6-1-1951

The Elkhorn Mine of Jefferson County, Montana

David D. Walker

THE ELKHORN MINE
OF JEFFERSON COUNTY, MONTANA

by
David D. Walker

A Thesis
Submitted to the Department of Geology
in Partial Fulfillment of the
Requirements for the Degree of
Batchelor of Science in
Geological Engineering
(Mining)

MONTANA SCHOOL OF MINES
Butte, Montana
June 1, 1951

THE ELKHORN MINE

OF JEFFERSON COUNTY, MONTANA

by
David D. Walker

A Thesis
Submitted to the Department of Geology
in Partial Fulfillment of the
Requirements for the Degree of
Batchelor of Science in
~~Geological~~ Mining Engineering

MONTANA SCHOOL OF MINES
Butte, Montana
June 1, 1951

TABLE OF CONTENTS

Introduction..page 1

Character of the Land's Surface.....................................page 2

History...page 6

Early History to December, 1899: condensed from Weed 7/.......page 6

History of the Mine from 1900 to 1950...........................page 7

General Geology...page 11

Igneous Rocks...page 12

Sedimentary Rocke...page 14

Contact Metamorphism..page 17

Historical Geology..page 18

Structural Geology..page 19

Economic Geology..page 21

General Characteristics...page 21

Geologic Relations..page 21

Outcrops..page 22

North Ore Shoot...page 22

Main Ore Shoots...page 22

South Ore Shoot...page 23

Intermediate Ore Bodies...page 23

Footwall or Chamber Deposits....................................page 23

New Discoveries (Chamber Deposits)..............................page 24

Mineralogy..page 25

General Character of the Ore in the Main Shoots.................page 25

Occurrence of Ore in the Sofia Workings.........................page 26

Ore Minerals of the Elkhorn Mine................................page 26

Gangue Minerals of the Elkhorn Mine.............................page 28

Writers Observations on Minerals now to be Seen.................page 28

TABLE OF CONTENTS

Relation of Zinc and Lead Content to Silver Content............page 30

Conclusions...page 32

Bibliography..page 33

LIST OF FIGURES

Figure 1: Index map showing location of Elkhorn mine...............page 2

Figure 2: View of Upper part of Elkhorn in 1918 looking north, and showing rugged topography in the background.......................page 4

Figure 3: The Elkhorn Mill, 1918.................................page 8

LIST OF PLATES

Plate I: Lower Tailings Pond of Elkhorn Mill

Mill on Lower Tailings...........................following page 9

Plate II The Sofia Workings...........................following page 10

Plate III Geologic Map Of Elkhorn Area...................following page 11

Plate IV Stratigraphic Correlation Chart................following page 16

Plate V Geologic Map of Area Between Helena and Butte...following page 19

Plate VI Outcrop of Elkhorn Ore Body...................following page 22

Plate VII Map of Mine Workings..........................following page 23

Plate VIII Polished Sections of Sofia Ore.................following page 26

Plate IX A, IX B Specimens of Sofia Ore...................following page 29

Plate X Graph Showing Silver-Lead-Zinc Relation........following page 31

T H E   E L K H O R N   M I N E
O F   J E F F E R S O N   C O U N T Y,
M O N T A N A

by
David D. Walker

INTRODUCTION

In the mining industry there is an old saying that "An old mine, if it was a mine of large production, never dies". This is certainly true of the Elkhorn Mine of Jefferson County, Montana. In 1901, after yielding metals valued in excess of five million dollars, it was considered worked out. Since that time the mine has passed through the hands of several owners, none of whom have failed to realize a profit from it. Although at no time since its zenith did it ever regain its once great production, it did provide a livelyhood for those who worked it. Now with the American Smelting and Refining Company interested in it, perhaps it will once again become an important producer.

With this view in mind the writer has chosen the Elkhorn mine as the subject of a thesis to be submitted to the Department of Geology of Montana School of Mines in partial fulfillment of the requirements for the degree of Bachelor of Science in Geological Engineering.

In 1902 an extensive report of the mine and the surrounding district was compiled by Walter Harvey Weed, and Joseph Barrell 7/. The "Weed Report", as it has become popularly known, has served as a guide for practically all persons interested in the mine. Now with renewed interest, and with activity increasing, it is desirable to bring the Weed Report up to date.

The writer, by means of this thesis, hopes to present new information not previously published, and to point out new interpretations pertaining to ore occurrence.

The Elkhorn mine lies near the eastern edge of Jefferson County, about 20 miles southeast of Helena, and 35 miles northeast of Butte (See Figure 1).

