been uplifted by intrusion of two separate stocks, which produced both longitudinal and radial fractures. Metamorphism is not strong, but igneous and sedimentary rocks both have been hydrothermally altered by low and medium temperature processes.

Metalliferous deposits contain lead, zinc, and silver and minor copper, manganese, and gold. The sulphide minerals are commonly associated with jasper and magnetite, and are found mainly in altered Paleozoic limestone.

Geological maps and geochemical dispersion patterns of the district and a few of the properties are presented, along with production data and historical information.

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INTRODUCTION

The Castle Mountain mining district was discovered in the 1880's and gained considerable prominence as a producer of lead, silver, and zinc. Since the turn of the century, however, the district has had an erratic history of production and activity.

In recent years, in expectation of better metal prices, lessees and owners have begun to reopen and develop a few of the larger mines. The small production, however, has all come from the Cumberland and Yellowstone mines.

PURPOSE AND SCOPE

The aim of this report is to present the results of two separate studies. The first included geological mapping and a study of the district's mineral deposits, ores, and economic potential. Intended to determine the feasibility of geochemical prospecting, the second study included a series of selected traverses and a grid soil-sampling program that covered the district.

FIELD WORK

Field work was done during the summers of 1963 and 1964. Virtually all the known mineral deposits were investigated, and accessible workings were mapped. Air photos were used in mapping and to find the various mines in the district. The laboratory investigations were made during the winter and spring months of 1963 and 1964.

PREVIOUS WORK

The oldest published report on the Castle Mountain district is that of MacKnight (1892), who briefly described some of the mines in the district. Published by the U.S. Geological Survey in 1896, the first geological study of the district and surrounding area was made by W. H. Weed and L. V. Pirsson in 1894. The report includes studies of the lithology, petrology, and general geology of the area. Stone (1909) mapped the Eagle Formation near Warm Springs Creek; Stone and Calvert (1910) made stratigraphic studies of the Livingston Formation; Gardner and others (1946) measured and described the Cretaceous, Jurassic, and Carboniferous formations; and Hanson (1952) studied the Cambrian stratigraphy of the mountains. Tanner (1949) made the first detailed geological map of the Castle Mountains, but his main interest was the correlation of the upper Cretaceous strata. Describing the iron and nonferrous mineral deposits respectively, Goodspeed (1945) and Roby (1950) made the only economic studies of the district.

ACKNOWLEDGMENTS

It is a pleasure to express gratitude for the cooperation and assistance given by supervisors, operators in the district, and colleagues; to Mr. U. M. Sahinen, associate director of the Montana Bureau of Mines and Geology, for sponsorship and consultation; to Dr. F. N. Earll for advice, guidance, constructive criticism, and consultation during the course of the field work; to Mr. C. R. Oliphant of White Sulphur Springs, Mr. Carl Voss of Helena, Mr. Jack Oliver of Harlowton, and Messrs. George Volseth, Kay Burg, Paul Grande, and Claude Wessel of Martinsdale, who were most generous with their time and who allowed free access to their properties and private files; and to Messrs. D. C. Lawson, F. P. Jones, and R. B. Holmes for invaluable assistance rendered in assaying, rock analysis, and map preparation.

LOCATION AND ACCESSIBILITY

The Castle Mountain district, Meagher County, Montana (Fig. 1), as the term is used in this report, lies principally within T. 8 N., R. 8 E., plus the western and southern sections of T. 8 N., R. 9 E., and T. 9 N., R. 8 E. (Pl. 1). The central part of the district is approximately 10 miles northwest of Lennep, at lat 46° 28' N., and long 110° 41' W.

The district is accessible by four gravel roads; two from Lennep, one from Checkerboard, and one from White Sulphur Springs, the county seat of Meagher County. The only maintained road, however, is from Castle to Lennep, which is connected to White Sulphur Springs by 35 miles of improved gravel and paved roads.

The main line of the Chicago, Milwaukee, St. Paul, and Pacific Railroad passes through Lennep and Ringling, where a branch line from White Sulphur Springs connects.

SURFACE FEATURES

TOPOGRAPHY

The Castle Mountain mining district is a mountainous area on the eastern slope of the Castle Mountains. In the map area, the mountains have a maximum relief of approximately 2,600 feet, from Castle at about 6,000 feet to the summit of Elk Peak at 8,606 feet. Most of the mines are in upland gulches and on rounded ridges at altitudes between 6,300 and 7,500 feet.

The topography of the map area is closely related to the paths of glaciers and to drainage patterns subsequently produced by active

down-cutting streams, which occupy narrow canyons. Steep slopes gradually grade into high-level parks, some of which are as much as 1 mile wide and 5 miles long.

The topography is also related to the folding of the sedimentary rocks. Anticlinal and synclinal ridges are clearly developed near Lennep, but in the map area the weaker sedimentary rocks and folds have provided channels only for the tributaries; the main creeks, at least in part, have been controlled by glacial paths and fracturing.

The igneous rocks are resistant to erosion, and their contacts are distinguished by a sharp steepening in slope. Of the sedimentary rocks, the Kootenai, Mission Canyon, and Belt form conspicuous ridges, whereas the Colorado, Big Snowy, and Park occupy topographic lows.

DRAINAGE

Numerous streams flow through the district and should provide ample water for all present and future mining and milling needs. The water originates in many mountain springs, and although some of the tributaries are dry in late summer, the main streams all have a permanent flow.

CLIMATE

The fairly moist climate of the Castle Mountains is noticeably different from the generally semiarid climate of the rest of Meagher County. Weather data have not been systematically collected in the map area, but on the basis of the statistics from Findon and Kings Hill the annual precipitation is estimated between 17 and 28 inches, including an annual snowfall of about 180 inches. The mean annual temperature is about 37 degrees, maxima in the 90's coming during the late summer months and minima in the -40's in January or February (Roby, 1950, p. 6).

In general, the climatic conditions are by no means prohibitive but are not very favorable for year around small operations.

VEGETATION

The slopes in the vicinity of the mining district are timbered with a dense growth of lodgepole pine and some fir and spruce. Native range grasses cover the open ridges and parks and is accompanied by sagebrush at the lower elevations.

Present and future mine operators should have little trouble in finding an ample supply of lodgepole, which if properly treated, makes acceptable mine timber.

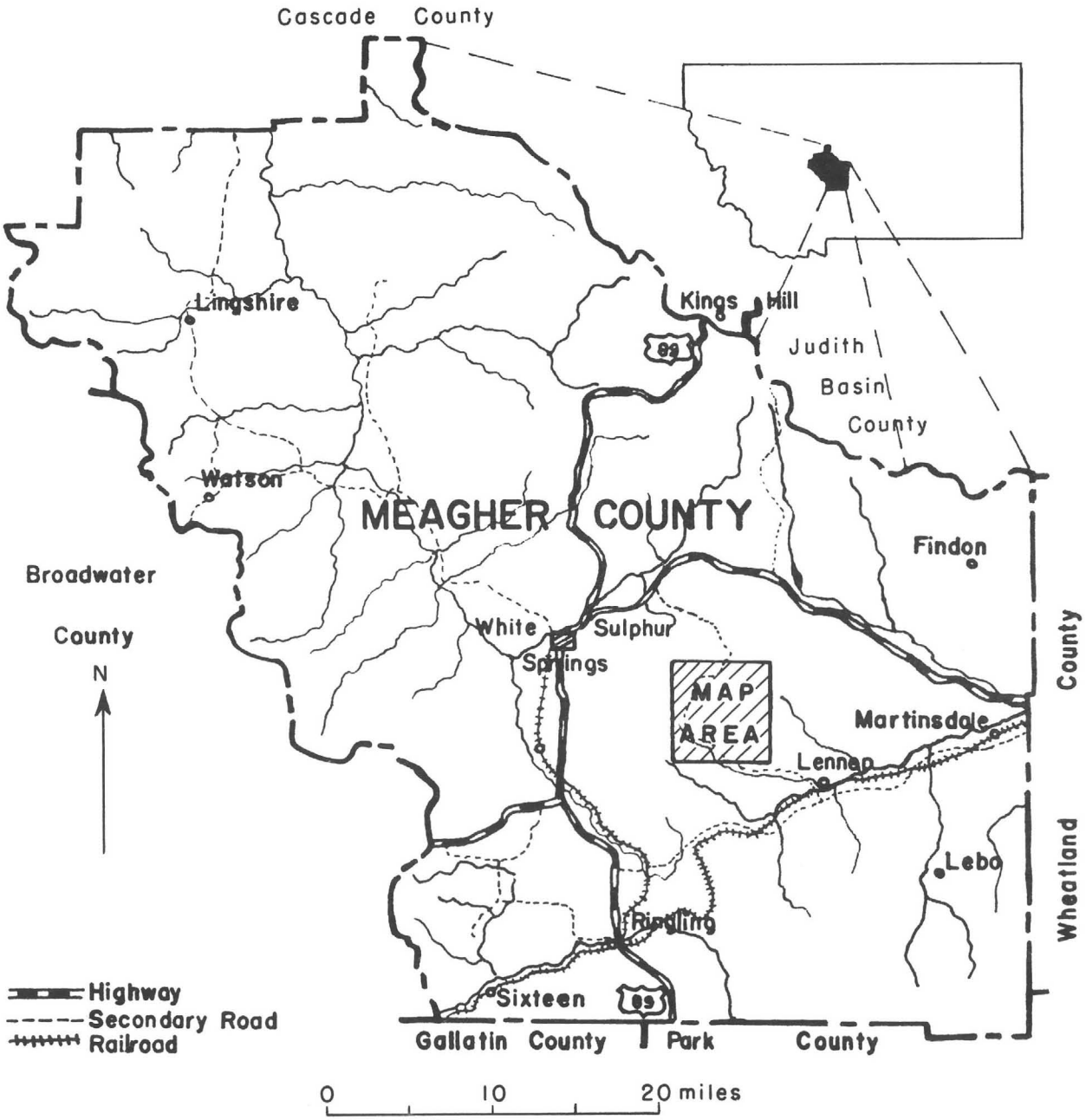


Figure 1.--Index map showing location of Castle Mountain district.

GLACIATION

Numerous glacial erratics cover the lower slopes adjacent to Alabaugh Creek. This debris is the most conspicuous evidence of glaciation in the district.

Valley glaciers originated on the flanks of Elk Peak where the ice accumulated in small recesses and carved out small cirques and glacial troughs. Following pre-existing stream-cut valleys, the glaciers removed a few of the surface irregularities but only slightly modified the original landscape.

Weed and Pirsson (1896, p. 144) stated that glacial evidence is most prominent from 7,000 to 5,400 feet, where both lateral and end moraines can be recognized. The lateral moraines are by far the more abundant. These deposits should more properly be termed glacial debris, as they are not distinguishable landforms. The debris consists chiefly of granitic rocks but includes some Precambrian and Paleozoic blocks. End moraines can be observed on the valleys of Boulder, Hamilton, and Fourmile Creeks.

GENERAL GEOLOGY

SEDIMENTARY ROCKS

Sedimentary rocks cover a large part of the map area and include a wide variety representing a vast interval of time--Precambrian to Cretaceous (Table 1).

The combined Jefferson and Three Forks, the Kibbey and Otter, and the Rierdon, Swift, and Morrison Formations were mapped as three units because of their small thicknesses or poor exposures. Belt shale and Lower Cretaceous shale were mapped as the Piegan and Colorado Groups respectively.

No major angular unconformities were observed within the district. The only angular unconformity reported in the area is that between the Cambrian and Precambrian strata. Tanner (1949, p. 11) reported that this angle ranges from 0 to 12 degrees. Major unconformities separate the Jurassic from the Pennsylvanian, and the Devonian from the Cambrian.

Stratigraphic sections were not measured within the district, as numerous studies have already been made in and near the map area. Thicknesses of the formations in this report are only rough estimates, hence may differ from those reported by previous workers (Weed and Pirsson, 1896, p. 30-55; Gardner and others, 1946, p. 30-36; Hanson, 1952, p. 35-36; and Tanner, 1949, p. 11-47).

Table 1. --Stratigraphic column, Castle Mountain mining district, Meagher County, Montana.

