STATE OF MONTANA
BUREAU OF MINES AND GEOLOGY
E. G. Koch, Director

BULLETIN 24

GEOLOGY AND ORE DEPOSITS OF THE SOUTHERN TIDAL WAVE MINING DISTRICT MADISON COUNTY, MONTANA

by

Willis M. Johns

MONTANA SCHOOL OF MINES
BUTTE, MONTANA
November 1961

C O N T E N T S

C O N T E N T S, Cont'd.

I L L U S T R A T I O N S

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ABSTRACT

Sediments of Paleozoic age unconformably overlie the Pony and Cherry Creek Series of Precambrian age in the Tidal Wave district. Paleozoic rocks have been folded by a principal stress from the west and slightly south of west into a broad syncline trending north and smaller anticlines and synclines whose axes trend northwest.

Three fault groups occur in the district. Early northwest-trending faults displace northeast faults. Northeast and east-trending faults appear to be related and may represent complimentary shear planes of a directed compression oriented approximately N. 70° to 80° E. Northwest faulting may be the result of a different stress condition related to Laramide intrusions and rejuvenation of Precambrian faults.

Mineral deposits, containing gold, silver, and lead with minor zinc and copper are fissure, replacement, and contact-metasomatic types. Pyrite and sphalerite with exsolution chalcopyrite are the principal minerals associated with the gold. Production of gold and silver has been essentially from fissure veins in Pony Gneiss. Larger producers in the district have been the Lottie, Carolina, Crystal Lake, High Ridge, and Bryzant properties. The district is largely inactive at the present time.

INTRODUCTION

The Tidal Wave district, essentially a producer of gold, silver, and lead, is fifty miles southeast of Butte, Montana (fig. 1). The district lies on the west flank of the Tobacco Root Mountains. This north-south trending range, approximately forty miles in length, extends north from the vicinity of Virginia City, Montana, to about eight miles south of Whitehall, Montana. The Tobacco Root Mountains are bounded on the east by the Madison River Valley, and on the west by the valley of the Jefferson River.

The Tidal Wave district, one of the larger mining districts in the Tobacco Root Mountains, was described by Winchell (1914, p. 15) as lying between Wet Georgia and South Boulder creeks. However, the area described in this report is more restricted and only includes that area which is bounded on the east by the township line between Rs. 4 and 5 W., on the west by the mountain front, on the north by Bear Gulch, and on the south by Wet Georgia Gulch.

Twin Bridges, Sheridan, and Silver Star are towns located 5½ miles west, 7 miles south, and 15 miles north of the district respectively, and are easily reached from Butte by U. S. Highway 10 and State Highway 41.

Secondary roads lead to various canyons along the range front. Bear Gulch and Wet Georgia Gulch roads are passable for passenger cars, but other canyon roads in the district necessitate the use of small trucks or four-wheel drive equipment. Sections of the old Virginia City stagecoach road are still visible along the bench west of the range front; the road is impassable at the present time.

The Northern Pacific Railroad and the Chicago, Milwaukee, St. Paul, and Pacific Railroad pass through Jefferson Valley connecting the towns of Butte and Whitehall, Montana. A south spur, the Alder Branch of the Northern Pacific Railroad, connects Twin Bridges, Sheridan, and Alder with the main line.

PURPOSE AND SCOPE

The purpose of this study is to present a detailed geologic map of the area and to describe the ore deposits of accessible mines and prospects.

Field work commenced June 24, 1957, and was terminated September 1, 1957. Additional time was spent during the fall of 1957 sampling and collecting pertinent information on mines and prospects. Twelve properties were mapped and sampled. Approximately twenty sections were mapped geologically on aerial photographs obtained from the Commodity Service Corporation, Salt Lake City, Utah. The Deer Lodge National Forest map was used as a base map.

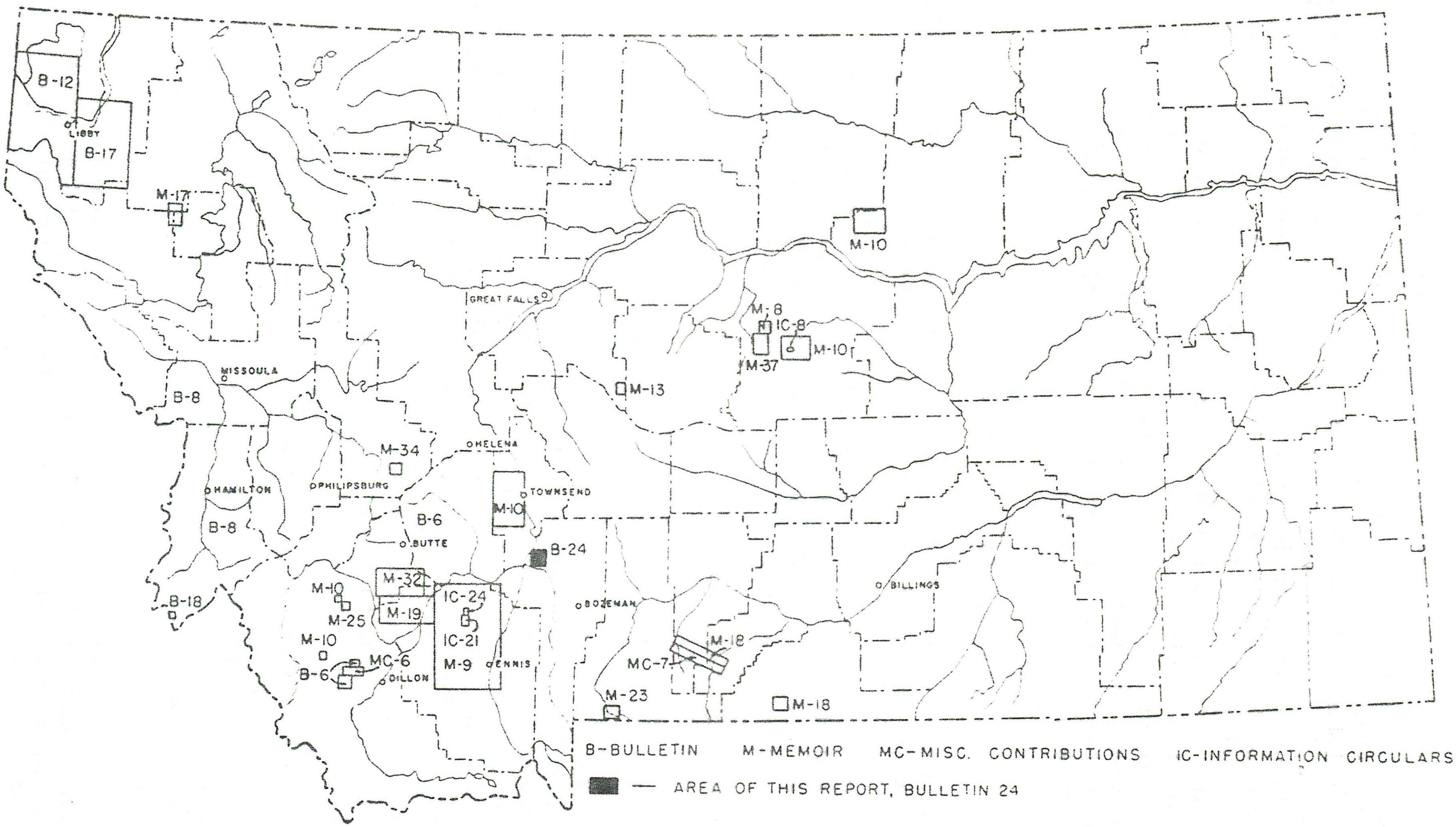

Figure 1—INDEX MAP SHOWING PUBLICATIONS OF THE MONTANA BUREAU OF MINES AND GEOLOGY ON METAL MINING AREAS.

B 6, Bannack and Argenta; B 8, Missoula and Ravalli Counties; B 12, Kootenai-Flathead; B 16, Jefferson County; B 18, Columbian-rare-earth, Ravalli County. M 8, North Moccasin Mountains; M 9, Tobacco Root Mountains; M 10, Gold in Broadwater, Beaverhead, Phillips, and Fergus Counties; M 13, Niehart; M 17, Hog Heaven; M 18, Chromite; M 19, Rochester; M 23, Jardine-Crevasse Mountain; M 25, Hecla; M 32, Highland Mountains; M 34, Zosell (Emery); M 37, South Moccasin Mountains. MC 6, Badger Pass; MC 7, Stillwater. IC 8, Silver Dyke; IC 21, Potosi; IC 24, Strawberry-Keystone.

PREVIOUS WORK

Previous work in the district and adjacent areas are of both a detailed and reconnaissance type. A report by Reid (1957) presents a detailed study of Precambrian metamorphic rocks in the north end of the Tobacco Root Mountains. A report by Reyner (1947) subdivides Paleozoic formations in the Tidal Wave district. During World War II, Darby (1946) prepared a detailed report and geologic map of the Johnston-Moffet property in the Tidal Wave district. The results of a diamond drilling program are included. Tansley, Schafer, and Hart (1933) described the general geology and the mines and prospects of the Tobacco Root Mountains. Winchell (1914) examined mining districts in Silver Bow, Madison, Jefferson, and Beaverhead Counties, Montana. Peale (1896) and Hayden (1872) were among the first to publish results of early geological reconnaissances in southwestern Montana.

HISTORY OF THE AREA

The Tidal Wave district is named after the Tidal Wave mine, which was the first patented ground in the district.

Activity commenced in the early sixties when prospectors found rich float and high-grade ore outcropping at the surface. Rich ore was hand mortared and panned, or hauled to an arrastre for treatment. Some arrastres in the district were in operation as late as 1890. Small-scale placer operations were attempted in Goodrich Gulch and placer tailings can still be observed in the main gulch above the forks of the creek.

Activity in the district declined between the years 1870 and 1880. The construction of the Northern Pacific and the Chicago, Milwaukee, St. Paul and Pacific Railroads in 1896 and the extension of the Alder Branch of the Northern Pacific Railroad in 1869 stimulated renewed mining throughout the district. New milling methods for the extraction of gold and silver, and cheaper transportation made mining ventures again profitable. Several properties subsequently produced considerable gold and lead-silver ore.

During 1880, William Owsley acquired and operated several lead prosepcts at the junction of Little Bear and Bear Gulches. A small lead furnace was erected for the recovery of lead and gold. The Tobacco Root Mining, Milling, and Smelting Company acquired property near Smelter Mountain in Bear Gulch. The Bielenberg and Higgins property, located at the head of Bear Gulch, became a substantial producer of both high and low-grade ore. At different periods in the history of the operation, arrastres, stamp mills, and a cyanide plant were used to treat ores from the Bielenberg and Higgins property.

The Moffet-Johnston mine was being actively developed during the latter part of the nineteenth century, and Winchell (1914) stated that the first orebody had been intercepted in the Moffet tunnel prior to his visit in 1904.

Between 1900 and 1920, the Krueger property in Dry Gulch, the Richmond Group, the Crystal Lake and Schmidt properties, and the Carolina mine in Goodrich Gulch were operated either by the owners or by lessees. A cyanide plant was erected at the mouth of Little Bear Gulch to treat gold ores from Bear Gulch properties and a mill was constructed on the south fork of Goodrich Gulch to treat ore from the Crystal Lake property.

Active properties in Dry Georgia Gulch during this period were the High Ridge, Sunflower, and Corncracker; and in Wet Georgia Gulch area they were the Ella, Dullea, Lone Star, and Argenta properties.

In 1933 an increase in the price of gold again stimulated mining activity throughout the district. Leasing was particularly active and the High Ridge, Bryzant, Richmond Group, Carolina, and Crystal Lake properties became the essential producers in the district. Since the close of World War II, only sporadic activity has taken place in the area.

ACKNOWLEDGMENTS

W. S. March, Jr., Associate Director, and U. M. Sahinen, Chief, Geological Division of the Montana Bureau of Mines and Geology suggested the area for study. Dr. B. W. Brown and Dr. F. N. Earll gave valuable suggestions and critically read the manuscript. Don Schweitzer and Don Lawson assisted in the field. C. J. Bartzen, Analyst, Montana Bureau of Mines, assayed all samples and T. J. Cash drafted the underground maps and surface assay plan.

G E O G R A P H Y

TOPOGRAPHY

Elevation of the district varies from 5,000 feet along the front of the range to about 9,500 feet atop peaks and higher ridges. The topography is moderately subdued along the range front and toward the southern part of the district. The ridges and peaks within the eastern half of the district are steep and rugged. The mountain front ends abruptly against a broad alluvium-covered "bench" which decreases in slope as it approaches the Jefferson and Ruby Rivers. Spurs between canyons are sharply truncated along the range attesting to fairly recent movement along the fault which borders the range on the west.

The elevation of the region is the result of block faulting in which the downthrown block forms the broad intermontane Jefferson valley while the upthrown block forms the Tobacco Root Mountains.

CLIMATE AND VEGETATION

The climate is semi-arid, with an annual rainfall of about 10 inches per year. The Civil Aeronautics Authority at the Butte Airport reports an annual average precipitation of 8.97 inches from 1955 to 1957 at Twin Bridges, and average maximum and minimum temperatures of -32° F. to 93° F. Considerable snow is found on high peaks and ridges in the district as late as July, and permanent snow fields are found in the Tobacco Root Mountains. Snow does not affect field operations until late November.

The larger part of the Tidal Wave district lies within the Deer Lodge National Forest where spruce, fir, cedar, and pine cover most of the slopes and ridges. The lower slopes of Dry Georgia and Wet Georgia Gulches are sparsely covered with bunch grass.

G E O M O R P H O L O G Y

The Tidal Wave district is composed of metamorphic, sedimentary, and igneous rocks. Following deposition of Paleozoic sediments on a folded and metamorphosed Precambrian basement complex, the region underwent folding and faulting. Igneous intrusion followed and the surface was subsequently modified by forces of erosion and deposition to its present state.

DRAINAGE

Drainage within the district is dendritic and most streams are intermittent. Stream gradients are as much as 600 to 700 feet per mile. Drainage is to the east. The Ruby and Jefferson Rivers form the headwaters of the Missouri River-Mississippi River system which ultimately drains into the Gulf of Mexico.

ALPINE GLACIATION

Pleistocene alpine glaciation, in the Tobacco Root Mountains, is confined to the higher peaks and valleys. It is best developed at the head of Bear Gulch where a precipitous cirque occurs. The valley is U-shaped from the cirque to Bear Lake, which is about a mile above the mouth of the canyon. Below the lake, the valley is V-shaped indicating the glacier did not extend to the mouth of the gulch.

The material impounding Bear Lake has been described by Winchell (1914, p. 151) as glacial moraine, and by Tansley and Schafer (1933, p. 6) as landslide debris. Surface material consists of coarse, angular, and sub-rounded limestone and quartz monzonite boulders and cobbles without the inter-mixture of sand and pebbles one would expect to find in a terminal moraine.

Apparently the surface material was derived from the slopes opposite the lake, perhaps as superficial landslides which covered the underlying glacial moraine. A landslide showing evidence of recent movement is located on the south side of Bear Gulch about one-half mile above the lake.

Frequent snowslides occur at the head of Bear Gulch during the winter months, as in the winter of 1957 a snowslide covered the portal and dump of the Bielenberg and Higgins adit. In previous years, snowsildes have caused suspension of operations at the property for short periods of time.

ALLUVIAL FANS AND PEDIMENTS

A "bench," described by Tansley and Schafer (1933, p. 4) and by Reyner (1947, p. 4) as an alluvial fan, extends from the front of the range into the Jefferson Valley. It is best developed between Wet Georgia and Dry Boulder Gulches where it ranges in width from three to five miles. Reid believes that at least part of the bench is a pediment, with alluvial fans of glacial outwash present as a thin cover on the pedimented surface.

Interbedded sands and gravels, exposed in a borrow pit one-half mile east of Twin Bridges, indicate the valley was filled with sediments deposited by a river meandering across a relatively mature valley. Recent uplift could have increased the stream gradient and enabled the river to cut through previously deposited alluvium to form the present Jefferson and Ruby valleys, while the higher non-dissected gravels remained.

The near-proximity of bedrock is suggested by the presence of boulders and cobbles on the surface one-half mile from the front of the range north of Bear Gulch. The boulders do not originate from the adjacent slopes, but rather from the erosion of a thin veneer of alluvium overlying bedrock. If this inference is correct, at least that part of the bench bordering the range front may be a pediment representing the downthrown block of the Tobacco Root fault. The central portion of the bench and valley may be filled with Tertiary gravels and Bozeman lake beds. The surface of the bench is covered by gravels derived from glacial outwash and alluvium from the bordering range, deposited as alluvial fans at and along the mouths of gulches. Quaternary alluvium fills the stream channels traversing the bench.

GENERAL GEOLOGY

METAMORPHIC ROCKS

The oldest rocks in the area, pre-Beltian in age, are metamorphosed gneisses and schists (fig. 2). Tansley and Schafer (1933, p. 8) gave the name Pony Series to the older series exposed

AGE	FORMATION		APPROX. THICKNESS	GENERALIZED LITHOLOGY
MISSISSIPPIAN	MADISON	MISSION CANYON	1200'	Massive cliff-forming gray fossiliferous limestone.
		LODGEPOLE	1000'	Thin-bedded gray and black fossiliferous limestone containing shale layers.
DEVONIAN	THREE FORKS		250'	Black and green shales, locally metamorphosed.
	JEFFERSON		1000'	Black and white-colored dolomite which has fetid odor when broken.
	MAYWOOD-RED LION		120'	Gray-to-red-to-yellowish sandy dolomite with a 10-ft. bed of green shale at base.
MIDDLE AND UPPER CAMBRIAN	PILGRIM		360'	Blocky gray mottled dolomitic limestone generally forming cliffs and ridges.
	PARK		150'	Black and green shales generally forming depressions and valleys.
	MEAGHER		480'	Black and gold mottled dolomitic limestone generally forming cliffs and ridges.
	WOLSEY		240'	Gray and green shales generally forming depressions and valleys.
	FLATHEAD		150'	Pink cross-bedded quartzite.
PRECAMBRIAN	PONY SERIES		+5000'	Dark-gray hornblende, biotite, and white quartz-feldspar gneiss. Locally, subordinate layers of amphibolite, quartzite, and hornblendite, subordinate mica and magnetite schist. The metamorphics contain metabasalt sill and dikes near the base.
	CHERRY CREEK SERIES			Dark gray hornblendite, biotite, and quartz-feldspar gneiss. Subordinate layers of amphibolite and hornblende. Some magnetite schist, sillimanite and garnet schist. Relatively abundant layers of marble and quartzite. Randomly scattered metabasalt sills and dikes throughout.