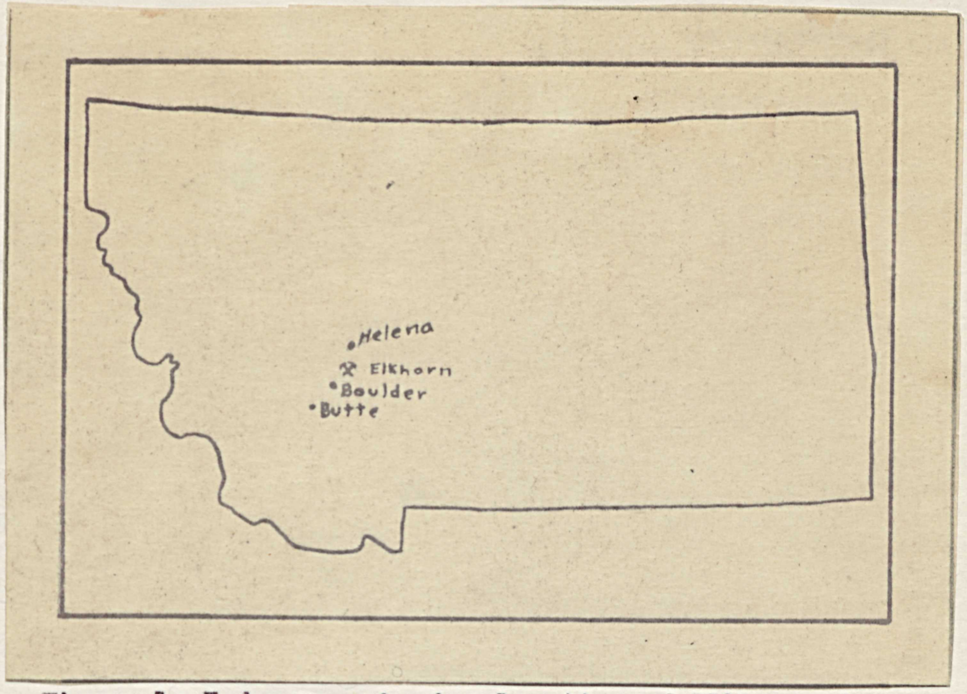


Figure 1: Index map showing location of Elkhorn mine.

The nearest shipping point is at Boulder, 18 miles by road, southwestward.

The town of Elkhorn and the mine may be reached from the town of Boulder, county seat of Jefferson County, by following the Boulder-Whitehall highway about 8 miles southeastward, then turning northward on a good dirt road in Elkhorn Creek Valley, and following it for about 10 miles.

The writer gratefully acknowledges the guidance of Dr. E. S. Perry of the Geology department and wishes to thank him for his cooperation and patience during this study. Thanks are also due to Dr. A. M. Hanson of the Geology Department for the use of his stratigraphic sections which appear herein.
Much of the information on the mining and geology as known prior to 1902 has been taken from the "Weed" report.

Special thanks are due Mr. D. C. Walker, who because of important ownership in the Elkhorn mine for 34 years, became very well acquainted with the mine, and passed much valuable information about the mine to the writer.

CHARACTER OF THE LAND'S SURFACE

The district, lying in the mountainous area of southwestern Montana, has a relief of about 3000 feet, and Elkhorn is 6570 feet above sea level. The steep slopes are soil covered, although good rock exposures are plentiful, and heavy pine timber is present on about one-half of the surface. Limestone areas are generally barren of timber, perhaps due to shallow soils or rapidly sinking water.

Figure 1: View of the upper part of Elkhorn in 1918 looking north, and showing rugged topography in the background.

Southwestern Montana has an annual rain fall of about 15 inches, but snow may accumulate at Elkhorn to depths of about 7 feet or more. The winters are long and rigorous, temperatures commonly reaching 10 to 20 degrees below zero. The annual mean temperature is about 42 degrees.

The town of Elkhorn, with a population of about 600 in the 1890's, but now supporting no more than a dozen families, lies near the head of a high mountain valley where a sudden broadening of the valley occurs. Elkhorn Creek in its lower reaches is almost canyon-like, but in its upper reaches spreads broadly into a plateau area interupted by mountain peaks. The scenery is rugged, and the view from the town is a broad one, including a mountain range in the background. The town itself is built upon a steeply sloping boulder apron, which is the front of a glacial moraine deposited in the upper valley of the creek.

HISTORY

(Early History to December, 1899: condensed from Weed 7 /.)

The Elkhorn Mining District was prospected during the 1860s, but extensive development did not begin until the late 1870s when ore was produced from a claim known as the "A.M.Holter". The original owners, who sold the mine to A.M.Holter in 1883, had errected a 5-stamp, wet-crushing, free-milling amalgamation plant with which they had obtained results satisfactory to them. As depth increased, however, "the oxidized ores became refactory and the loss in treatment amounted to as high as 50% of the silver values. In 1881 the mine had been developed to a depth of 300 feet, and the nature of the ore made it evident that a new mill would have to be erected and chloridization adopted. (7:411). During the year of 1882 the mill was idle for the greater part of the time. In 1883 Holter took over the mine, and organized the Elkhorn Company. A 10-stamp chloridizing mill with a capacity of about 11 tons a day was built. This resulted in a saving of 90% of the values in the ore, and in a bullion product aggregating $188,375 in silver and $2, 320 in gold for the first ten months after installation. The bullion produced 900 fine in silver with a little gold; the principle impurity being copper. "The Old Elkhorn Company increased its battery of stamps to 20, then to 25, and worked the mine down to the 80 foot level where lean ore was encountered." The company,not being sure whether or not the property was worked out, sold it in 1888 to an new company organized in London, England. A man by the name of Henry Bratenover acted as the mediary in this transaction. The new company kept the name of the old company, remodeled the mill, and began active development and mining which resulted in the production of 6,500,00 ounces of silver and 5,000 of gold between the years 1888 and 1900. The mine was in continuous operation from 1884 to 1900 except for a short interval of a few months when broken pumps resulted in flooding of the 500-foot level. This property is the only large mine which has operated in this district.