Age		Stratigraphic unit		Thickness (feet)	Lithology
Quaternary	Recent	Alluvium			Silt, sand, and gravel
	Pleistocene	Glacial debris			Unsorted sand, gravel, and boulders
Cretaceous	Upper	Montana Group	Hell Creek	1,000±	Gray tuff and sandstone
			Lennep	300	Dark sandstone and shale
			Bearpaw	900±	Black shale and siltstone
			Judith River	1,200	Brown tuff and sandstone
			Eagle	450	White sandstone and gray siltstone
	Lower	Colorado Group		2,300	Interbedded shale and sandstone
		Kootenai		380	Sandstone and red siltstone
Jurassic		Morrison		350	Brown siltstone
		Ellis Group	Swift	42	Brown sandstone
			Rierdon	15	Gray limestone
Pennsylvanian(?)-Mississippian		Amsden		400	Pinkish-gray limestone
		Big Snowy	Otter	150	Green shale
			Kibbey	120	Red siltstone
		Mission Canyon		400	Massive gray limestone
		Lodgepole		800	Blue-gray limestone
Devonian		Three Forks		145	Thin-bedded limestone
		Jefferson		520	Massive buff to brown dolomitic limestone
Cambrian		Red Lion (Dry Creek Member)		60	Tan siltstone and shale
		Pilgrim		280	Blue-gray limestone and limestone conglomerate
		Park		360	Black shale
		Meagher		160	Alternating limestone and siltstone
		Wolsey		400	Green micaceous shale
		Flathead		125	Pink sandstone and quartzite
Precambrian	Belt Series	Piegan Group			Red argillite and gray limestone

Precambrian

Belt Series. --Named and described by Peale (1893, p. 12), the Belt rocks are generally thought to be Algonkian in age. Tanner (1949, p. 13) correlated the 2,500 feet of Belt argillite within the map area with the Spokane Formation, but these rocks may represent the Spokane, Empire, Helena, and March Formations recognized in the nearby Belt Mountains (Ross, 1963, p. 3). No attempt to differentiate these sediments was made; they are referred to the Piegan Group.

Mostly chocolate color to deep purple, the Belt argillite near Blackhawk is intensely altered and forms sharp ridges. Several prospects have investigated iron and copper in the calcareous part, which possibly represents the Helena Formation.

Cambrian

Flathead Formation. --The Flathead Formation is composed of fine- to coarse-grained quartzitic sandstone. In most of the map area the formation is completely metamorphosed to metaquartzite, individual grains being indistinguishable with the naked eye; scattered hematite grains give the rock a speckled appearance. Farther from the intrusive bodies the formation can be divided into two units. Composed of large pink quartz grains, the basal 50 feet of the formation is cross bedded. The upper 75 feet is composed of fine clear to white quartz grains. Both members are cemented by silica, and the formation forms a conspicuous ridge near Blackhawk.

Wolsey Formation. --The Wolsey Formation can be divided into three units--a lower 50 feet of dark-brown fissile shale and siltstone, a middle 250 feet of tan to brown thin-bedded limestone and siltstone, and an upper 100 feet of tan to olive-green micaceous shale and calcareous siltstone. The formation is nonresistant and occupies a depression between the Flathead and Meagher Formation.

Meagher Formation. --In the map area, the contact between the Meagher Formation and the Wolsey is poorly defined and gradational. The Meagher is composed of 40 feet of alternating limestone and siltstone beds overlain by 120 feet of dirty limestone. The lower thin-bedded limestone and siltstone beds are mostly tan to buff but contain a few olive-green shale beds similar to those in the Wolsey.

Park Shale. --Approximately 360 feet of gray to black Park Shale crops out in the map area. The shale is metamorphosed to hornfels in the vicinity of the Yellowstone mine, where it resembles Belt argillite. Farther from the intrusive body the formation is nonresistant and its outcrop is marked topographically by a slight depression.

Pilgrim Limestone. --The Pilgrim Limestone is approximately 280 feet thick in the map area. The lower 75 feet of the formation is easily distinguished by the pebble conglomerate beds. The upper limestone beds are buff and display intraformational conglomerate limestone lenses. Close to intrusive bodies the limestone is recrystallized, and cherty seams and lenses weather in relief. Some ore was deposited in the metamorphosed limestone.

Red Lion Formation. --The Red Lion Formation is represented in the map area by the Dry Creek Member, which is composed of 60 feet of tan to green shale interbedded with red siltstone layers. Near the Judge mine, the shale is metamorphosed to chocolate-color hornfels that forms a ridge 2 to 4 feet high.

Devonian

Jefferson Limestone. --The Jefferson Limestone is composed of approximately 520 feet of massive dolomitic limestone generally characterized by a fetid odor. The limestone grades from buff to brown away from intrusive contacts. Where the limestone is recrystallized, some ore deposits may occur.

Three Forks Shale. --The Three Forks Formation is not a mappable unit in the Castle Mountains. Weed and Pirsson (1896, p. 38) assigned 145 feet of thin-bedded limestones to this formation, but in the map area the formation could not be distinguished, as intrusive rocks have obscured its normal character.

Mississippian

Lodgepole Limestone. --Approximately 800 feet of blue-gray to dark-gray thin-bedded limestone constitutes the Lodgepole Limestone in the map area. These beds are very fossiliferous and together with the Mission Canyon Formation, they form large outcrops and support many ridges. Near the intrusive bodies, the formation is completely recrystallized, and ores mined from deposits in the marble have contributed much of the district's production. Except where the rocks are metamorphosed, the upper contact with the Mission Canyon Formation is distinct.

Mission Canyon Formation. --Massive buff to gray limestone of the Mission Canyon Formation overlies the Lodgepole Limestone. It is 400 feet thick, generally light in color, and is characterized by numerous concretions of brown chert. The formation is very cavernous, and two small natural bridges can be seen on Warm Springs Creek. Where sharply folded, the limestone is brecciated and iron stained. Mines in the Mission Canyon Formation have contributed at least half of the district's production.

Kibbey Formation. --The Kibbey Formation consists of 120 feet of thin-bedded limestone, sandstone, and siltstone. Generally marked by a belt of red soil, the lower contact with the Mission Canyon is very distinct. Less definite is the upper contact, where the red siltstone and limestone layers grade into the buff limestone and pale-green shale of the Otter Formation.

Otter Formation. --The Otter Formation is composed of 150 feet of alternating layers of shale and thin-bedded limestone. Near the lower contact the shale is green, but it gradually darkens upward to gray and black toward the upper contact with the Amsden Limestone. The limestone beds are generally buff or mottled pink.

Mississippian-Pennsylvanian

Amsden Limestone. --Approximately 400 feet of pink to blue-gray Amsden Limestone crops out in the district. This limestone is thin-bedded and mottled pink near the lower contact, but toward the upper contact it is slightly dolomitic and darker. An accurate age has not been established for the formation in the map area, but probably both Mississippian and Pennsylvanian rocks are included.

Jurassic

Rierdon(?) Formation. --The presence of the Rierdon Formation within the map area is questionable, but 15 feet of dark-gray fossiliferous limestone was assigned to the formation.

Swift Formation. --The Swift Formation consists of 42 feet of calcareous sandstone, which can be divided into two units, a lower 3 feet of brown conglomerate and an upper 39 feet of reddish sandstone. The basal conglomerate contains both calcareous and siliceous pebbles and has a greenish cast, owing to its contained glauconite.

Morrison Formation. --The Morrison Formation is approximately 350 feet thick in the district and consists of reddish-brown siltstone in the lower half and gray siltstone in the upper half and contains many thin beds of sandstone. The formation is nonresistant. Tanner (1949, p. 45) pointed out that seams of shale and coal can be found near the contact with the Cretaceous sandstone. This relationship was not observed within the district, but was observed on Checkerboard Creek, where a coal bed has been worked.

Cretaceous

The Cretaceous sediments are unmineralized and were not studied except for the purpose of establishing contacts. Contacts are the same as those thosen by Tanner (1949), who studied the beds in detail.

Kootenai Formation. --The Kootenai Formation is composed of approximately 380 feet of sandstone and siltstone. Within the map area the formation can be divided into two separate lithologic units. The lower unit seems to rest unconformably on the Morrison Formation and is composed of nearly 100 feet of cross-bedded gray to reddish sandstone, conglomeritic near the base and locally metamorphosed to a metaquartzite that forms a sharp ridge. The upper unit is composed of approximately 280 feet of red to purple siltstone and silty sandstone.

Colorado Shale. --Consisting of about 2,300 feet of black shale and alternating beds of sandstone and siltstone, the Colorado Shale has not been studied in enough detail to permit subdivision of the group into separate formations. From Tanner's (1949, p. 47) description, three major lithologic units persist, a lower unit of black fissile shale interbedded with lenses of sandstone, a middle unit of drab to green shale, and an upper unit of gray to tan fissile shale.

Eagle Sandstone. --The Eagle Sandstone can be divided into two separate units. The lower 300 feet of the formation consists of white cross-bedded coarse-grained sandstone interbedded with some siltstone beds. Numerous coal seams in the siltstone beds have been prospected without success on Warm Springs Creek. The upper 150 feet of the formation is composed of gray siltstone and calcareous sandstone, which forms a small ridge near Warm Springs Creek.

Judith River Formation. --Sediments mapped as the Judith River Formation are actually the Judith River and Claggett Formations combined, but the two cannot be separated in the map area (Stone and Calvert, 1910, p. 745). Approximately 1,200 feet thick, the formation is composed of brown to gray tuff and fine-grained sandstone.

Bearpaw Shale. --Approximately 900 feet of black fissile shale and siltstone make up the Bearpaw Formation in the map area. Tanner (1949, p. 70) divided the formation into two units, the lower composed of black fissile shale and the upper composed of dark-gray claystone and siltstone.

Lennep Formation. --The Lennep Formation is approximately 300 feet thick in the district and is composed of dark tuffaceous sandstone and dark shale (Stone and Calvert, 1910, p. 746). The formation generally forms conspicuous orange ridges and contains several gabbroic sills.

Hell Creek Formation. --The Hell Creek Formation is reported to be 900 to 1,000 feet thick near the map area (Tanner, 1949, p. 17). Only a small patch of Hell Creek beds crop out in the area. These beds consist of medium to dark-gray tuff and fine-grained sandstone.

Quaternary Deposits

Unconsolidated deposits composed of silt, sand, gravel, and large boulders are common in the district. The ridges are commonly covered by glacial debris, and stream channels have been filled with alluvial deposits.

IGNEOUS ROCKS

The igneous rocks of the district are generally acidic and consist mainly of varieties of the granite group. Basic dikes are present in the district and generally represent a late stage intrusion of an early differentiate.

Several periods of igneous activity can be recognized in the district. The oldest intrusive body, the Blackhawk stock, is composed of diorite. A few basic dikes and possibly some andesitic flows outside the district are associated with this early intrusion. After the initial igneous activity had ceased, the main mass of granite was forced into the sedimentary rocks west of the diorite stock. The granite of the Castle stock is exposed over an area of approximately 33 square miles, and is roughly ten times the size of the Blackhawk stock. Associated with the Castle stock are large sheeted zones and radial dikes. Violent eruptions followed the intrusions, and masses of rhyolite and rhyolite breccia were ejected.

Intrusive Rocks

Granite. --The Castle stock is composed of fine- to medium-grained granite and granite porphyry. The porphyritic nature of the rock is best exhibited near Elk Peak, where numerous feldspar phenocrysts exceed $\frac{1}{2}$ inch in length. The groundmass, however, is generally fine-grained and composed of subhedral grains of feldspar and dark quartz.

Orthoclase, oligoclase, quartz, biotite, and hornblende are the chief rock-forming minerals, named in decreasing order of abundance. On fresh exposures, the rock is light colored and locally has a pinkish tint, owing to the orthoclase phenocrysts. The feldspars are somewhat kaolinized, and all biotite is slightly altered to chlorite. Accessory minerals include magnetite, zircon, and a small amount of apatite. Weed and Pirsson (1896, p. 100) reported that tourmaline and fluorite are very common in the stock to the north of the map area.

That the stock should be named the Castle Mountain is understandable, as the granite weathers into high crags or castles.

Diorite. --The chief rock of the Blackhawk stock is medium-grained diorite but toward the southern and eastern boundaries of the stock the rock is granodiorite, which weathers much the same as the granite of the Castle stock.

In the central portion of the stock the rock is composed of oligoclase, the mineral present in greatest quantity, and orthoclase, biotite, and some augite. A few rounded grains of quartz can be found. Toward the contact with sedimentary rocks, the diorite is more acidic, and many grains of quartz can be observed.

The eastern section of the stock near Blackhawk resembles pinkish-gray granite. Tanner (1949, Pl. 1) mapped the diorite and granodiorite facies as separate stocks, but both masses seem to be parts of a single stock. Tanner also showed Cambrian limestones separating the stocks, but what he observed may have been a small roof pendant.

Dacite Porphyry. --The dacite porphyry intrusive bodies were formerly classified as quartz porphyry by Tanner (1949) and Weed and Pirrson (1896). These rocks are found as intruded sheets and dikes around the edge of the Castle stock.