Figure 2.--Stratigraphic column of the Tidal Wave District.

at Pony, Montana, and Cherry Creek Series to the younger series of gneisses, schists, quartzites, and crystalline limestones exposed at Cherry Creek southeast of Virginia City, Montana. In the Tidal Wave district, Pony Gneiss underlies the greater part of the area drained by Wet Georgia and Dry Georgia Creeks (pl. 1, in pocket). Cherry Creek rocks are exposed east of Nugget Gulch. Belt arkoses and conglomerates are missing throughout the district.

Cherry Creek Series

The Cherry Creek Series, as described by Reid (1957, p. 5), has alternate bands of hornblende, biotite, and quartz-feldspar gneiss (leptite) with subordinate beds of amphibolite, quartzite, crystallized limestone, sillimanite, and anthophyllite schist, and garnet amphibolite. Metabasalt dikes and sills are randomly scattered throughout the series. Reid (1957, p. 21) believes the Cherry Creek metamorphic rocks are older than the Pony Series.

The age relationship of the Pony and Cherry Creek Series is debatable. Reid based his conclusion of age relations on stratigraphic evidence; the Pony Series appears to overlie Cherry Creek rocks in the north end of the Tobacco Root Mountains. Tansley and Schafer (1933, p. 9) state that the Pony Series has features common to both sedimentary and igneous rocks while the sedimentary origin of the Cherry Creek metamorphic rocks is unquestionable. The structure and mineral composition of Pony rocks is much more complex than that of the Cherry Creek which might indicate an earlier origin.

Fritzche (1933, p. 20) believes the gneisses and schists of the Silver Star district, located about fifteen miles north of Twin Bridges, are Pony Series metamorphics because of the similarity in composition to known Pony rocks. The absence of the Cherry Creek would have to be explained by erosion, faulting, or nondeposition if they are younger than the Pony, but if they are older they would underlie the Pony. Age determinations of diagnostic minerals of the two series, and age determinations of pegmatites may shed some light on the problem.

Pony Series

Reid (1957, p. 3) describes the Pony Series as alternately banded hornblende, biotite and quartz-feldspar layers with subordinate layers of amphibolite, quartzite, and hornblendite. Some mica schist, magnetite schist, and serpentine does occur. Metabasalt dikes and sills are found throughout both series; however, the dikes and sills are particularly abundant near the Pony-Cherry contact. Pegmatite dikes, cutting the foliation of the Pony Gneiss, are found in Wet Georgia Gulch. Accessory minerals in Pony rocks include magnetite, zircon, and apatite.

SEDIMENTARY ROCKS

Mostly sediments of Paleozoic age cover the Southern Tidal Wave district; however, in the eastern and southern portions

Pony and Cherry Creek rocks of Precambrian age are also exposed. Paleozoic sediments may have extended over the central portion of the Tobacco Root Mountains as broad folds that were subsequently eroded, exposing the Pony and Cherry Creek rocks.

Sediments, exposed in the Tidal Wave district, include quartzites, shales and dolomitic limestones of Middle Cambrian age, dolomites and shales of Devonian age, and limestones of Mississippian age as described by Berry (1943, p. 10-18), Hanson (1952, p. 12-18), and Reyner (1947, p. 6-9) at Three Forks, Montana; South Boulder Creek, Madison County, Montana; and in the Tidal Wave district, Madison County, Montana.

The author mapped the Upper Cambrian Red Lion and Lower Devonian Maywood rocks as one unit since poor exposures of the contact between the two formations made them difficult to separate. Sappington sandstone is described by Berry (1943, p. 16) as Lower Mississippian in age. No exposures of this formation were observed in the field.

A profound erosional or nondepositional unconformity exists between Cambrian and Devonian time as Ordovician and Silurian sediments are missing throughout most of southwestern Montana.

Cambrian Formations

Flathead Quartzite.--The Flathead Quartzite of Middle Cambrian age unconformably overlies the Pony Series in the Tidal Wave district. The formation is 150 feet thick, consisting of cross-bedded fine-to-medium-grained, pink-to-tan-colored quartz grains cemented with silica. A six inch conglomerate bed at the base forms a distinctive marker bed. Interbedded quartzite and shale beds are present toward the top of the formation. The quartzite is resistant to weathering and generally forms distinctive outcrops.

Wolsey Formation.--The Wolsey Formation of Middle Cambrian age is about 240 feet thick and conformably overlies the Flathead Quartzite. Thin-bedded tan-to-olive-colored shales predominate at the base and center. Toward the top of the formation interbedded tan-to-brown limy sandstone layers and light gray micaceous shale beds are present. The shale forms distinctive topographic depressions. Small irregularly-shaped depressions in the shale are believed to be worm tracks.

At the High Ridge and Ella mines the normal lithology of the Wolsey Formation is replaced by a series of medium-to-thick bedded, red-to-maroon colored sandstones and siltstones interbedded with more finely laminated gray-green shales. This lithology attains a thickness of approximately 50 feet at the High Ridge mine, and is, in part, overlain and underlain by normal Wolsey beds. Directly behind the house at the High Ridge mine the underlying Flathead Quartzite beds have been removed through movement along a bedding fault so that the Wolsey lies directly on top of Precambrian Pony Gneiss. This fact, plus the similarity in appearance of these Wolsey beds to Beltian metasediments, has lead to persistent rumors that Missoula Group (Beltian) rocks are exposed in the Tidal Wave district. The error of this belief is clearly shown just to the east of the High Ridge fault, and at the Ella mine where the normal stratigraphic sequence is preserved, and at the Bullidick and Carolina mines where the red-maroon sequence in the Wolsey Formation narrows to but 2 or 3 feet in thickness.

Meagher Formation.--The Meagher Formation, conformably lying between two shale members, is a massive medium-to-dark-gray mottled dolomitic limestone. The black and gold mottling is a distinctive feature contrasting black cryptocrystalline material with tan-to-rust-colored spots in a medium-to-dark-gray matrix. The Meagher unit forms rugged cliffs and is silicified north of the Bullidick and Main Street prospects.

Park Formation.--The Park Shale, assigned by Hanson (1952, p. 16) to Middle Cambrian time, is 150 feet thick and lies conformably between the Pilgrim and Meagher formations. The shale varies from green to tan in color, and where altered to hornfels in the vicinity of the Bear Gulch stock, the shale is black, siliceous and pyritized.

Pilgrim Formation.--Pilgrim dolomitic limestone of Upper Cambrian age overlies the Park Shale conformably and consists of about 360 feet of blocky, massive, medium-to-light-gray mottled material forming cliffs and ridges. Mottling in the Pilgrim Formation is that of two contrasting shades of gray. Pilgrim mottling is not as conspicious as mottling in the Meagher Formation and the texture is fine-grained to cryptocrystalline.

Red Lion and Maywood Formations.--The Red Lion and Maywood Formations, described by Hanson (1952, p. 17) as Upper Cambrian and Lower Devonian, have a combined thickness of 120 feet. The base of the Red Lion Formation consists of 10 feet of tan-to-olive-green shale beds overlain by interbedded gray-to-tan-colored purplish dolomite, brown siltstone, and sandstone. One excellent exposure of the two formations occurs along the face of a cliff at the forks of Goodrich Gulch northwest of the Bismuth prospect.

Devonian Formations

Devonian Formations are represented by the Maywood dolomite, sandstone and siltstone (Lower Devonian), the Jefferson dolomite (Middle and Upper Devonian), and the Three Forks Shale (Upper Devonian). Berry (1943, p. 14) assigned the Jefferson Dolomite to Middle and Upper Devonian age based on the presence of fossils found in the formation near Logan, Montana. Devonian members overlie each other without angular unconformity; however, a distinctive stratigraphic break occurs between Cambrian and Devonian time.

Jefferson Formation.--The Jefferson dolomite is distinctive because of its stratigraphic position and diagnositc fetid odor when broken. The formation varies from a black fine-grained dolomite to a light-to-dark-gray dolomite. The formation is cliff-forming and approximately 1,000 feet thick.

Three Forks Formation.--The Three Forks Shale consists of 200 feet of black, green, and gray shales conformably overlying Jefferson Dolomite. Reyner (1947, p. 8) identified crinoid stems, brachiopods, and bryozoa in the formation. The soft thin-bedded shale erodes to form saddles and valleys.

Mississippian Formations

Madison Group.--The Madison group, consisting of the Lower Lodgepole Formation and the Upper Mission Canyon Formation, contains about 2,200 feet of light-gray and dark fine-grained calcareous beds.

The Lodgepole Formation includes approximately 1,000 feet of fine-grained, dense, thin-bedded, black cliff-forming limestone. Reyner (1947, p. 9) identified brachiopods, horn corals, crinoid stems and bryozoa throughout the formation.

The Mission Canyon Formation includes about 1,200 feet of massive gray cliff-forming limestone, the texture of which is gradational from fine-to-coarse-grained material from base to top. Chert horizons are present. Reyner (1947, p. 9) identifies brachiopod shells and horn corals, which are abundant, near the top of the formation. In Goodrich Gulch there are small calcite veinlets traversing bedding planes and filling cavities with calcite crystals.

Cenozoic Deposits

The broad intermontane valleys contain Tertiary sands, gravels, conglomerates, and Bozeman lake beds. Alluvial fans bordering the mountain ranges consist of unsorted material derived from stream erosion and glacial outwash deposited during late Tertiary time.

River and stream channels are filled with Quaternary alluvial deposits of unconsolidated sands and gravels.

IGNEOUS ROCKS

The earliest igneous activity occurred prior to Beltian time and consisted of the intrusion of basalt dikes and sills, and pegmatite dikes into the Pony and Cherry Creek rocks.

During late Paleozoic time mountain-building followed by igneous activity resulted in the formation of the Tobacco Root batholith which is exposed about eight miles east of the Tidal Wave district. According to Reid (1957, p. 11) a lead-alpha age determination on zircon from the batholith indicates that it is 66 million years old. This would date the intrusion as being Late Cretaceous or early Tertiary.

The stock and sills in Bear Gulch may be related to the batholith in age, although the only definite statement regarding age of these intrusives that can be made is that the stock is post-Madison and the sills intrude Jefferson Dolomite of Middle Devonian age. Reid believes that sills and dikes in Paleozoic rocks are related to the Laramide Orogeny although there is no definite evidence to prove this statement.

Quartz Monzonite and Monzonite

In lower Bear Gulch a small stock intrudes Madison Limestone, Jefferson Dolomite and Three Forks Shale. Specimens from the Johnston-Moffet property, from the west contact of the quartz monzonite and limestone in Bear Gulch, from the south end of the stock, and from its eastern contact, were obtained for megascopic descriptions. The specimens are light-gray medium-to-coarse-grained rocks, containing sodic plagioclase, orthoclase, quartz, biotite, hornblende, and augite. Some specimens are porphyritic; phenocrysts of sodic plagioclase are up to one-quarter inch in length. Accessory minerals are apatite and magnetite. The stock is classified as quartz manzonite.

Xenoliths are found along the margins of the stock. They are rounded to subangular and contain phenocrysts of plagioclase and hornblende in a dark groundmass of plagioclase, hornblende, biotite and augite. (See fig. 3.) In some fragments the mafic minerals make up a large percentage of the rock's components which approach diabase in composition. The majority of fragments are classified as diorite. Tansley and Shafer (1933, p. 15) believe these inclusions to be cognate xenoliths representing an earlier-formed dioritic phase which was broken after solidification, the fragments becoming incorporated as inclusions in the parent magma from which it originated. Winchell (1914, p. 150) believes them to be fragments of foreign rocks which were absorbed or partially absorbed by the magma during intrusion of limestone, shale and dolomite. He describes fragments containing hornblende and plagioclase with subordinate titanite, apatite, and calcite, or with borders of epidote and zoisite. Others described are composed of quartz and feldspar while those near gneiss-quartz monzonite contacts have gneissic banding. Fragments containing abundant calcareous minerals may originate from limestone; others exhibiting banding may originate from gneiss. Evidence of texture, mineralogy and occurrence near contact zones indicate that these xenoliths may be incompletely absorbed fragments of country rock.

Another intrusive, exposed one-half mile east of the Bear Gulch stock, is described by Reyner (1947, p. 14) as a monzonite sill composed of gray medium-grained rock containing orthoclase, plagioclase, hornblende, and biotite with accessory apatite and

and magnetite. This body intrudes Jefferson Dolomite and may be an outlier of the Bear Gulch stock since the rock type is similar except that it lacks quartz. The attitude of the contact between monzonite and dolomite is difficult to determine because of poor exposures.

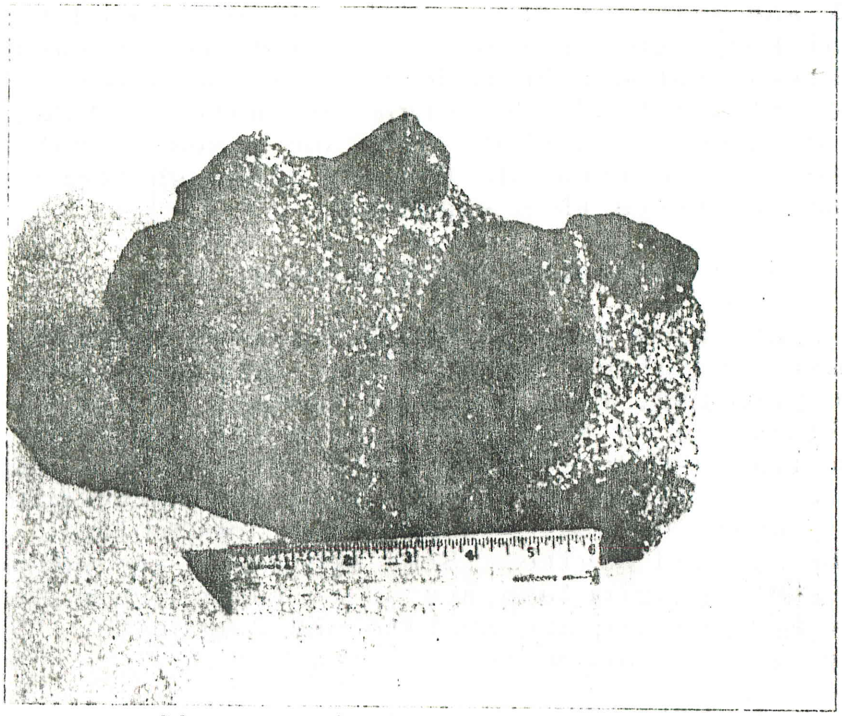

Figure 3.--Photograph showing xenoliths from contact zone of Bear Gulch stock.

Porphyritic Granite and Syenite

A sill exposed along the eastern part of the mapped area extends from Smelter Mountain south to Mt. Baldy. Specimens were taken at the head of Little Bear Gulch, north of Smelter Mountain and on the south slope of Smelter Mountain.

Megascopically, the specimens north of Mt. Baldy have white orthoclase phenocrysts in a fine-grained red-brown groundmass of orthoclase and quartz. Accessory minerals are hematite, pyrite, apatite, and magnetite. Reyner (1947, p. 14), and Tansley and Schafer (1933, p. 16) classify the sill as porphyritic granite. Specimens from the sill taken in the vicinity of Smelter Mountain have light-colored phenocrysts of orthoclase in a medium-grained groundmass of orthoclase, plagioclase, hornblende, and biotite. Reyner classified the sill as porphyritic syenite.

Andesite

A sill in Cambrian Wolsey Shale is exposed about a quarter of a mile southwest of the Argenta mine near the center of sec. 26, T. 3 S., R. 5 W. Unaltered specimens are dark gray with small white phenocrysts of plagioclase in a dark-gray fine-grained groundmass containing plagioclase, biotite, and hornblende. Pyrite is an accessory mineral. Some specimens are stained with manganese dendrites and iron oxides. Others have been strongly altered to sericite and kaolin.

G E O L O G I C   H I S T O R Y

The earliest record of sedimentation and igneous activity in southwestern Montana is found in the pre-Beltian Pony and Cherry Creek rocks. These metamorphic rocks were folded, faulted, and metamorphosed during Precambrian time and to a minor extent during the Laramide Orogeny in Cretaceous-Tertiary time.

During Beltian time the Belt geosyncline, receiving sediments from an eastern landmass, was gradually depressed. Several thousand feet of arkose, shale, and conglomerate were deposited in the basin. The Tobacco Root area may have been relatively high during Beltian time since Belt rocks are not found in the area; the nearest outcrops of Belt rocks are found about six miles north of the Tidal Wave district in the Renova Hot Springs area. Deiss (1935, p. 111) believed that the shoreline extended much farther south than the present outcrops indicate during the deposition of Belt sediments. If this interpretation is valid, Belt rocks deposited in the area have been removed by erosion.

The Beltian surface was reduced to a near-level peneplain before seas encroaching from the northwest and southwest deposited the Middle Cambrian Flathead Quartzite with remarkable continuity and uniform thickness over southwestern Montana. Interbedded sandstone and shale layers near the Flathead-Wolsey contact in the Tidal Wave district indicate a fluctuating shoreline. As the sea advanced eastward the muds and sands of the Wolsey Formation were deposited in deeper water.

Meagher Limestone was deposited in deep water as the shoreline advanced eastward. Hanson (1952, p. 15) states that the dolomite in its western extension is clearly post-depositional in origin, dolomitization having destroyed most recognizable features such as conglomerate zones, oolitic and pisolitic beds.

Following deposition of the Meagher Formation, the seas retreated westward as the landmass emerged or the geosyncline became stable. After deposition of Park Shale the sea advanced eastward again to deposit the Pilgrim Limestone which Hanson (1952, p. 23) believes was dolomitized shortly after being deposited.