"In 1896 the ore in sight was nearly exhausted, and preparations were made to abandon the mine; but Mr. Walter S. Kelly (the manager) by careful exploration work disclosed new ore bodies and continued to work the property until December 1899. In the autumn of 1899 it became apparent that the expense of pumping, which necessitated heavy fuel bills, combined with the small extent and low grade of the ore in sight, would not watrant further operation of the mine. The cost of ore extraction had steadily risen during the last few years until in 1898 it reached a total of $15.60 per ton, while the expense of milling increased to $9.05 per ton. It was therefore decided to close down the property and abandon it. However, the closing down of the mine,in 1899, did not mean it would not produce again.

History of the Mine from 1900 to 1950

The following information comes orally from Mr.D.C.Walker of Elkhorn, Montana. The mine remained idle for the next two years, and then was bought in 1901 by J.Henery Longmaid for $18,000. He acquired the Sofia claim lying adjacent to, and south of the Elkhorn property, formed the Elkhorn Silver Mining Company, and then turned the entire property over to this company for $25,000. From 1901 until the summer of 1912 the Elkhorn Silver Mining Company operated the mine, but was forced to shut down owing to low silver prices, higher zinc content of the ore, and increased operating cost.

Longmaid found that the old system of salt roast was very ineffective on the highly refractory ores, and caused too high an operating expense to warrent use of it. He solved this problem by using straight gravity concentration by means of jigs and tables which produced a larger extraction at a greatly reduced cost. This improvement of milling methods, together with improved mining methods, cut his operating costs to about $7.50 per ton, which was a very great improvement over the cost of $25.10 per ton that the Old Elkhorn Company had been paying. This also enabled him to mine and mill ores of a much lower grade than the Old Elkhorn Company had been able to use. Longmaid followed a method of mining remnants of ore called "bone picking" by the miners, and did very little exploratory work. He mined mainly ore that his predecessors had been unable to handle. He did, however, discover in the foot wall some new deposits of large extent and good value.

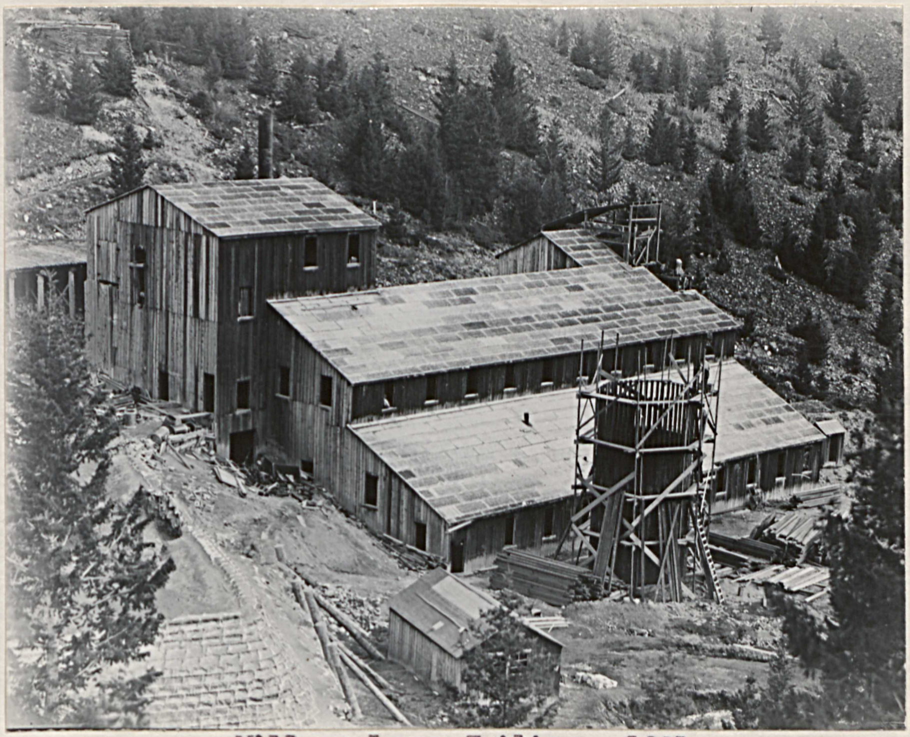
Figure 3: The Elkhorn Mill, 1918

Also, he followed the usual procedure of shipping the higher grade ores to the smelter without milling. Altogether, high grade ore and products of milling yielded 4,000,000 ounces of silver and much lead and zinc.

