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

by

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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

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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.

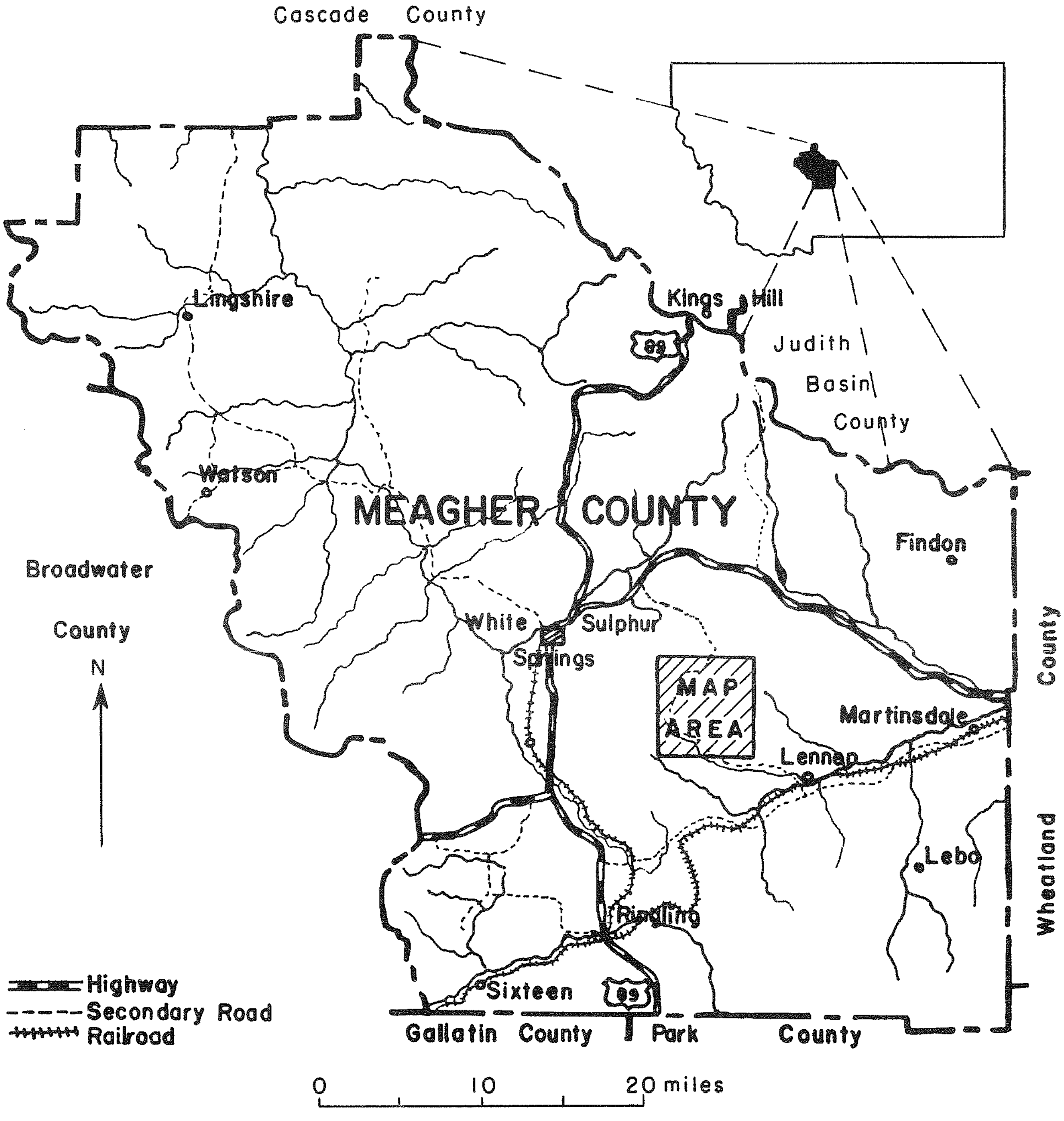

Figure 1.--Index map showing location of Castle Mountain district.

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

<u>Granite</u>.--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.

<u>Diorite</u>.--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.

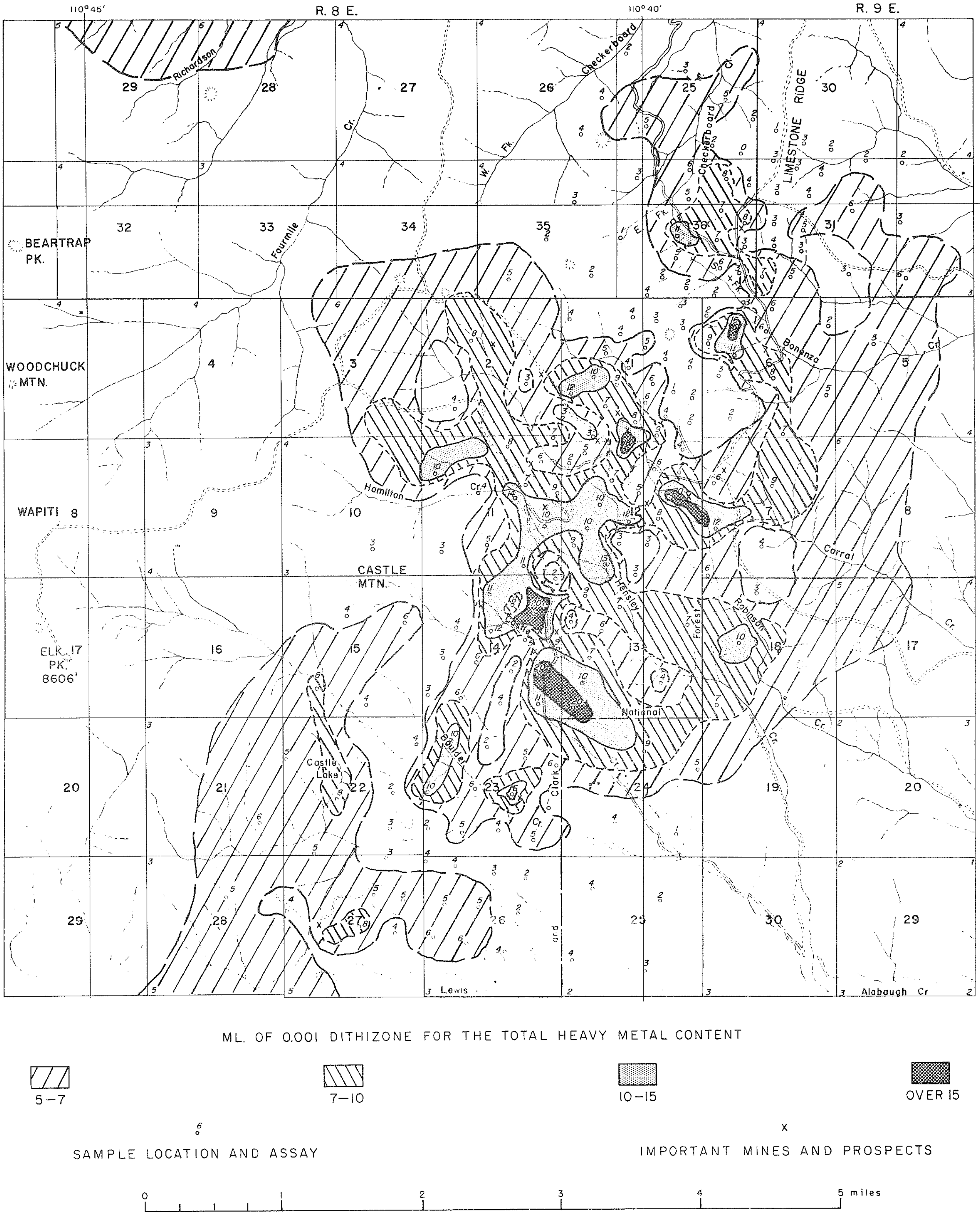

Figure 2.--Geochemical anomaly map, heavy metals.

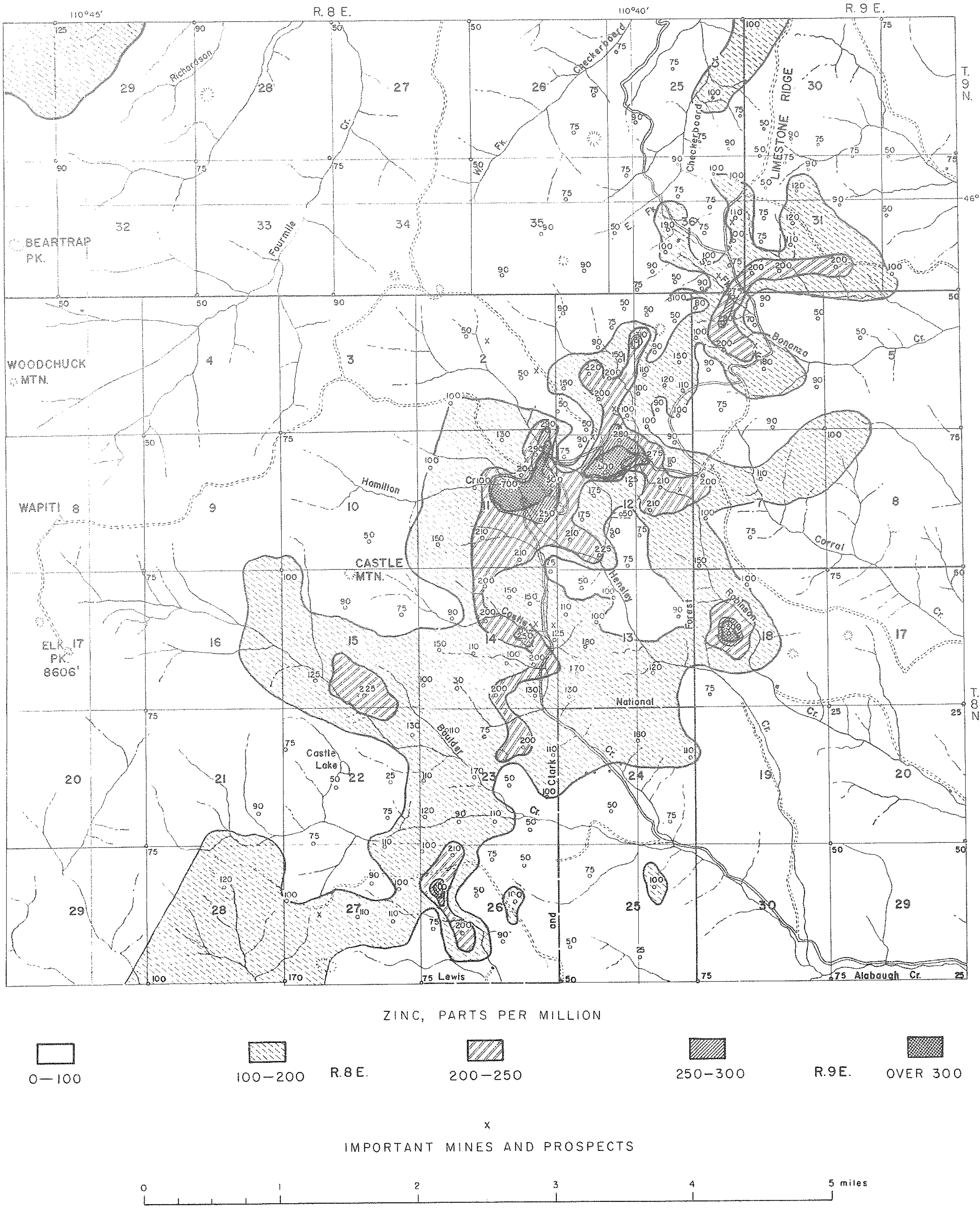

Figure 3.--Geochemical anomaly map, zinc.