Withdrawal of the sea during Late Cambrian time resulted in the deposition of Red Lion shales, siltstones, mudstones, sandy dolomites, limestones and conglomerates.

Early Ordovician limestones and limestone conglomerates were formed in a deeper sea and subsequently eroded, the erosion surface may have extended into the Red Lion Formation. During Early Devonian time Maywood dolomites and limestones were deposited in a retreating sea followed by the deposition of the petroliferous Jefferson Dolomite in a brackish sea in Middle and Upper Devonian time. Following deposition of the Jefferson Dolomite the seas retreated to deposit the Upper Devonian Three Forks Shale.

In Mississippian time encroachment of the sea upon the landmass resulted in the deposition of more than 2,000 feet of limestone of the Madison group.

At the end of the Mesozoic era, the Cordilleran region underwent a period of diastrophism. Paleozoic and Mesozoic sediments were thrown into broad folds, the stress responsible for the mountain-building forces originating from the southwest. Folding was closely followed by faulting and thrusting. Intrusives such as the Tobacco Root batholith and the Boulder batholith were intruded, in some instances along zones of structural weakness. Ore deposition was associated with the intrusions.

During Pleistocene time alpine glaciation in the higher valleys cut deep cirques to form cirque lakes at the heads of canyons and deposition of glacial moraine took place in the valleys. Weathering and stream erosion are presently at work reducing the topography.

S T R U C T U R A L   G E O L O G Y

METAMORPHIC ROCK STRUCTURE

Pre-Beltian rocks crop out in the southern part of the Tidal Wave district where erosion has exposed the Pony and Cherry Creek metamorphics. Pony metamorphics strike N. 20° E. to N. 50° E. and dips range from about 40° NW near the Pony-Cherry Creek contact to 60° to 80° NW in Dry and Wet Georgia Gulches. As one proceeds north the strike swings from about N. 50° E. to east-west with northwest dips of 70° to vertical.

Because of the rather limited extent of Precambrian metamorphics in the district, complexity of structure, and restricted time for surface field mapping, no attempt was made to map them in detail. However, the following geologic features were noted in the district: No conclusive evidence of the presence of isoclinal folding, as described by Reid (1947, p. 13), was observed in the district; rather, the structural pattern appeared to be that of broad asymmetrical or overturned folds with small superimposed flexures on the relatively steep-dipping flanks. Stratigraphically, Pony Gneiss overlies Cherry Creek metamorphics in Nugget Gulch, an identical relationship which Reid (1957, p. 21) describes in the Northern Tobacco Root Mountains. Fritzche (1933, p. 20) mapped metamorphic rocks in the Silver Star district striking east-west and dipping south. He tentatively correlated these rocks with

Pony metamorphics in the Tobacco Root Mountains. Pony rocks in the northern part of the Tidal Wave district strike northeast-to-east and dip north. Reid, and Tansley and Schafer mapped the trend of the Pony-Cherry Creek contact beginning near the mouth of Nugget Gulch and striking northeast up the gulch, swinging across the head of Wisconsin Gulch with a northeast-to-easterly trend, to terminate at the Tobacco Root batholith. Within the intrusive the contact apparently swings abruptly to the southeast. The elongate batholith follows the trend of the contact. Pony rocks outcrop northeast of the intrusive, while Cherry Creek rocks are exposed to the southwest. Undoubtedly the contact emerges from the south end of the batholith beneath alluvium in the Madison valley near the town of McAllister, Montana. Pony rocks occur east of the valley and Cherry Creek rocks outcrop to the west. South of McAllister, Tansley and Schafer map the contact as trending in a southerly direction for about two miles at which point it swings to a southwest direction toward Virginia City, Montana. In plan the trend of this contact is like an inverted "U" in which Pony rocks outcrop on the west and east flanks of the Tobacco Root Mountains and Cherry Creek rocks outcrop in the center. The trend of the contact indicates that the structure may be a north-plunging anticline, batholithic intrusion taking place near the crest and along the east limb.

SEDIMENTARY ROCK STRUCTURE

A broad symmetrical syncline, with east and west limbs dipping 50°, extends in a northerly direction from Dry Gulch. The axis of the structure has been obliterated by the Bear Gulch stock, but south of the stock the axial plane curves southeast-to-easterly and begins to nose out at Dry Gulch. Along the front of the range the corresponding anticlinal limb of the syncline has been faulted along its crest by a north-south striking normal fault. The west side of the fault has been downthrown approximately 1,500 feet.

An east-west fault trends up Dry Gulch bringing Jefferson Dolomite into contact with the Pilgrim Formation. The south side of the fault has moved westward and upward. South of Dry Gulch the continuation of the syncline is represented by plunging Cambrian formations from Flathead Quartzite to Pilgrim dolomitic limestone inclusive, nosing out toward the head of Dry Gulch and Goodrich Gulch. The trend of the axial plane is nearly east-west.

Toward the south end of the district the parallel-trending folds are smaller. At Goodrich Gulch an anticline with two flanking synclines plunges northwest and begins to terminate in the NW$\frac{1}{4}$ of section 22, T. 3 S., R. 5 W. Section D-D' (see pl. 1 in pocket) shows the position of a small asymmetrical anticline and syncline. Two other small folds, an anticline and syncline, are located between the High Ridge and Ella properties. The anticline has been broken by a northeast-trending fault which obscures the axis of the fold.

IGNEOUS ROCK STRUCTURE

Stocks

The Bear Gulch stock, a north-south trending elongate body, is one and one-half miles long by one-half mile wide. Its contacts are steep to vertical. Contact-metamorphic effects are weak south of Bear Gulch, but to the north these effects are widespread. Along the contact with limestone and in isolated limestone blocks within the intrusive, tactite bodies of garnet, diopside, epidote, and specular hematite have been formed. Corundum occurs on the ridge east of the Moffet tunnel. Quartz monzonite weathers easily to a residual soil cover but the limestone, especially where it has been silicified, stands out as bold outcrops. A block of limestone in contact with a shale bed is observed where the shale had been metamorphosed to hornfels.

East of Bear Lake the Jefferson Dolomite exposed along the Bear Gulch road has been altered to light-colored cryptocrystalline rock in which the diagnostic petroliferous odor has been destroyed. From this it would appear that an igneous body may underlie the sediments east of Bear Lake at shallow depth.

The Bear Gulch stock intrudes Paleozoic Formations along the trough of a syncline whose axis swings from north-south to a south-east trend at Dry Gulch. A major fault, hereafter referred to as the Center fault, has been mapped to the southwest boundary of the stock. This fault probably continued along the axis of the syncline (obliterated after intrusion) and provided a zone of structural weakness which extended to considerable depth to tap the magma source. Numerous joints and shears transect the igneous mass, some of which may be shrinkage joints formed during solidification of the intrusive. Some of the small faults and shears, however, probably reflect continued movement along this zone weakness.

Dikes

Small dikes of both acid and basic composition are scattered throughout the district, the majority are found intruding Pony Gneiss. Outcropping metabasalt dikes are mapped adjacent to the Krueger, Corncracker, High Ridge and Walker properties. Metabasalt dikes are noted in the No. 8 adit of the Richmond Group and the Lottie mine. Pegmatite dikes large enough to map occur near the Lone Star prospect and near the mouth of Wet Georgia Gulch.

Sills

A sill, in contact with Meagher Limestone, extends south from Smelter Mountain, crosses Bear Gulch to the head of Dry Gulch where it trends southeast out of the mapped area. The sill is from 200 to 300 feet in thickness and remains in contact with Meagher Limestone throughout its length. The absence of Flathead Quartzite and Wolsey Shale suggests a thrust in which Meagher beds were faulted over Flathead and Wolsey Formations. This is substantiated somewhat by the occurrence of another low-angle thrust in Wolsey and Flathead beds in sec. 35, T. 3 S., R. 5 W.

A monzonite intrusive, sill-like in surface exposures, intrudes Jefferson Dolomite about one-quarter mile east of Bear Lake. The similarity of rock texture and mineralogical composition may indicate a genetic relation to the stock. A fault exposed in Goodrich Gulch strikes toward the sill and could have exerted structural control on its emplacement.

An andesite sill lies between Flathead Quartzite and Wolsey Shale at the head of Wet Georgia Gulch. It is located near the center of sec. 26, T. 3 S., R. 5 W. and may extend a considerable distance south toward the Ella mine. Residual soil covers the outcrop which makes it difficult to determine its strike length.

FAULTS

Faults in the Tidal Wave district are numerous and complex, and possibly owe their existence to a combination of forces exerted at different intervals of geologic time. However, the normal and high-angle reverse faults can be grouped into northwest-trending, east-trending and northeast-trending sets. In the southeast portion of the map area a low-angle trust fault (Ella Fault) occurs, and to the west is the major Front Range fault (Tobacco Root fault). A description of these faults follows:

Northwest Faults

The first group, the Northwest series, trends from north to N. 50° W. Included in the group are the Range, Front, Jefferson, Richmond, Krueger and Fork faults. The parallel Range and Front faults strike N. 30° to 45° W. where they cross Pony Gneiss west of Wet Georgia Gulch, but swing to a more northerly direction where they enter Paleozoic sediments. The Front fault dips 55° E. at its southern extremity and increases to about 65° near the Tidal Wave mine. The east side of this fault is downthrown whereas the Range fault has a reverse movement, thus the block between the two faults is a horst which has been upthrown about 1,000 feet. These faults merge with the Jefferson fault to continue as one structure toward the mouth of Goodrich Gulch.

The steep dipping Jefferson fault strikes N. 40° W. Its position is shown by a fault scarp between the Jefferson Dolomite and the Madison Limestone. Southwest of the Bullidick prospect the fault splits. The west segment dips east while the eastern segment has a westerly dip. A small horst which has been displaced about 150 feet lies between the two faults. These segments of the fault were not found southeast of the Corncracker mine.

The Richmond fault trending across the heads of the right and left fork of Goodrich Gulch terminates near the mouth of Dry Gulch. Striking northeast near the Schmidt property, its strike swings to N. 55° W. near the Eagle and Hummingbird mines and continues on this strike to Dry Gulch. The fault has a steep dip to the east near Dry Gulch and is vertical in the Goodrich Gulch area. Displacement has been rotational, the south side moving up at the eastern end while the north side moved up at the western end. The pivot point of rotational movement would appear to be near the A, B, and C faults. (See pl. 1.) Another possibility is that the Richmond fault may not be a continuous unit, but rather the fault may split into two or more segments which could account for opposite directions of movement along its apparently continuous strike.

The Krueger fault parallels the range front for nearly a mile north of Dry Gulch and may be a subsidiary fault of the Tobacco Root fault. This high-angle normal fault brings Meagher beds (west block) into contact with Pony Gneiss, the Meagher block having been dropped approximately 1,500 feet. The fault strikes N. 10° W. and dips 75° W. to vertical. A subsidiary fault located about 100 feet to the west parallels the Krueger fault for a short distance.

The steeply dipping Fork fault, striking N. 50° to 70° W., follows Goodrich Gulch from the forks to the range front. The south side of the fault moved eastward and down with respect to the north side. The fault trace follows the axis of a small anticline located at the forks of the gulch.

East-Trending Faults

The second group includes the east-striking vertical fault near the Alaska ranch reservoir and two east-trending faults in Dry Gulch. The larger fault in Dry Gulch hereafter referred to as the Dry Gulch fault follows the course of the valley. Age relationships between east and northwest-trending faults are not definite. The east-trending faults may be contemporaneous with northeast faults and younger than northwest faults.

The east-striking fault located near the Alaska ranch reservoir trends S. 80° E. and follows the course of the gulch. The north side is downthrown and displaced to the west.

The Dry Gulch fault has a strike which is variable from S. 80° E. to N. 80° E. The fault can be traced for a distance of about 2 miles. The south side is displaced upward and to the west. A short fault exposed in adits near the mouth of Dry Gulch strikes east and dips south. This fault is displaced by the Krueger fault, but the Krueger fault and another small north-trending fault appear to be displaced by the Dry Gulch fault. Thus, the age relationship between these fault groups is not clear.

Northeast Faults

The most recent faults, and also the greatest in number in the area, belong to the Northeast group which offset northwest structures. Northeast-striking faults include the Center, East Center, A, B, and C faults, Carolina, Schmidt, Argenta, Goodrich, and High Ridge faults.

The Center fault is one of the larger structures in the district and strikes N. 40° E. and dips from 40° to 60° W. The fault parallels the axis of a syncline for a short distance north of Dry Gulch and terminates against the Bear Gulch stock. The east side has moved upward relative to the west side, a vertical component of displacement amounting to about 3,500 feet. The Center fault appears to have exerted structural control on the emplacement of the Bear Gulch stock. To the south the Center fault splits into three segments. This main branching continues south and southwest to merge with the Jefferson fault in the vicinity of the Bullidick property. The East Center fault, located several hundred feet east of the Center fault, strikes parallel to and is probably contemporaneous with the Center fault. The west side of this structure has been upthrown bringing Pony gneiss into contact with Upper Cambrian sediments.

The A, B, and C faults are related high-angle structures striking N. 40° E. They displace Middle Cambrian sediments and the Richmond fault to form a complicated fault pattern. In cross-section (see pl. 1) the displaced blocks between the faults are like stair steps, from east to west each block has moved downward relative to the adjacent block. These faults projected across sections 13 and 14 correlating with faults in Bear Gulch. In this area the surface is covered with mantle rock and timber and definite evidence of coninuity is lacking.

The Carolina fault trends N. 45°-50° E. and can be traced from near the head of Dry Georgia Gulch northeasterly to the Carolina mine where it displaces the vein, on to the head of the west fork of Goodrich Gulch paralleling the C fault for about one and one-half miles. In the south half of section 13 a circular hill is capped by Pilgrim rocks overlying Park Shale. This hill is a part of a graben or down-dropped block between the northern part of the Carolina fault and the Richmond fault, which, in turn, is part of a larger graben between the Carolina fault and the Schmidt fault. Southwest extension of the Carolina fault is suggested by the linear trend of Dry Georgia Gulch.

The Schmidt fault strikes from N. 40° to N. 80° E. It dips both east and west along its stirke and displaces the Argenta fault in the north half of section 26.

The Argenta fault strikes from N. 30° to 85° E. and dips to the south. It displaces the Argenta vein at the head of Wet Georgia Gulch. The north side moved downward relative to the south side.

The Goodrich fault, striking north to N. 45° E., parallels Goodrich Gulch for a mile and has exerted structural control on drainage. The fault dips east and the east block moved up relative to the west block.

The High Ridge fault is actually a fault zone consisting of several parallel faults which were subsequently filled by vein material. Prior to mineralization the zone displaced lower Middle Cambrian Formations. The structure strikes N. 45° E. and dips 60° to the southeast. It is exposed in 4 adits at the High Ridge property. It continues on a northeast strike into the Meagher Formation. The east side of the fault has moved up relative to the west side.

Thrust Fault

The Ella thrust fault, one of the youngest faults in the district, is a bedding plane fault which strikes north to northeast and dips 25° W. (near the Ella mine) to 30° E. (in the No. 1 level of the High Ridge mine). The thrust plate has moved in a southeasterly direction and displaced the High Ridge vein and the Schmidt faults.

Front Range Fault

The Tobacco Root fault, paralleling the front of the range, is covered by alluvium. However, its presence is indicated by the linear-trending mountain front, faceted spurs, and the presence of bent or bowed sedimentary beds at the front of the range near the Alaska ranch. The Tobacco Root fault strikes about N. 30° E. and with the west block moving south and down relative to the east.

Relationship of Faulting to Ore Deposits

Faulting is perhaps the most important structural control for the formation of ore deposits in the district. Vein material has filled pre-existing fault fissures throughout the Pony Series. Known veins that were formerly fault fissures are the High Ridge, Krueger and Bryzant.

Flat-dipping veins that follow bedding are usually found in Flathead Quartzite or Wolsey Shale although some occur in Pilgrim and Meagher beds. During folding, slipping of competent beds over incompetent produced fractures which were later filled with vein material.

A favored horizon for bedding fractures is the Wolsey Shale or near the upper horizon of the Flathead Quartzite where interbedded quartzites and shales predominate. Known veins following bedding planes in these horizons are the Richmond Group and the Carolina.

SUMMARY

In the northern part of the district a sharp anticline and a broad syncline trending north were folded by a principal stress oriented essentially east-west. South of Dry Gulch the axis of the syncline changes direction to the northwest indicating a change in direction of the deformative forces. In the central and southern parts of the district the axes of smaller anticlines and synclines trend northwest, the principal stress responsible for folding originating from a direction very slightly south of west. The presence of the thick Madison Limestone north of Dry Gulch would favor the formation of a broad structure, while the thinner formations south of Dry Gulch would favor the formation of smaller, tighter folds such as those observed.

The trend of folding in the district varies from a north-south direction to slightly west of north. The east-trending and northeast faults, which may be related groups, would appear to represent complementary shear planes of a directed compression which was oriented approximately N. 70° to 80° E. Movement is therefore postulated to have been strike-slip, at least during original deformation. Movement was right lateral for the Northeast group, and left lateral for the East group although outcrop patterns indicate there was a dip-slip component of movement, either at the time of original deformation or at some later date. The third group, the northwest faults, are approximately perpendicular to the axis of compression which would indicate different stress conditions. The resultant forces of intrusion may be responsible for part of the faulting in this group. The other faults probably occurred along pre-existing planes of weakness in Pony rocks.

Some faults in the East and Northeast groups have considerable strike-slip movement, while others seem to have had largely dip-slip movement. The dip-slip component may have been aggravated by later uplifts of the structure which masked original movements. This may have occurred in local areas where uplift was related to intrusion.

A flat-dipping lead-silver vein crosses the High Ridge vein near the portal of No. 1 adit. The strike parallels that of the Ella thrust. This vein does not appear to displace the High Ridge vein and may be an earlier thrust with the Ella fault formed as a subsidiary structure without appreciable movement. Post-mineral adjustment along the Ella thrust resulted in minor displacement of the High Ridge vein.

The Tobacco Root fault may belong to the late Northeast group. Recent movement along this structure has probably occurred, but the fault may have originated at some earlier date.