From 1912 to 1916 the mine and mill lay idle, and eventally the equipment, except that which had no immediate value, such as old pumps and boilers, was sold. In the summer of 1916 the property was purchased by Henningson, Stackpole, and Walker for $25,000. These owners, shortly afterpurchasing the property, shipped about 6,000 tons of tailings to the smelter at East Helena during the good price of silver caused by the First World War. In August, 1921 a cyanide plant and mill was put into operation on the lower tailings piles. It operated profitably until 1923, but then shut down because of a new low price for silver; about 332,112 ounces of silver were produced during 16 months of operation. Virtually nothing more was done on the tailings or the mine until 1928 when a sub sidiary of the Ardsley-Butte Mining Company of Butte, Montana, under local management, of Lyman Carlston, abtained a lease and Bond on the propert y. This company confined their work to cleaning out, deepening, and enlarging the shaft 300 feet south of the Elkhorn shafts on the Sofia claim. At a depth of 100 feet they drove cross-cuts easterly and westerly, encountering in both cross-cuts stringers of ore about 75 feet from the shaft. Following up these stringers, they were led to footwall chamber deposits about 70 feet from the shaft cross-cuts. The ore deposits to the west of the shaft, about 25 to 30 feet long, 12 feet in width, and 15 feet in thickness was of a good quality suited both for shipping and milling. The hanging wall had not yet been exposed. The ore shoot to the east of the shaft was of about the same length as the one to the west, but it was only 7 feet wide, and seemed to be of lower value at that point. This work was pursued in spite of the price of silver dropping to 25 cents per ounce. When the "crash" of 1929 came it forced the closing of the entire operation.

In 1935 a lease was given to A.F.MacLeane of Spokane, Washington on the remaining tailings. Mr. MacLeane assigned his lease to the Elkhorn Metals Incorporated which was under the general management of Mr. MacLeane,

Lower Tailings Pond of Elkhorn Mill As They Appeared in 1921



Mill on Lower Tailings, 1921

and under the local management of Rowland King. This company built a 200-ton flotation mill and operated it until the summer of 1937. It produced 16,237 ounces of silver and 2496 tons of concentrates averaging 53 ounces per ton in silver. A mandatory drop in the price of silver destroyed the chances of a profit and forced them to shut down. Once again the Elkhorn property was idle and it remained so until the spring of 1942 when a lease on the entire property was given to Mr. Stuart McKee who shipped no ore and confined his operations to installation of equipment at the Sofia shaft for hoisting, pumping and air compressing. Mr. McKee subleased the tailings to Mr. Mastin Taylor who shipped 62,116 tons of tailings to the American Smelting and Refining Company at East Helena, from 1942 to 1951. The tailings supply is now almost depleted. The low-grade tailings material, containing much silica, was needed by the smelter to balance furnace charges.

In 1945 Mr. Wade V. Lewis of Boulder took over Mr. McKees' lease on the mine workings. Mr. Lewis pumped the Sofia shaft dry, and continued the eastern crosscut to where it intersected the workings of the big mine. He is also driving a drift on the 400 level toward the Keene property north of the Elkhorn mine in the hope of encountering more deposits in that locality. Also Mr. Lewis has sunk an exploratory winze about 100 feet deep on the westerly crosscut, 50 feet from the Sofia mine shaft.

In the summer of 1949 Mr. Lewis interested the American Smelting and Refining Company in the mine, and a lease is being negotiated between the company and the owners. Plans are made to start exploration work at some date subsequent to the final signing of the lease. To January, 1951, Mr. Lewis has shipped 6,118 tons of crude ore to the smelter at East Helena.