The purpose of this traverse was twofold, to find the vein and to establish the reason for driving the northernmost drift of the Powderly adit. This drift is now caved and seemingly followed a northwest-trending dike.

Examination of Figure 4 shows a strong peak 10 to 20 feet downhill from the observed vein. This downslope movement of the metal ions is characteristic of surveys of this type. The peak, however, would be expected in sample 10, and the moderate values there may possibly indicate that the sampling depth was not great enough.

Samples 4, 5, and 6 do not show any significant values, and it may be assumed from this traverse that mineralization near the surface along the dike is not sufficient to produce ore.

Citrate-soluble heavy metal and lead analyses provide the most clearcut indication of the location of the vein. It can be noticed that although the zinc values continue high, the lead values drop sharply, away from the vein. This phenomenon is in accord with the mobility of these two metals in a basic environment.

Traverse 2, Judge

Two traverses were made east of the townsite of Blackhawk near the Judge mine. Sample spacing was 20 feet, and a 0.2-gram sample was used as the results were expected to be low.

Traverse 2-A was started east of the Blackhawk fault and proceeded west beyond the fault. The purpose of this traverse was to investigate the possibility of mineralization along the fault. The traverse is approximately 125 feet north of the intersection of the fault and a dacite porphyry dike (Fig. 5). If the fault were mineralized, the mineralization would be expected at or close to the intersection, and this traverse would be expected to show abnormal values in samples 5 and 6. The samples were tested for citrate-soluble heavy metals but no anomalous values were found to warrant further testing. This traverse by no means disproves the possibility of mineralization along the fault, but only suggests that the fault is not mineralized near the traverse.

Traverse 2-B was established from north to south across the longest and most continuous dacite porphyry dike in the Blackhawk area. This dike is believed to have served as the channelway for the solutions that mineralized the ore produced from the Judge, Annie Maude, and Alice mines.

Examination of Figure 5 shows a strong peak south (downslope) of the observed dike. These values suggest a slight amount of mineralization associated with the dike and may indicate that the parallel dike to the south extends farther west than previously mapped.

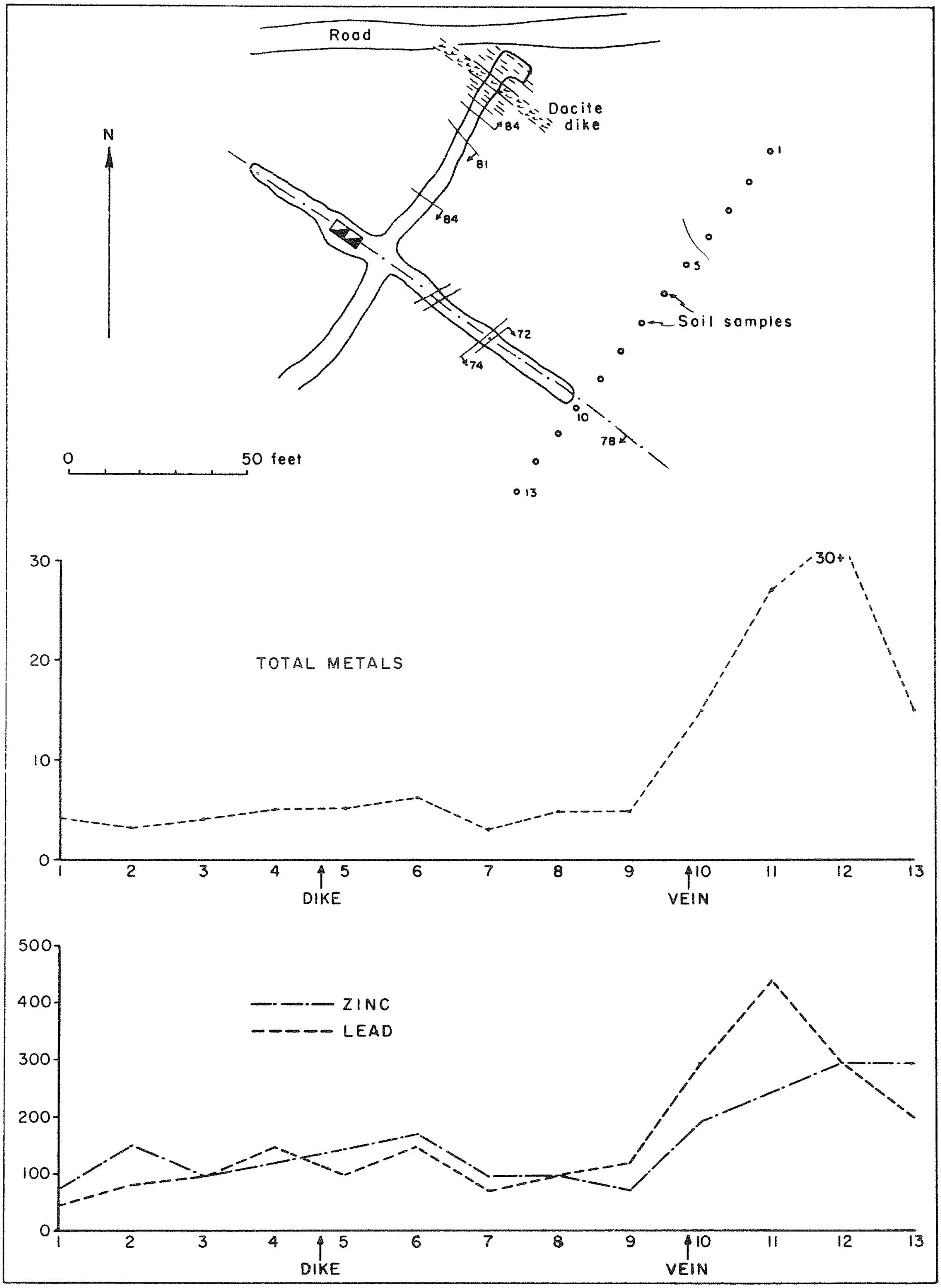

Figure 4.--Traverse 1, Powderly.

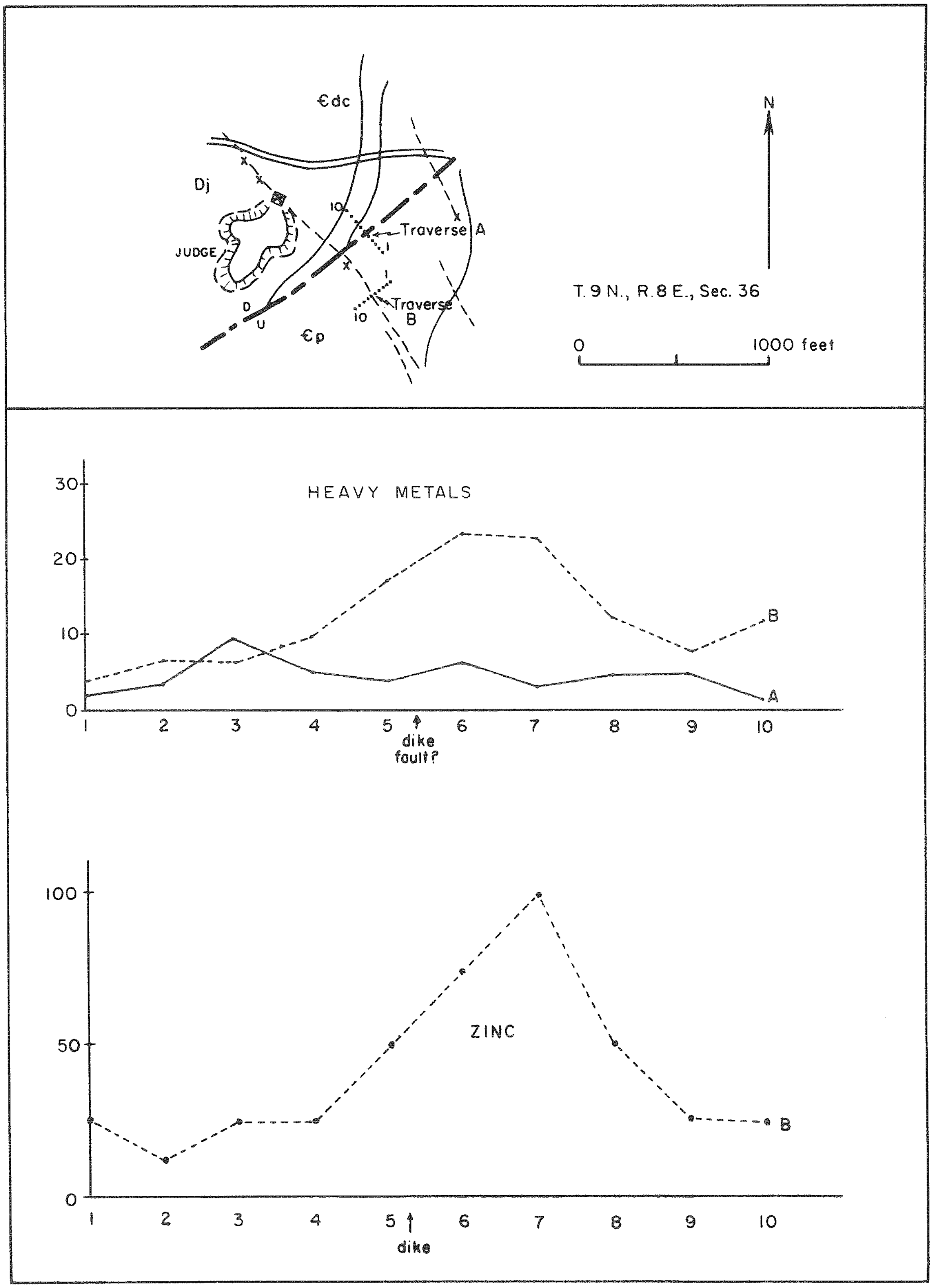

Figure 5.--Traverse 2, Judge.

If the southern dike does extend farther west, then both dikes may have served as channelways and should be prospected farther east as well. The traverse was successful in that it established the fact that the dacite dikes are intimately associated with the oreshoots of the Blackhawk area.

Traverse 3, Belle of the Castle

The third soil-sample traverse was parallel to the Belle of the Castle claim line. The sample spacing of the first attempt to locate the Belle veins was 25 to 50 feet. The principal vein was expected to cut across the side line of the claim between samples 5 and 8. Examination of Figure 6 shows that the highest value was in sample 3. A second traverse of samples taken at a greater depth seemed indicated to establish a definite location of the mineralized structure.

Sample spacing of the second traverse was approximately 8 feet, and these samples were tested for copper and zinc. Figure 7 shows that dispersion pattern for these two elements. It can be observed that values for copper are high in samples 15 and 16 and for zinc in samples 13 and 15, indicating the presence of a mineralized structure at or near sample 15. Samples 19, 20, and 21 also show abnormal values for copper but only normal traces of zinc. As the metal of the area is principally copper, zinc is not necessarily diagnostic. In any case, the traverse is too short to establish another mineralized zone.