The rocks are felsitic and mostly gray. Near the Castle stock the rock is speckled by dark subrounded quartz phenocrysts but farther from the contact the quartz phenocrysts are less abundant.

The rock is composed of oligoclase, orthoclase, quartz, biotite, and hornblende. Feldspars are partly kaolinized, and the biotite is altered to chlorite. Near the Yellowstone mine the rock assayed 66 percent SiO_2 compared to 69 percent SiO_2 near the granite stock. Weed and Pirsson (1896, p. 99) reported local sericitization and alteration of the biotite and hornblende to magnetite.

Two separate stages of dacite intrusion were observed. In the Hensley Creek area, strongly mineralized dacite porphyry dikes cut older dacite sheets.

Syenite Porphyry. --Four sills form conspicuous ridges south of the townsite of Castle where they have intruded Cretaceous sedimentary rocks. The igneous rocks consist of a dense gray groundmass of feldspar containing large phenocrysts of hornblende and pink orthoclase. Biotite, partly altered to chlorite, is also present. Tanner (1949, p. 57) pointed out that the orthoclase feldspar phenocrysts are aligned parallel to the strike of the sills.

Extrusive Rocks

Rhyolite. --Rhyolite, exposed along Fourmile and Bonanza Creeks, is typically gray to yellow and contains a few phenocrysts of quartz and white feldspar. The composition ranges from rhyolite to possibly rhyodacite, depending on the silica content, which seems to differ considerably in different parts of the same flow.

STRUCTURE

Regional Folding and Faulting

The Smith River intermontane valley is bordered on the east by the Little Belt Mountains and on the west by the Big Belt Mountains. Within this valley and northwest of the Crazy Mountains, rise the Castle Mountains as a distinct geographic unit related to neither of the Belt ranges.

Flanking the Castle Mountains on the east and west are two large anticlinal folds, which plunge to the southeast. On the west lies the Warm Springs anticline, which is cut in the center by the Castle stock. This anticline is overturned to the east on its southern end near Warm Springs Creek. Weed and Pirsson (1896, p. 23) believed that this anticline is related to the southeastern end of the Big Belt anticline. On the eastern flank of the stock is a lateral offshoot of the Little Belt anticline.

The Castle Mountains also lie near the eastern border of the Rocky Mountain disturbed belt. Thrust and normal faults trending northwest are common north and east of the map area.

Folds

Many small folds are found within the map area. The largest of these is the Corral Creek anticline. This anticline, whose axial trace trends S. 24° E., plunges about 16° to the southeast. Flows of rhyolite cover the central part in the map area but the Mission Canyon Limestone is exposed south of the flows. Farther north the Blackhawk stock interrupts the anticline but the effects of folding can be observed in Belt argillite north of this stock.

Along the same trend as the Corral Creek anticline lies a smaller fold just east of the townsite of Blackhawk. The small anticline plunges about 32° to the southeast. Belt rocks are exposed in the core of the anticline, and a longitudinal fault cuts its western flank.

Along the south border of the diorite are several smaller folds, which seem to have been produced by the intrusion. The axial traces of these folds generally trend parallel to the Corral Creek anticline. Broadly, however, the area between Corral Creek and Warm Springs Creek is a north-trending syncline. The synclinal fold is excellently exhibited in the Cretaceous beds 2 miles east of Castle where the fold trends S. 18° W., and plunges about 42° to the south.

Approximately 1 mile east of Castle Lake, Alabaugh Creek cuts through the center of a small anticlinal fold whose axial trace trends S. 20° E. This anticline, which is cut off at the north by the Castle stock, has Big Snowy

beds exposed in its core near the granite contact. The anticline plunges about 31° to the southeast. Adjoining the anticline on the west is a tightly folded syncline. Plunging about 22° to the southeast, the syncline trends N. 54° W. Altered shale of the Colorado Group is exposed in the core of the syncline near Castle Lake.

Fractures and Faults

Faults and fractures in the district can be placed in four separate groups according to their age and strike. The oldest faults in the area are longitudinal faults associated with the Blackhawk stock. The largest fault of this group is a northwest-trending vertical fault north of the townsite of Blackhawk. It has a length of approximately 2 miles. Locally, the fault may be a high-angle reverse fault, as the Pilgrim Limestone is slightly overturned on the western limb of the Blackhawk anticline, owing to drag folding. This fault also has some rotational movement, the northern part having greater vertical displacement. Where the fault cuts across the East Fork of Checkerboard Creek, Meagher Limestone is in contact with Belt rocks. This relationship represents a total displacement of not less than 300 feet. The pivot point of the fault is on the North Fork of Bonanza Creek east of the townsite of Blackhawk.

Radial faults and fractures also were produced while the sedimentary rocks were being domed by intrusion of the Blackhawk stock. The largest of these radial fractures are north of the townsite of Blackhawk, and they have been filled with material similar to the granodiorite of the stock. Three larger dikes can be traced for several miles to the east, but little or no displacement of the sedimentary rocks was noticed.

The second group of faults and fractures is associated with the Castle stock. Radiating from the center of the stock, the structures are generally vertical. They have been filled with dacite porphyry and are excellently exhibited in the Paleozoic limestone near Blackhawk and in the Belt argillite between Hensley and Robinson Creeks.

Longitudinal faults generally parallel the eastern edge of the Castle stock. Hamilton, Hensley, and Robinson Creeks have actively exploited these planes of weakness, which generally trend north to northwest. There is little strike-slip movement on the faults but the Hamilton Creek fault has a vertical displacement of at least 150 feet.

The fourth group of faults and fractures includes those that have been mineralized. In general these faults offset the older dikes and slips but have little strike-slip displacement. In general, the veins are believed to be younger than the dike-filled fractures because the dikes are believed to have provided the channels for the mineralizing solutions. The fault vein on which

the Blackhawk and Alice mines are located is observed to offset the northeast-trending dikes approximately 5 to 10 feet to the right. In the Corliss mine, however, the dike-filled fault offsets the vein 3 to 4 feet to the left.

Precambrian-Cambrian Problem

An interesting structural problem is provided by the absence of the Flathead and at least part of the Wolsey in the central portion of the district. Near Boulder Creek, the Meagher Formation is separated from Beltian rocks by a sheet of dacite porphyry, which is generally less than 100 feet thick.

Several explanations for this peculiar situation are possible, but because of the poor exposures no definite solution to the problem is offered. Nondeposition seems very likely because the basal Cambrian formations are known to have extreme variations in thickness. Because of the complicated series of faults required, faulting seems less likely to account for the absence of the sediments. Compressive squeezing could possibly account for the absence of part of the Wolsey Formation but is unlikely to explain the disappearance of the Flathead Formation. Assimilation of the sediments is also possible, but the dacite sheet would be expected to become more acidic with the addition of silica from the Flathead. Additional field work would be needed before an adequate explanation is apparent.

MINING HISTORY AND PRODUCTION

The Castle Mountains remained relatively unknown until they were first noticed by Captain James Clift, who passed by the mountains on his exploratory march across Montana in 1869. The igneous core and other rock formations of the mountains, however, were not recognized until Captain W. H. Ludlow, accompanied by geologists G. B. Grinnel and E. S. Dana, made their exploratory trip along the Musselshell in 1873 (Weed and Pirsson, 1896, p. 17).

A few prospectors may have passed through the mountains on their way to the copper veins at Copperopolis in the 1870's, but these men failed to recognize the favorable geologic conditions in the mountains. The first prospector known to have really examined the area was C. Barnes, the U.S. Postmaster of White Sulphur Springs, who first began to prospect the hills and gulches of the Castle Mountains in 1881. Realizing the mineral potential of the district, he continued to prospect and in 1884 located the Blue Bull claim on Robinson Creek and the Princess on Alabaugh Creek. News of these two locations aroused a few other prospectors, but it was not until the Hensley family discovered the rich Cumberland and Yellowstone oreshoots that a sincere interest in the area began.

Reports of the Hensley's strike spread rapidly, and virtually overnight three booming mining camps sprang to life. Castle Town, the largest of these camps, was located on Castle Creek, a mile below the Cumberland mine. At the peak of its career Castle Town boasted a population exceeding 1,500, and numerous business establishments were set up to accommodate the tremendous influx of people (personal communication, C. R. Oliphant).

Numerous partnerships and several companies were immediately formed to work the claims as soon as they were discovered. The ore was first shipped by ox and mule team 75 miles to Livingston, Montana. From Livingston, the ore was then shipped to eastern smelters for processing. It was soon realized that if the mines were to continue to develop, the ores would have to be smelted locally.

In 1887 construction of the first smelter began on Alabaugh Creek. The smelter was built to treat the ore from the Yellowstone mine. The following year a newer and more modern smelter was constructed at the Cumberland mine site to treat the large tonnage that was being extracted from this property. This smelter processed ore from 1889 to 1893, and at the peak of its production could treat 35 tons of oxidized lead ore per day. As the mines developed, however, the ore changed from oxide to sulphide, and the smelters could not efficiently treat it, owing to increasing zinc content with depth.

G. C. Swallow (Swallow and Trevarthen, 1890, p. 17), inspector of mines for Montana, stated that in 1889 the Connellsville coke used in the furnaces cost the smelters $45 per ton delivered at the plants, that refining costs ran $16 per ton, and that the expense of shipping to Aurora, Illinois, was $22 per ton. He then estimated that if a railroad were built into the area the mines could save $15 to $20 a ton. The smelters soon closed, and the residents of Castle then began trying to promote a railroad into "Leadville" as they fondly called the district.

Immediate dreams of a railroad, however, were shattered when Congress demonetized silver in 1893. This action quickly put an end to the district's brief but vigorous life, and the mines closed in swift succession.

R. A. Harlow finally promoted enough money to construct a railroad from Loweth to Leadboro, half a mile below Castle Town. The line was known as the Jawbone because of the amount of persuasion and discussion it took to raise the funds. After the railroad was built, the district experienced a small revival from 1896 to 1898. Most of the ore shipped by the Jawbone, however, came from the stockpiled ore left on the dumps, and the largest producer, the Cumberland, never reopened, owing to the low prices of silver and lead (Roby, 1950, p. 17).

After the dumps from the Cumberland and Yellowstone mines had been shipped to East Helena, the district again lapsed into a state of inactivity and Castle Town soon became a ghost town. Sporadic mining continued on a small scale throughout the years, but not until 1957 were regular shipments again produced from the district. Since 1957 the Cumberland and the Yellowstone have both been active and have shipped considerable ore.

The following chronological account of mines and production of ore in the Castle Mountain district is compiled from annual volumes of the Report of the Director of the Mint (1888-1903), Minerals Resources of the United States (1905-1931), Minerals Yearbook (1932-1963), and from smelter returns recorded in East Helena. Only the largest producers are mentioned, and the ensuing notes are restricted to mines described in this report.

1888--Considerable development took place in the district, and the Cumberland, Yellowstone, and Great Eastern mines shipped most of the district's ore to eastern smelters. Meagher County produced $100,000 in silver, most of which came from the Castle Mountains.

1889--The two smelters in the district processed the Cumberland and Yellowstone ores and produced $36,355 in silver, $16,550 in gold, and 2,120,000 pounds of lead bullion. Other producers shipped several cars of lead ore, which yielded 76,459 ounces of silver.

1890--The Cumberland smelter produced 500,000 pounds of lead bullion and more than 20,000 ounces of silver from the Cumberland mine.

1891--Becoming Montana's largest lead producer, the Cumberland mine produced more than 5,000,000 pounds of lead bullion from 13,000 tons of ore. This mine produced almost half of the district's total production.

1892--The Cumberland mine produced only 300,000 pounds of lead. The district's production of 3,279,811 pounds came mostly from the Yellowstone, Jumbo, Great Eastern, and Judge mines.

1893--Except for the Cumberland mine, the district's mines were worked only by lessees, who produced several tons of lead and manganese ore from near-surface workings.

1894--Jay Anderson worked the Judge mine and produced most of the 98,094 pounds of lead recorded from Meagher County.

1895--Lessees produced most of the 383,385 pounds of lead from shallow shafts and dumps.

1896--The Jawbone Railroad was constructed to Leadboro, and considerable ore was removed from the mine dumps. The county production is given as 501,620 pounds of lead.

1897--R. A. Harlow shipped most of the district's ore from the Cumberland and Yellowstone dumps. Of the ore, 8,486 tons from the Cumberland dump yielded 5,952,776 pounds of lead and 133,542 ounces of silver. The Great Eastern also reported a production of 35 to 40 tons per day and the Powderly mined a high-grade oreshoot on Robinson Creek.

1898--The Judge mine, together with the Jumbo, accounted for most of the Meagher County production of 6,000,000 pounds of lead and 99,207 ounces of silver.