The Sofia Workings, 1929

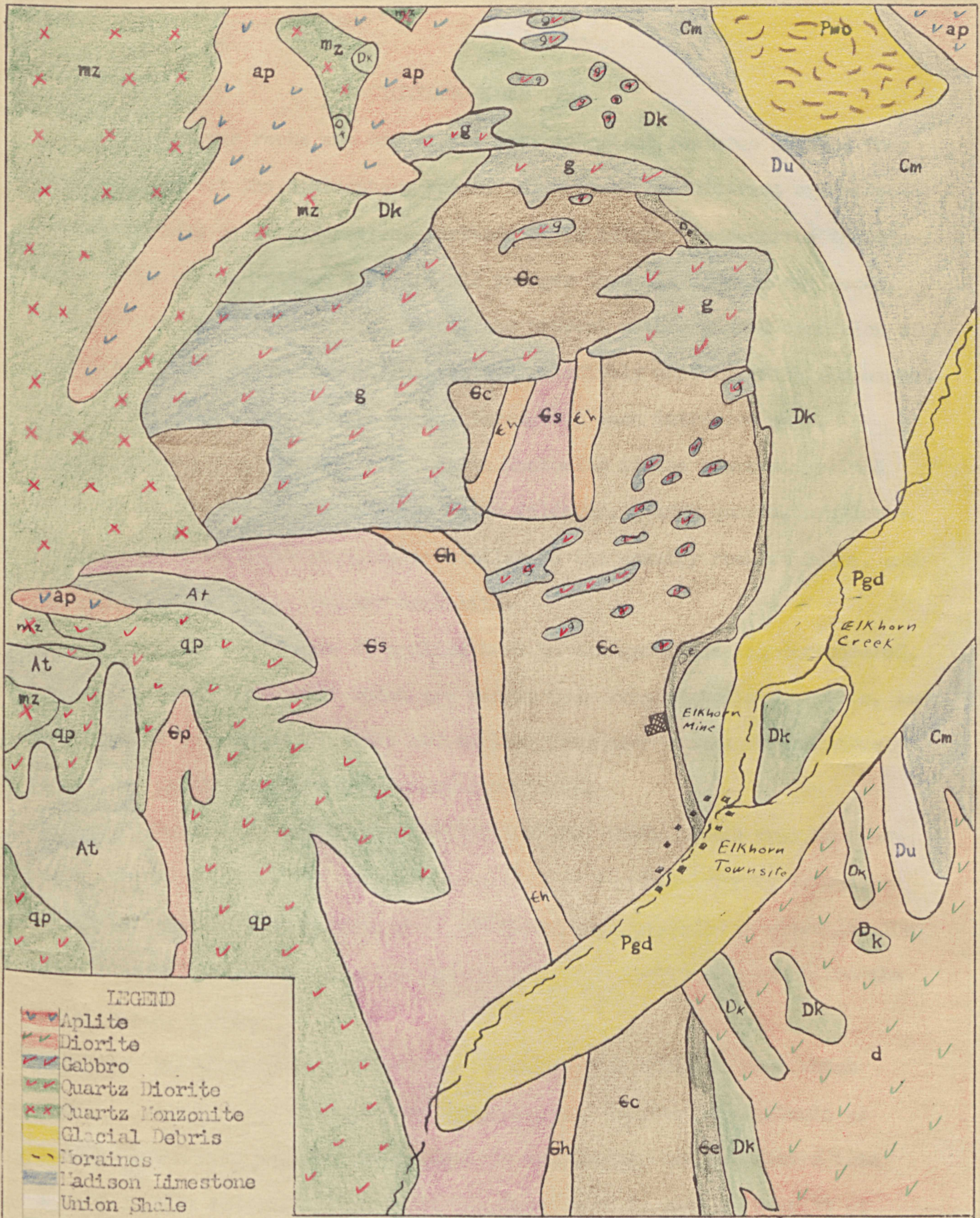
The Sofia Workings, 1949

GENERAL GEOLOGY 7/

The Elkhorn district lies at the eastern margin of the Boulder batholith, an intrusive granitic mass 25 by 75 miles in extent. Rocks bordering the batholith, in this locality, are folded and altered limestones, sandstones, and shales of Paleozoic age. They comprise the long ridges lying east of Elkhorn. A large variety of rock formations and rock types are present and, although the district covers but a small area, evidence of a long series of profound disturbances can be found within it. The Elkhorn region is excellent for geological studies of many kinds.

The sedimentary rocks are so metamorphosed locally that their original characteristics may be obscured. However, the sedimentary origin is apparent, and the attitude of the beds can be made out. The sequence of formations observed here is similar to, or the same as, that in adjacent regions. The sedimentary rocks embrace a part of the pre-Cambrian Belt series, together with practically all of the paleozoic formations of Montana; and Mesozoic strata are present one to three miles east of Elkhorn. The Tertiary lake deposits do not occur in this district, but are found a few miles to the south.

The igneous rocks, intrusive into the sediments, range from gabbros and diorites which are oldest, to aplitic granite which is youngest; and andesitic lavas comprise a large part of the Elkhorn mountains two to five miles northeast and east of the district. The ore deposits, essentially replacements of dolomitic Cambrian limestones, are related to the contact processes accompanying the intrusions, and are thought to be late Cretaceous or early Tertiary in age.



LEGEND

- Aplite
- Diorite
- Gabbro
- Quartz Diorite
- Quartz Monzonite
- Glacial Debris
- Moraines
- Madison Limestone
- Union Shale
- Keene Limestone
- Cemetery Limestone
- Hobo Gulch Fm.
- Starmont Limestone
- Elkhorn Shale
- Alpreston Quartzite
- Turnley Hornstone

GEOLOGIC MAP OF ELKHORN AREA
Jefferson County, Montana

After U.S.G.S. Report No. 22

Scale 1" —— 1000'

IGNEOUS ROCKS 7/

The igneous rocks are one of the most important features because they underlie and cut the sedimentary rocks, and west of the district are wide-spread in outcrop at the present surface. It is helpful to describe the igneous rocks first, because they are all younger than the sedimentary rocks, and because their intense heat caused the present metamorphosed condition of the sedimentary rocks. The intrusives are relatively uniform, with the exception of the Gabbro and diorite rocks, throughout each intrusive mass.

Quartz Monzonite (Granite): The Quartz Monzonite is the coarsest grained rock in the district, and contains white feldspar, glassy quartz, dark hornblende, and dark brown mica. It is similar to the country rock at Butte, and throughout much of the Boulder batholith.

Aplite-Granite: This name is applied here to designate the lighter colored, sugary textured "granites" which are nearly free from augite and biotite, and which occur as pegmatitic dikes and smaller intrusive bodies in the normal rock. The aplite weathers into rounded surfaces.

Gabbro: The Elkhorn gabbro, a dark, bluish-gray rock, ranges from anorthosites to pyroxenites. The most basic variety is distinguished by irregular grains of augite and magnetite in a felted mass of labradorite crystals. The gabbro occurs in small intrusive masses, the largest of which is called the Black Butte, stock.

Diorite: The diorite is a fine-grained, dark-gray, plutonic rock which closely resembles the fine-grained gabbro. Fresh diorite is difficult to locate as the rock is very susceptible to weathering, and decomposes into a soft friable material. When found the fresh rock is seen to consist of feldspar, hornblende, and augite crystals embedded in a matrix of white calcite.

Quartz-Diorite-Porphyry: This rock is distinguished by phenocrysts of plagioclase in a groundmass of fine grained quartz diorite. It covers a large part of the southwest section of the district, and forms talus-covered slopes. Good exposures are rare because the surface in this locality is obscured by vegetation.