O R E   D E P O S I T S

CLASSIFICATION

Mineral deposits in the district formed through hydrothermal processes are fissure veins and irregular replacement bodies associated with jointing or bedding-plane fractures and favorable beds. Contact metasomatic type deposits occur where igneous rock intruded sedimentary beds and the liquids associated with the magma replaced sediments along contacts.

Fissure Veins

Productive veins of the fissure type occur in Pony Gneiss, Flathead Quartzite and Wolsey Shale, and, to a minor extent, in Meagher and Pilgrim Limestone.

Veins in Pony Gneiss vary in width from several inches to 2 feet, whereas veins in Middle and Upper Cambrian rocks are usually one-half inch to 1 foot in width. Mineralization appears to be genetically associated with stocks, dikes and sills which are believed to have been intruded during the Laramide Orogeny.

Fissure veins contain abundant quartz, native gold and silver, with minor lead, zinc and copper sulfides. At Smelter Mountain and in Wet and Dry Georgia Gulches, flat bedding-plane veins containing lead and silver mineralization with minor gold values occur in Pony Gneiss, Pilgrim Limestone, Flathead Quartzite and Wolsey Shales. The Lone Star and Smith prospects are examples of this type.

Metasomatic Replacement

Irregularly shaped orebodies in Meagher and Pilgrim dolomitic limestone conform to bedding planes and contain lead and silver with minor copper, zinc, and gold. The Tidal Wave mine is representative of this type of deposit though no specific ore controls were noted. However, there may have been a stratigraphic control since the deposit is located near the middle of the Pilgrim Formation.

Contact-Metasomatism

Contact-metasomatic orebodies are found along contacts of quartz monzonite and Madison Limestone at the Johnston-Moffet property. Copper mineralization is in tactite zones which attain widths of 150 feet. Traces of gold and silver occur in the ore. Copper oxides, carbonates and silicates are exposed in trenches and pits.

MINERALOGY AND PARAGENESIS

During the course of the investigation 143 samples from vein outcroppings, underground workings, mine dumps and ore bins were selected for assay. The results are included in the appendix of this report. Samples were used for panning, X-ray, and polished-section study.

The majority of prospects in Wet and Dry Georgia Gulches are in the oxidized zone where fissure veins contain native gold and silver, quartz, pyrite, magnetite, goethite, hematite, sericite and kaolinite. A flat-dipping vein, exposed underground at the High Ridge mine and the Dullea prospect, contains argentiferous galena with minor sphalerite, chalcopyrite, anglesite and magnetite. A few prospects in Meagher dolomitic limestone have azurite, malachite, chrysocolla, goethite, and hematite exposed in surface pits and trenches.

Sulfide ore was found on the Eagle dump, in the Lottie, Lone Star, and Johnston-Moffet properties. Minerals identified in sulfide specimens were galena, sphalerite, chalcopyrite, native silver, pyrite, magnetite, siderite, calcite, quartz, sericite, kaolinite, with minor iron oxides.

Samples of oxidized ore from the High Ridge and Hummingbird mines containing gold and silver were sized to -20 +35 mesh, panned, and the material examined with a microscope. Sparse white-to-yellow-colored native gold and silver, sparse fresh and tarnished pyrite, magnetite, hematite, and quartz were identified in the pannings. Native gold occurred as minute particles and irregular dendritic scales and masses difficult to see with the naked eye.

Eleven specimens from the Tidal Wave, High Ridge, Lottie, Carolina, and Eagle mines, and specimens from three prospects in Wet and Dry Georgia Gulches were studied under the reflecting microscope. Minerals identified were pyrite, sphalerite with exsolution chalcopyrite, native gold (?), galena, siderite, magnetite, calcite, milky quartz, clear quartz, goethite, and hematite. Chalcopyrite intergrowths and blebs were distributed along the crystallographic axes of sphalerite. These minute inclusions showed a mottled or emulsion texture with seriate arrangement which is diagnostic in most instances of exsolution chalcopyrite in sphalerite. The presence of copper in sphalerite was confirmed by X-ray diffraction methods by Dr. C. W. Haynes on samples of ore from the Lottie and Eagle mines.

Paragenetic relationships between the minerals indicate an early period of clear quartz followed by auriferous pyrite, sphalerite with exsolution chalcopyrite and contemporaneous native gold (?), followed by galena. Native silver fills small fractures and is considered late in the paragenetic sequence. (A period of brecciation followed the deposition of the sulfides at the Lottie mine.) Deposited last was gangue mineralization, consisting of siderite and/or calcite and quartz.

Gold occurs with the early sulfides but none was found by microscopic examination. Gold was found by assaying carefully selected specimens of pyrite and sphalerite. Native gold was found with magnetite particles in pannings. The magnetite could be either a late mineral or have had a secondary origin from the alteration of auriferous pyrite.

Hand-sorted pyrite and sphalerite from the Eagle mine was assayed for gold and silver content. The assays indicate a higher gold content in sphalerite than in pyrite by a ratio of 2.5 to 1.

Buerger (1934, p. 530) believes that chalcopyrite and sphalerite in solid solution unmix between temperatures of 350° to 400° C. This would fix the approximate temperature of formation of the chalcopyrite, while the gangue minerals being later, would presumably have formed at a somewhat lower temperature.

It is the writer's opinion that this sulfide mineral assemblage indicates that these deposits belong to the hypothermal or high-temperature classification of Lindgren (1933, p. 212). The primary sulfide minerals were formed from ascending hydrothermal solutions, and surficial leaching of the upper portions of veins has resulted in an enrichment in gold and silver to form economic deposits.

If the above-average gold content in sphalerite, indicated by assays of Lottie and Eagle ores, is constant throughout the district, high sphalerite assays in the sulfide zone may be used as indicators for economic oxidized portions of veins above workings in the sulfide zone.

D E S C R I P T I O N O F M I N E S

BEAR GULCH

Johnston-Moffet Property

This property is developed by the Johnston tunnel near Bear Lake and the Moffet tunnel and Mountain View shaft located near the top of the ridge on the south slope of Coal canyon. The property, located since 1900, actively developed several small orebodies found in the Moffet tunnel.

During World War II, a U. S. Bureau of Mines exploration program by R. N. Roby (1946, p. 1-12), investigated the property to determine ore reserves. The program included detailed geologic mapping and diamond drilling to determine the extension and grade of orebodies on the property. Results of tests on the amenability of ore to flotation and leaching were also made and are included in Roby's report.

Chalcopyrite occurs in a tactite composed of garnet, diopside and epidote, with minor pyrite, magnetite, and specular hematite. Roby (1946, p. 2) reports a 638 ton shipment of ore in 1916 to the East Butte Smelter. The ore averaged 2.32 percent copper, 0.39 oz. of silver, and 0.018 oz. of gold. Another shipment totaling 407 tons from the Mountain View shaft, surface trenches, and an open cut on the Stella claim averaged 2.84 percent copper, 0.68 oz. of silver, and 0.024 oz. of gold.

The property consisting of 15 patented claims covering an area of 143 acres is inactive at the present time.

Little Bear Gulch Properties

Little Bear Gulch Creek is a north-flowing tributary of Bear Gulch Creek entering the canyon near the base of Smelter Mountain. A porphyritic syenite sill lies in contact with the Meagher formation. Small irregular replacement bodies of argentiferous galena occur in Meagher beds above the contact. Hart (1933, p. 36) reports jasper ore containing fine gold on the Giant claim. All claims in the district, including the Grouse, Little Bear, and the Copper King, are inactive at the present time.

Hamilton Prospects

The Hamilton prospects in Bear Gulch and on the west and north slopes of Smelter Mountain are in Precambrian Pony Gneiss and Jefferson Dolomite. Two claims recently located by Jim Hamilton of Twin Bridges, Montana, have the No. 1 and No. 2 adits located about 150 feet southwest of the B. & H. fault (fig. 4). A small fault strikes N. 50° W. in the No. 1 adit. Malachite stains are present near the portal. A 6-inch vein of calcite with manganese and iron oxides has been displaced a few inches by a fault in the No. 2 adit.

DRY GULCH

Krueger Property

The Krueger property in Dry Gulch was aquired by Otto Krueger in 1931. Homer Hunt had formerly leased the ground. The property consists of 2 unpatented claims and the patented Edwin Forest claim on which the Krueger mine is located. Several small adits are located on the north slope of Dry Gulch at the mouth of the canyon on unproductive ground from which no ore has been shipped.

The Krueger mine is developed by an adit and a shaft which is inaccessible at the present time. A north-trending vein of the fissure type in Pony Gneiss varies from 1 to 2 feet wide and splits into 2 segments (fig. 5) near a small winze 100 feet from the portal. A fault located about 60 feet north of the portal displaces the west segment 10 feet to the east. Vein material shows weak to moderate sericitization although wall rock alteration is weak to absent.

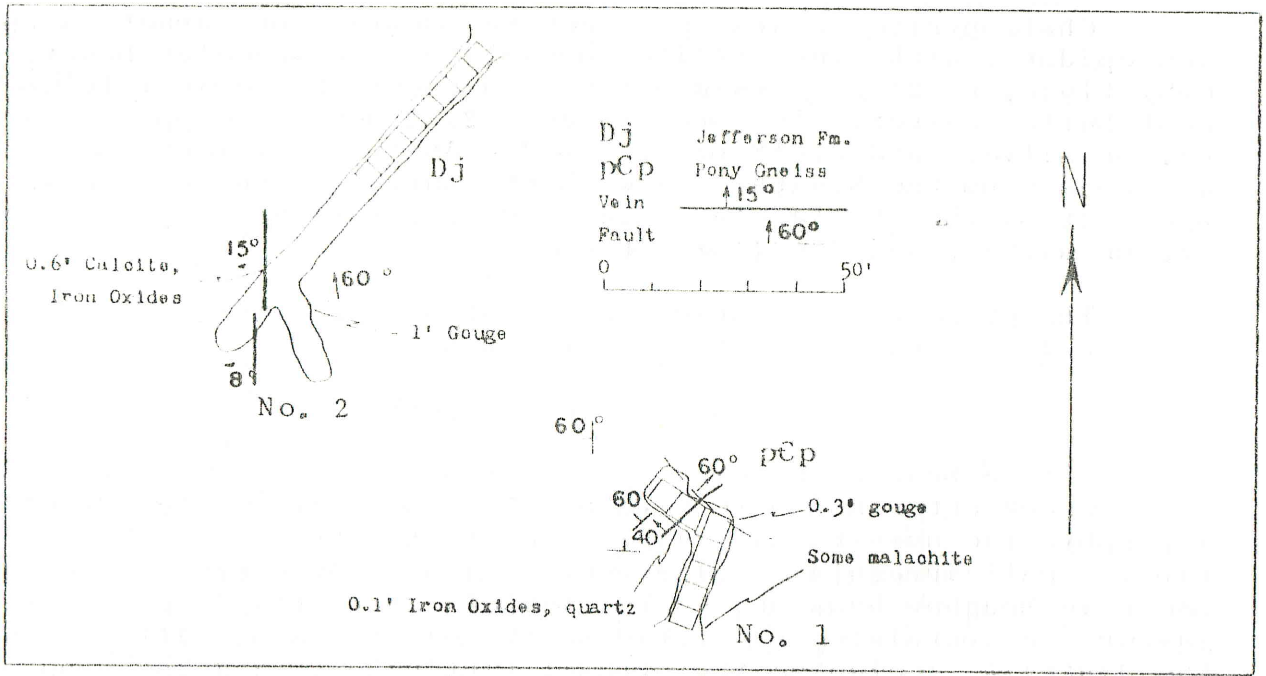

Figure 4.--Geologic plan of adits 1 and 2, Hamilton Prospect, Madison County, Montana.

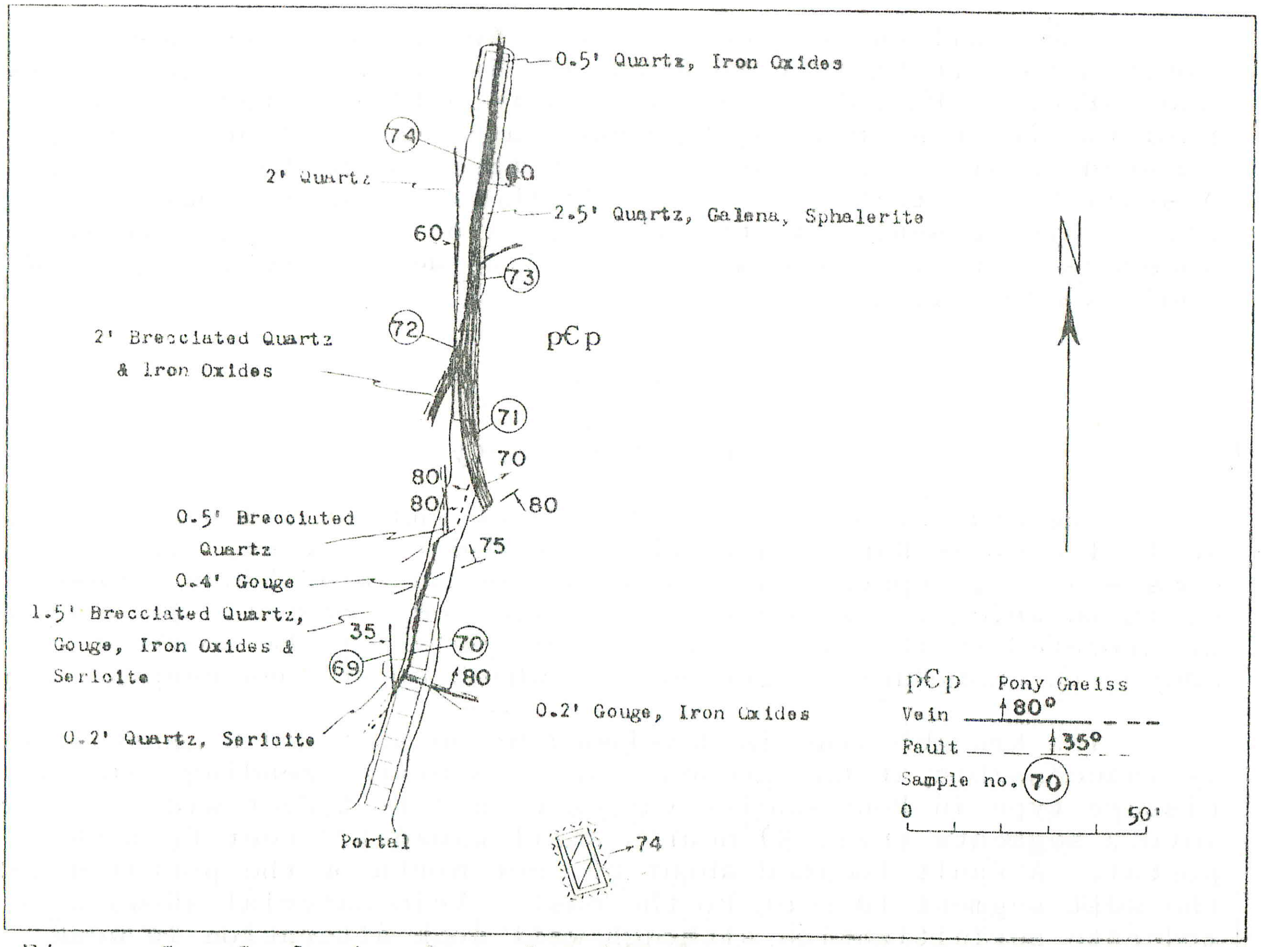

Figure 5.--Geologic plan of 5,945-foot adit level, Krueger Mine, Madison County, Montana.

A 150-foot shaft located about 650 feet northeast of the Krueger mine was sunk on an argentiferous galena vein containing some gold. The vein strikes in a northerly direction and dips about 60° E. The vein is in gneiss and is reported to assay about $60.00 per ton. The Krueger mine has produced about 8 carloads of ore containing silver-gold values amounting to about $18.00 to $20.00 per ton. At the present time the property is in an unsettled estate and has been inactive for several years.

GOODRICH GULCH AND ADJACENT AREAS

Richmond Group

The Richmond group on the north fork of Goodrich Gulch was originally located by the Richmond brothers at the turn of the century, and was subsequently operated by them for many years. In 1936 the property was acquired by Jack Richmond, Al Jacobs and Ben Payne who operated it until 1942. During this 6-year period, production amounted to about $33,000 from the Eagle and Hummingbird adits, the major part of which came from the Eagle. The ore, containing about 3.5 ounces of gold per ton, came from small quartz veins trending parallel to bedding planes in Flathead Quartzite and Wolsey Shale.

Adit No. 4 (fig. 6) in Flathead Quartzite has an andesite sill dipping 35° W. 45 feet in from the portal. A quartz vein striking N. 60° E. has been faulted. Gouge and broken vein material assays a trace to 0.01 ounces of gold and 0.30 to 1.70 ounces silver per ton.