Traverse 4, Yellowstone

Traverse 4 consisted of twelve separate east-west lines across the observed contact of a dacite porphyry dike and Pilgrim Limestone. Sample spacing was approximately 30 feet, and the samples were tested for lead (see Appendix). It was expected that the anomalies would occur adjacent to the contact, as all the observed oreshoots are contact metasomatic deposits. Results show consistent high values 60 to 100 feet east of the contact, indicating that the lines were too far west to establish the exact location of any mineralized zones.

The two most likely explanations of the abnormal values east of the contact are (1) a mineralized zone or favorable bed that parallels the dike to the east, and (2) a parallel dacite porphyry sheet related to the mineralization. Whatever the case, the values obtained certainly warrant further exploration.

Miscellaneous Traverses

Other traverses in the district did not indicate sufficient mineralization to justify graphical illustration. Two of these traverses, however, did indicate dacite dikes, in much the same manner as Traverse 2-B.

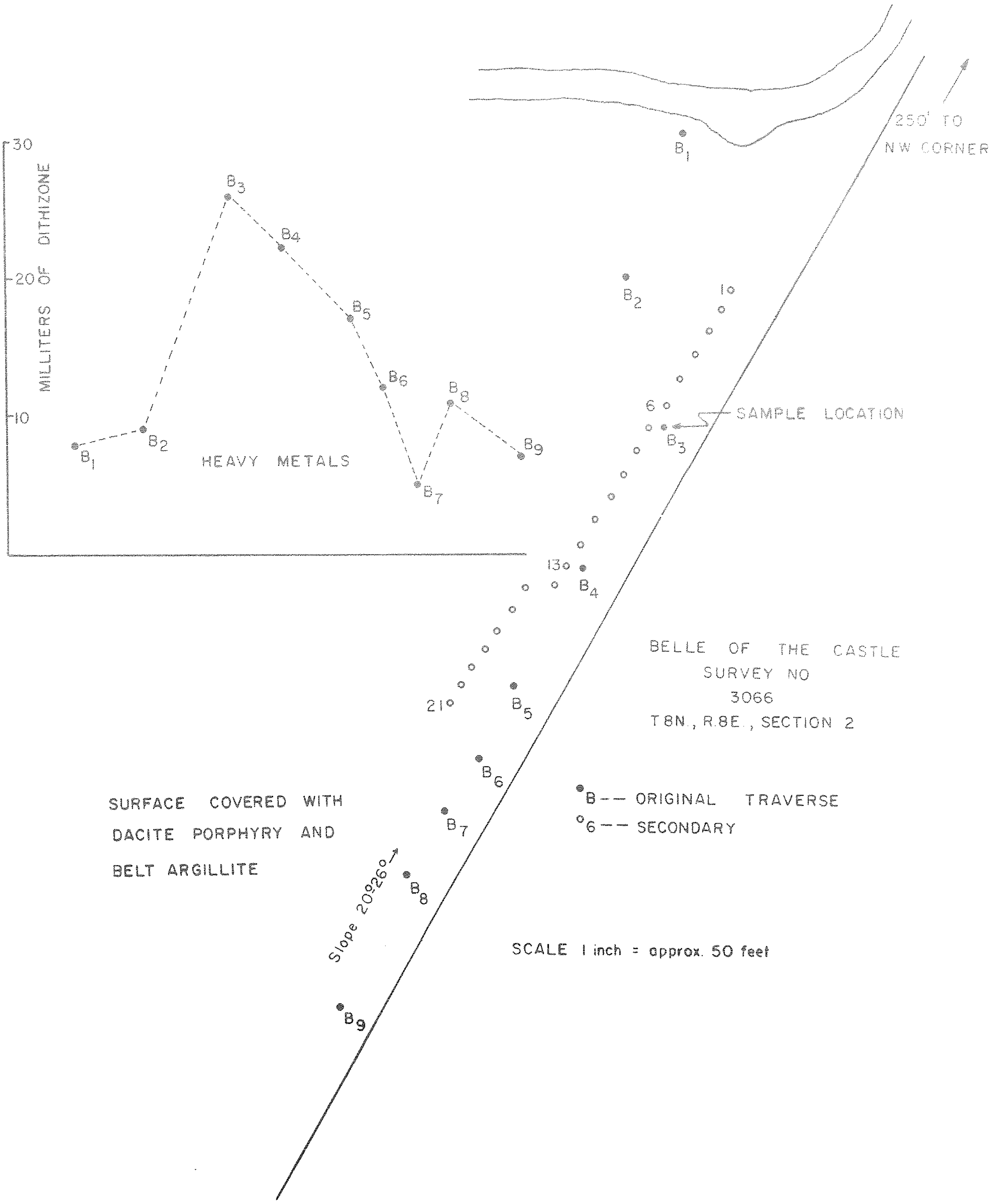

Figure 6.--Traverse 3, Belle of the Castle.

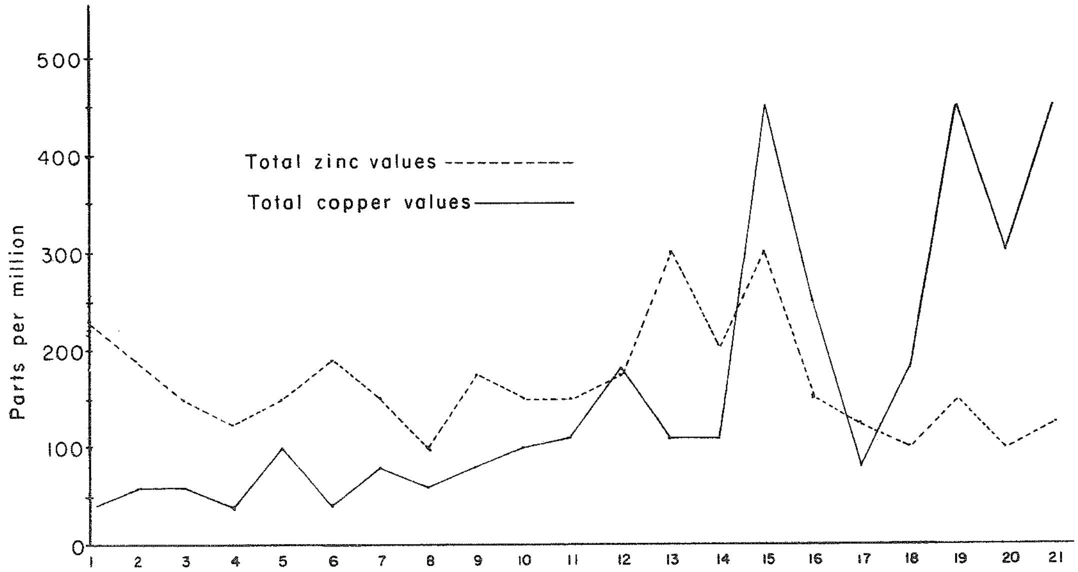

Figure 7.--Traverse 3, Belle of the Castle vein.

DESCRIPTION OF MINES AND PROSPECTS

The descriptions of the following mines and prospects have been derived from several sources. The information as to the length and width of most ore bodies is hearsay and has been credited to the source.

During the time of the investigation, almost all of the mines were inaccessible, hence much of the information is based upon poor surface exposures and may be partly incorrect. As for the historical records, the best information on the extent of development, the tenor of the ores, and the nature of the ore deposits is undoubtedly incomplete or in error. For these omissions and errors, the author wishes to express his regret.

In general, the arrangement of the descriptions of the various mines and prospects follows from the larger producers.

CUMBERLAND MINE (Pb, Ag)

In 1891 the Cumberland mine was the largest single producer of lead ore in the State of Montana. The Cumberland is located three-fourths of a mile north of Castle Town at an altitude of 6,300 feet. The property, comprising the following group of claims, is owned by Russell Manger of White Sulphur Springs, Montana (Pl. 4).

Claim	Survey no.
Cumberland	2865
Merrimac No. 1	3491
Stonewall Jackson and Millsite	2867A-2867B
Monument and Millsite	2864A-2864B

The history of the Cumberland is that of the district itself, and therefore a historical account of the mine is given. Work near the mine began in the late months of 1884, but not until 1886 did Lafe Hensley and his sons discover and locate the Cumberland. In 1887 a group of White Sulphur Springs businessmen formed the Cumberland Mining and Smelting Company to develop the mine. A shallow discovery shaft was sunk along the ore zone and soon afterwood a two-compartment vertical shaft was sunk to intersect the ore zone at approximately the 200-foot level. From these shafts, the first ore was produced in May 1888 and shipped to the Chicago and Aurora Smelting Company in Illinois. Reports state that this 10.5-ton shipment averaged 60.7 percent lead and carried 27.4 ounces of silver per ton (Roby, 1950, p. 17).

After a sufficient quantity of commercial ore had been developed, it was found advisable to sink a new shaft farther from the workings because of ground conditions. The new shaft was started at a lower elevation near the bottom of the hill. This project, a three-compartment, 480-foot vertical shaft, is believed to have given access to only one level, the 250-foot, which corresponded to the 500-foot level of the discovery shaft. Ore and waste was rapidly hoisted by a 16 by 48-inch double cylinder engine, and the rapid inflow of water was bailed with the hoisting equipment and pumped by two duplex Knowles pumps through 6-inch discharge pipes (Hogan and Oliver, 1892, p. 42).

J. Kennedy Tod purchased the controlling interest in the mine after the smelter closed and spent considerable money in developing and investigating the ore zone. A thorough report of the mine's ore reserves was made by W. B. Parsons during this period. At the time of purchase, it was generally understood that a railroad was soon to be built into the area. Owing to the collapse of the silver market, however, the mine ceased operations completely by 1894 (Weed and Pirsson, 1896, p. 153).

The Cumberland mine was the largest producer in the district, but a complete record of its production is not available. An estimated 27,000 tons of ore was processed either by eastern or local smelters between 1888 and 1892. This ore yielded not less than 10,000,000 pounds of lead. The tenor of the ore was high, as shown by the 8,646 tons shipped by R. A. Harlow, which averaged 35 percent lead and contained 15.7 ounces of silver per ton. The mine was generally inactive from the turn of the century until after the Korean war. Since 1959 the mine, operated by HOCO, Inc., has steadily been producing 25 to 50 tons per month; the ore has averaged 19.6 percent lead and 6 ounces of silver per ton. The total mine production is estimated at 18 to 20 million pounds of lead and more than 620,000 ounces of silver (personal communication, C. R. Oliphant).

A few lessees worked the mine after the turn of the century. Between 1943 and 1944 lessees under the direction of John Oliphant sank a small shaft on the ore zone. This ore averaged 37.5 percent lead and contained 10.3 ounces of silver per ton. The work was later abandoned upon reaching a caved zone above an old stope, and attention was then shifted to developing the ore zone by an adit driven westward from the old slag dump. When the mineralized zone was reached, however, the hanging wall caved and work was stopped in 1945. Later, with a Reconstruction Finance loan, the old shaft was dewatered, but the mineralized zone was also caved on the 500-foot level. Further work was then canceled and the Cumberland lay idle until 1948 when the ore zone was diamond drilled by R. C. McLean. A 682-foot hole was angled 30 degrees in a northwest direction from a point near the portal. The hole cut 10 feet of ore on the west edge of the crescent-shaped ore zone, and sludge samples assayed 19.1 percent lead, 5.35 ounces of silver, and 0.245 ounce gold (personal communication, C. R. Oliphant).