1899--The Jumbo, Judge, and Powderly mines produced nearly all of Meagher County's 7,500,000 pounds of lead and 405,630 ounces of silver.

1902--Lessees produced a small tonnage from the Judge and Jumbo mines. The Copper Bowl and Copper Kettle claims also produced 2,000 tons of iron-copper ore.

1903, 1908, 1911, 1912--A small production is reported from the district, and the Powderly is credited with being the most active mine.

1914--The district produced 12,308 pounds of zinc from oxidized ore near the Robinson area.

1916--A small tonnage of argentiferous copper ore was produced from the Milwaukee and Copper Kettle claims.

1917--The Milwaukee and Ruby adit claims produced argentiferous copper ore, and the Yellowstone shipped a few cars of lead-silver ore.

1918--Copper ore was produced from the Ruby adit. Some iron ore was also reported from the Hensley Creek area.

1919--Five mines produced 41 tons of lead ore valued at $1,706. The Ruby adit also shipped one car of copper ore.

1920--A few small lots of copper ore were reported to have been shipped from the Hensley Creek area.

1922--The Copper Bowl claim reported some development ore.

1924--James Perry shipped 892 tons of lead slag from the Cumberland dump, which assayed 0.47 ounce silver per ton, 5.9 percent lead, and 2.6 percent zinc.

1925--Lead slag was shipped from the Cumberland dump, and the Castle Mountain Mines, Inc., shipped development ore from the Homestake group of claims. This company completed considerable drifting and raising and planned to be on a milling basis in 1926.

1926--The Yellowstone, Jumbo, Homestake, and Cumberland mines were all active. The mines and dumps produced 2,412 tons of slag and 443 tons of ore, which yielded 2,070 ounces of silver, 5,532 pounds of copper, and 413,001 pounds of lead. Most of this production came from the Yellowstone property.

1927--Fourteen hundred tons of slag from the Yellowstone smelter was shipped to East Helena.

1930--No production was recorded, but the Great Western group reported 1,500 feet of tunnel work.

1933-1937--Lessees reported development work on several properties.

1939--The Belle of the Castle claim shipped a small lot of copper ore, and the Great Eastern produced 1,532 pounds of lead and 31 ounces of silver.

1943--From a small shaft on the Cumberland claim, John Oliphant produced 178 tons of ore, which yielded 94,900 pounds of lead and 1,845 ounces of silver.

1944--Lessees shipped 108 tons of ore from the Cumberland waste dump, which yielded 44,300 pounds of lead and 180 ounces of silver.

1946--The Yellowstone mine produced 48 tons of lead-silver ore, which yielded 1 ounce of gold, 193 ounces of silver, 15,000 pounds of lead, and 1,500 pounds of zinc.

1947--The district produced 2,500 pounds of lead and 53 ounces of silver.

1949--The district produced 17 tons of ore.

1950--The Silverton Mines, Inc., operated the Cumberland mine. The Yellowstone mine also operated, and together they produced 51 tons of ore, which yielded 8,000 pounds of lead, 2,000 pounds of zinc, and 294 ounces of silver.

1951--The Cumberland and Yellowstone mines produced 188 tons of ore, which yielded 108,000 pounds of lead, 6,000 pounds of zinc, and 1,885 ounces of silver.

1952--Producing 321 tons of ore, the Cumberland and Yellowstone mines were both active.

1953--A small output of lead ore was reported from the Cumberland and Great Eastern mines.

1954--Glenn Franklin produced lead ore from the Cumberland mine.

1955--From the Copper Kettle claim the D. & V. Mining Company produced 36 tons of copper ore, which assayed 2.5 percent copper and 0.5 ounce silver. The Cumberland mine also reported 89 tons of development ore.

1956--A small lot of lead ore was reported from the Cumberland mine.

1957--The H. O. Mining Company opened 80 feet of shaft, drove 100 feet of new development drift, and sank 50 feet of winze at the Cumberland mine. From these workings, the company produced 59,689 pounds of lead.

1958--The Cumberland mine was operated by the H. O. Mining Company, who shipped 1,103 tons of ore, which yielded 497,785 pounds of lead.

1959--Operating the Cumberland mine, the H. O. Mining Company and the Cumberland Mines Company produced 552 tons of ore.

1960--HOCO, Inc., operated the Blackhawk and Cumberland mines, and the Hamilton Mines Inc. operated the Yellowstone mine. The district produced 350,000 pounds of lead, nearly 4,000 ounces of silver, and 44,000 pounds of zinc. Of this amount, the Cumberland produced 340,342 pounds of lead.

1961--Operating the Cumberland mine, HOCO, Inc., shipped 559 tons of ore, which yielded 288,483 pounds of lead. The Yellowstone mine produced the rest of the district's production.

1962--HOCO, Inc., mined 653 tons of ore from the Cumberland mine; it yielded 4 ounces of gold, 4,182 ounces of silver, 266,000 pounds of lead, and 16,000 pounds of zinc.

1963--Producing until August, HOCO, Inc., operated the Cumberland mine. The Yellowstone mine, operated by George Voldseth, uncovered

a new oreshoot south of the shaft. The Copper Bowl and the Powderly were also active.

1964--The Yellowstone and Powderly mines produced more than 200 tons of lead ore and accounted for the district's production. At the Cumberland mine, considerable development was done, but as of September, no ore had been shipped.

Records of the mineral production from the various districts in Meagher County are either incomplete or not available for the years prior to 1932. Roby (1950, p. 16) compiled all the recorded production figures from 1883 to 1947 and stated that the county had produced not less than 4,250,000 ounces of silver, 29,439,740 pounds of lead, and 34,207 pounds of zinc. Virtually all of the county's lead and most of its silver production is known to have come from the Castle Mountain district, as it is the only major producer of these metals in the county. The district has also produced a considerable part of the county's zinc, copper, and manganese.

Since 1948, the district is credited with 1,444,700 pounds of lead, 22,752 ounces of silver, and 129,700 pounds of zinc. Considering that 90 percent of the lead, 50 percent of the silver, and 50 percent of the zinc recorded in the county prior to 1948 was produced from the Castle Mountain mines, the district is credited with not less than 27,940,466 pounds of lead, 2,147,752 ounces of silver, and 146,803 pounds of zinc.

ORE DEPOSITS

CLASSIFICATION

Irregular replacement bodies associated with bedding-plane fractures, jointing, and favorable beds occur adjacent to or at some distance from igneous intrusive bodies. Fissure veins also occur in the district. All of the mineable deposits were formed through hydrothermal processes.

Contact-Metasomatism

Ore deposits of the contact-metasomatic type are found along the contacts between Paleozoic limestone and intrusive dacite porphyry, and are by far the most abundant type of deposit in the district. The best example of a contact-metasomatic deposit is in the Yellowstone mine, where several oreshoots occur adjacent to a dacite porphyry sill in warped Pilgrim (Cambrian) limestone.

Metasomatic Replacement

Deposits of the metasomatic replacement type are very irregular and discontinuous, and most are confined by bedding planes. Considerable development work is required per ton of ore. The largest producer in the district, the Cumberland mine, is an excellent example of metasomatic replacement.

Fissure Veins

Production veins of the fissure type have been of minor importance in the district because of their lower grade. These veins occur in the Robinson Creek area, the Powderly veins being the most important.

Replacement Veins

Replacement deposits occur along single fissures or bedding-plane cracks in favorable limestone. Replacement of the favorable bed may persist for hundreds of feet. Referred to as jasper leads, the veins range from 2 to 10 feet in width, and jasper is the main mineral.

PARAGENESIS

The sequence of mineral deposition has been interpreted from open space fillings, mineral intergrowths, textures, and mineral replacements. Specimens were collected and studied from the various mines in the district. As the district covers a considerable area, the paragenetic relationships may differ in different mines, but it was found that the various sequences of mineral deposition are similar except for a few minor variations.

The earliest mineralization involved the introduction of iron-rich solutions, which replaced favorable limestone units in the Precambrian and lower Paleozoic sedimentary rocks. In the vicinity of Hensley and Robinson Creeks, large masses of magnetite crop out. The magnetite represents a high-temperature stage of mineralization and is found only close to intrusive bodies. Samples collected from the Belle of the Castle and Iron Chief mines show three distinct types of iron deposition. The earliest is nearly pure magnetite, which has a distinct cuneiform fracturing pattern. The second stage is pyrite, and the third again magnetite. The pyrite is cut by the second stage magnetite, and much of this magnetite is characterized by exsolution laths of hematite. Hematite veins are also believed to be related to this late magnetite deposition and probably represent the low-temperature phase of the iron mineralization. The relationship between the late-stage sulphide and magnetite-hematite deposition is not clearly understood, but may be related to the various periods of igneous activity.

Jasperoidization followed the early iron deposition. Large areas of favorable limestone were altered to jasperoid and jasper-filled open

fractures and cavities. Jasper cemented the fractured magnetite and possibly obtained its iron coloration from the magnetite. This siliceous stage continued intermittently throughout the sulphide deposition.

Following the large initial silica deposition came a normal sequence of sulphides. Pyritohedral pyrite formed in the open spaces, and massive pyrite replaced large volumes of the limestones adjacent to solution channels. Preservation of bedding was observable on a large scale but not in individual specimens. After deposition of the pyrite the ores were fractured.

Chalcopyrite was probably the next major mineral to be deposited. Bornite and an unknown mineral believed to be a variety of the enargite group were also deposited during this period, but their relationships could not be determined. Chalcopyrite is the main mineral and chalcopyrite and sphalerite began to be deposited before second-stage pyrite deposition.

Deposition of pyrite followed the copper mineralization; pyrite has partly replaced all the pre-existing minerals. Relict grains of these minerals occur as small blebs and irregular masses in the pyrite, producing a poikilitic texture.

Introduction of a minor amount of crystalline quartz interrupted the sulphide deposition. Some fracturing followed this brief silica stage.

Sphalerite was probably the next mineral to form. Crystal aggregates fromed in open fractures, and massive sphaleritie filled large voids and partly replaced the pre-existing minerals. The sphalerite contains much iron, and that in the Blackhawk area may be termed marmatite. Pyrrhotite(?) as small blebs within the sphalerite was also noticed, and it may have separated out of the solution because of an excess of iron. Chalcopyrite is also common as blebs and stringers within the sphalerite. These linear blebs show an emulsion texture suggesting exsolution. As chalcopyrite and sphalerite exsolve at about 400° C, the deposits probably formed at about this temperature (Buerger, 1934, p. 528).

Galena followed sphalerite in order of deposition, and it fills the open fractures of the early minerals. Galena has massively replaced all the pre-existing minerals and is the most abundant sulphide mineral.

No silver minerals were observed in the polished sections, but secondary native silver and silver chlorides have been reported from the Merrimac and American claims. The primary minerals that may have provided the silver are the silver sulfosalts or the tetrahedrite group.

Iron and manganese carbonates were also found at a few of the mines. They were deposited later than the sulfides, but their interrelationship is unknown, as only one specimen of primary manganese carbonate was found.

Rhodochrosite was observed at the Yellowstone mine, where it formed crusts that coated fractures in galena. The manganese deposition is believed to represent a late low-temperature stage of mineralization in a peripheral zone surrounding the sulphides. Siderite was found at several different mines and was deposited as a late gangue mineral.

Late chalcedonic quartz occurs as films, and fills small fractures in the jasper and sulphides. It is not certain, however, whether this mineral is related to the hypogene mineralization.

Enrichment is minor in the district, and it has been reported that there is little difference in the silver content of the oxidized and the primary ore. Weed and Pirsson (1896, p. 154) did state, however, that the gold content is greater in the oxidized portion of the ore in the Cumberland mine. At most of the mines some copper enrichment is indicated by the presence of chalcocite and covellite, which have replaced chalcopyrite and galena.

Oxidation has proceeded incompletely to a depth of nearly 500 feet at the Cumberland mine. Oxidation depths at the other mines differ considerably, but at most of them oxidation extends well below the 100-foot level. Zinc and copper are almost completely removed or oxidized to smithsonite, malachite, azurite, chrysocolla, cuprite, tenorite, and scarce native copper. Pyrite is converted to goethite and limonite, and the manganese minerals are completely oxidized to psilomelane and pyrolusite. Galena is oxidized to cerussite and anglesite as far down as the 460-foot level of the Cumberland mine. Cerussite has been the chief mineral mined from the district and accounts for most of the ore value.

ORESHOOTS

High-grade oreshoots occur in the mineralized zones as individual pipes and pods. The pipes are fairly continuous and conformable to the bedding. The largest pipe mined in the district lay along the hanging wall of the Cumberland mine and was mined from the surface to a point below the 500-foot level.