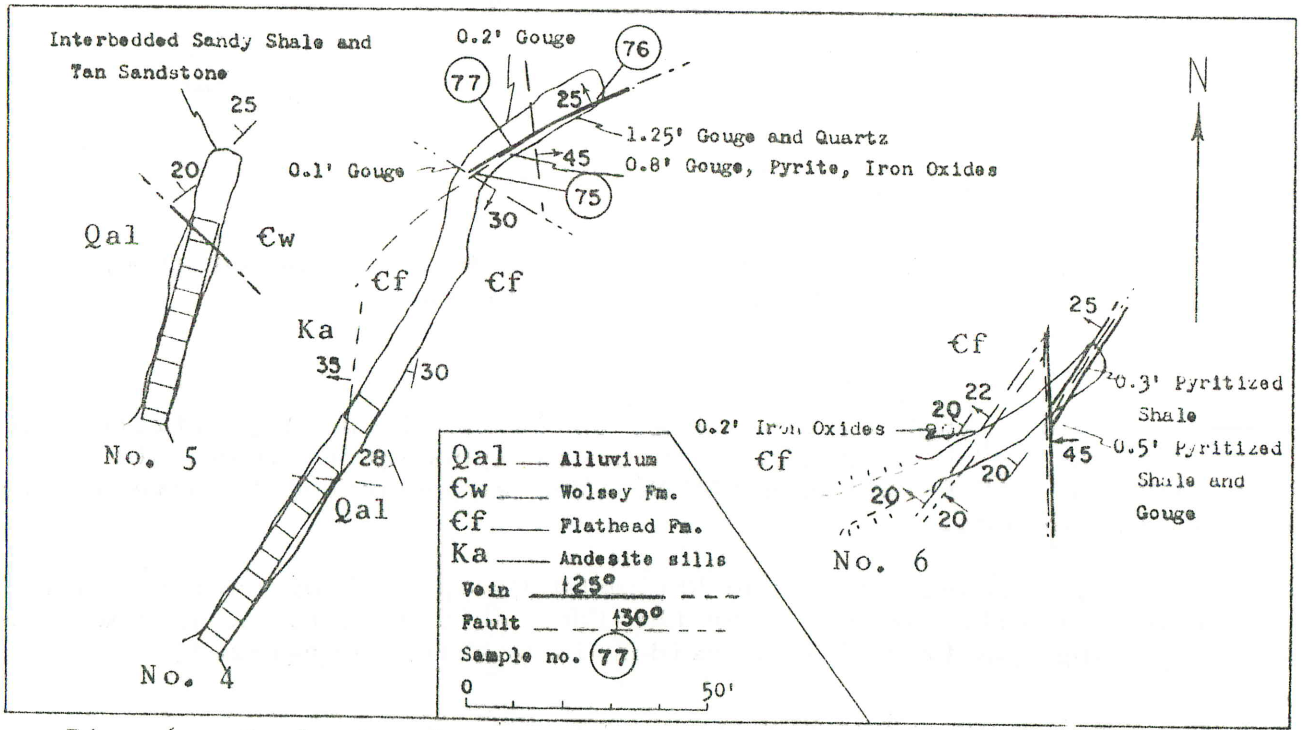

Fig. 6.--Geologic plan of adits 4, 5 and 6, Richmond group, Madison County, Montana.

No. 5 adit (fig. 6) is located northwest and above No. 4 and is in interbedded sandy shale and tan sandstone beds of the Wolsey Formation.

No. 6 adit (fig. 6), to the east and above No. 5, is located in interbedded quartzite and shale beds of the upper Flathead Quartzite. Small fractures at contacts between shale and quartzite contain iron oxides. A north-striking reverse fault which dips 45° W. displaces quartzite and shale beds.

The Eagle adit (fig. 7) has produced considerable ore containing about 3.5 to 4 ounces of gold per ton. The portal is in the upper Flathead Formation; however, Wolsey Shale was apparently intercepted beyond the caved part of the tunnel as it covers the surface of the dump. A narrow vertical stringer containing native gold was found at the portal of the tunnel.

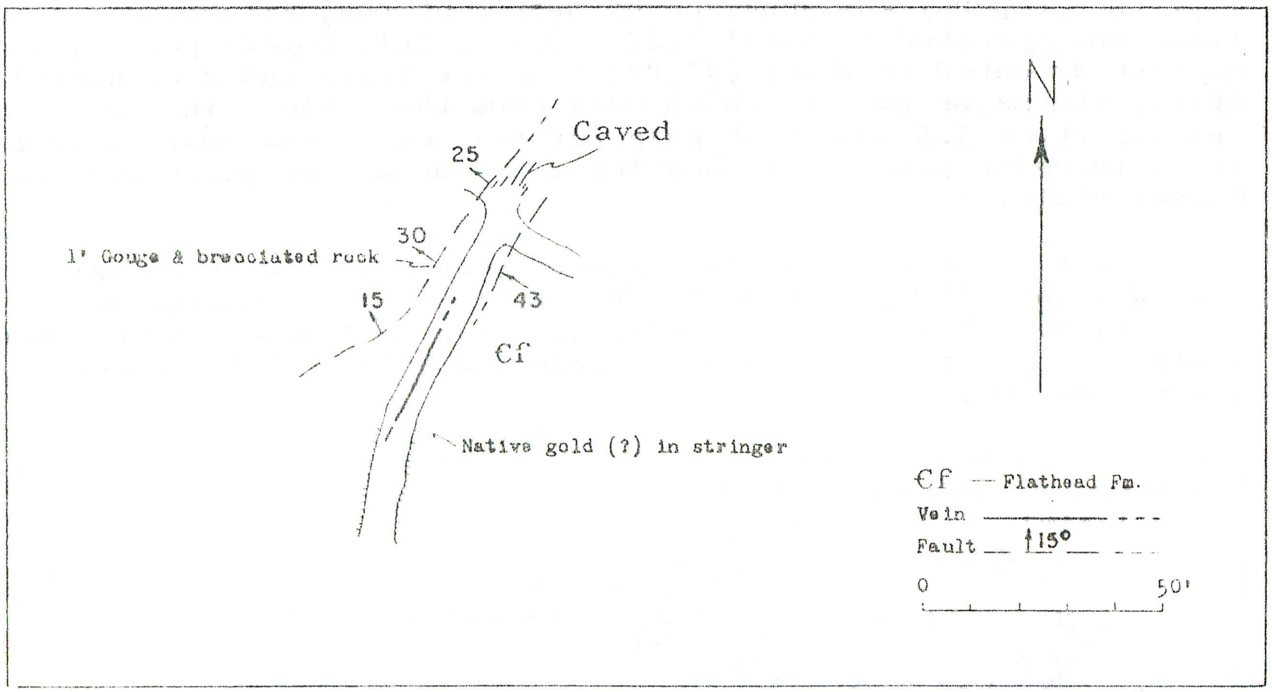

Figure 7.--Geologic plan of Eagle Mine, Richmond group, Madison County, Montana.

The Hummingbird mine (fig. 8) is in Flathead Quartzite which strikes N. 30° E. and dips 30° N. Two productive veins strike N. 50° and 70° E. and dip 20° N. Ore was reported to have assayed $115.00 per ton.

No. 8 (fig. 9) of the Richmond group in Pony Gneiss has a metabasalt sill located near the face of the adit. A narrow vein containing quartz and iron oxides is weakly mineralized.

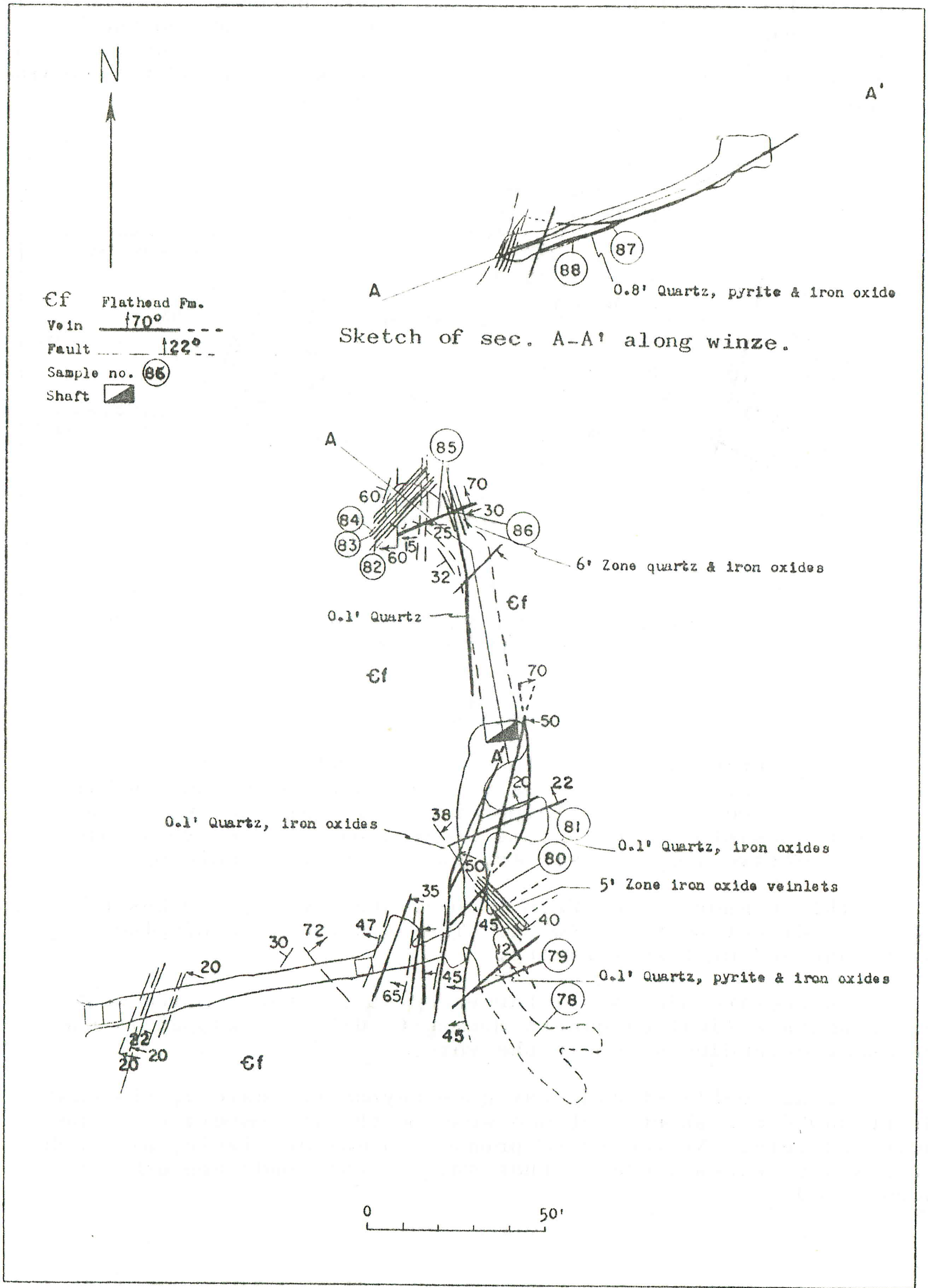

Figure 8.--Geologic plan and section of Hummingbird Mine, Richmond group, Madison County, Montana.

The No. 9 adit (fig. 9) is located 95 feet northwest of No. 8 and 180 feet southeast of the Hummingbird portal. This adit, in Pony Gneiss, encountered several small northeast and northwest-trending veins. Two veins assay 0.5 and 0.25 of an ounce of gold per ton. A 4-foot stringer zone at the face of the adit, containing quartz and iron oxides, is weakly mineralized.

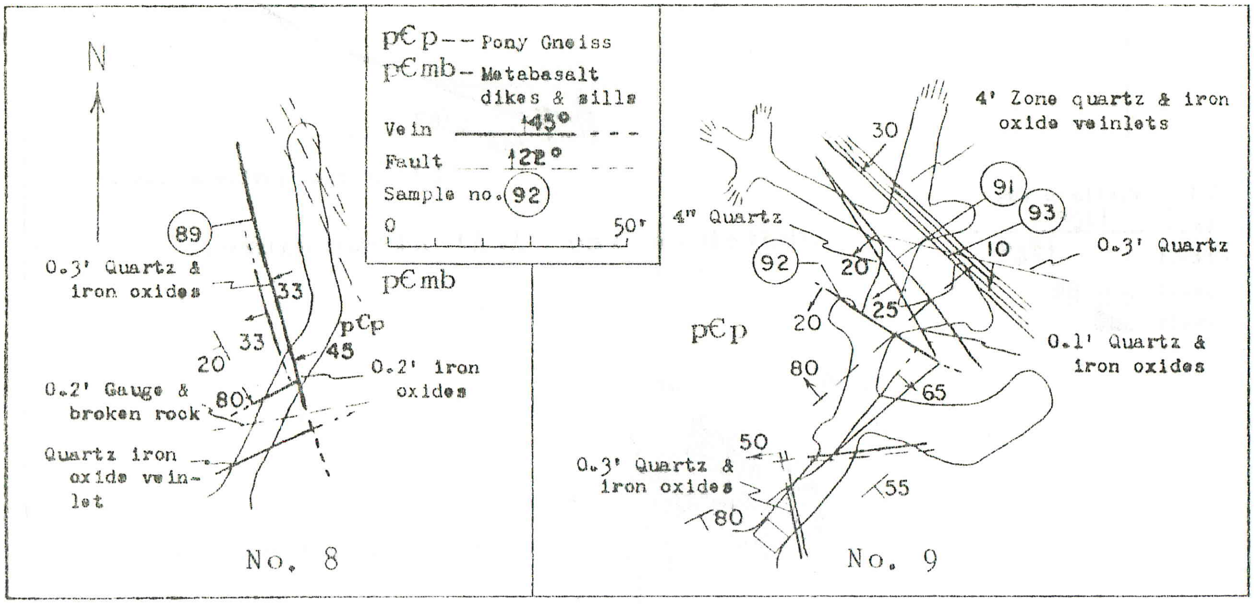

Figure 9.--Geologic plan of adits 8 and 9, Richmond group, Madison County, Montana.

Lottie Mine

The Lottie mine (fig. 10) on the north fork of Goodrich Gulch, NW$\frac{1}{4}$ sec. 23, and across the canyon from the Hummingbird mine, was relocated by V. Tripplet and J. Shipp in 1956. The property consists of two claims located on a quartz vein which contains native gold and silver, sphalerite and chalcopyrite.

This fissure vein, from 1 to 2.5 feet wide, strikes from an easterly direction to S. 50° E. The vein has been displaced by northeast and northwest faults.

An adesite dike was intercepted at the face of the west drift and a silicified quartz monzonite dike was mapped in the crosscut extending south of the vein.

Considerable stoping was done beyond the cave in the east drift and for a short distance west of the intersection of the adit and vein. No record of production was available, although stopes and raises indicate that some 50 railroad cars could have been mined.

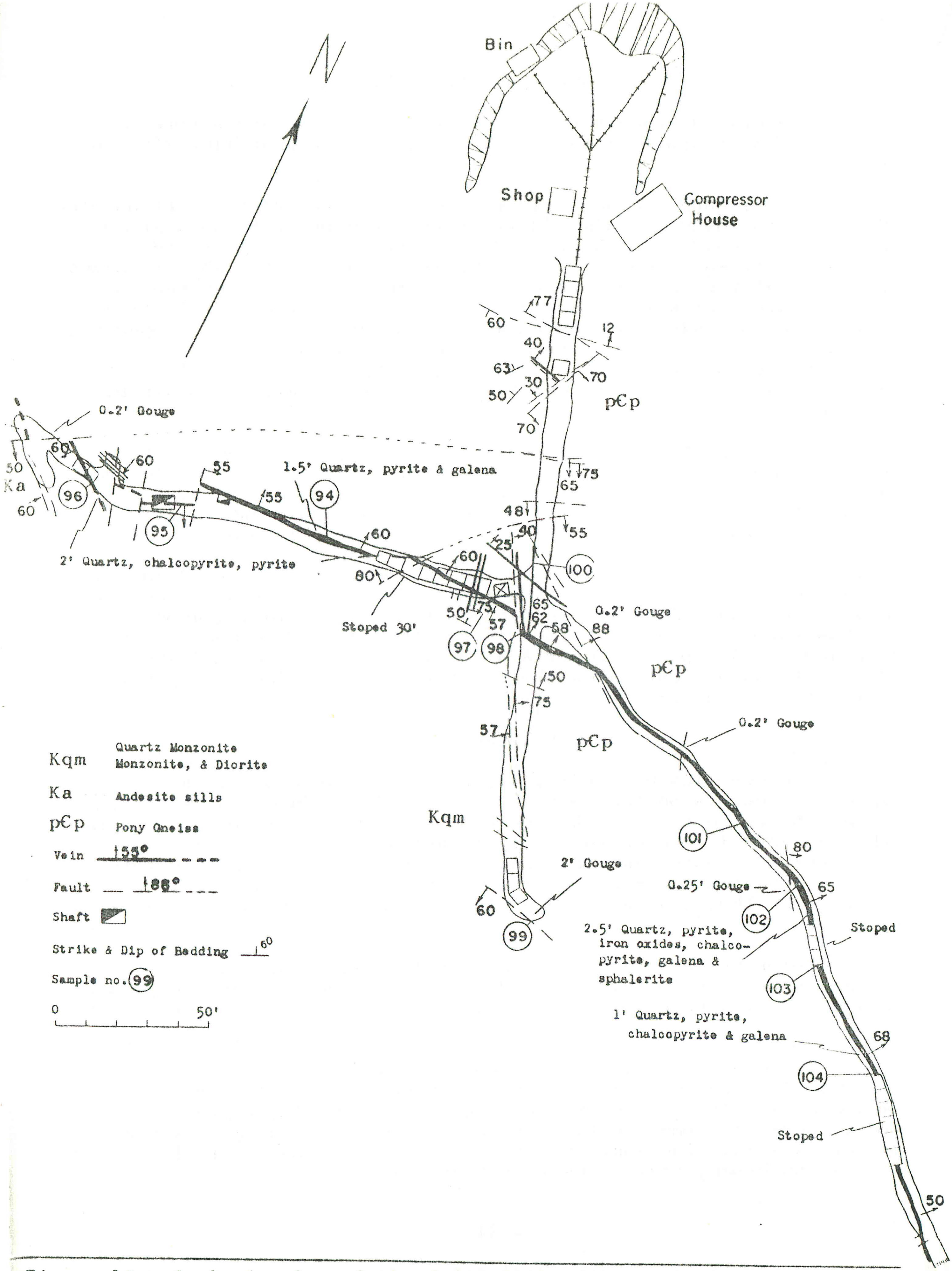

Figure 10.--Geologic plan of the 6,875-foot adit level of the Lottie Mine, Madison County, Montana.

Crystal Lake Property

The Crystal Lake property is located on the south fork of Goodrich Gulch approximately $\frac{1}{2}$ mile south of the Carolina mine in sec. 26.

Mr. O. Anderson, an early prospector in the district, found rich float on the Goldie claim and later sold the property to a group who mined considerable high-grade ore from the Blacksmith adit. The property was acquired by E. Pulver and associates who organized the Crystal Lake Mining Company. Buildings were constructed to accommodate a crew of about fifty men. A tramway was built to convey ore to a newly constructed mill in Goodrich Gulch that operated for about one month. The property has been inactive since the early twenties except for sporadic activity by lessees. The patented claims have been recently acquired by B. Paige from Alder, Montana.