As a result of this drill hole, the Silverton Mines, Inc., began to open up the 500-foot level and did considerable development work but dropped its lease in 1951. Because of the improved metal prices during and after the Korean war, interest again turned to the Cumberland. HOCO, Inc., supervised by C. R. Oliphant, drifted both north and south in the ore zone from an inclined shaft. Considerable ore was mined from the northern part of the structure on the 80- and 130-foot levels. It was later found advisable to open the adit level and to connect with the upper workings. In 1960 this work was successfully completed through the caved zone. Since 1960 two other levels have been opened and considerable ore has been developed and mined (Pl. 2). A winze was sunk from the adit level and connected with the old two-compartment shaft, which was found to be open from a point above the 200-foot level for an unknown distance below the 300-foot level. In the future, this shaft may prove useful in the ventilation of the workings.

Weed and Pirsson (1896, p. 153) described the Cumberland ore zone as a surprisingly regular pod that dipped 60° to the southwest. On the surface the ore zone is 8 feet wide at its maximum width and can be traced for about 60 feet. The ore occurs along a flexure in the Mission Canyon Formation, which at the Oliphant shaft strikes N. 15° E., and dips 44° E. As depth is attained the ore zone becomes wider and steepens in dip.

On the adit level the ore zone, at its maximum limits, is roughly 30 feet wide and 75 feet long. In general, the ore zone strikes N. 75° E., and dips 60° S. (Pl. 2). Commercial ore occurs within the ore zone as separate shoots and pods, most of which terminate abruptly. On the upper levels, the largest oreshoot occurs along the hanging wall and is fairly continuous throughout the workings. The footwall on this level is hard green and white mottled limestone containing many clay seams, and the hanging wall is sugary white limestone.

The ore zone on the 500-foot level is nearly 75 feet wide and 90 feet long. One large oreshoot was mined from the 500-foot level and is believed to be caved 70 to 80 feet above the sill (Pl. 2). Lakes (1950, no. 4) stated that one shear zone near the oreshoot strikes N. 75° E., and dips 60° SE. The attitude of this shear zone is believed to be the same as that of the ore zone. Several sources also state that on this level a large horse of jasper separates the hanging and footwall oreshoots. Weed and Pirsson (1896, p. 154) stated that a crosscut was driven westward where it cut two quartz porphyry dikes before reaching the granite contact on the 500-foot level. The granite-limestone contact was reported to have a dip of 65° E.

Further ore was developed by a 250-foot winze, which followed the hanging wall oreshoot downward from the 500-foot level. From this winze, some 10 to 15 percent lead ore was developed, but was not found profitable to mine. In general, the richness of the ore zone decreased sharply below the 500-foot level, where pyrite is more abundant (Weed and Pirsson, 1896, p. 154).

In long section the ore zone is fairly regular except for a gradual increase in dip of the footwall. Between the 400- and 500-foot levels the footwall is stated to be nearly vertical (Pl. 2). Four definite though transitional zones occur in the Cumberland. From the surface downward they are an iron gossan, a cerussite zone, a galena zone, and a pyritiferous zone. The cerussite zone is the largest and most important, extending down to the 450-foot level.

Zinc rarely exceeds 3 percent in the ore and is present as sphalerite and smithsonite. The galena is slightly argentiferous and averages 1 ounce of silver for every 2 to 3 percent lead. Gold and copper are of minor importance. The chief gangue minerals of the mine are iron oxides, jasper, and limestone.

YELLOWSTONE (Pb, Ag)

The Yellowstone mine is located on the ridge between Hensley and Hamilton Creeks at an altitude of 7,200 feet. The Yellowstone group, comprising the following claims, is owned by Hamilton Mines, Inc., and leased by George Voldseth of Lennep, Montana (Pl. 4).

Claim	Survey no.
Yellowstone	3065
Millsite	3065B
Prelude (Lamar)	3069A
Iron Reserve	
Reserve	

Discovered in 1886, the southernmost oreshoot was developed by a 250-foot discovery shaft. The first smelter erected in the district was known as the Hensley smelter and was built to treat the ores being mined from this shaft. Later, two other oreshoots were discovered north of the first, and they were also developed by shafts. The northernmost shaft was reported to have attained a depth of 415 feet and was in a galena oreshoot at the time the mine closed (personal communication, George Voldseth).

The mine is in a sheeted zone where irregular dacite porphyry sills separate Cambrian sedimentary rocks (Pl. 3). The oreshoots are en echelon along the contact of a large sill with Pilgrim Limestone. Local flexures in the limestone seem to have localized the ore. In the vicinity of the shaft the limestone strikes N. 2° W. The adit cuts Park and Pilgrim strata, which dip to the east. The Pilgrim is bleached and partly recrystallized, whereas the Park is silicified and altered to argillite. Argillization seems to be the dominant alteration process affecting the intrusive rocks, and no high-temperature minerals were observed.

In recent years the northernmost shaft has been reopened to a depth of 70 feet, where it intersects the oreshoot in the lowest set. The oreshoot dips slightly to the west on the surface but on the 70-foot level the ore dips 59° west. This shaft has now developed approximately 800 tons of ore and was being sunk another 30 feet.

The southern and middle oreshoots are presently covered, and the attitude of the contact zone could not be determined. The middle oreshoot, however, is believed to have hard blue limestone as either a hanging or footwall (Pl. 3). This unit forms a small ridge on the footwall side of the northern oreshoot and may have served as an impermeable wall for the rising mineralizing solutions.

Ore from the mine consists of galena and cerussite cemented in a brown jasper. The ore also contains considerable zinc and payable amounts of gold in the lower levels. Jasper is the major mineral along the contact and can be traced to Hamilton Creek. Magnetite also occurs in the jasper and samples can be found on the surface near the discovery shaft.

GREAT EASTERN AND GREAT WESTERN (Pb, Ag, Mn)

The Great Eastern-Great Western group is located on the ridge northeast of Hamilton Creek (Pl. 4). Owned by J. F. Brophy, the group consists of the following claims (Roby, 1950, p. 21):

Claim	Survey no.
Great Eastern	3277
Great Western	2605
Bamboo Chief	3275
Elkhorn	3276

The Great Eastern was located in 1886 and became one of the larger mines in the district. Sunk vertically for 300 feet, the main shaft then inclined toward the east. The shaft had three levels, and a total of 825 feet of drifts and crosscuts had been driven by 1890 (Roby, 1950, p. 21). On the 100-foot level, several small oreshoots were cut and considerable low-grade ore was developed. In general, the lower levels were said to have been less profitable, as jasper formed the major part of the vein. At one time an adit from Hamilton Creek was proposed to drain the mine and to open up the mineralized zone 380 feet below the shaft collar (Roby, 1950, p. 21).

A fractured zone in the Pilgrim Limestone is mineralized. This limestone lies in the sheeted zone, and dacite prophyry sills are exposed east and west of the workings. The intrusive rocks and the partly recrystallized limestone generally strike N. 10° W., and dip 60° to 80° E. Manganese oxides form a large concentric peripheral zone around the lead ore bodies at the mine.

Production records are incomplete, but MacKnight (1892, p. 100) stated that the mine had produced 500 tons of ore. The mine later reported a considerable production in 1897. No work has been reported in recent years, but the dumps have been sampled repeatedly for manganese ore.

JUMBO (Pb, Ag)

The Jumbo mine is located less than a quarter of a mile north of the Cumberland and was one of the larger producers in the district (Pl. 4). The Jumbo group, consisting of the following claims, is owned by J. F. Brophy of Red Lodge, Montana (Roby, 1950, p. 19).

Claim	Survey no.
Jumbo	3265
Ontario	3266
Mint	3267
Jefferson Davis	3268
Jumbo Fraction	3269
Bone of Contention	3270
Len Lewis	3324
Severence	3325

Ore was discovered in 1886 and was developed by several shallow shafts and pits. The main shaft was 200 feet deep and had two levels (Hogan and Oliver, 1892, p. 42). Production figures are incomplete but the mine was one of the last to stop working after most of the district had closed. The mine is estimated to have produced not less than $80,000 in lead and silver. Nearly a third of this is reported to have been produced by lessees who shipped ore from several small pods developed by a

500-foot drift on the 100-foot level. The largest of these oreshoots was 20 by 30 feet at its maximum dimensions and assayed 40 percent lead containing as much as 20 ounces of silver per ton of ore.

The geology is similar to that at the Cumberland, and the ore occurs as small pods and pipes in large parallel jasper replacement leads. One jasper lead has a strike length of more than 300 feet, and at its maximum width exceeds 10 feet. The east wall near the oreshoot south of the main shaft is composed of a dacite porphyry dike, which strikes N. 62° E., and dips slightly to the north.

From dump evidence, all the ore must occur adjacent to these intrusive bodies. The Mission Canyon Formation, in the vicinity of the oreshoots, is brecciated by local flexures in the limestone and by small shear zones, which trend N. 10° W. The limestone in the area strikes N. 14° E., and dips 55° E.

The ore was similar to that of the Cumberland, but the rich shoots decreased rapidly in value with depth. Below the 100-foot level the grade was only 10 to 15 percent lead.

JUDGE (Pb, Ag)

The Judge mine is located near the road to Checkerboard, about a quarter of a mile northeast of the townsite of Blackhawk. The claim, Survey No. 2439A, is owned by J. F. Brophy.

Weed and Pirsson (1896, p. 154) stated that the oreshoot was 20 feet long and ranged from a few inches to 4 feet in width, and at the time of Weed's visit, the mine was shipping ore by team to White Sulphur Springs and then to Helena when all other mines had been forced to close.

The main shaft was sunk in 1891 on the oreshoot. The extent of the workings are unknown but Bryne (1898, p. 18), the inspector of mines for Montana, stated that the main shaft was inclined and 230 feet deep. It is also known that prospect drifts were driven 180 feet northeast and 135 feet southwest along the mineralized contact.

The mine is situated on the west flank of a south-plunging anticline. Ore occurs along the contact of decomposed Jefferson Limestone and a dacite porphyry dike (Fig. 8). Limestone in the vicinity of the shaft trends north and dips 57° west. The strike of the ore at the collar of the shaft is N. 57° E., and the dip is 72° NW. The northeast-trending dikes are not mineralized, but they sufficiently altered and fractured the sedimentary rocks to provide solution channels for the ore-bearing fluids.