Where the dip changes, the pipes may be considerably enlarged. The changes in dip of the favorable limestone create swells and pinches in the pipes. Irregular pods of various sizes lay between the hanging and footwall of the Cumberland deposit. Many of these pods were only a mine set in size. Most were found near axes of change in dip of the limestone. Other pods project into the walls with no apparent control.

No suitable explanation for the oreshoots within the veins or brecciated zones can be given, owing to the inaccessibility of the workings. The position of solution cavities in limestone and the period of time required for solidification of the silica may have played an important role in localizing the oreshoots.

DEPTH OF MINERALIZATION

The type of mineralization in the Castle Mountain district suggests that the ores were deposited under mesothermal conditions. The vertical range for these deposits has not been established, but the largest mine in the district, the Cumberland, reached a zone characterized by a large ratio of pyrite to valuable sulphides at approximately 700 feet. This change in mineral content is believed to represent the bottom of the oreshoot. Other mine structures in the district are not as large as the Cumberland and are not believed to contain consistent mineral deposits for depths much greater than 700 feet (Weed and Pirsson, 1896, p. 155).

STRUCTURAL CONTROLS

It is well-known that belts of igneous intrusions are belts of ore deposits (Bateman, 1958, p. 304). Although much the greater portion of the igneous intrusive rock is nonmineralized, the ore deposits are intimately associated with such rock. The most important igneous rock type related to mineralization in the Castle Mountain district is the dacite porphyry, which has sheeted and cut the limestone beds. The porphyry, in general, merely provided deep-seated channels for the mineralizing fluids.

Local folding of the limestone seems to be the second most important factor localizing mineralization. Tension cracks, formed by the folding of the strata, provided channels along the crests and troughs of the individual folds. Where these folds are associated with intrusive dacite, ore may be found. The crescent-shaped Cumberland and Yellowstone oreshoots illustrate sulphide replacement along these flexures.

Brecciation and fracturing have also played an important part in localizing mineralization at the Blackhawk, Iron Chief, and other properties. Where such zones occur near intrusive dacite, ore may be found.

Filling of solution cavities may be more important than realized. Cavities produced by the modification of pre-existing openings, such as joints and fissures, have provided adequate space for ore deposition. At least in part, this feature is believed to have controlled the emplacement of the Corliss vein.

Open fractures have also provided space for ore deposition, the most important veins of this type being in the Robinson Creek area.

STRATIGRAPHIC CONTROLS

No one formation has proved to be more favorable than any other. Three formations seem to stand out, however, for the size and value of ore deposits contained. They are the Mission Canyon, the Jefferson, and the Pilgrim.

Several features common to the favorable units within these formations can be recognized. Where sulphides have replaced these units, the limestone tends to be slightly dolomitic. Bleaching and decomposition of the favorable units by the intrusive rock is also a noteworthy feature. The rocks are believed to have been brittle enough to crack readily under slight stress. This characteristic produced the permeability necessary for replacement.

In most mines, tough beds adjacent to the brittle units may or may not have provided impervious base rocks in the troughs of folds. The hard impervious footwall of the Cumberland and possibly the Yellowstone illustrate this feature.

The acidity of the sedimentary rocks seems to have influenced the type of deposition. Copper is the major mineral in the impure Precambrian limestone, which is much more siliceous and altered than the nearby Paleozoic limestone units that favored replacement.

ALTERATION

Both contact and hydrothermal alteration were noted in the map area. Contact metamorphism is widespread near the intrusive bodies, but hydrothermal alteration is restricted to the mineralized zones.

CONTACT METAMORPHISM

Metamorphism of the sedimentary rocks adjacent to intrusive rocks is widespread and easily recognized. The most striking effects occur between Blackhawk and Robinson where, adjacent to the diorite, the limestone has been bleached and recrystallized into marble for considerable distances. Near Blackhawk the marble is coarsely granular, and broad cleavage plates of calcite can be found.

Near the contact the marble contains agglomerations of contact minerals. Green garnet in grains and nests is commonly associated with diopside and phlogopite. Weed and Pirsson (1896, p. 93) stated that masses of brown vesuvianite are common in the nests of garnet.

The adjacent shale, especially that in the Belt Series and the Dry Creek, is baked into tough hornstone, which forms topographic ridges above the Paleozoic limestone. Argillization and possibly some silicification seem to be the dominant processes affecting these strata.

The diorite, in general, shows few effects near the chill zone. The only noticeable differences were finer groundmass and fewer phenocrysts. Weed and Pirsson (1896, p. 93) stated that chloride has replaced biotite

adjacent to the contact, and that fine leaves of white mica were observed interbedded in the phenocrysts.

Metamorphism along the granite contact is similar to but less extensive than that associated with the diorite. The most striking metamorphic changes produced by the granite are to be found near the head of Alabaugh Creek. Here, the Colorado Shale has been metamorphosed to tough argillite resembling that of the Belt Series.

Sandstone beds in the Kootenai have also been affected by the granite. The normal sandstone is now a well-cemented metaquartzite. The limestone beds are generally unaffected except near the Cumberland mine. Here, however, the alteration is believed to be more closely related to the mineralizing fluids than to the granite.

Near the contact, the granite generally is finer grained, and fewer phenocrysts can be observed. Weed and Pirsson (1896, p. 92) pointed out a very interesting relationship between the dacite porphyry sheets and the granitic stock:

> One of the most interesting examples of endomorphic contact metamorphism afforded by the granite is that which may be seen in the excellent exposure on Fourmile Creek where the granite abuts against the ends of the sedimentary beds and passes out between them in intruded sheets. Within a distance of 20 feet it passes from granite-porphyry and into typical quartz porphyry in the intruded sheet.

Weed studied several thin sections of samples from the exposure and recognized several stages of gradational change. From Weed's description, the granite near the contact is fine grained and porphyritic, the quartz of the groundmass assumes an idiomorphic form, and biotite and iron oxides are the only dark minerals. The next stage is characterized by a panidiomorphic structure and rounded quartz grains. Farther from the contact, quartz is observed in micropegmatite structures with the feldspars. The last and final stage is an abrupt conversion to quartz porphyry, the groundmass being a fine-grained allotrimorphic mixture of quartz and feldspar. Phenocrysts remain nearly the same size but are fewer (Weed and Pirsson, 1896, p. 92).

The dacite porphyry sheets are also widely affected, ferromagnesian minerals being much altered to hematite, which gives the dacite a reddish cast.

HYDROTHERMAL ALTERATION

Alteration zones, resulting from the interaction of water-rich late magmatic fluids with pre-existing solid rocks, have long been recognized as guides to ore, and the Castle Mountain district is no exception. The relationship between the alteration products and the ore deposits is a very interesting one and can be used as a general guide to ore.

Alteration of the more impure limestone units, especially those in the Belt, Meagher, and Pilgrim, is much more extensive than that of the younger formations in mineralized areas. In the Hensley Creek area, large volumes of the Precambrian limestone have been altered to tactite. Garnet is the chief mineral; epidote is confined to the mineralized area. Chloritization is common in argillaceous strata.

Of all the alteration products, jasperoid is the most abundant near the ore deposits. This association between jasperoid and ore is so common that jasperoid has become the chief guide to ore in the district.

Carbonate was the most common original rock prior to jasperoidization, although Precambrian shale has also been subjected to this type of alteration. Howd (1957, p. 130) suggested that in the East Tintic district, bicarbonate solutions containing free CO and SiO_2 caused the jasperoidization of limestone and dolomite. He also stated (p. 132) that jasperoid, although not infallible, can be used as a general guide to ore if sufficient traces of base metals can be detected. No samples of jasperoid were tested by geochemical methods, but it is believed that a distinction between barren and productive jasperoid could be made.

GEOCHEMICAL STUDIES OF THE DISTRICT

GRID SURVEY

The aim of the geochemical reconnaissance survey of the Castle Mountain district was to establish mineralized zones, eliminate barren ground, and draw attention to local areas of interest. The survey is similar to that conducted by F. N. Earll (1964, p. 30) in the Winston district. As in his studies, soil samples were taken without reference to lithology, structure, or topography. In the Winston district, however, the country rock is composed mainly of volcanic rocks, whereas igneous and various sedimentary rocks crop out in the Castle Mountain district. This diversity has made the interpretation of data extremely difficult, as the solubility of the different soils differs considerably.

The grid survey of the Castle Mountain district covers an area of approximately 40 square miles. The district was divided into two separate areas, the productive limestone units and the nonproductive surrounding area. Sampling of the nonproductive area was at 1-mile intervals. The productive limestone beds generally trend N. 15° E., and a series of lines was established to cross these formations. Sample spacing of these lines was set, initially, at $\frac{1}{2}$-mile intervals. Flexibility in the direction and sample spacing, however, was necessary in order to avoid contamination, and to cover the most interesting areas.

Upon the completion of the soil sampling, 244 grid samples had been taken, and 14 of the original sites were resampled as a check on accuracy. Sample locations were determined from a semicontrolled mosaic; extreme accuracy of location was not attempted. Most of the district is well sodded, and samples were taken in the orange soil horizon, which is overlain by a loose humus layer. Depth to this horizon varies from place to place, but at most sites it is 6 to 8 inches below the surface.

The first analysis performed on the samples was the measurement of total heavy metal by the citrate-soluble method. A 0.1-gram cut of the -80 mesh fraction was analyzed for readily soluble copper, lead, and zinc. After these results were appraised, thirty selected samples from the Cumberland and Yellowstone areas were analyzed for lead and zinc by the hot nitric acid extraction method. Results were then interpreted and it was found that the results of the zinc analyses outlined the mineralized areas extremely well. On the other hand, lead values were very erratic, presumably because sample spacing was too great in the basic soil environment to reveal the numerous but extremely small ore deposits. Therefore, zinc was the only individual metal mapped for the district. Results are stated in parts per million (ppm) of metal in the soil.

Maps were then prepared and contours drawn. Contours, or lines connecting points of equal metal content, separate distinct areas within the district. The areas encompassed by these contours are presumed to have equal metal content in the soil. In general, it was found that this type of interpretation does sufficiently delineate the areas associated with the mineralization. In the Castle Mountain district, however, this assumption may be in error, owing to the great differences in lithology and the extremely small mineralized zones.

Analysis of Heavy-Metal Anomalies

The first analysis performed on the grid-survey samples was the determination of the citrate-soluble total heavy metal content. In order to obtain the normal background, the results from each geologically distinct part of the area were averaged. The mean of these values was then taken to represent the normal background for the district.

Inspection of the anomaly map (Fig. 2) will disclose that normal background for the area is approximately 4 and that the threshold as defined by Hawkes and Webb (1962, p. 27) is approximately 7. Ordinarily, anomalies are expected to show peaks at least three times threshold, but in the Castle Mountain district most of the mines are surrounded by values ranging from 10 to 15, results that exceed 15 representing distinct anomalies.

The strongest anomalies shown on the map occur just north and just south of the Cumberland mine. The northernmost anomaly encompasses the area near the Merrimac and Broadway mines. The southernmost anomaly may represent the southern extension of the Cumberland mineralized zone. The abnormal sample collected east of the road, however, is unexplained. The sample was taken near a small dacite porphyry sill. Several small pits have explored the contact zone but without success. Smoke from an old smelter that operated for three years may have contaminated the area, but it seems unlikely that contamination from that source would be so pronounced. Other anomalies encompass the downslope areas near the California and Powderly mines.

Two additional strong anomalies are present in the area. One of these is near the contact of diorite with limestone in sec. 6, T. 8 N., R. 9 E., and this anomaly is repeated in the zinc analysis. No prospect pits were observed near the sample site, and thick overburden completely covers the contact zone. The second unexplained anomaly occurs in sec. 23, T. 8 N., R. 8 E., in limestone of the Amsden Formation and is close to a few prospect pits that have explored a few small mineralized pods. Little evidence is present to suggest that further prospecting of the location is warranted, as the beds are well exposed and have undoubtedly been thoroughly prospected.

Analysis of Zinc Anomalies

After the grid-survey samples were analyzed for citrate-soluble heavy metals, they were then tested for zinc content by means of the nitric acid method of extraction. Zinc, because of its mobility in basic environments and because of its presence in all the known ore deposits, was expected to indicate broad mineralized areas.

Examination of the zinc-anomaly map (Fig. 3) shows that the average background value of samples collected from each geologically distinct part of the area is approximately 75 parts per million (ppm), and that the threshold value that outlines mineralized area is approximately 200 ppm. From further appraisal of the results it was concluded that values of 250 ppm or greater should be regarded as significantly anomalous.