The property is developed by two adits, the Blacksmith adit on the Sunbeam claim (formerly the Goldie claim), and the Elenora adit on the Elenora claim. These adits are on parallel fissure veins striking in a northerly direction and dipping about 25° to 30° W. Hart (1933, p. 36) reports that the Elenora vein is about 2 feet wide and contains finely crystalline gold-bearing galena and auriferous pyrite. The Sunbeam vein is 2 to 3 inches wide and contains coarse native gold and coarsely crystalline gold-bearing galena. A fault trending northeast and dipping about 60° S. has thrown the veins to the left. The fault is a normal fault and Hart (1933, p. 37) reports a downward displacement of about 250 feet and has estimated the production of oxidized shipping ores prior to 1920 at approximately $200,000.

Carolina Mine

The Carolina mine (fig. 11) presently owned by F. Harvey of Twin Bridges, is on the south fork of Goodrich Gulch in SW$\frac{1}{4}$ sec. 23 about 800 feet above the creek on the south slope of the canyon. The property is one of the early locations in the district and consists of 1 patented claim and 2 unpatented. The Smith estate owns a patented claim which crosses the portal of the Carolina adit. The Thompson patented claim is located south of the Carolina property.

Prior to 1938 Mr. Banatz acquired a five-year lease on the mine. From 1939 to 1940 J. Reid of Twin Bridges leased the property and production from gold-bearing sulfide and oxide ores amounted to about $25,000.

The Carolina vein strikes north to N. 30° E. and dips about 30° W. The ore is auriferous pyrite with native gold, iron oxides and quartz. The northeast-striking Carolina fault, reported by Reid (personal communication) to be 10 feet wide, displaces the Carolina vein. The south block of the fault dropped relative to the north block, fault offset is to the left.

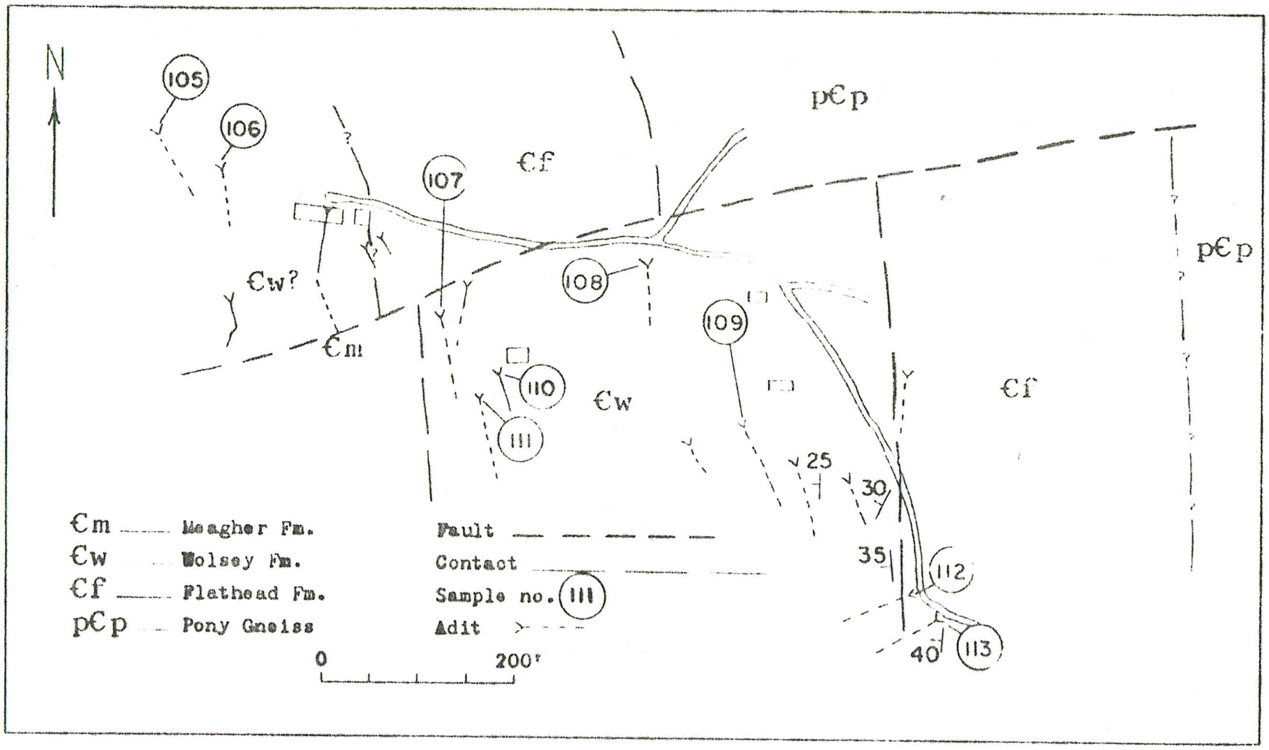

Figure 11.--Assay plans of mine dumps of Carolina Mine and adjacent adits, Madison County, Montana.

Reid mined large blocks of sulfide ore from the fault zone and made an auriferous pyrite concentrate in a small mill located in Goodrich Gulch about 1 mile below the Crystal Lake mill. The sulfide ore and oxide ore from the fault zone assayed about 3 ounces of gold per ton. The sulfide ore from the fault zone containing quartz and auriferous pyrite is believed by Reid to be drag ore.

Tidal Wave Mine

The Tidal Wave mine consists of 2 caved shafts, 3 adits, and numerous pits and cuts on the south slope and on the ridge southeast of the adits in sec. 28.

Irregularly shaped orebodies occur in Pilgrim Limestone. Mineralization consists of argentiferous galena with minor gold values. The siliceous ore sampled in a cut at the top of the ridge contained iron oxides and malachite. The orebodies appear to conform to bedding planes in Pilgrim beds along which jointing and minor fracturing occurred. The property has been inactive for a long period of time.

Smith Prospect

The Smith prospect has been leased and optioned to E. J. Smith of Twin Bridges, Montana. The lessor is E. L. Craddock of Sheridan. The property is on the Plainview claim which joins patented ground in the Tidal Wave group. It is located a short distance south of the mouth of Goodrich Gulch and has an inclined shaft and an adit in Pilgrim Limestone (fig. 12). The shaft is on a vein whose surface outcrop is several inches wide. The vein strikes N. 80° E. and dips 23° to 40° N. At the base of the shaft the argentiferous galena vein is about 7/10 of a foot wide.

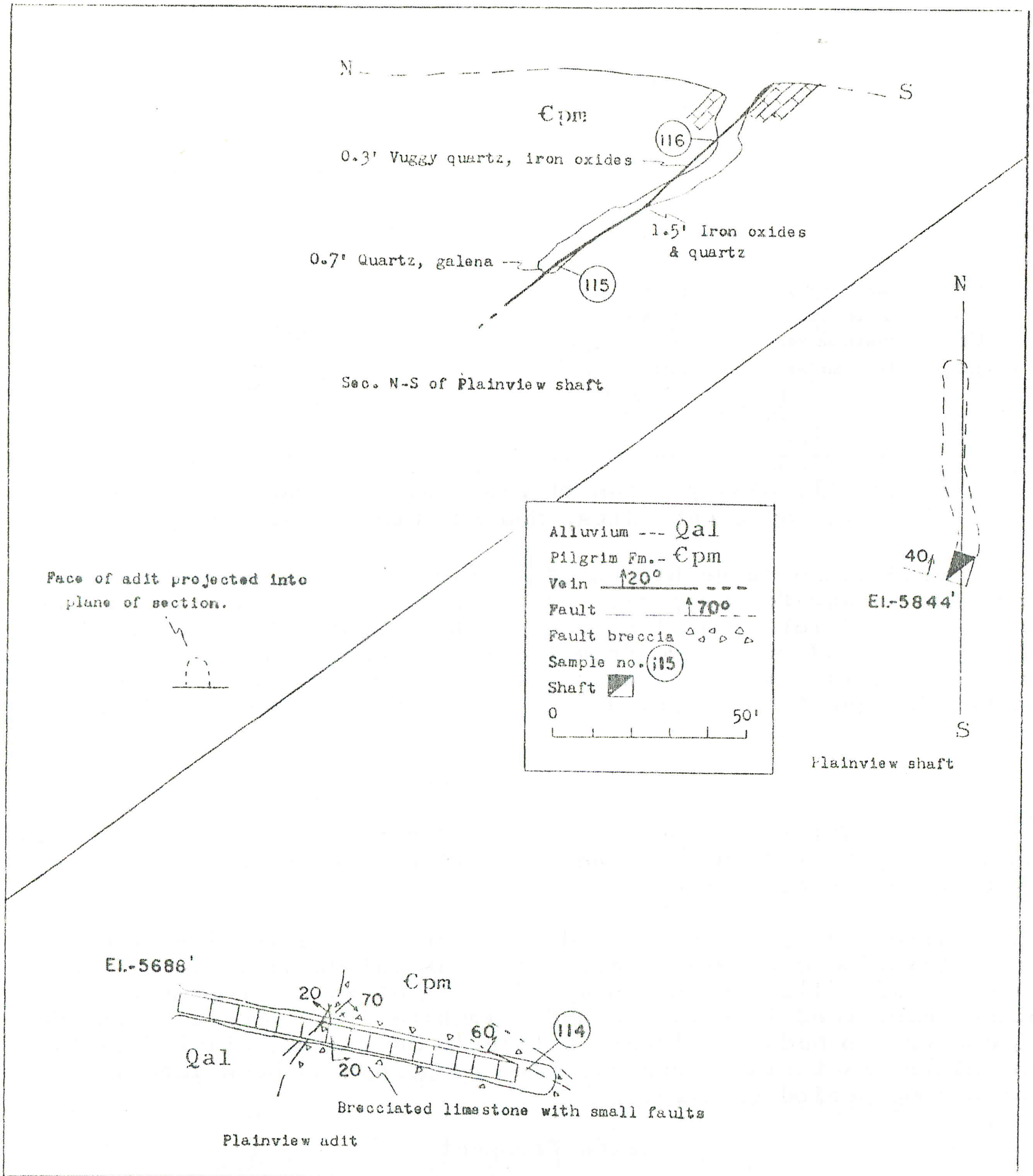

Figure 12.--Geologic plan of Plainview adit and cross section of Plainview Shaft, Madison County, Montana.

The adit will intercept the downward extension of the vein at the base of the shaft if continued on a bearing of N. 85° E. for a distance of 100 feet.

Schmidt Prospect

The Schmidt property is located on the right fork of Goodrich Gulch several miles above the Crystal Lake mill. A fissure vein in Pony Gneiss trends about N. 40° E. on this property. This vein dipping about 60° to 80° E. contains auriferous pyrite, chalcopyrite and sphalerite. The property has been inactive for a considerable period of time.

Urbane Prospect

The Urbane property (fig. 13) located a short distance up the north fork of Goodrich Gulch in sec. 22 consists of Adits No. 2 and 3 in Pony Gneiss. The lower adit, No. 3, is on a 4-foot brecciated fault zone trending N. 20° E. and dipping about 45° to 50° W. The fault in No. 3 adit correlates with the west segment of the Center fault. No. 2 adit, located northwest of the portal of No. 3, is about 20 feet stratigraphically below the Flathead-Pony Gneiss contact.

DRY GEORGIA GULCH

High Ridge Mine

The galena vein outcropping near the portal of No. 1 adit (fig. 14) was reported to have been discovered by O. Anderson prior to 1880. In the early eighties Winchell (1914, p. 156) stated the property was operated by Dahler & Elling. Mr. Ellis of Twin Bridges acquired the property which he leased until 1937. In that year J. C. Roberts and J. Reid bought the property which is reported to have produced $200,000 in the following 5 years. The mine was leased to B. Brant of Silver Star in 1944, and to F. Starner in 1955. In 1955 J. Reid assumed complete ownership of the property.

The mine is developed by 4 adits, an intermediate level and several cuts and pits. An argentiferous galena fissure vein outcropping near the portal of No. 1 adit (fig. 14) strikes in a northerly direction and dips about 30° E. High-grade portions of the vein were stoped near the house. The vein contours the hill west of the portal of No. 1 adit. In the upper adit (fig. 15) the vein varies from one to 6/10 feet in width. It strikes N. 30° E and dips from 55° E. to vertical. The vein when entering Flathead beds, narrows to ¼ inch. A fault with right throw striking N. 30° W. displaced the vein 10 feet. About 300 feet northeast of the portal of No. 1 adit the vein splits into 3 or more parallel-trending segments which strike N. 40° E. and dip from 50° to 70° E. Three hundred and eighty feet from the portal a right-throw fault striking N. 10° W. displaces the vein about 4 feet. This fault may correlate with the structure in the upper adit.

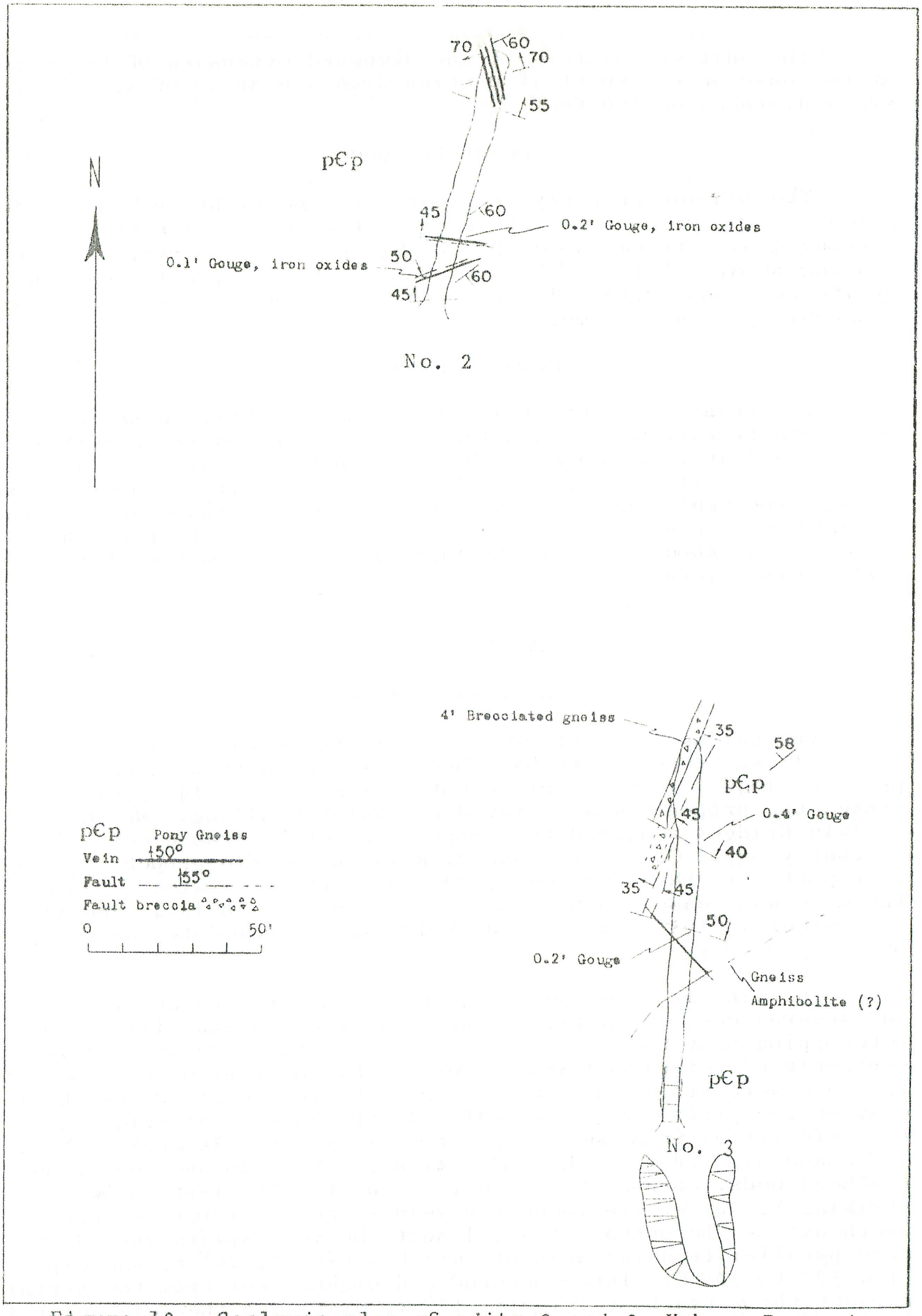

Figure 13.--Geologic plan of adits 2 and 3, Urbane Property, Madison County, Montana.