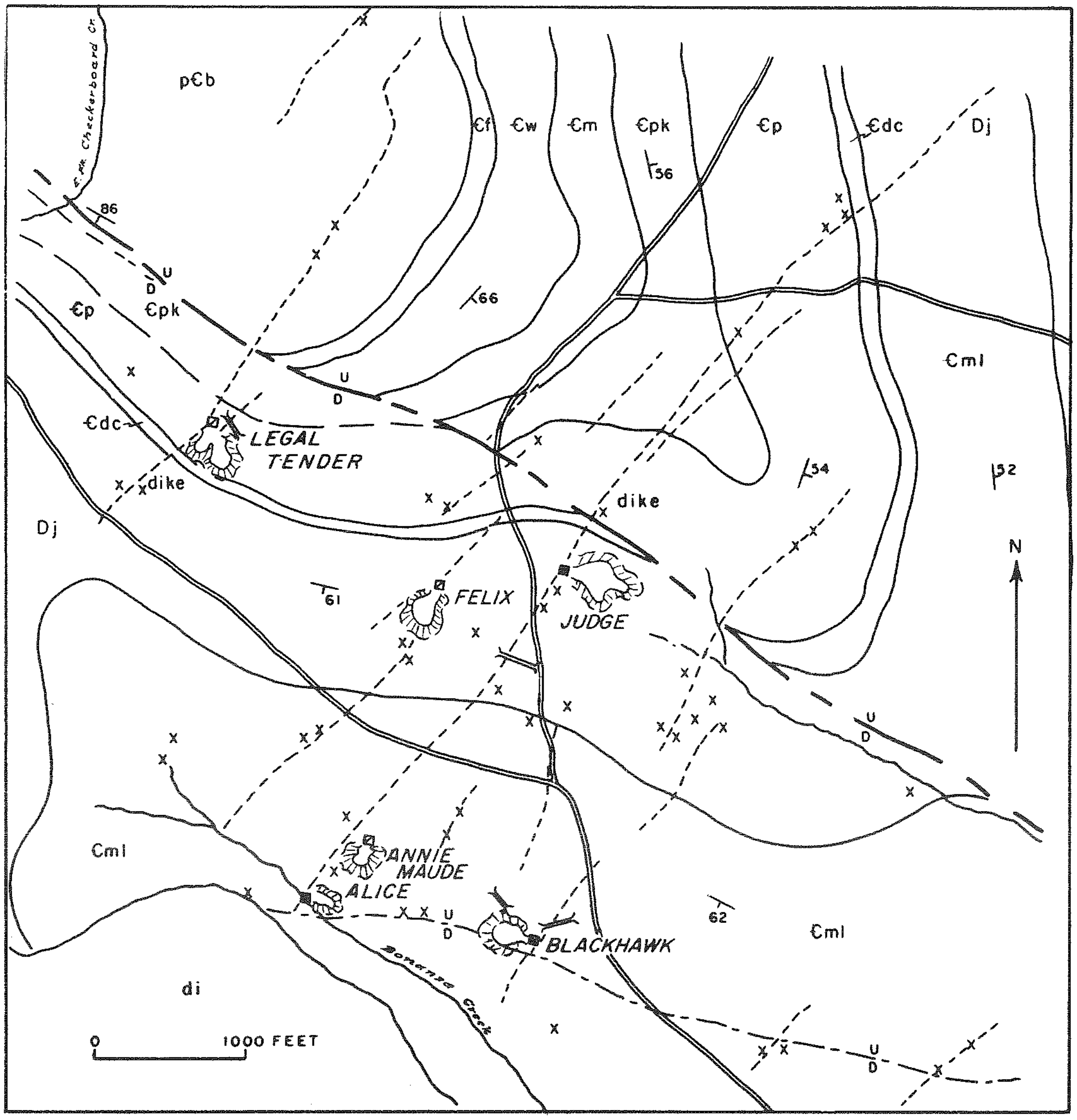

Figure 8.--Surface map of the Blackhawk area, Castle Mountain district, sec. 36, T. 9 N., R. 8 E.

The mineralization is similar to that of the rest of the district; galena and its oxidation products occur in a jasperoid gangue. Lead gradually gives way to manganese along the contact to the west.

BLACKHAWK AND ALICE (Pb, Ag, Mn, Fe)

The Blackhawk-Alice group lies near Bonanza Creek next to the townsite of Blackhawk (Pl. 4). Owned principally by Russell Manger of White Sulphur Springs, the group is composed of the following claims.

Claim	Survey no.
Blackhawk	1932
Bondholder	1930
Alice	2877
Altha	2749
Annie Maude	2424

The Blackhawk mine was developed by a 130-foot shaft and 300 feet of drifts and crosscuts (Roby, 1950, p. 24). On the surface the ore body is more than 30 feet in maximum width. The ore body occurs along a brecciated zone, which has a strike length exceeding 5,000 feet, trends N. 78° W., and has a slight vertical displacement, the western side being downthrown. Associated with the orebody and brecciated zone are northeast-trending dikes, which undoubtedly provided the channels for the mineralizing solutions (Fig. 8).

The ore body is believed to be 100 feet wide on the 100-foot level, and Weed and Pirsson (1896, p. 154) stated that the ore contained 5 to 15 ounces of silver per ton. A 3-foot lead oreshoot occurs on the footwall just north of the caved shaft, and a trench sample cut across the oreshoot assayed 14.1 percent lead, 5.15 percent manganese, 14.15 percent iron, 24 ounces of silver, and 0.02 ounce gold per ton.

One 100-ton sample was shipped to East Helena in recent years and the ore assayed about 5.5 percent lead and about 5.5 ounces of silver per ton. This sample was cut from a channel 25 feet wide for approximately 100 feet along the strike of the replacement vein by C. R. Oliphant.

The ore body is in recrystallized Lodgepole Limestone and is approximately 1,000 feet from the diorite contact. Of all the mines in the district, the Blackhawk ore body seems to be one of the most promising because of its size. The ore would require milling, however, in order to ship a suitable product.

The mineralogy is similar to the rest of the district. Galena and manganese and iron oxides are cemented in brown jasper.

The Alice mine is northwest of the Blackhawk, and ore float can be found along the brecciated zone between the two. The Alice was developed by an 85-foot shaft sunk on a small replacement shoot. This shoot assayed 37 percent iron and 10 percent manganese (Roby, 1950, p. 24). Because of a large inflow of water, however, the oreshoot was never really explored.

The Annie Maude is east of the Alice, and mineralization seems to be continuous between these two mines along a northeast-trending dacite porphyry dike. Iron and manganese oxides are the chief minerals.

LEGAL TENDER (Pb, Ag)

The Legal Tender, Survey No. 2392, is just north of the Alice and is owned by Russell Manger of White Sulphur Springs.

Several shallow shafts have been sunk on the property and have exposed a wide jasperoid replacement zone in Pilgrim Limestone. The main shaft, stated by Weed and Pirsson (1896, p. 154) to have been 75 feet deep, was sunk on a 2- to 3-foot jasper replacement lead, which strikes N. 54° E., and dips 48° E. A crosscut on the bottom level of this shaft was believed to have cut a mineralized zone 19 feet wide. Ore occurs as small pods within this zone and was very rich, according to the Castle newspapers.

Mineralization follows a zone of fractures caused by flexures in the limestone. Dacite porphyry dikes also cut through the limestones in the vicinity of the shaft, and they provided the channels for the mineralizing solutions (Fig. 8). The ore is similar to that in the rest of the district, except that manganese oxides form a major percentage of the mineral content.

IRON CHIEF (Pb, Ag, Fe)

The Iron Chief, Survey No. 3050, is on the slope west of Robinson Creek, about half a mile north of the townsite of Robinson (Pl. 4). The claim is administrated by Nellie Wilson of Roundup, Montana (Roby, 1950, p. 23).

The property was developed by a two-compartment shaft, which was serviced by a 40-horsepower steam engine. Swallow, Trevarthen, and Oliver (1891, p. 42) stated that the shaft was 270 feet deep in 1890 and that there were workings on the 100- and 200-foot levels. Supposedly the prospectors hit a blind shoot of high-grade ore 50 feet below an iron-capped surface.

Weed and Pirsson (1896, p. 154) stated that the mine shipped ore that assayed 50 percent lead and 20 to 30 ounces of silver per ton. Samples from the shaft dump indicate that the sulfides replaced a brecciated zone in the Lodgepole marble, which continues southward into the California claim. Silty members of the Lodgepole Limestone have been metamorphosed and resemble the altered Belt sedimentary rocks. Epidote, diopside, and other metamorphic minerals are common. Dacite porphyry found on the dump indicates that the mineralized zone is adjacent to the intrusive body.

In the vicinity of the mine, the only natural exposure is fine-grained magnetite cemented by jasper. This outcrop trends east and is about 70 feet long, 20 feet wide, and 20 feet high. Other iron-bearing rocks crop out east of this exposure and represent selective replacement near dacite intrusive bodies (Goodspeed, 1945, p. 13).

POWDERLY (SILVER DOLLAR) (Pb, Ag)

The Powderly mine, owned by Kay Burg of Martinsdale, Montana, is about half a mile below the townsite of Robinson. The group consists of several unpatented claims and has been known by several names. The principal vein was discovered about 1887, and the Powderly was the last mine to cease operations after the break in the price of silver.

Two veins occupy fractures which strike N. 55° to 59° W., and dip 77° to 87° SW (Fig. 9). Each is 2 to 3 feet wide and consists chiefly of jasper. A smaller vein is believed to lie between the two larger veins, but no accurate attitude of the structure could be determined.

Only the southernmost vein has been prospected. It was developed by a shaft and by an adit that intersects the vein between the 50- and 60-foot level. Only one stope, just west of the main shaft, was mined from this adit.

In recent years the eastern end of the vein has been stripped, and a 16-ton sample was shipped in 1964. The tenor of the ore was low and showed that some upgrading would be required to produce a suitable product.

The Cleopatra, now known as the Forget-Me-Not claim, is also a member of this group. It is north of the Powderly on the road to Blackhawk. The vein occupies a fracture, which strikes N. 49° W., and dips 84° SW. Mineralization is similar to that in the Powderly. Seemingly an inclined shaft was sunk on an oreshoot that raked to the east. A replacement lead cuts across the vein near the collar of the caved workings. This lead, which strikes N. 42° W., and dips 60° SW, is conformable to the bedding of the Lodgepole.

CALIFORNIA (Pb, Ag, Mn, Fe)

The California mine is just north of the old town of Robinson on the slope west of Robinson Creek (Pl. 4). Consisting of the California, Survey No. 3538, and Hendricks, Survey No. 3539, the California group is owned by J. Oliver of Harlowton, Montana.

A 140-foot shaft was sunk on a lead-manganese ore body at the intersection of a jasper lead and a brecciated zone. The jasper lead is conformable to the bedding of the Lodgepole but ends abruptly against the brecciated zone, which strikes N. 77° W., and dips 80° NE. The mineralization continues northward to the Iron Chief workings and southward into a barren brecciated marble zone, which is explored by several shallow pits. In the vicinity of the shaft the marble strikes N. 29° E., and dips 60° SE.