Andesites: The original character of these rocks has been greatly masked. In general they range from light to dark gray in color, and from microcrystalline to porphyritic in texture. The rocks are readilly disintegrated and on slopes of the higher peaks long rough piles of blocky talus develop. They may be both intrusive and extrusive in origin, and their great thickness indicates a long period of vigorous volcanic activity.

Diorite-Porphyry: This rock may be found in the extreme southwest corner of the district. It is a fine grained rock possessing a crystalline texture with a spotted appearance, but otherwise of uniform character. Dark clusters of hornblende and biotite in the gray groundmass give rise to this spotted appearance.

SEDIMENTARY ROCKS 2/ 4/ 7/

The stratified rocks cover a relatively small part of the district, and their normal characters have been in a large part obliterated locally by the metamorphism they have undergone. The altered strata are traceable eastward or southward into corresponding unaltered strata. "The rocks are all tilted and dip easterly at angles from 30° to 55°." Lithologic distinction and subdivision are difficult in the area of metamorphism, and sometimes impossible to make from hand specimens alone. The rocks have been divided into lithologic units and correlated with the beds in near-by parts of the state, although a different set of local names has been used. Descriptions of the various formations follow:

Pre-Cambrian (Late Proterozoic)

Turnley Hornstone: The Turnley hornstones are the oldest strata in the region, and correspond in age to the Spokane shale of the Belt series, to which they are similar in appearance and composition. The lower, basal beds are about 200 feet thick, and weather to a good soil. About 200 feet of quartzitic hornstones overlie the basal beds, thus making a total thickness of not less than 400 feet in this locality.

Alpreston Quartzite: This formation is a white, altered, and indurated sandstone or quartzite about 125 feet thick. It is well exposed and may be correlated with the Flathead quartzite of middle Cambrian age.

Starmont Limestone: This formation, equivalent to the Meagher limestone, was named by Weed from exposures found at the Starmont mine. A granite-porphyry intrusion separates it from the Alpreston quartzite. The formation consists of two members, the lower being made up of 250 feet of light-gray easily-weathered limestone. The upper member comprises 350 feet of bluffforming, weather-resistant, relatively pure limestone. The total thickness of this formation is about 600 feet.

Hobo Gulch Lime-Shale: This formation lies conformably between the Starmont limestone and the Cemetery limestone. The lowest member, corresponding to the Park shale, is an 18 foot shale member. Another member of black limestone, nearly 100 feet thick, topped by a 35 foot band of "crinkled" limestone comprises the remainder of the formation. The limestone horizons correspond to the lower portion of the Pilgrim formation. Total thickness of the formation is about 155 feet thick.

Cemetery Limestone: This limestone occurs at Elkhorn cemetery and derives its name from that place. It's total thickness is approximately 650 feet. There are several members: The lowest of which consists of 70 feet of a blue limestone; the next above, 50 feet in thickness, is a dark-blue limestone; the third member is made up of several hundred feet of light-blue limestone; the top 200 feet includes a white or light-gray limestone having a crystalline granular texture. The Cemetery dolomite-limestone at Elkhorn corresponds to the Pilgrim dolomite found in the rest of the state. Most, if not all, of the ore deposits lie in this formation.

Elkhorn Hornstone: "The Elkhorn hornstone", which is correlated with the Dry Creek shale, is about 40 feet thick as measured from exposures in the Elkhorn mine. It is particularly important because it appears to be a "cap rock" for the ore deposits. It consists of thin-bedded dense quartzites and fine-grained calcareous shales much indurated.

Devonian

Keene Limestone: Ordovician and Silurian strata are absent in this area, and Devonian strata overlie Cambrian strata. The Elkhorn hornstone is overlain by the Keene limestone which corresponds to the Jefferson formation.

The Cambrian Yogo formation, which may possibly be included in the Keene formation, consists of 500 feet of poorly exposed limestones. The basal beds are blue gray, and the upper beds are of a lighter color and are of a more thickly bedded character.

Union Shale: The Union shale is an easily recognizable formation. It compares in age to the Devonian Three Forks shale, and is about 130 feet thick. The bottom or basal member is a band of black shale 30 feet thick. The upper member is a siliceous limestone about 100 feet thick.