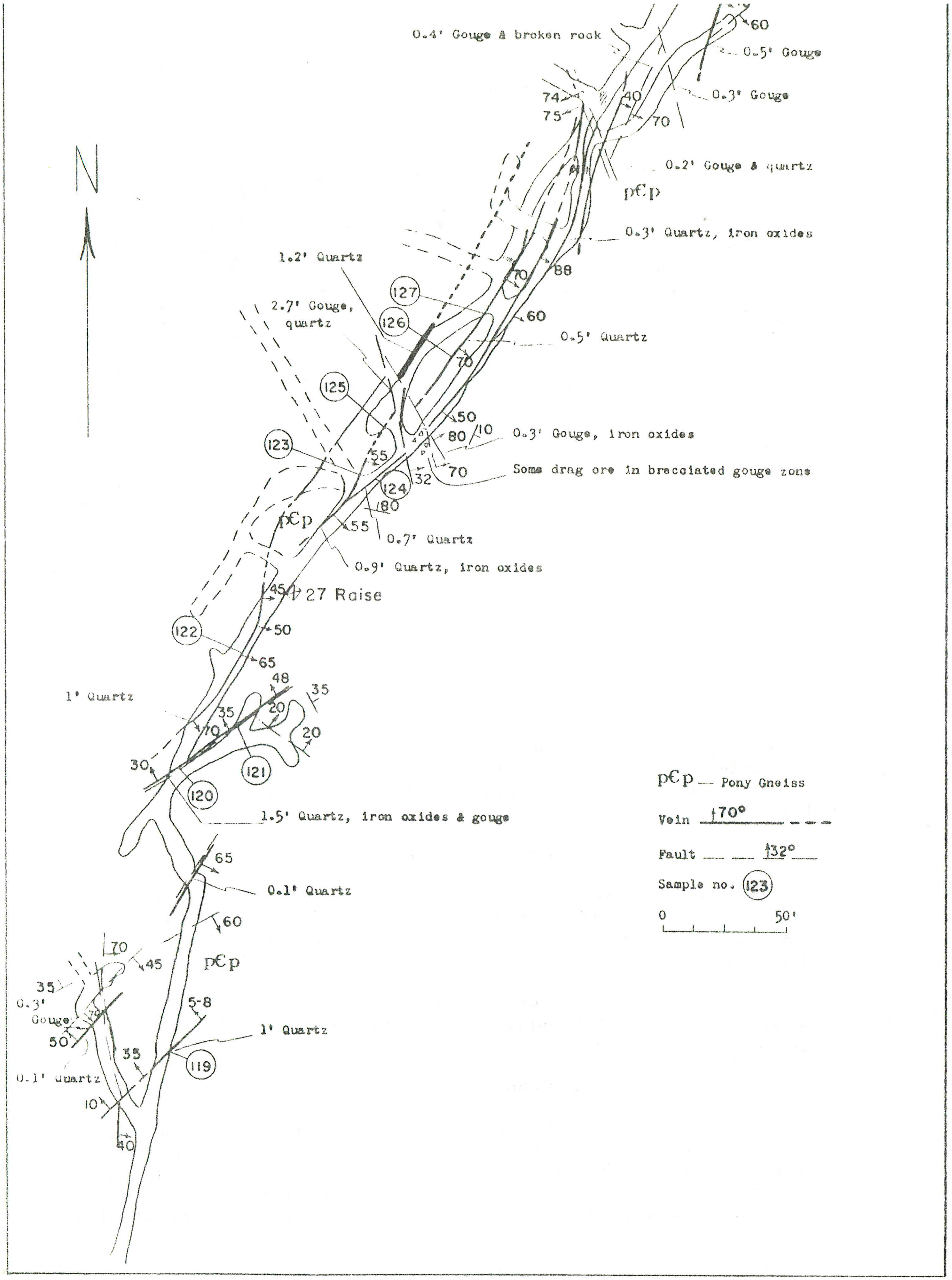

Figure 14.--Geologic plan of the No. 1 level of the High Ridge Mine, Madison County, Montana.

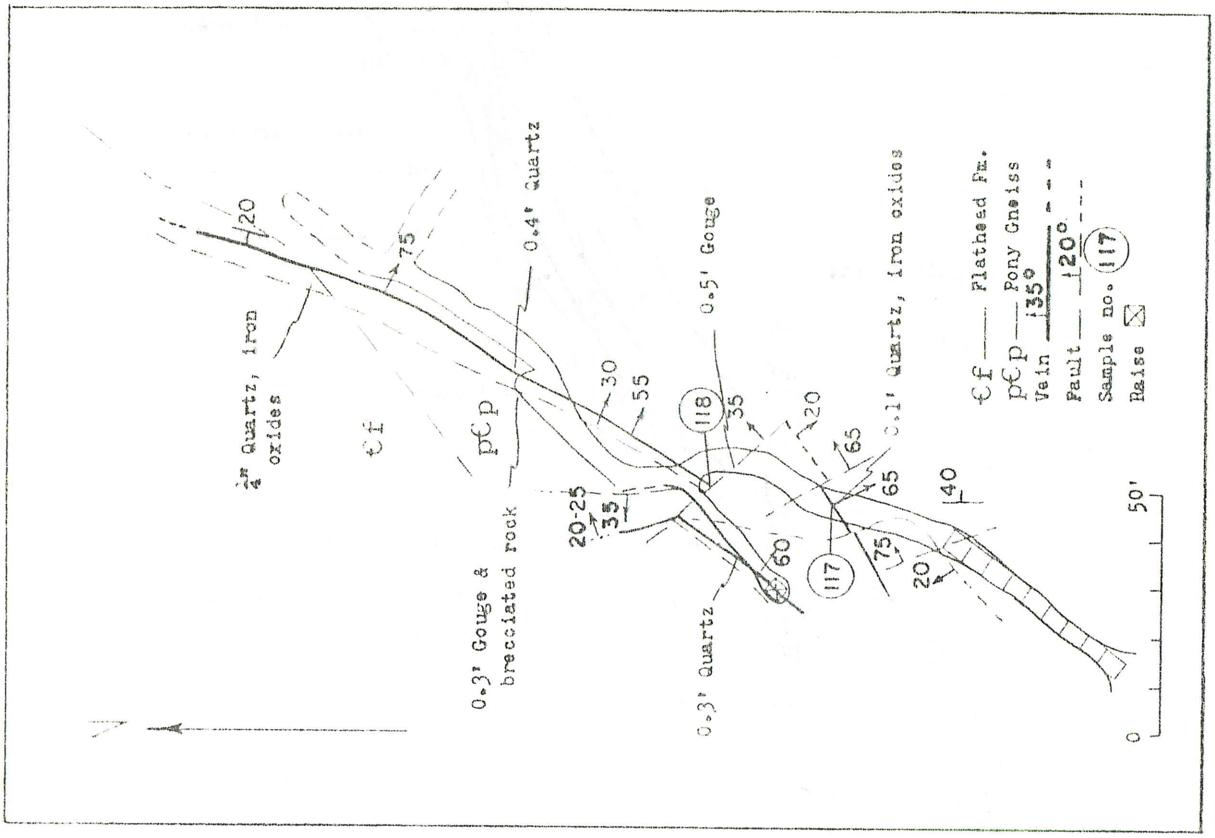

Figure 15.--Geologic plan of the upper adit High Ridge Mine, Madison County, Mont.

The segments of the vein contain quartz, native gold and silver. Major production from the mine came from the veins east of No. 27 raise. Between 1944 and 1950 the mine produced approximately 500 tons of ore. No production from the property has been recorded since 1950.

Corncracker Mine

The Corncracker fissure zone is in Pony Gneiss. The zone has been intensely altered and Hart (1933, p. 38) reports bands of auriferous pyrite several inches wide that strike N. 25° E. and dip 70° E. A gross production of $30,000 is reported prior to 1933.

The property is leased to Mr. Steiner of Missoula and Mr. Bugdon of Twin Bridges, Montana. Approximately 450 tons of ore were shipped between 1944 and 1950.

Bryzant Mine

The Bryzant property, formerly the Deutchland mine, operated during World War I and the late thirties. The fissure vein is in Pony Gneiss. It has been developed by an inclined shaft and numerous cuts and pits for a strike length of 1,600 feet. A 2-foot vein containing galena, sphalerite, iron oxides and quartz, strikes

N. 5° W. and dips 80° E. Wall rock has been moderately sericitized and kaolinized. A pillar at the surface assayed 38 percent lead. The property shipped 34 tons of ore in 1945.

Sunflower Mine

The Sunflower adits were not accessible. Hart (1933, p. 37) reports that the property is developed by 2 adits on a northeast-striking fissure vein displaced by a northeast fault. The vein contains argentiferous galena, gold, and sphalerite, and is about 2 feet wide. The property is owned by Mr. Turk and Mr. Rodman of Butte, Montana.

Main Street Prospect

The prospect on the ridge between the High Ridge and Ella properties in Meagher Limestone is developed by cuts and a short adit. Dump rock contained chrysocolla, malachite, quartz and iron oxides. No mineralization was found in the adit, a small discontinuous ore lense may have occurred as an irregular replacement body in limestone.

Cop Prospect

The Cop prospect in Pony Gneiss and Flathead Quartzite has been developed by several adits and a winze. High-grade ore was mined from the upper portions of the vein; however, the grade decreased with depth. Otto Krueger leased the property for a short period of time.

WET GEORGIA GULCH

Ella Mine

The Ella property located near the head of Wet Georgia Gulch is owned by B. Golden of Sheridan, Montana. The veins are in Pony Gneiss on patented and unpatented ground. A 4-inch vein striking northeasterly and dipping about 25° N. carries about an ounce of gold, 4½ ounces of silver and about 3 percent lead. The property was active during the summer of 1957.

Lone Star Prospect

This property is located near the head of Wet Georgia Gulch on the west slope of the canyon. Gus Heinz of Twin Bridges has recently relocated the property. The vein strikes N. 40° E. and dips about 35° N. The fissure vein varies from about 3 inches to 2 feet in width. The wider protions of the vein have been stoped out.

Dullea Prospect

The Dullea property is located near the head of Wet Georgia Gulch about one-half mile southeast of the Ella property. J. R. Dullea patented the ground in 1907. The mine was subsequently leased until the mid-twenties and has been inactive for the past 20 years.

Development work consists of several caved adits and one accessible adit and intermediate on the patented Rollette Lode. A brecciated quartz vein striking N. 20° E. and dipping 60° S. was intercepted at the face of the adit. An intermediate level about 100 feet above the adit is located on 2 parallel-trending galena veins striking about N. 20° to 45° E. and dipping 15° to 25° W. The quartz fissure vein at the adit face varies from 2 to 3 feet wide and appears to carry no values. The galena veins are 2 inches and $1\frac{1}{2}$ feet wide respectively.

Argenta Property

The Argenta property is located at the head of Wet Georgia Gulch near the Pony Gneiss-Flathead Quartzite contact. The property is developed by several adits which at the time of this survey were caved. Winchell (1914, p. 158) describes the ore as auriferous pyrite and galena in a quartz vein paralleling the footwall of an acidic dike in Pony Gneiss. The dike has a northerly strike and dips 15° W.

Heller Prospect

The Heller property is located about one-half mile above the mouth of Wet Georgia Gulch. Two fissure veins in gneiss are developed by a shaft and 3 adits. One vein developed by a shaft and several pits strikes N. 80° W. and dips 80° S. The other vein striking N. 55° E. and dipping 70° S. is developed by 3 adits. The vein varies from 1 to 2 feet wide and contains quartz, iron oxides and pyrite.

Other Prospects

A prospect near the center of sec. 35 (see sample no. 58 in Appendix) is developed by 2 adits on a 2-foot brecciated and mineralized zone. A dump sample of the ore assayed 35 oz. in silver and 0.04 oz. in gold. Native silver was identified in a polished section of the ore.

The Black Ace, developed by an inaccessible shaft, made small shipments in 1953 and 1954.

SUMMARY

Mineral deposits in the district occur in fissure veins in Pony Gneiss and Flathead and Wolsey beds as replacement bodies in

Meagher and Pilgrim Limestone, and as contact metasomatic deposits in Madison Limestone.

The greatest part of the production of gold, silver and lead has come from the leached zone. Gold and silver mineralization has been enriched through processes of oxidation.

Most veins in the district strike from a north to northeasterly direction. Northeast faults and some northwest faults have displaced veins from several feet to as much as 1,500 feet. The Argenta vein has been displaced by a northeast fault whose strike slip component is approximately 1,500 feet. Fissure veins in the district are associated with Precambrian and Late Cretaceous or early Tertiary dikes and sills. Replacement orebodies in limestone are irregular with little apparent structural control.

Contact metasomatic deposits are formed within and along contacts of a quartz monzonite stock with Madison Limestone. Large tonnage and marginal grade of orebodies are characteristic of this type of deposit.

The presence of Late Cretaceous dikes and sills associated with orebodies in the district and silicification of limestone in Bear, Goodrich and Dry Georgia Gulches suggest the presence of an igneous body underlying portions of the district at depth.

Important producers in the district during its early history were the Richmond, Crystal Lake, Carolina, Argenta, Ella and High Ridge properties. The increase in price of gold in the early thirties stimulated production throughout the district. The High Ridge, Eagle and Hummingbird properties in the Richmond group, and the Carolina, Corncracker and Ella mines were the major producers during this period. The High Ridge, Corncracker, Bryzant and the Black Ace properties have produced since 1944.

PRODUCTION

Production in the district prior to 1904 has not been recorded; however, Reyner (1947, p. 23) reports that for a 41-year period from 1904 to 1944, production in the district amounted to 51,088 tons of gold, silver, copper, lead and zinc ore valued at $1,210,000.

Production of ore from the district, according to the Minerals "Yearbook," from 1944 to 1955 inclusive, has amounted to 2,145 tons of ore valued at $70,575. Total production from the district from 1904 to 1955 amounted to 53,233 tons valued at $1,270,500.

Ore is shipped by truck or railroad to the American Smelting and Refining Company smelter at East Helena, to the International Smelting and Refining Company smelter at Tooele, Utah, or to the U. S. Smelting and Refining Company smelter at Midvale, Utah. Loading facilities for rail shipments are available at Twin Bridges and Silver Star on the Alder branch of the Northern Pacific Railroad.

CONCLUSIONS

Paleozoic sediments from Middle Cambrian Flathead Quartzite to Mississippian Madison Limestone unconformably overlie Pony Gneiss. A regional stress, oriented from a west to southwest direction, folded Paleozoic sediments into a broad syncline with smaller superimposed anticlines and synclines. Folded Paleozoic sediments may have extended over the Tobacco Root Mountains where subsequent erosion has exposed the Precambrian basement complex.

Three fault groups in the district trend northwest, easterly and northeasterly. Northeast faults displace the northwest faults. Northeast and easterly trending faults may be complementary shears oriented at an acute angle to the axis of compression. Northwest faults are approximately perpendicular to the axis of compression and parallel to the axial plane of folding. Thrust faults trend in a northwesterly direction, perpendicular to the deformative stress.

Fissure veins, replacement orebodies, and contact metasomatic mineralization occur in the district. Gold-silver and lead-silver mineralization occur in fissure veins, while silver-lead and copper mineralization are of replacement and contact metasomatic types. Abundant fissure veins occur in Pony Gneiss, while replacement and contact metasomatic-type bodies are found in limestone. Gold was deposited contemporaneously with sulfide mineralization. The gold content in sphalerite appears to be greater than that in pyrite.

Principal producers in the district were the High Ridge, Crystal Lake, Carolina, Richmond group, Corncracker and Ella mines.

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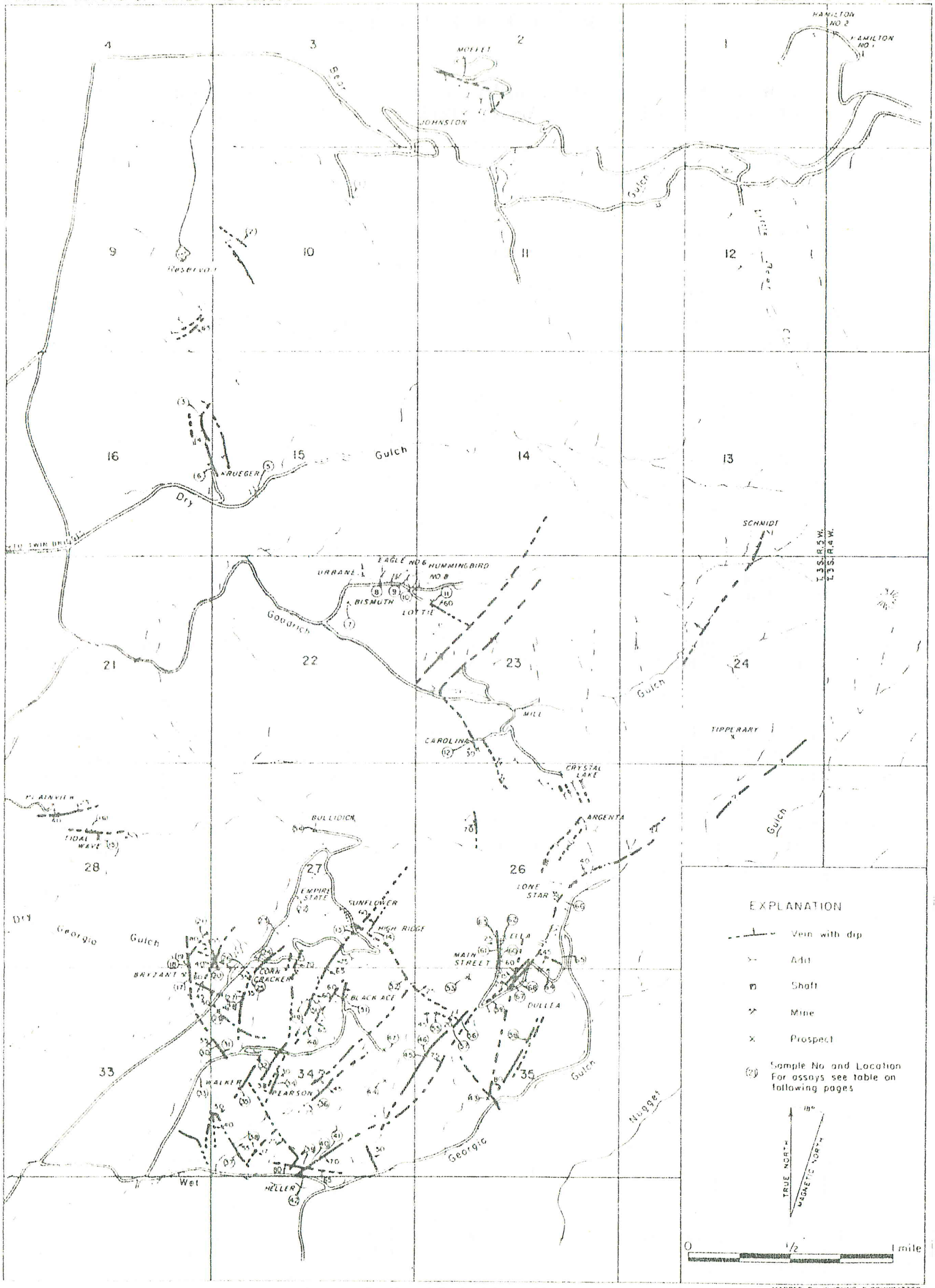