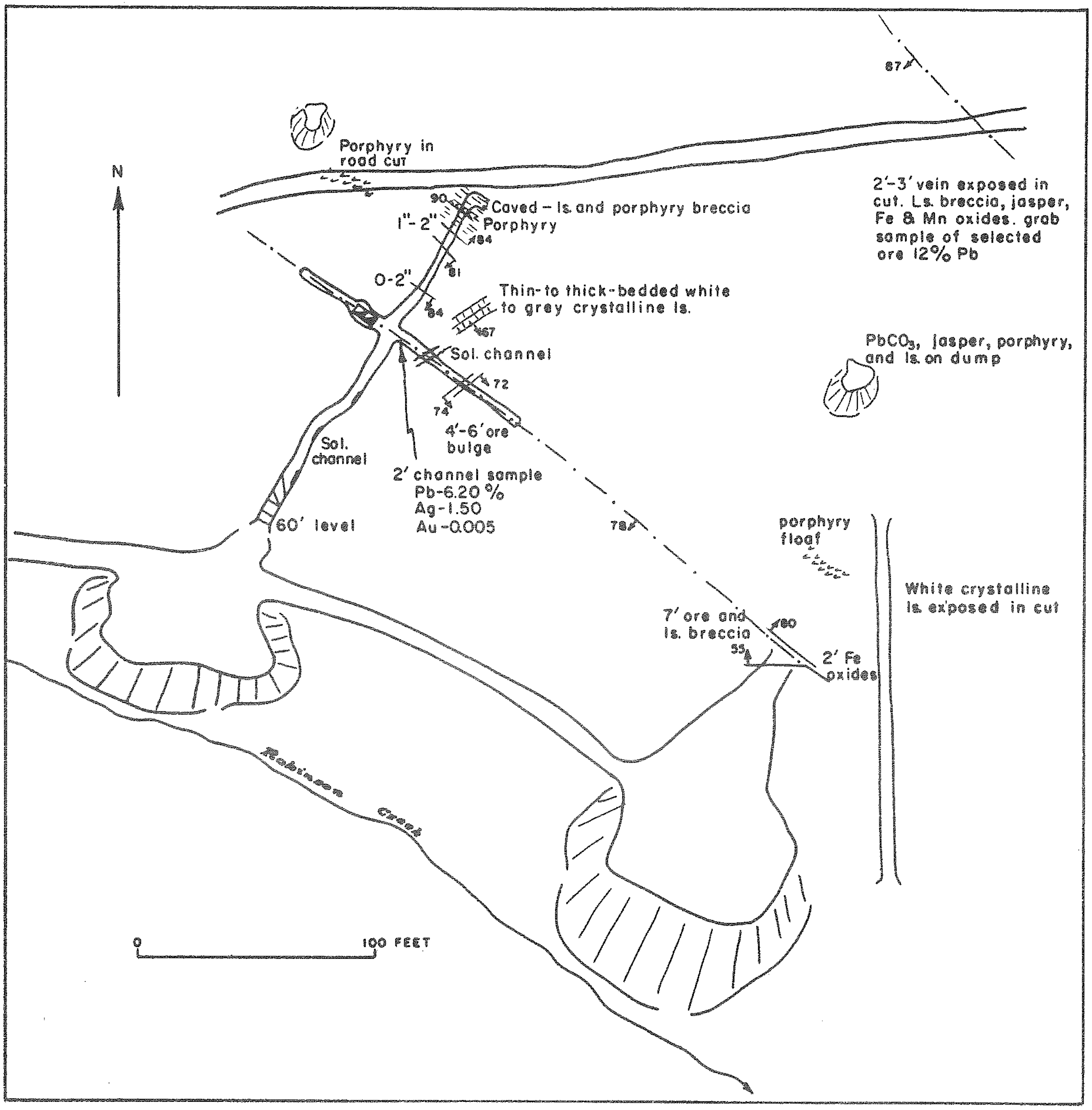

Figure 9.--Map of Powderly adit, Castle Mountain district, sec. 12, T. 8 N., R. 8 E.

The jasper-manganese vein, which contains as much as 20 percent manganese, also contains rich shoots of galena and cerussite. Weed and Pirsson (1896, p. 154) stated that in 1894 the mine was not sufficiently developed to show the extent of the oreshoot, but various sources reported that ore was developed for 70 feet by a drift on the 75-foot level. From surface indications, the ore zone seems to be approximately 9 feet wide and occurs in the Lodgepole.

No production records are available, but from 1889 to 1892 the mine is stated to have produced lead and manganese ore. Lessees were reported to have last operated the mine in 1897 but became discouraged because of the large amount of water that had to be pumped.

HOMESTAKE (Pb, Ag)

The Homestake group is on the ridge between Hensley and Robinson Creeks just southwest of the old townsite of Robinson (Pl. 4). Including the following claims, the group is owned by J. F. Brophy (Roby, 1950, p. 21).

Claim	Survey no.
Homestake	3220
Mary Anderson	3361
Mills Bill	3222
Blue Bird	3215
Hamden	3216
Hamden No. 2	3217
Corliss	3218
Hillside	3221

Workings on this group have prospected several small mineralized zones in the Lodgepole and Mission Canyon Formations. Most of the mineralized zones adjoin dacite porphyry dikes, which generally strike N. 40° to 60° W. Two of the old workings are accessible, the Corliss and Hamden adits.

The Hamden adit (Fig. 10) intersects a barren jasper replacement on approximately the 40-foot level. This replacement body shows the typical irregularity of the district's oreshoots. The shaft was sunk on a 4-foot oreshoot for 30 feet. The ore was stated to have been rich but as depth was attained, the lead pinched out. Two adits were then driven to intersect the jasper replacement shoot on the 40- and 125-foot levels. Both adits, however, broke into barren jasper.

The Corliss adit (Fig. 11) was driven on a vein that strikes N. 69° W. A barren dacite porphyry dike cuts across the vein, and at the intersection the vein is offset approximately 3 feet. The dike contains a few inclusions of marble but no mineralized fragments, indicating that the dike was not the mineralizer, but that mineralizing solutions simply percolated up along the fractures after the intrusion.

The vein is unusual in that the chief mineral is specular hematite. Jasper and manganese oxides are also present, but only in minor amounts. Because the dump is small, it seems probable that most of the hematite was shipped to the local smelters for flux.

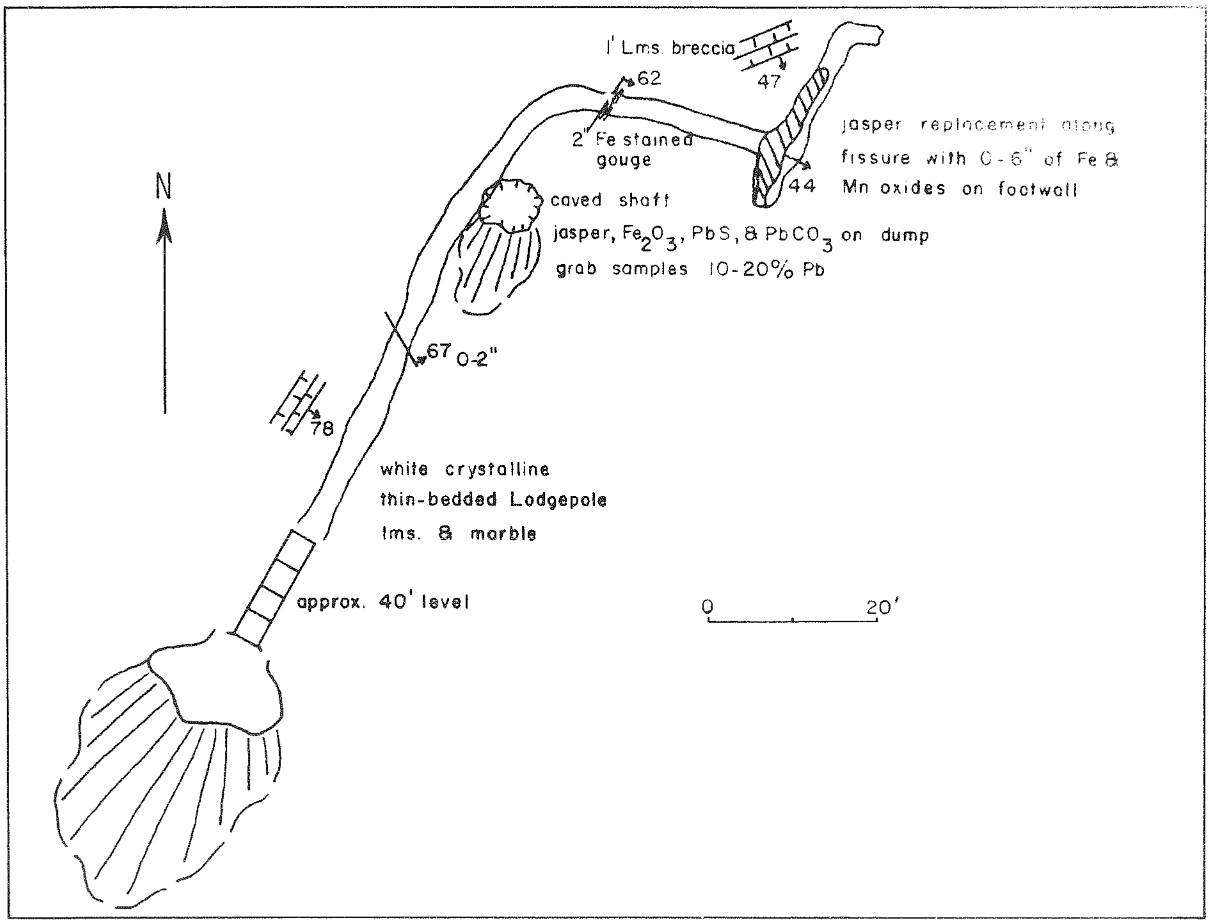

Figure 10.--Workings of Hamden mine, Castle Mountain district, sec. 12, T. 8 N., R. 8 E.

MERRIMAC (Pb, Ag, Fe, Mn)

The Merrimac mine is part of the Cumberland group and lies north of the Broadway claim (Pl. 4). The mine was developed by a 160-foot shaft and had 300 feet of drifts (MacKnight, 1892, p. 101).

The replacement body is in Lodgepole Limestone and has a maximum width of 30 feet. In a gangue of iron oxides and pyrolusite cemented by jasper, workable lead and silver ore is said to have been 3 to 6 feet wide and 20 feet long, and 2,000 tons was shipped to the Cumberland smelter, which paid $4 per ton for the iron, plus payments for the manganese and silver content (MacKnight, 1892, p. 101).

No igneous rock was found on the dump, but a large dacite porphyry dike is exposed 150 feet east of the shaft. Near a parallel jasper-iron structure east of the shaft, the marble strikes N. 16° W., and dips 59° E.

No lead minerals were found on the dumps, but numerous pseudomorphs after pyrite and some specular hematite can be found.

HIDDEN TREASURE (Pb, Ag)

The Hidden Treasure claim, Survey No. 2935, is on the ridge between Hensley and Robinson Creeks (Pl. 4). The claim is owned by Harold Mayn of White Sulphur Springs and is presently being leased by Claude Wessel of Checkerboard, Montana.

The mine began operations in 1888, and a 200-foot shaft and several surface pits developed the property. No production figures are available, but the mine is not believed to have produced any large tonnage, as the original lease was said to have been dropped for lack of ore.

The shaft was sunk just southeast of a jasper replacement lead, which has a strike length of approximately 600 feet. The lead ranges in thickness from a few inches to 6 feet and is conformable with the Lodgepole Limestone, which generally strikes N. 40° E., and dips 46° SE. Limestone adjacent to the shaft strikes N. 63° E., and dips 43° SE.

Specimens found on the dumps contain galena and its oxidation products in a jasper gangue.

SILVER STAR (Pb, Ag)

The Silver Star claim, Survey No. 3131, is owned by Paul Grande of Lennep, Montana. It is located on the ridge west of Robinson Creek, about half a mile below the townsite of Robinson (Pl. 4).

The mine was developed by two shafts, which were sunk along the contact of fractured limestone with a dacite porphyry sill. One shaft has an estimated depth of 75 feet and inclines 46° south. The replacement lead is 2 to 3 feet wide and strikes S. 76° W. On the southern end of the replacement lead is a vein, which strikes N. 49° W., and dips 82° S. Some excellent lead ore in a jasper gangue can be seen on the dump from a small pit on the vein, which is 2 to 3 feet wide.