The largest and most significant anomaly occurs in the area encompassing the Yellowstone-Great Eastern group of mines. This is

understandable, as the ores mined from this area are noted for their zinc content. The map also shows a strong anomaly northeast of the Yellowstone-Great Eastern area. This anomalous zone, which was indicated by the citrate-soluble analyses also, is repeated but is considerably enlarged to the southwest. This area includes the California, Hidden Treasure, Solid Silver, and possibly the Iron Chief mines.

Both the Cumberland and Blackhawk mines are marked by anomalies, but the anomalies in these areas are small and disappointing. To the south of the anomaly that surrounds the Blackhawk mine is an abnormal sample collected near the contact of diorite with limestone, and further investigation along this contact may be justified.

Additional anomalies also deserve comment. A strong anomaly in sec. 26, T. 8 N., R. 8 E., occurs in glacial overburden. The glacial debris and ice scouring extend to the west for approximately a mile, and it is likely that metal-bearing particles have been transported from the mineralized areas near the head of Alabaugh Creek. No anomalies occur west or north of the area, however, and it is possible that an ore body may have been almost completely removed by glacial and fluvial erosion. Another small anomaly in sec. 1, T. 8 N., R. 8 E., is centered downslope from a few prospects that have explored a few small iron-bearing veins that cut the diorite stock. The anomaly shown by the citrate analyses in sec. 18, T. 8 N., R. 9 E., is repeated, but is not believed to represent a mineralized zone, although syenite and dacite dikes lie just east and north of the area.

TRAVERSE SURVEYS

It is believed that closely spaced traverses to seek extensions of small oreshoots will be the most effective application of geochemical methods in the Castle Mountains. Many oreshoots and veins in the Castle Mountain district are covered, and other oreshoots can be expected below the surficial material. Under these conditions, geochemical methods should be used because the procedures are rapid and inexpensive.

Several traverses were established in a direction believed to be approximately at right angles to mineralized structures. Samples were analyzed for total amounts of lead, zinc, or copper, by the pyrosulfate-fusion method of extraction if the results of prior citrate-soluble analysis indicated further testing. Ideally, the sampling should be started outside the mineralized area and continued along the line until the mineralized area has been crossed.

Traverse 1, Powderly

The first sample traverse was started northeast of the Powderly shaft and extended southwest beyond the vein. Sample spacing was 10 feet.

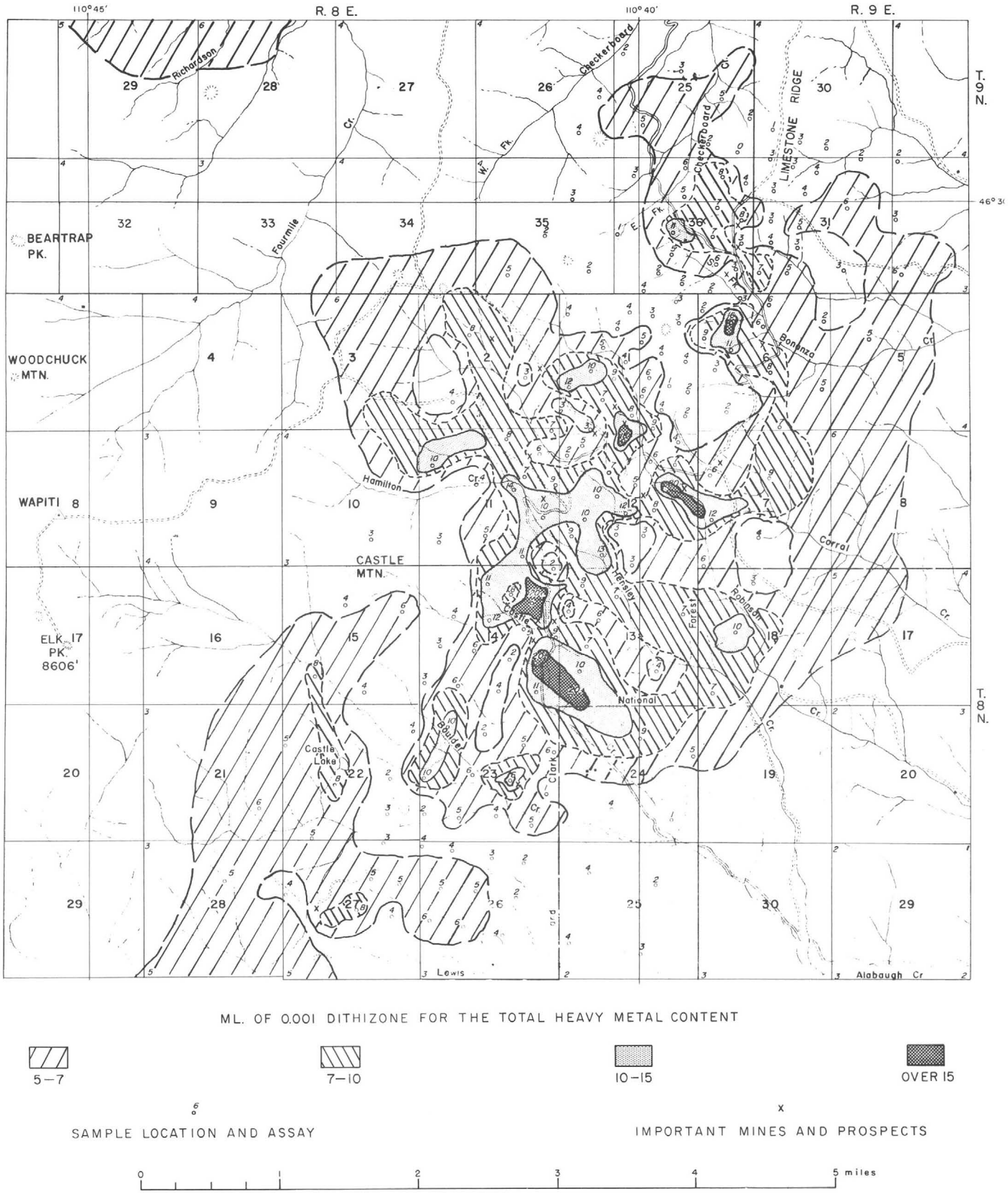
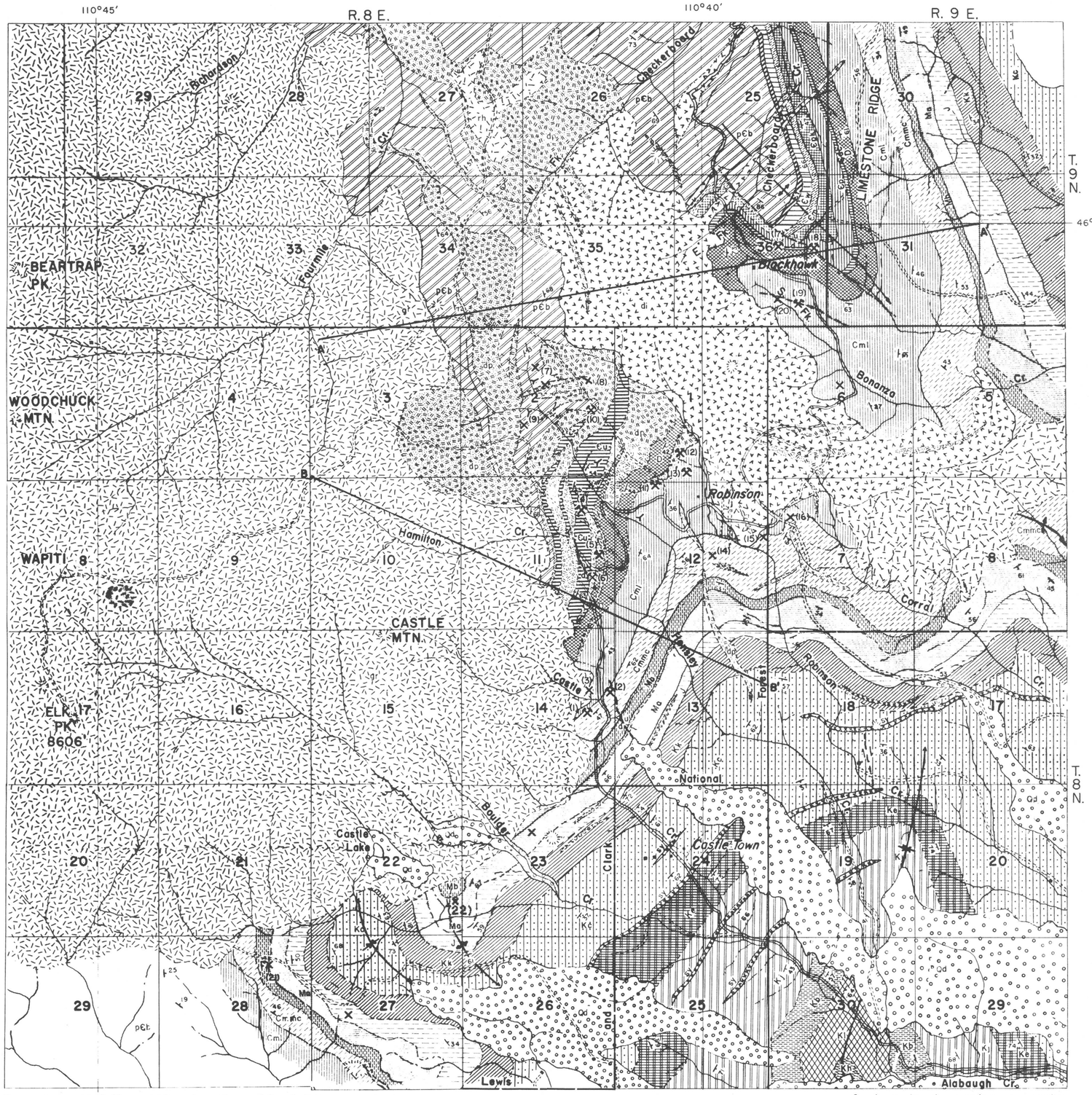


Figure 2. --Geochemical anomaly map, heavy metals.



Base from U. S. Forest Service Maps 46-110-310 and 46-110-240

Geology by A. S. Winters -1964-

EXPLANATION

SEDIMENTARY ROCKS

CENOZOIC — Quaternary
- Qd — GLACIAL DEBRIS

MESOZOIC — Cretaceous
- Kh — HELL CREEK FORMATION
- Kl — LENNEP SANDSTONE
- Kb — BEARPAW SHALES
- Kj — JUDITH RIVER FORMATION
- Ke — EAGLE SANDSTONE
- Kc — COLORADO GROUP
- Kk — KOOTENAI FORMATION

MESOZOIC — Jurassic
- J — MORRISON, SWIFT, RIERDON FORMATIONS

PALEOZOIC — Mississippian
- Ma — AMSDEN LIMESTONE
- Mb — BIG SNOWY GROUP
- Cmmc — MISSION CANYON FORMATION
- Cml — LODGEPOLE LIMESTONE

PALEOZOIC — Devonian
- D — THREE FORKS, JEFFERSON FORMATIONS

PALEOZOIC — Cambrian
- Єdc — DRY CREEK MEMBER
- Єp — PILGRIM LIMESTONE
- Єpk — PARK FORMATION
- Єm — MEAGHER LIMESTONE
- Єw — WOLSEY SHALE
- Єf — FLATHEAD SANDSTONE
- Єu — CAMBRIAN UNDIVIDED

PRECAMBRIAN — BELT SERIES
- pЄb — PIEGAN GROUP

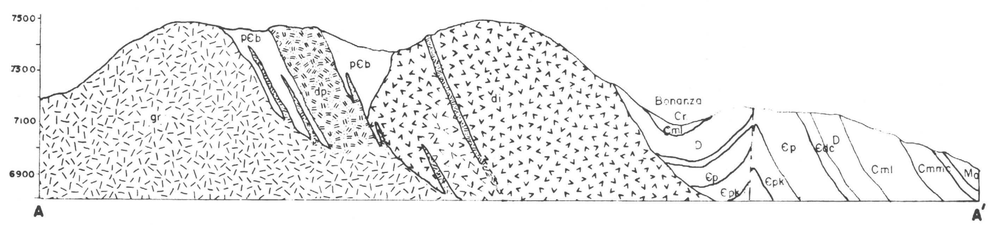
IGNEOUS ROCKS

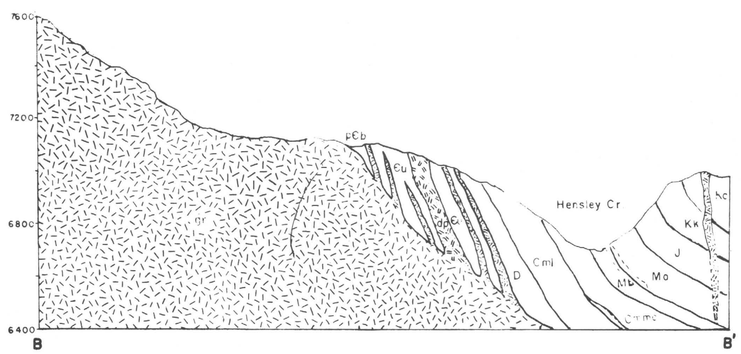
CENOZOIC — Tertiary
- sy — SYENITE
- rh — RHYOLITE
- dp — DACITE PORPHYRY
- gr — GRANITE
- di — DIORITE