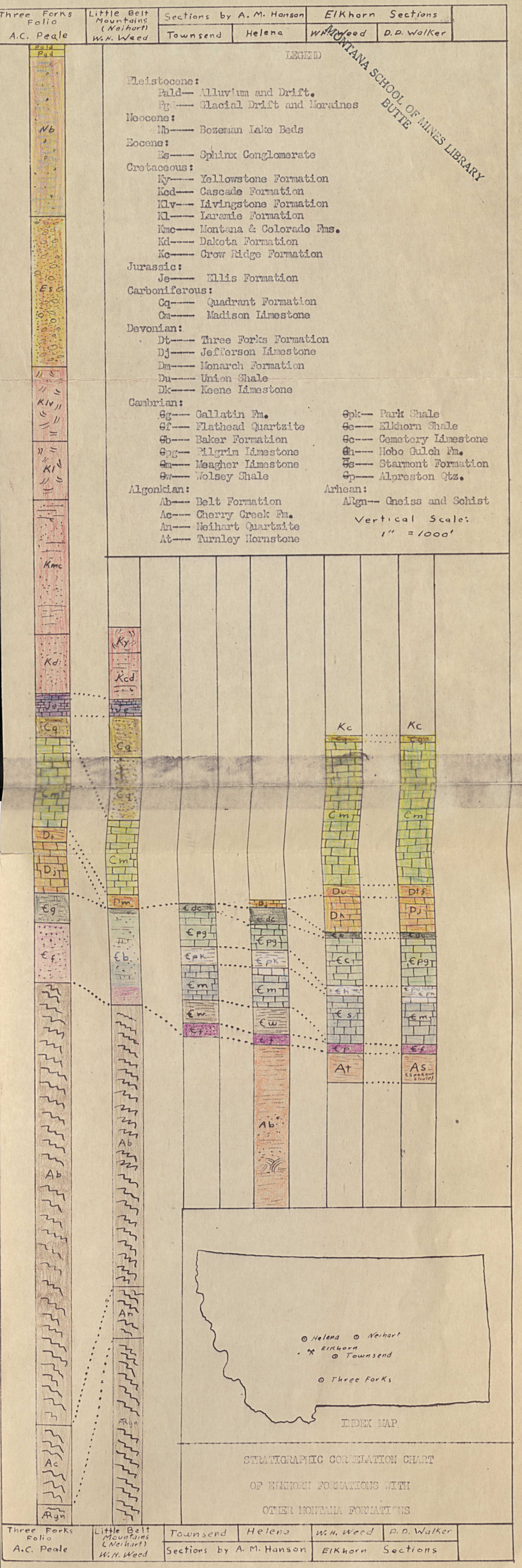
Carboniferous

Madison Limestone: This great limestone series is similar to the Madison in the rest of the state. It is very distinct, and in the Elkhorn region reaches a thickness of about 2000 feet. The lower half, comparing to the Lodgepole series, is dark-colored and argillaceous. The central portion is a cliff-forming pure white limestone. The upper beds are blue limestones with cherty seams. The central and upper parts probably correlate with the Mission Canyon series.

Quadrant Formation: This formation, composed of relatively pure pinkish quartzite, is very similar to the Quadrant in the rest of the state. Its thickness here is about 380 feet.

Mesozoic

Crow Ridge Formation: All the Mesozoic rocks in the area were classified by Weed under this name because of the difficulty to differentiate between the Jurassic and Cretaceous series. The totalthickness of the series is not known. These strata lie on the outskirts of the district and are not associated with valuable mineralization.



STRATIGRAPHIC CORRELATION CHART
OF ELKHORN FORMATIONS WITH
OTHER MONTANA FORMATIONS

CONTACT METAMORPHISM 7/

Shortly before Paleocene time the sediments and lavas of the Elkhorn district were intruded by bodies of liquid magma related to the Boulder Batholith. The intense heat of these intrusions caused thermal metamorphism and alteration of the sediments. Noticeable physical changes took place in the sediments. The pure limestones were bleached and converted into white marble; impure limestones became harder, more closely grained, and different in color. Sandstones were altered to quartzites. Shales and argillites were altered into hornstones; hard dense rocks having a conchoidal fracture.

The metamorphism also caused rearrangement of the individual grains and crystals forming the various rocks, and minerals causing new chemical compositions to form. However the typical contact metamorphic minerals, such as garnet and diopside, are in such fine grains, and the rocks are so massive and compact that these minerals are not conspicuous, and they may be difficult to recognize.

HISTORICAL GEOLOGY

The first sediments laid down in this area were those of the Pre-Cambrian Turnley formation. Marine sedimentation continued through Paleozoic and most of Mesozoic time, although long interruptions caused many gaps in the complete sequence. Late Mesozoic time (Cretaceous) ended with the laying down of a great lava series; this was followed by the Laramide orogeny. The entire sequence of folded strata and lava was then intruded by various bodies of molten material, now to be observed as quartz monzonite, diorite, gabbro, and other types. The mineralization is believed to have been closely associated with the intrusions, but probably occurred at a slightly later time, the ore-bearing solutions entering the adjacent rocks as an aftermath of the intrusions. During early Tertiary time erosion exposed the ore bodies.

Glaciation: In pleistocene time glaciers formed in the amphitheaters of the Elkhorn mountains and later moved down the upland valleys, where they left piles of glacial debris and moraines. The Elkhorn district was never covered by a great ice sheet, and the glaciers were of the local alpine type. A definite contrast may be noted between glaciated and unglaciated valleys. The soil of the glaciated areas is poor, very bouldery, and occasionally swampy, whereas the soil of the unglaciated areas is firm and lighter in color.