SOLID SILVER (Pb, Ag)

The Solid Silver claim, Survey No. 3219, is on Hensley Creek and is owned by Russell Manger of White Sulphur Springs, Montana (Pl. 4).

The claim is developed by an adit and two shafts, which prospected small jasper replacement pods in the Jefferson Limestone. Driven west from Hensley Creek, the adit followed the contact between dacite porphyry and limestone. Near the portal the limestone strikes N. 2° E., and

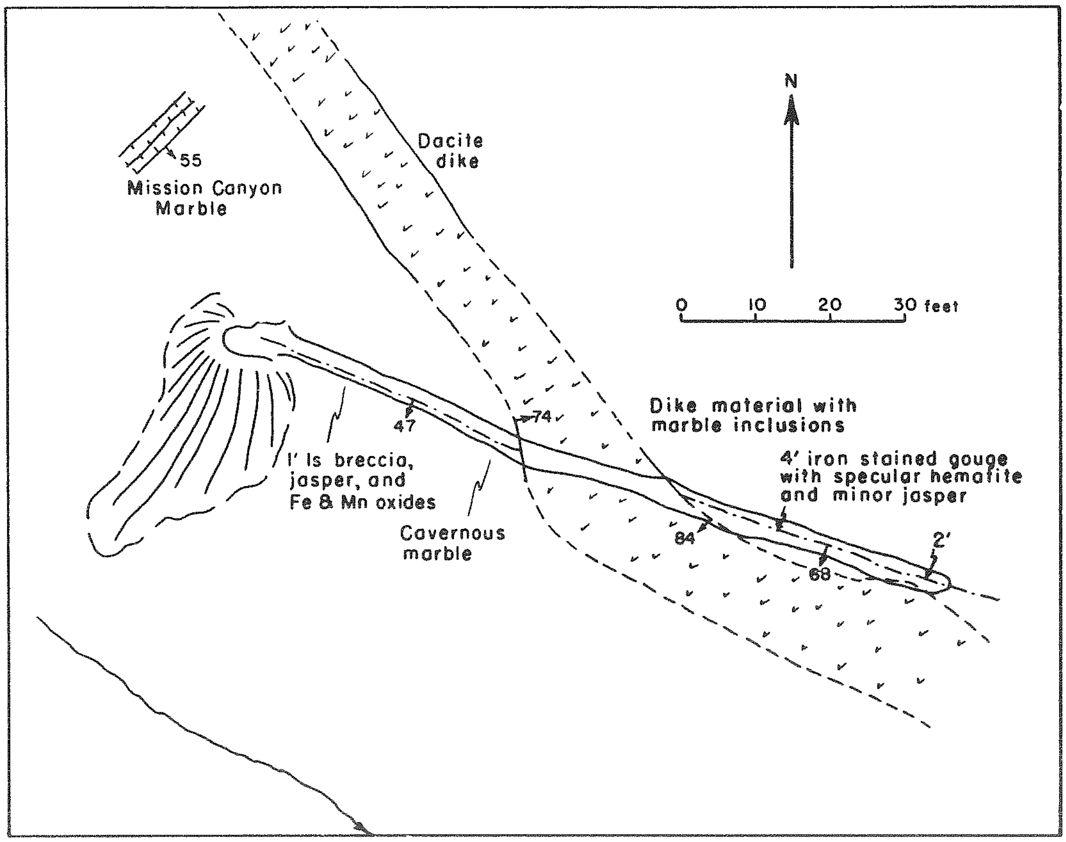

Figure 11.--Map of Corliss adit, Castle Mountain district, sec. 12, T. 8 N., R. 8 W.

dips 64° E. The shafts, on the ridge east of Hensley Creek, were sunk on 2- to 3-foot jasper leads in dolomitic limestone, which strikes N. 56° E., and dips 82° SE.

From dump evidence, the ore is adjacent to dacite porphyry intrusive rock.

BROADWAY (Fe, Mn, Pb, Ag)

The Broadway claim, Survey No. 4699, is just north of the Cumberland (Pl. 4) and is owned by J. F. Brophy of Red Lodge, Montana. Originating near the Cumberland end line, the lead consists mainly of iron and manganese oxides cemented in a jasperoid quartz.

The favorable structure is 80 feet wide, and separate mineralized swells occur in en echelon offsets along a strike length of 300 feet. The main shaft was reported to be 60 feet deep and to have been sunk on a small oreshoot, which pinched out at the bottom of the shaft.

The favorable structure is 50 to 70 feet from the granite contact, and dacite porphyry can be seen on the dumps. Limestone in the vicinity of the shaft strikes N. 16° E., and dips 56° E. The mineralized swells are generally conformable to the Lodgepole Limestone, but the oreshoot is said to have dipped to the west toward the granite contact (personal communication, C. R. Oliphant).

BELLE OF THE CASTLE (Cu, Ag, Fe)

The Belle of the Castle claim is on Hensley Creek in section 2 and is owned by Mrs. T. H. Hurrah of Kellogg, Idaho. The mine was developed by a shaft and two adits.

The shaft was sunk on a 6-foot vertical shear zone, which strikes N. 52° W. According to Jack Oliver, the adit level penetrated a large iron-bearing structure 100 feet from the portal and another magnetite, pyrite, and chalcopyrite ore body 175 feet from the portal. The adit also intersected the shear zone on which the shaft was sunk.

The copper minerals were originally chalcopyrite, chalcocite, and covellite, but are now oxidized to cuprite and tenorite. These oxides occupy small veinlets, mostly less than 2 inches wide, in the shear zone. The shear zone cuts both the Belt argillite beds and a large dacite porphyry sill, but the best ore seems to be in the porphyry.

COPPER BOWL AND COPPER KETTLE (Cu, Fe)

A group consisting of four unpatented claims is held by Carl Voss of Helena, Montana. The group includes the Copper Bowl and Copper Kettle and is about a mile northwest of the townsite of Robinson on Hensley Creek (Pl. 4).

The claims were developed as iron deposits, and 2,000 tons of iron ore was shipped as smelter flux in 1902. The ore assayed 53 to 61 percent iron and as much as 2.3 percent copper.

The claims are developed by two adits and two pits plus several smaller prospects. In recent years most of the work has been centered around the open pit on the Copper Kettle claim (Fig. 12). A 36-ton sample was shipped from this pit to East Helena in 1955 and assayed 2.5 percent copper and 0.5 ounce silver per ton. The ore consisted of copper carbonates and silicates plus iron oxides (personal communication, Carl Voss).

The deposits are in the northern part of a sheeted zone, which extends from Hamilton Creek to Hensley Creek. In the vicinity of the claims the Belt argillite beds, besides being sheeted, are also cut by east-trending dikes, which are directly associated with the mineralized zones (Fig. 12).

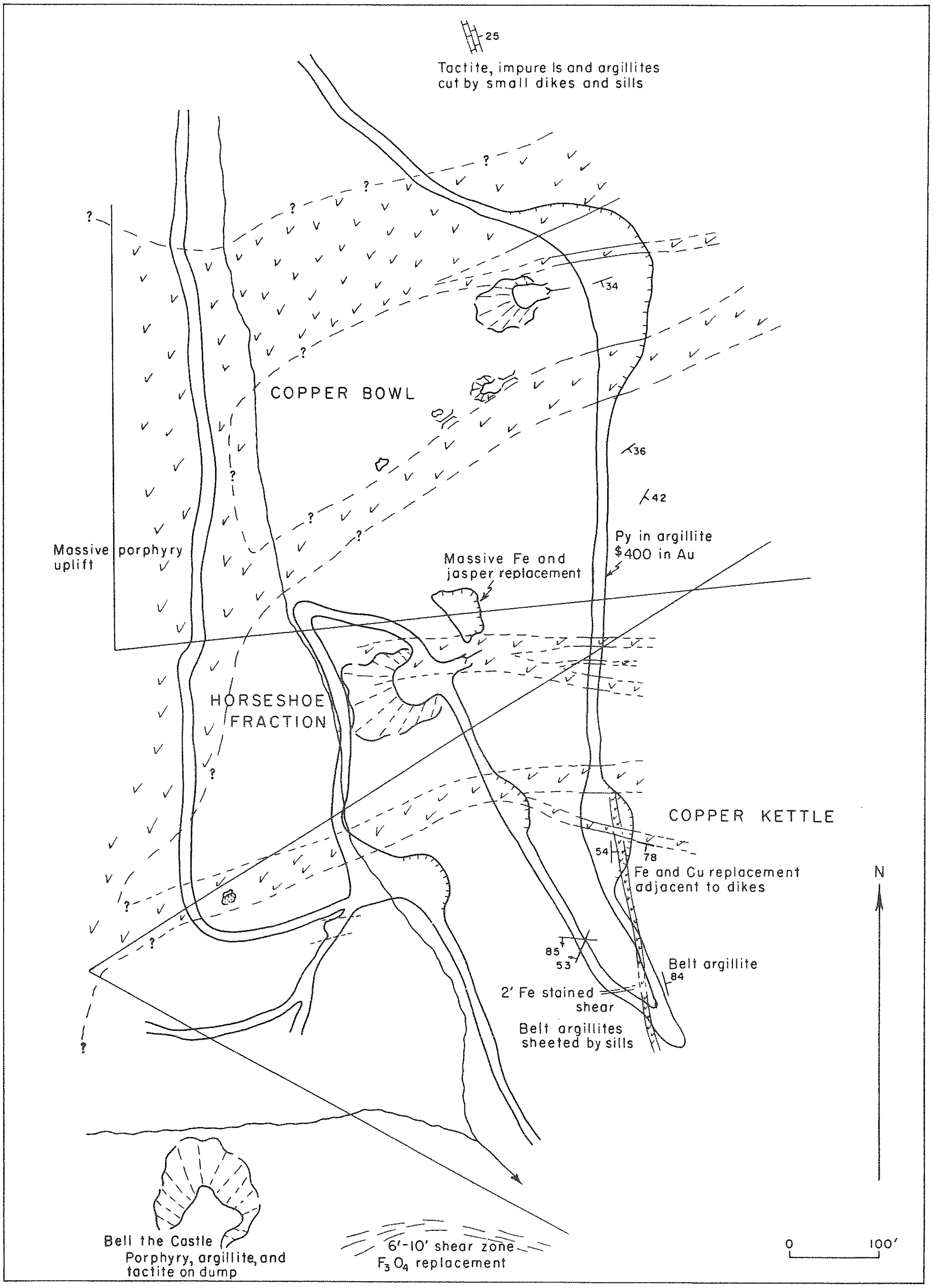

Figure 12.--Surface map of Copper Bowl-Copper Kettle.

The relationships between the mineralized zones and these dikes, which altered the Belt argillite and impure limestone, can be seen in the upper adit (Fig. 13). In this adit, the replaced strata strike N. 72° E., and dip 34° S. Two dikes cut the strata and acted as channelways for the mineralizing solutions.

The primary ore minerals, in many places cemented by jasper, are fine-grained magnetite, pyrite, and minor chalcopyrite. Copper oxides have formed at and near the surface, and a replacement lens of low-grade copper ore has been developed over a width of 80 feet on the Copper Kettle claim. It is also interesting to note that the dacite porphyry on this property contains disseminated sulfides of copper, iron, and zinc.

MILWAUKEE (Cu)

The Milwaukee claim is on the ridge between Hensley and Robinson Creeks about a mile northwest of the old town of Robinson (Pl. 4).