TRUE NORTH — MAGNETIC NORTH — 20°

SYMBOLS
- MINE
- PROSPECT
- ADIT
- CONTACT
- FAULT
- ANTICLINE
- SYNCLINE
- STRIKE AND DIP (67)

0 — 1/2 — 1 MILE
SCALE

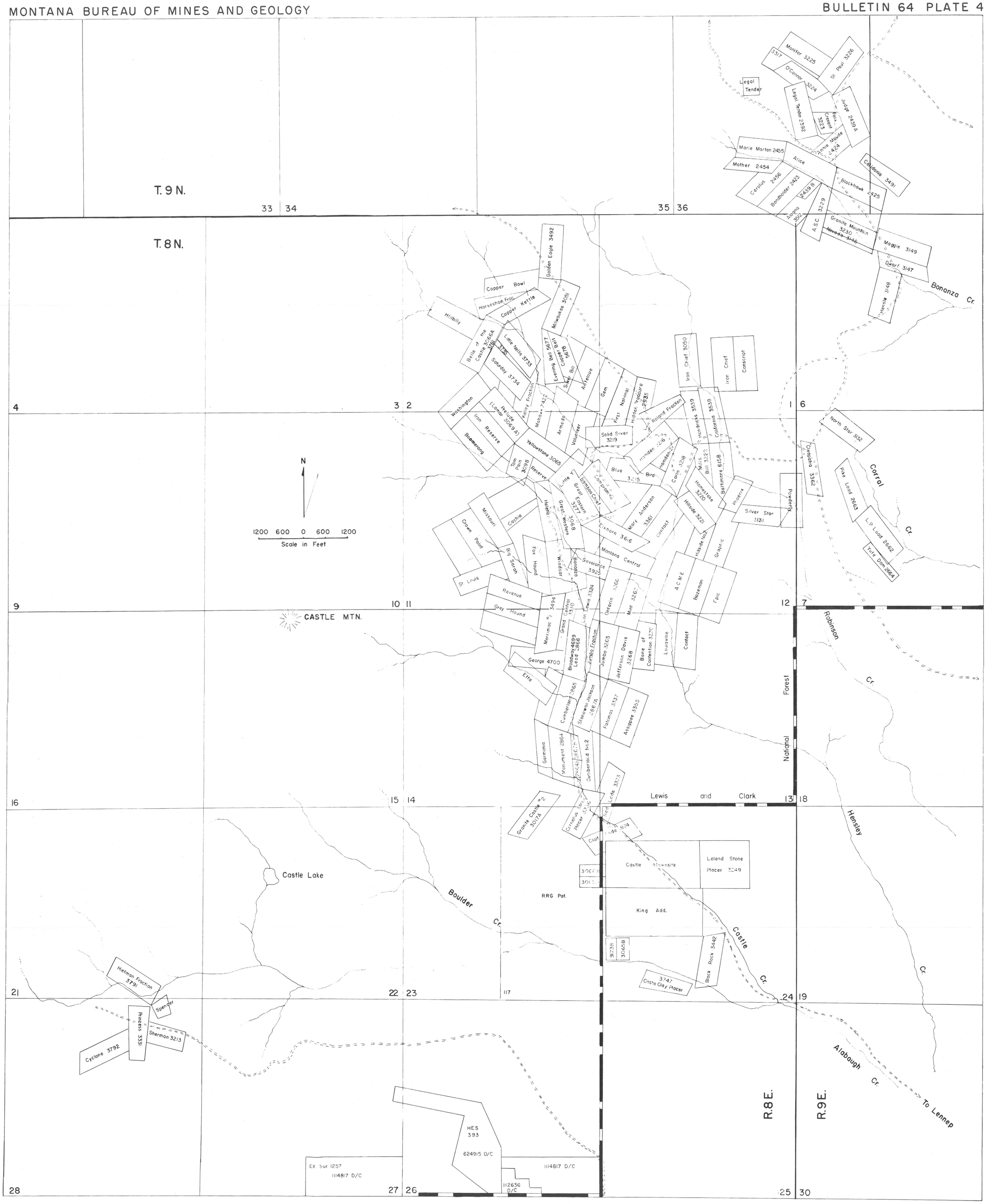




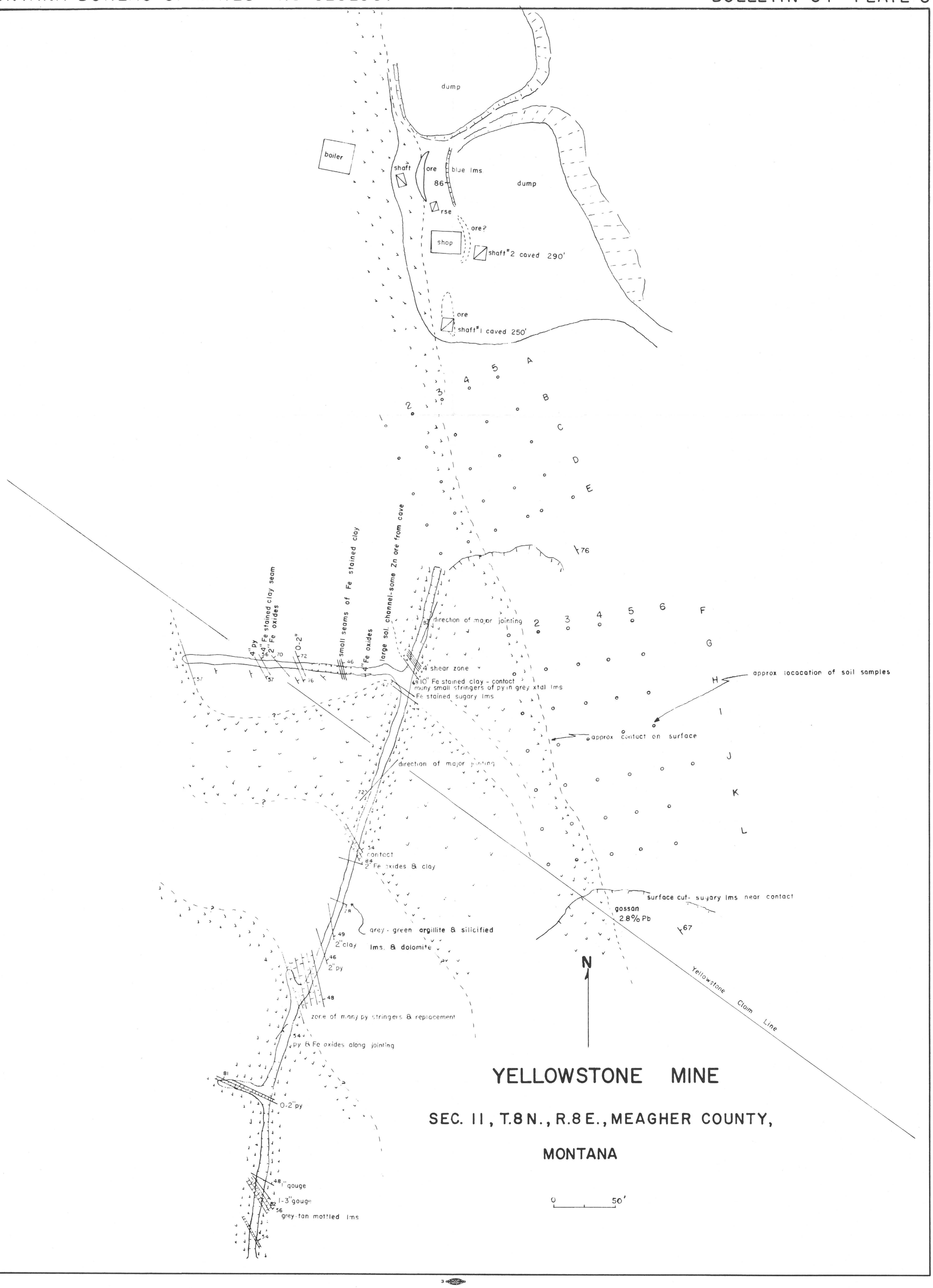
GEOLOGIC MAP OF THE CASTLE MOUNTAIN MINING DISTRICT MEAGHER COUNTY, MONTANA

IMPORTANT MINES AND PROSPECTS

(1)	Cumberland	(12)	Iron Chief
(2)	Jumbo	(13)	California
(3)	Broadway (Lead)	(14)	Homestake
(4)	Yellowstone	(15)	Powderly
(5)	Great Eastern	(16)	Cleopatra
(6)	Great Western	(17)	Legal Tender
(7)	Copper Bowl	(18)	Judge
(8)	Golden Eagle	(19)	Blackhawk
(9)	Belle of The Castle	(20)	Alice
(10)	Milwaukee	(21)	Princess
(11)	Hidden Treasure	(22)	American