MAPPED BY W. JOHNS, D. SCHWEITZER

SURFACE ASSAY PLAN, SOUTHERN TIDAL WAVE DISTRICT, MADISON COUNTY, MONTANA

APPENDIX

Assays from Surface Veins, Mine Dumps, Ore Bins, and Underground Workings

Sample No.	Property	Location	Sample Width	oz/ton Au	oz/ton Ag	%/ton Cu	%/ton Pb	%/ton Zn	%/ton Fe
1	Bear Gulch Adit	$NE\frac{1}{4}$ sec. 10	0.2'	0.04	0.80	0.32	trace	trace	3.0
2	Surface Pit	$NW\frac{1}{4}$ sec. 10	---	0.04	0.10	0.30	trace	0.50	3.4
3	North Krueger Adit	$NE\frac{1}{4}$ sec. 16	0.3'	0.04	0.10	0.42	0.70	0.80	5.2
4	North Krueger Adit	$NE\frac{1}{4}$ sec. 16	0.9'	0.01	0.30	0.08	trace	0.50	3.2
5	South Krueger Shaft	$SW\frac{1}{4}$ sec. 15	0.2'	0.28	0.40	0.26	trace	0.50	2.8
6	Krueger Mine	$SE\frac{1}{4}$ sec. 16	---	0.02	2.70	0.14	2.50	trace	---
7	Bismuth Prospect	$NE\frac{1}{4}$ sec. 22	---	0.08	0.10	trace	trace	1.80	9.1
8	Richmond Eagle Mine	$NE\frac{1}{4}$ sec. 22	---	0.44	3.20	0.72	2.10	12.60	7.8
	Richmond Eagle Mine	$NE\frac{1}{4}$ sec. 22	---	0.76	0.80	0.74	0.40	8.30	21.7
9	Richmond Hummingbird Mine	$NE\frac{1}{4}$ sec. 22	---	0.16	0.20	0.08	trace	0.80	7.1
10	Richmond Adit No. 9	$NW\frac{1}{4}$ sec. 23	---	0.36	1.0	0.14	2.0	trace	4.2
11	Lottie Mine	$NW\frac{1}{4}$ sec. 23	---	0.24	24.0	0.28	1.0	3.20	6.6
	Lottie Mine	$NW\frac{1}{4}$ sec. 23	---	0.10	1.90	0.80	0.40	2.80	4.1
12	Carolina Mine	$SW\frac{1}{4}$ sec. 23	---	trace	0.10	trace	trace	0.50	5.8
	Carolina Mine	$SW\frac{1}{4}$ sec. 23	---	0.18	0.70	0.10	0.80	trace	9.0
13	High Ridge Mine	$SE\frac{1}{4}$ sec. 27	---	0.16	9.50	0.60	35.0	7.60	---
14	High Ridge Mine Adit No. 1	$SE\frac{1}{4}$ sec. 27	---	3.20	16.20	0.80	0.40	2.80	4.1
15	Tidal Wave Mine	$NW\frac{1}{4}$ sec. 28	---	.04	7.7	0.60	12.70	0.50	5.0
16	Tidal Wave Mine Center Adit	$NW\frac{1}{4}$ sec. 28	0.5'	0.01	0.70	0.24	0.60	0.80	7.4
17	Bryzant Shaft	$NE\frac{1}{4}$ sec. 33	---	trace	trace	0.06	trace	trace	9.5
18	Bryzant Stope	$NE\frac{1}{4}$ sec. 33	2.0'	0.08	2.0	0.08	38.80	3.0	3.0
19	Bryzant Stope	$NE\frac{1}{4}$ sec. 33	2.0'	0.005	0.10	trace	1.0	trace	2.2
20	Prospect	$NE\frac{1}{4}$ sec. 33	1.0'	0.16	0.10	0.10	0.50	0.50	9.3
21	Prospect	$SE\frac{1}{4}$ sec. 28	---	0.44	6.60	0.08	6.30	trace	11.3
22	Prospect	$SW\frac{1}{4}$ sec. 27	---	0.07	1.0	0.22	1.80	2.10	13.0
23	New York Prospect	$SW\frac{1}{4}$ sec. 27	---	0.25	1.0	0.20	0.50	trace	3.1
24	Cop Prospect	$SW\frac{1}{4}$ sec. 27	---	0.065	trace	trace	trace	0.70	10.0
25	Cop Prospect	$NW\frac{1}{4}$ sec. 34	---	0.09	0.30	0.14	0.50	0.50	9.0

APPENDIX.--Assays from surface veins, mine dumps, ore bins, and underground workings, (cont'd).

Sample No.	Property	Location	Sample Width	oz/ton Au	oz/ton Ag	%/ton Cu	%/ton Pb	%/ton Zn	%/ton Fe
26	Cop Adit 126' E. of portal	NW¼ sec. 34	0.1' 0.2'	0.04	0.10	0.12	trace	trace	---
	Cop Adit 103' E. of portal	NW¼ sec. 34	0.1'	0.05	0.10	0.08	trace	trace	6.3
	Cop Adit 81' E. of portal	NW¼ sec. 34	2.5'	trace	0.10	trace	trace	trace	6.7
	Cop Adit 54' E. of portal	NW¼ sec. 34	0.2'	0.01	0.10	0.04	trace	trace	6.5
27	Surface Vein in Pit	NW¼ sec. 34	0.2'	0.12	0.50	trace	0.50	trace	8.2
28	Surface Vein	NW¼ sec. 34	0.3'	0.22	0.10	0.10	trace	0.50	4.5
29	Rex Prospect	NW¼ sec. 34	---	trace	0.20	0.10	trace	trace	5.4
30	Fork Prospect Surface Pit	NW¼ sec. 34	---	0.56	0.20	trace	2.50	0.50	5.8
31	Fork Adit 10' from portal	NW¼ sec. 34	0.5'	0.01	0.10	0.10	0.50	trace	6.3
	Fork Adit 100' from portal	NW¼ sec. 34	3.0'	trace	0.10	trace	0.40	trace	3.6
	Fork Adit 100' from portal	NW¼ sec. 34	3.0'	trace	0.20	0.14	0.40	trace	3.2
	Fork Adit 130' from portal	NW¼ sec. 34	2.0'	trace	0.20	0.14	trace	trace	5.7
32	Surface Vein in Pit	SW¼ sec. 34	0.5'	trace	0.10	trace	trace	trace	7.2
33	Surface Float	SE¼ sec. 33	---	0.01	0.20	0.16	0.50	trace	2.2
34	Pearson Prospect	SW¼ sec. 34	---	0.38	1.20	0.28	0.50	trace	1.8
35	Surface Pit	SW¼ sec. 34	---	0.09	2.30	trace	trace	trace	4.5
36	Falcon Prospect	SW¼ sec. 34	---	0.32	0.20	0.10	trace	0.50	1.8
37	Surface Vein in Pit	SW¼ sec. 34	1.0'	0.04	0.20	trace	trace	0.80	1.6
38	Surface Vein in Pit	SW¼ sec. 34	2.0'	0.06	0.10	0.28	0.50	trace	4.0
39	Heller Adit on Hazel A Claim	SW¼ sec. 34	1.0'	0.04	0.10	trace	0.80	trace	2.0
40	Heller Adit on Hazel A Claim	SE¼ sec. 34	2.0'	0.04	trace	0.10	trace	trace	2.0
41	Heller Adit on Hazel A Claim	SE¼ sec. 34	1.5'	0.01	0.20	0.14	trace	trace	3.1
42	Heller Adit on Hazel A Claim	SE¼ sec. 34	1.0'	0.20	0.10	0.20	0.50	trace	8.5

APPENDIX.--Assays from surface veins, mine dumps, ore bins, and underground workings (cont'd).

Sample No.	Property	Location	Sample Width	oz/ton Au	oz/ton Ag	%/ton Cu	%/ton Pb	%/ton Zn	%/ton Fe
43	Surface Cut	SW¼ sec. 35	1.2'	trace	0.10	trace	0.40	trace	2.1
44	Surface Pit	SE¼ sec. 34	---	0.01	0.20	0.18	trace	0.05	8.3
45	Surface Cut	NW¼ sec. 35	---	0.16	0.60	trace	0.80	trace	6.5
46	Surface Vein	NW¼ sec. 35	---	0.96	2.60	0.08	0.80	0.50	8.0
47	Surface Cut	NE¼ sec. 34	0.2'	trace	trace	trace	trace	trace	3.6
48	Adit	NW¼ sec. 34	---	0.02	0.30	trace	0.80	trace	4.3
49	Adit	NW¼ sec. 34	---	0.70	11.60	trace	0.50	trace	14.3
50	Adit	NW¼ sec. 34	---	1.80	8.40	0.04	trace	trace	8.7
51	Black Ace Mine	NE¼ sec. 34	---	2.06	1.30	0.06	0.40	0.80	14.7
52	Adit (Vein sampled at face)	NE¼ sec. 34	0.5'	0.02	0.10	trace	0.80	trace	4.5
53	Main Street Prospect	NW¼ sec. 35	---	0.28	1.50	12.40	0.40	0.70	6.4
54	Bullidick Prospect	NE¼ sec. 27	---	0.24	0.20	0.10	trace	0.50	2.8
55	Caved Adit	NW¼ sec. 35	---	0.30	3.20	trace	5.20	0.50	9.8
56	Surface Pit	NW¼ sec. 35	---	0.72	4.0	0.12	4.0	0.50	18.0
57	Surface Vein	NW¼ sec. 35	1.0'	0.04	0.60	0.14	trace	0.50	5.2
58	Caved Adit	NE¼ sec. 35	---	0.04	35.0	0.24	0.50	0.50	6.2
59	Caved Adit	NW¼ sec. 35	---	0.005	0.20	0.06	trace	trace	7.8
60	Bismark-Nugget Caved Adit	SW¼ sec. 26	---	0.16	2.60	0.20	2.40	0.50	9.0
61	Vein Outcrop of Bismark-Nugget Gp.	SW¼ sec. 26	1.0'	0.14	0.70	trace	0.80	trace	6.7
62	Ella Mine	SW¼ sec. 26	---	0.02	1.60	trace	2.0	trace	6.5
63	Ella Mine 50' from portal at Junction	SW¼ sec. 26	0.5'	1.06	4.50	trace	2.80	0.50	4.3
64	Caved Adit	SE¼ sec. 26	---	0.84	2.80	0.18	1.30	0.50	23.1
65	Caved Adit	SE¼ sec. 26	---	0.50	3.20	trace	0.40	2.30	22.3
66	Lone Star Propsect	SE¼ sec. 26	---	0.42	9.60	0.20	28.40	1.50	10.0
67	Dullea Prospect Intermediate Level	NE¼ sec. 35	0.2'	0.08	0.10	0.50	0.50	0.08	8.0
68	Dullea Prospect Intermediate Level	NE¼ sec. 35	1.6'	0.06	1.1	trace	2.50	0.50	5.8

APPENDIX.--Assays of Underground Adits, Drifts, and Winzes

Sample No.	Property	Sample width in feet	Type	Oz. Au	Oz. Ag	% Cu	% Pb	% Zn	% Fe
69	Krueger Mine	0.2	normal	0.04	0.10	0.26	0.50	0.50	8.0
70	Krueger Mine	1.6	normal	0.08	0.30	trace	0.50	trace	4.6
71	Krueger Mine	1.6	normal	trace	0.10	trace	0.80	0.50	2.8
72	Krueger Mine	2.3	normal	0.16	0.50	trace	trace	0.50	5.0
73	Krueger Mine	2.3	normal	0.08	0.10	trace	0.50	trace	2.9
74	Krueger Mine	2	normal	0.28	0.10	0.10	0.05	trace	6.4
	Krueger Mine		selected dump sample	0.02	2.70	0.14	2.50	trace	---
75	Richmond Group Adit No. 4	1.0	normal	0.01	1.70	trace	trace	trace	2.1
76	Richmond Group Adit No. 4	1.7	normal	0.005	0.30	0.12	trace	trace	3.2
77	Richmond Group Adit No. 4	0.8	normal	trace	0.40	0.08	trace	trace	3.2
	Richmond Group Hummingbird Mine	---	dump sample	0.16	0.20	0.08	trace	0.80	7.1
78	Richmond Group Hummingbird Mine	0.1	normal	0.54	2.80	0.36	2.30	trace	14.7
79	Richmond Group Hummingbird Mine	0.1	normal	2.60	3.0	0.10	trace	trace	11.6
80	Richmond Group Hummingbird Mine	5.0	normal	0.01	0.10	0.10	trace	trace	---
81	Richmond Group Hummingbird Mine	0.1	normal	1.60	2.20	0.10	0.50	trace	9.9
82	Richmond Group Hummingbird Mine	1.5	normal	0.08	0.90	0.10	trace	trace	6.2
83	Richmond Group Hummingbird Mine	1.0	normal	0.01	0.10	0.06	trace	trace	4.5
84	Richmond Group Hummingbird Mine	4.0	normal	0.04	0.10	trace	0.50	trace	3.8
85	Richmond Group Hummingbird Mine	5.5	normal	0.06	0.10	0.10	trace	trace	---
86	Richmond Group Hummingbird Mine	6.0	normal	0.02	0.10	0.10	0.40	trace	5.3

APPENDIX.--Assays of underground adits, drifts, and winzes (cont'd).

Sample No.	Property	Sample width in feet	Type	Oz. Au	Oz. Ag	% Cu	% Pb	% Zn	% Fe
87	Richmond Group Hummingbird Mine	0.8	normal	0.05	0.10	0.08	trace	trace	2.9
88	Richmond Group Hummingbird Mine	2	normal	0.05	0.40	0.10	trace	trace	3.8
89	Richmond Group Adit No. 8	1.2	normal	0.01	0.30	nil	nil	nil	---
90	Richmond Group Adit No. 9	4.0	normal	trace	trace	0.12	trace	trace	3.90
91	Richmond Group Adit No. 9	0.75	normal	0.44	1.30	---	---	---	---
92	Richmond Group Adit No. 9	0.25	normal	0.28	0.10	0.12	trace	0.50	13.7
93	Richmond Group Adit No. 9	0.5	normal	0.04	0.40	0.06	---	---	---
	Lottie Mine	---	selected dump samp.	0.24	24.0	0.28	1.0	3.20	6.6
94	Lottie Mine	1.5	normal	0.45	2.10	trace	1.60	4.60	4.8
95	Lottie Mine	0.5	normal	0.20	1.60	0.22	0.40	1.50	3.0
96	Lottie Mine	1.0	normal	0.005	1.40	0.16	trace	trace	---
97	Lottie Mine	2.0	normal	0.32	1.70	0.26	1.0	1.2	8.0
98	Lottie Mine	1.0	normal	0.02	0.30	0.12	trace	trace	2.6
99	Lottie Mine	3.5	normal	trace	0.10	0.10	trace	trace	---
100	Lottie Mine	0.5	normal	0.005	0.20	0.06	trace	trace	---
101	Lottie Mine	1.5	normal	trace	0.10	trace	trace	trace	---
102	Lottie Mine	1.0	normal	0.10	0.40	0.08	trace	2.0	3.8
103	Lottie Mine	3.0	normal	0.03	0.30	0.06	trace	trace	---
104	Lottie Mine	1.0	normal	0.16	1.6	0.18	2.50	0.70	6.4
	Carolina Mine	---	ore bin sample	trace	0.10	trace	trace	0.50	5.8
105	Carolina Group Plate 14	---	dump samp.	0.32	0.10	---	---	---	---
106	Carolina Group Plate 14	---	dump samp.	0.32	0.10	---	---	---	---

APPENDIX.--Assays of underground adits, drifts, and winzes (cont'd).

Sample No.	Property	Sample width in feet	Type	Oz. Au	Oz. Ag	% Cu	% Pb	% Zn	% Fe
107	Carolina Mine	---	selected dump samp.	3.20	1.0	trace	trace	0.50	4.3
108	Carolina Group	---	selected dump samp.	trace	0.40	0.14	trace	0.50	4.5
109	Carolina Group	---	selected dump samp.	0.24	0.60	0.10	trace	trace	---
110	Carolina Group	---	selected dump samp.	0.06	0.60	0.12	---	---	---
111	Carolina Group	---	selected dump samp.	0.01	0.60	---	---	---	---
112	Carolina Group	---	selected dump samp.	0.42	0.30	trace	0.50	trace	4.5
113	Carolina Group	---	selected dump samp.	0.60	0.80	0.08	trace	trace	4.3
114	Plainview Adit	8.	normal	0.005	trace	trace	trace	0.50	6.5
115	Plainview Shaft	0.7	normal	0.03	11.20	0.24	30.40	trace	6.2
116	Plainview Shaft	1.5	normal	0.04	0.10	0.14	8.30	2.70	8.0
117	High Ridge Upper Adit	0.1	normal	0.04	0.10	trace	trace	trace	3.3
118	High Ridge Upper Adit	0.15	normal	3.40	8.40	trace	trace	trace	4.4
119	High Ridge No. 1 Adit	1.0	normal	0.05	0.80	0.06	3.70	1.3	2.6
120	High Ridge No. 1 Adit	1.0	normal	0.10	0.40	0.04	trace	trace	5.0
121	High Ridge No. 1 Adit	0.5	normal	0.06	1.20	0.40	0.50	3.70	5.3
122	High Ridge No. 1 Adit	1.0	normal	0.06	1.80	0.12	trace	0.50	1.7
123	High Ridge No. 1 Adit	0.6	normal	0.04	0.10	trace	trace	trace	1.8
124	High Ridge No. 1 Adit	0.6	normal	0.04	0.10	0.18	trace	0.50	2.0

APPENDIX.--Assays of underground adits, drifts, and winzes (cont'd).

Sample No.	Property	Sample width in feet	Type	Oz. Au	Oz. Ag	% Cu	% Pb	% Zn	% Fe
125	High Ridge No. 1 Adit	0.7	normal	trace	0.30	0.14	trace	1.10	5.1
126	High Ridge No. 1 Adit	1.0	normal	0.25	2.0	0.12	trace	trace	2.6
127	High Ridge No. 1 Adit	1.0	normal	0.57	6.6	0.08	trace	0.50	3.0
128	High Ridge No. 1 Adit	---	selected ore	3.20	16.20	0.80	0.40	2.80	4.1
129	High Ridge Lower Adit	0.1	normal	3.06	16.30	0.12	0.40	2.80	4.1