A few small shipments of copper ore were made from the claim, but little information about the mine is available. Development consists of several pits and a 160-foot shaft, which was sunk along the contact of a large dacite porphyry intrusive body with dense, baked Belt sedimentary rock. The sedimentary rocks seem to be a lenticular roof pendant, which trends west and dips south.

Two veins are exposed on the claim. Predominantly composed of copper silicates and carbonates, the vein nearest the shaft is 2 to 4 feet wide, strikes N. 80° W., and dips steeply south. The second vein, near the ridgetop road, strikes N. 80° E. and consists of jasper containing minor copper, lead, and iron. Belt argillite near the shaft is greatly altered, and chlorite is abundant.

RUBY ADIT (Cu)

Formerly known as the Vandor mine, the Ruby adit is just west of the Milwaukee claim and was driven into the same roof pendant.

Considerable copper can be found as replacement lenses and as coatings in the Belt argillite strata, which strike west and dip to the south (Fig. 14). Low-grade ore, which gradually pinches out past the second stope, has been mined from a 1- to 3-foot copper-iron replacement bed.

Two barren igneous intrusive bodies are exposed near the end of the adit. Chloritization and iron replacement affect the sedimentary rocks adjacent to the dacite porphyry sill nearest the portal, now caving at this location. Considerable shearing parallels the intrusive mass.

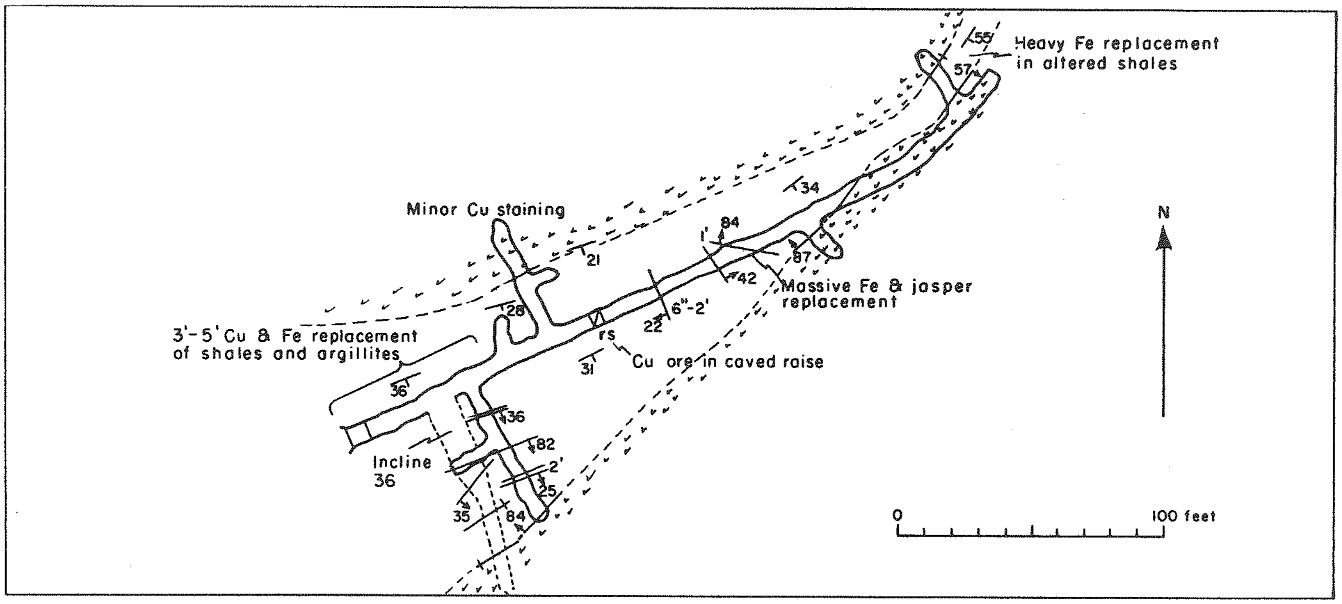

Figure 13.--Map of the Copper Bowl adit, Castle Mountain district, sec. 2, T. 8 N., R. 8 E.

PRINCESS (Pb, Ag)

The Princess claim, Survey No. 3331, is on the ridge between Alabaugh and Warm Springs Creeks approximately a mile southwest of Castle Lake (Pl. 4).

A replacement pod in the Amsden Limestone was developed by a 45-foot shaft and 70 feet of crosscuts (MacKnight, 1892, p. 102). The minerals of the pod consist chiefly of jasper but include some galena, cerussite, and copper oxides.

The limestone in the vicinity of the shaft strikes N. 72° W., and dips 45° NE. No igneous rocks were found near the workings.

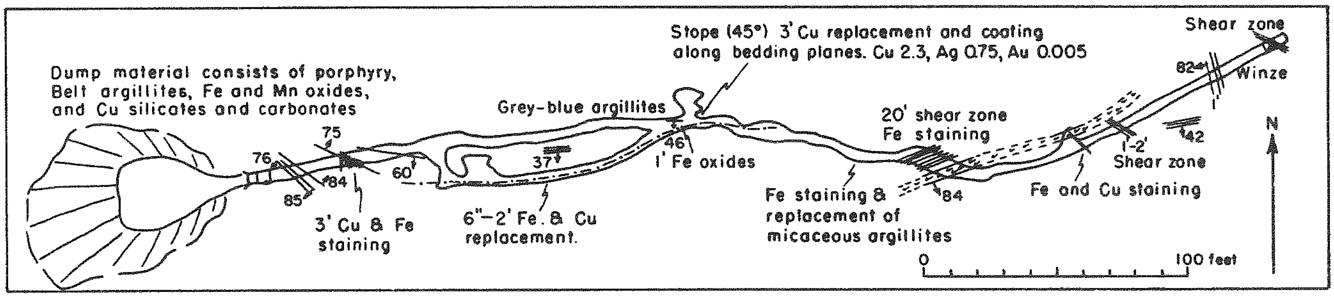

Figure 14.--Map of Ruby adit, Castle Mountain district, sec. 2, T. 8 N., R. 8 E.

GOLDEN EAGLE (Cu, Fe)

Located just to the north of the Milwaukee, the Golden Eagle claim, Survey No. 3492, was developed by a small shaft, which explored a fractured zone in dacite porphyry. Mineralized rock consists of several small iron-stained veinlets, which strike N. 70° W., and dip 78° N.

ANTELOPE (Ag)

The Antelope claim lies just southeast of the Milwaukee (Pl. 4). A series of parallel jasper replacement pods along the contact of dacite porphyry sills with Jefferson(?) Limestone has been developed by shallow pits and shafts.

A 4-foot jasper lead, which strikes N. 24° E. and dips 71° W., is exposed in the main shaft. No ore minerals were observed, but several reports state that small lots of silver ore were produced.

ETTA (Fe, Ag)

Located west of the Cumberland, the Etta claim was developed by a 100-foot shaft and 500 feet of crosscuts (MacKnight, 1892, p. 102). The vein lies wholly within the granite and strikes N. 38° W. No ore minerals, other than iron oxides, were observed on the dump.

FELIX CREXENT (Pb, Ag)

Owned by Russell Manger, the Felix Crexent, Survey No. 3223, lies just north of the Judge mine. The oreshoot lies along the contact of a dacite porphyry dike with Jefferson Limestone (Fig. 8). Ore minerals occur in sugary limestone, and very little jasper can be found on the dump. A sample of this iron-stained sugary limestone was assayed by C. R. Oliphant and found to contain more than 5 percent lead and 5 ounces of silver per ton.

AMERICAN (Ag)

The American claim is on Alabaugh Creek 1 mile west of Castle Town. According to C. R. Oliphant, the Hensley brothers originally located the claim and shipped several lots of high-grade ore in the 1890's. Extracted from three small adits, the ore occurs in a mineralized zone that has a strike length of approximately 200 feet. This zone is conformable with the Amsden Limestone, which strikes N. 36° W., and dips 52° E. No silver minerals were found, but silver chlorides have been reported from a magnetite replacement pod north of the main shaft (personal communication, Carl Voss).

GRASSHOPPER (Pb, Ag)

The Grasshopper mine, owned by Russell Manger, lies west of the map area in the Fourmile district. Weed and Pirsson (1896, p. 155) stated that the mine was developed by a 200-foot shaft, which was sunk on a small ore shoot in the Jefferson Limestone. The granite contact is exposed just south of the mine. Several carloads of high-grade silver ore have been shipped from the mine, but no silver minerals were revealed in a polished section of galena from the mine.

SUGGESTIONS FOR PROSPECTING

Virtually all the ore deposits within the district are associated with jasper and iron oxides. These minerals provide excellent ore guides, can readily be recognized, and can be found by geophysical methods. Silicified beds are generally more resistant than the adjacent limestone and can be traced as small ridges.

Simple exploratory work should be concentrated in the competent or altered limestone near igneous intrusive bodies. Once float ore or gangue is found, the prospector may trench or use geochemical methods to determine the exact position of the metals. When a shoot is found the only safe method of developing the ore is to sink on it. Because many of the shoots do not extend for any greater distances vertically than they do horizontally, crosscutting is inadvisable.

The district does not seem to be favorable for large mining operations, but several small operations could conceivably return a profit if they could efficiently exploit the small oreshoots. A few mines could produce a moderate tonnage of low-grade low-cost ore, but as this ore would require milling, the ore reserves would have to be proved sufficient to warrant the erection of a mill.

SUMMARY AND CONCLUSIONS

The Castle Mountain district contains numerous small but rich ore deposits. Profit gained from the extraction of the ore, however, depends upon the prevailing metal prices and mining efficiency.

The geochemical grid survey of the district can be said to have been successful in that the sample analyses indicated the broad mineralized zones. The procedure failed, however, to detect the Judge, Felix, and Legal Tender ore bodies. This is especially disappointing in that samples were collected adjacent to the mine dumps. Closely spaced traverses seem to be the most promising geochemical method of prospecting in the Castle Mountain district.

The Castle Mountain ore can be readily concentrated by gravity methods. Installation of a simple mill would facilitate mining by making it possible to plan and adhere to a systematic method of extraction. At present the mines must extract only the ore rich enough for direct shipment to East Helena.

The Castle stock is near the intersection of the Crazy Mountain synclinal axis and the Little Belt-Big Snowy arch. This relationship suggests that further exploration is warranted in the Castle Mountains.

APPENDIX - - Geochemical analyses, Yellowstone mine

Sample no.	Lead, ppm	Sample no.	Lead, ppm
A-1	75	G-1	25
A-2	125	G-2	150
A-3	150	G-3	150
A-4	150	G-4	350
A-5	375	G-5	400
B-1	125	H-1	150
B-2	50	H-2	50
B-3	150	H-3	100
B-4	50	H-4	150
B-5	125	H-5	350
C-1	200	I-1	25
C-2	125	I-2	25
C-3	125	I-3	300
C-4	50	I-4	125
C-5	125	I-5	400
D-1	50	J-1	100
D-2	50	J-2	75
D-3	50	J-3	100
D-4	125	J-4	150
D-5	50	J-5	200
		J-6	350
E-1	100	K-1	25
E-2	100	K-2	150
E-3	100	K-3	50
E-4	300	K-4	350
E-5	350	K-5	450
E-6	300		
F-1	125	L-1	100
F-2	175	L-2	225
F-3	375	L-3	150
F-4	400	L-4	175
F-5	400	L-5	350

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