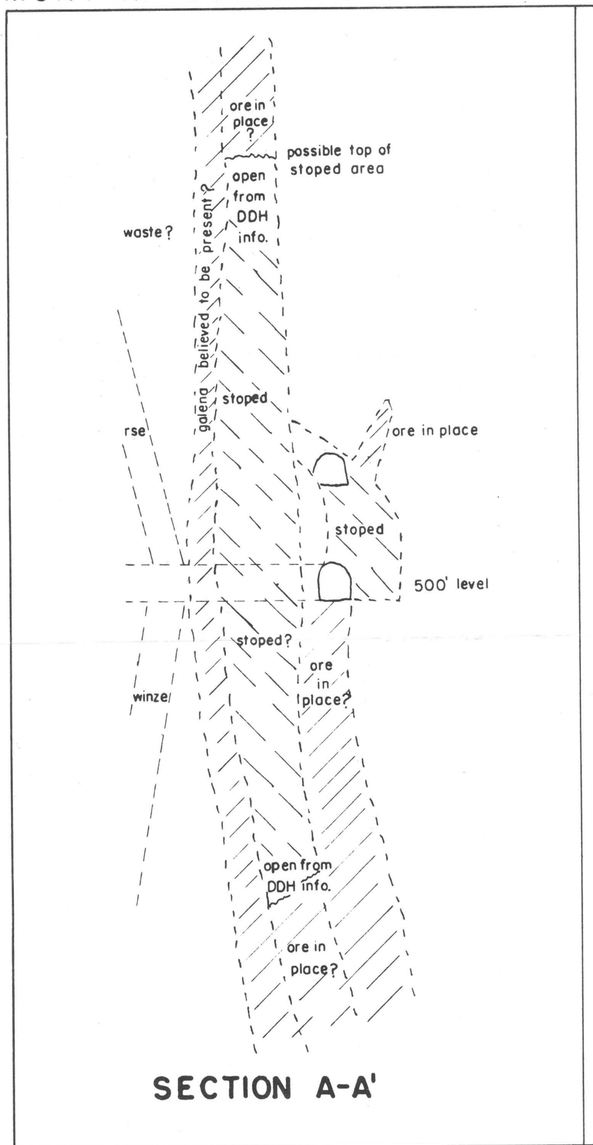


CLAIM MAP OF THE CASTLE MOUNTAIN MINING DISTRICT, MEAGHER COUNTY, MONTANA

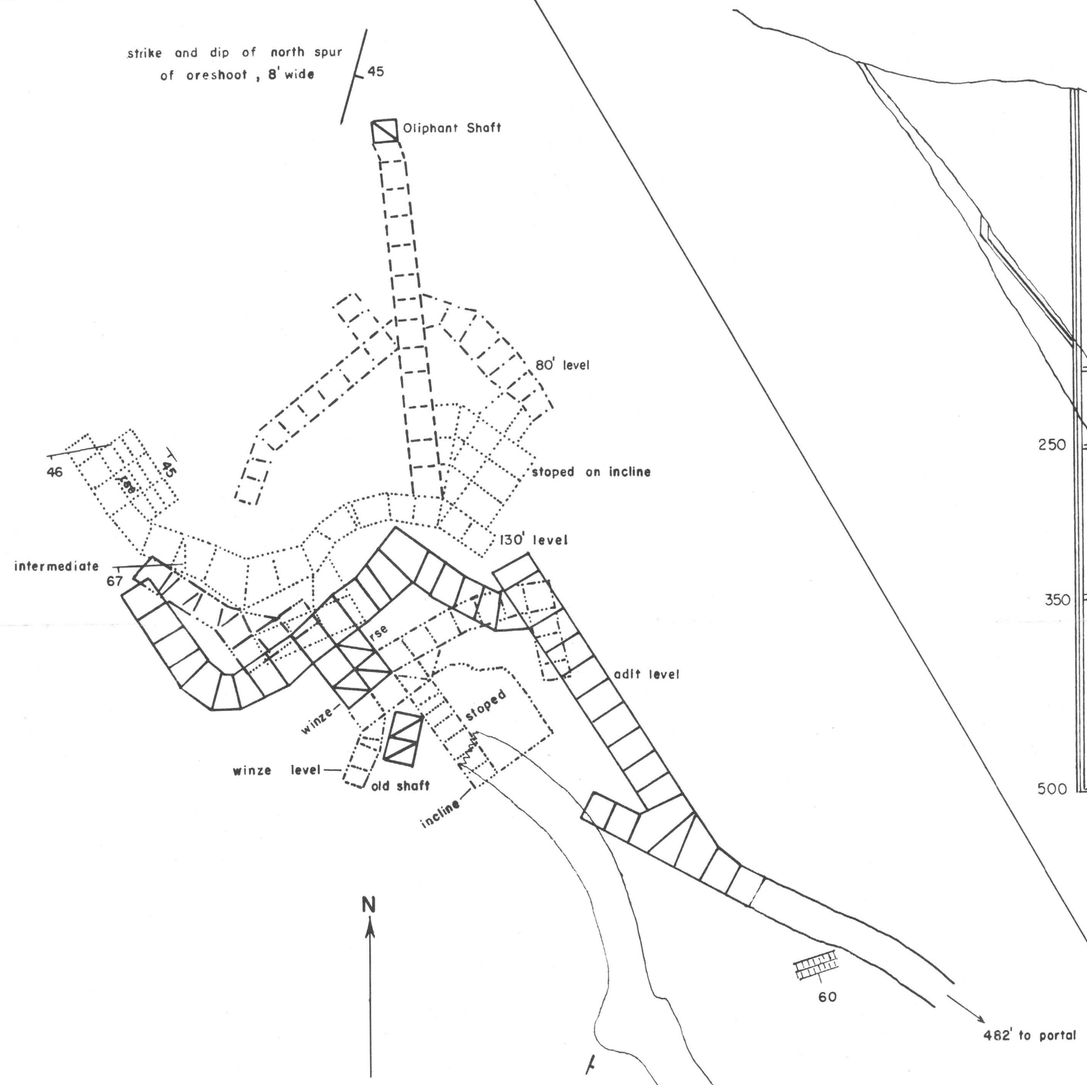


YELLOWSTONE MINE

SEC. 11, T.8 N., R.8 E., MEAGHER COUNTY, MONTANA

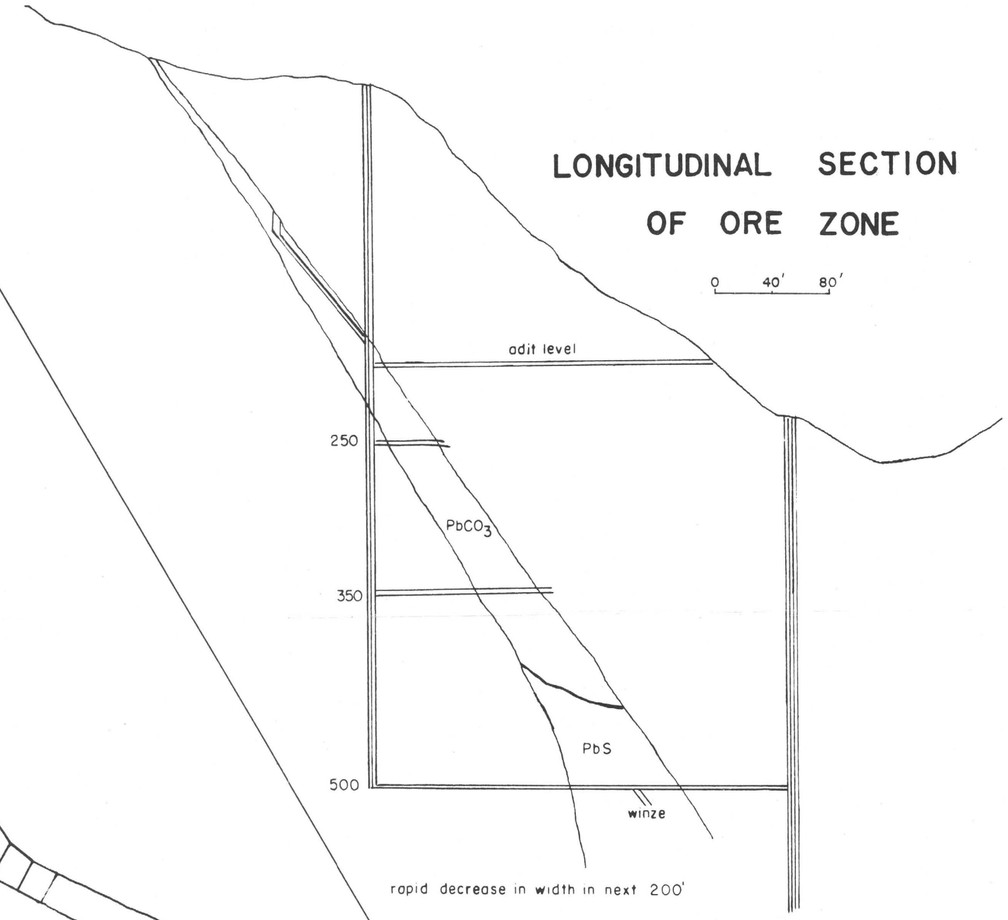


SECTION A-A'



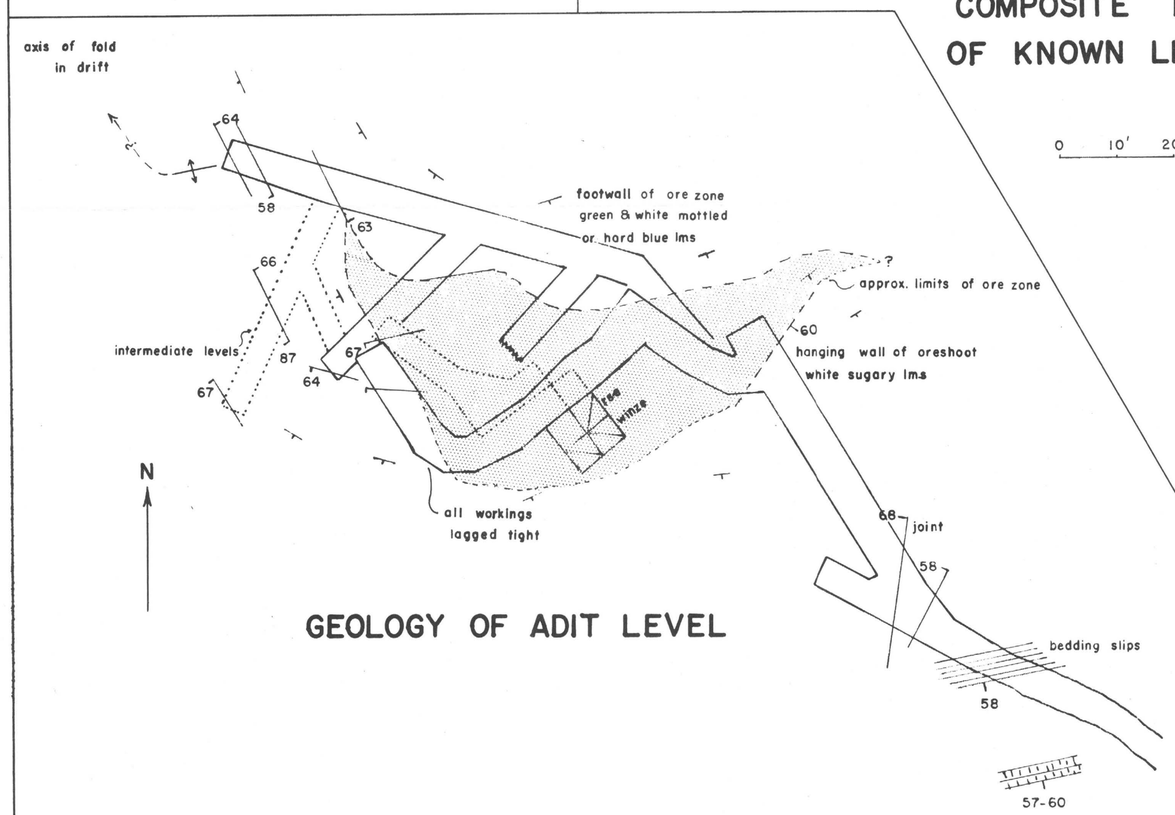
COMPOSITE PLAN OF KNOWN LEVELS

0 10' 20'

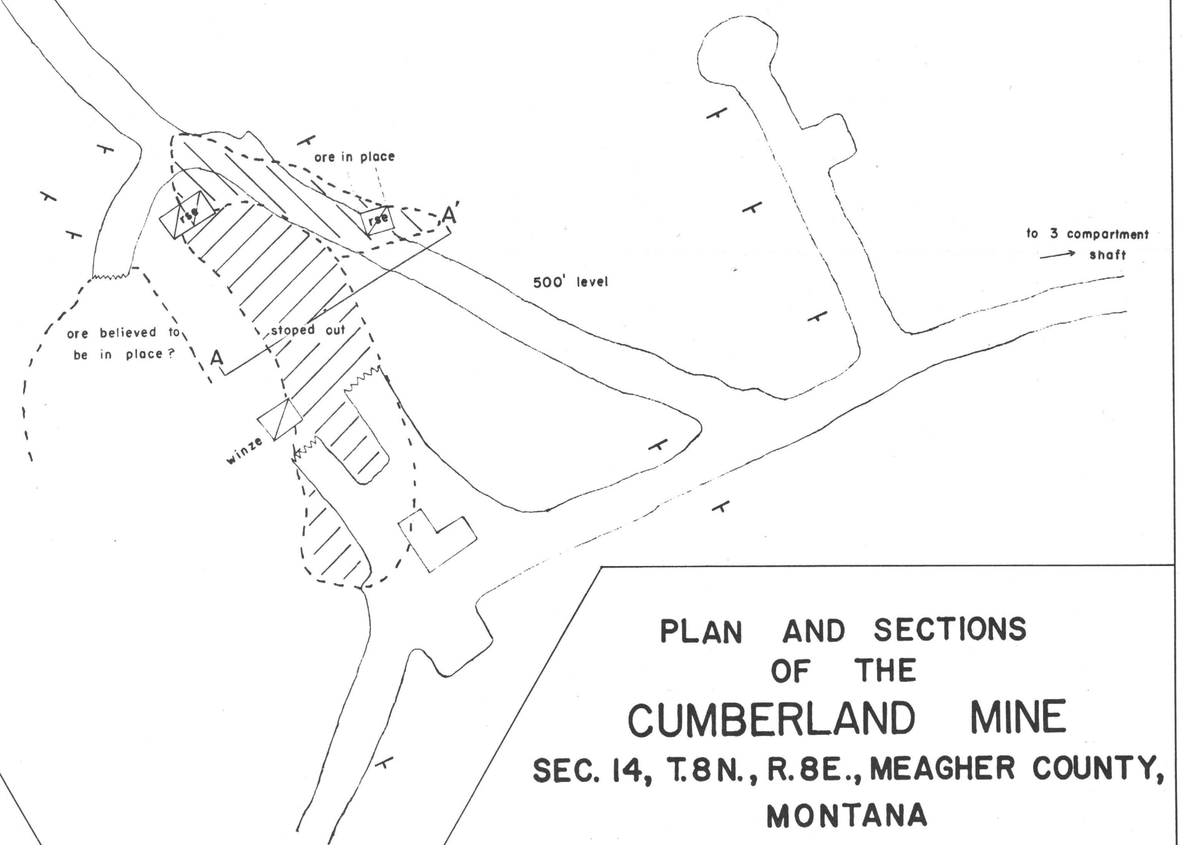


LONGITUDINAL SECTION OF ORE ZONE

0 40' 80'



GEOLOGY OF ADIT LEVEL



PLAN AND SECTIONS OF THE CUMBERLAND MINE

SEC. 14, T.8N., R.8E., MEAGHER COUNTY, MONTANA

500' Level adapted from Arthur Lakes 1950