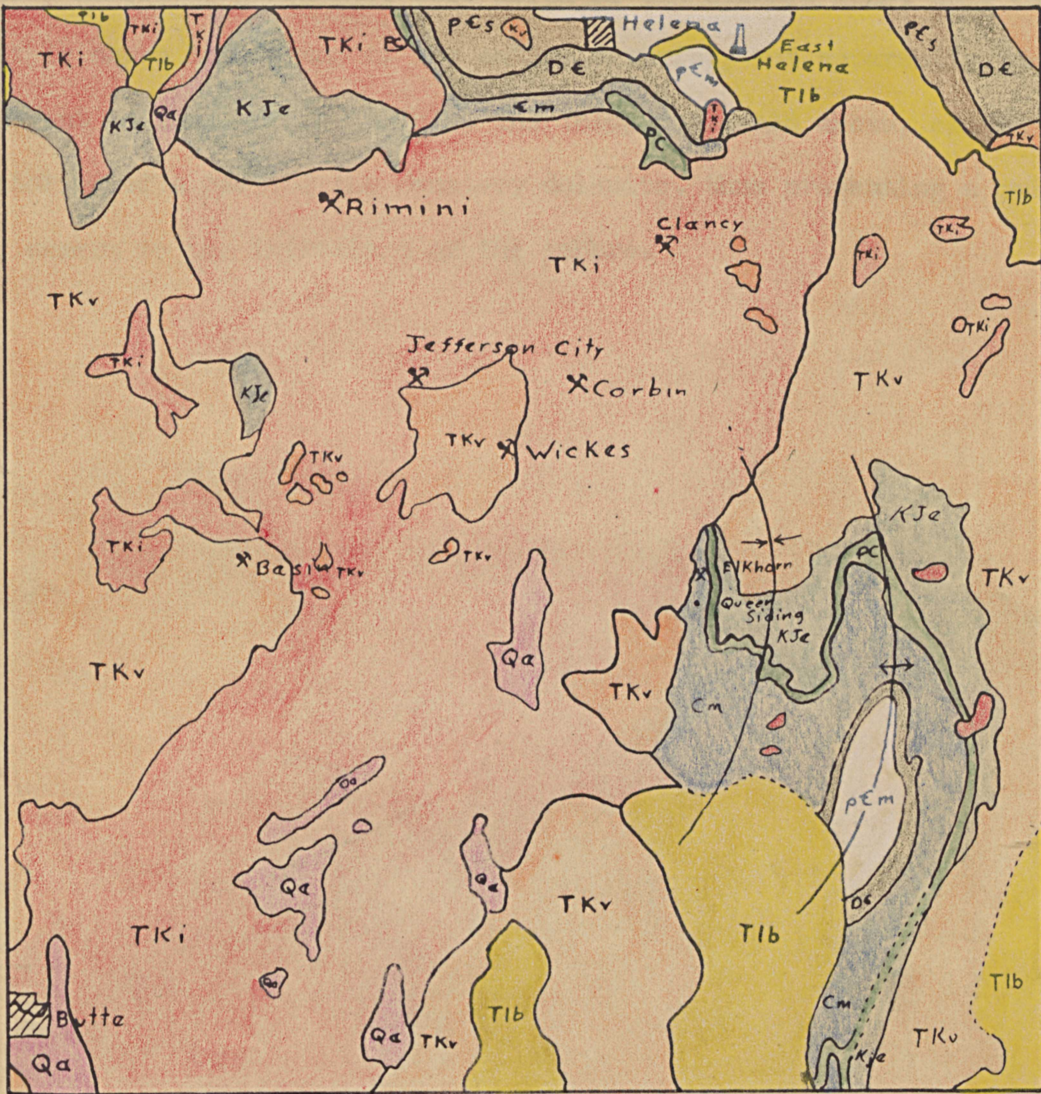
STRUCTURAL GEOLOGY 7/

The Elkhorn district and the surrounding territory is a region in which the rocks are sharply folded, but in the district itself the topographic relief does not reflect the geologic structure.

A large syncline, about 12 miles long and 5 miles wide, trends northerly about three miles east of the town of Elkhorn, and an anticline of about the same size, and with the same trend, lies three or four miles further east. Rocks of the Boulder batholith just west of Elkhorn cut off the sedimentary series to the west. Upper Cretaceous rocks lie in the trough of the surface syncline and Pre-Cambrian rocks of the Belt series are exposed on the crest of the anticline, a stratigraphic sequence embracing approximately 5500 feet of strata. The mines lie on the western limb of the large syncline near the margin of the intrusive rocks where the general eastward dip of the strata ranges from 30 to 55 degrees.

The larger folds are modified by small open folds or flexures which,at the mines,strike northeasterly. These flexures are so slight in the mining district that they are scarcely noticeable, but they appear to have influenced the upward circulation of the solutions, and hence may have an important bearing on the localization of the ore deposits. According to Weed "The ore deposits occur in two of these lesser flexures, which coalese near the surface to form one relatively broad arch." (7:472) on the west limb of the large syncline mentioned above.

Large scale faulting is not known to be present in the district. Small faults are mentioned, and although they do not appear to have displaced the Elkhorn ore body, they may be responsible for brecciation in the adjacent Sofia ore bodies. Weed describes a small fold merging into a fault which



GEOLOGIC MAP OF AREA BETWEEN HELENA AND BUTTE, MONTANA

Scale 0 Miles 10

After Geologic Map of Montana, 1944

Legend

Qa	Recent Alluvium
Tlb	Tertiary Lake Beds
TKi	Intrusives
Tkl	Livingstone Volcanics
Tkv	Undifferentiated Volcanics
Kje	Kootenai through Ellis
PC	Permian and Carboniferous
DЄ	Devonian through Cambrian
pЄm	Missoula group
pЄs	Siyeh group
Cm	Carboniferous madison limestone

crosses Alpreston gulch 1500 feet north of the Elkhorn mine. Only one other fault is shown in his map of the entire district, but apparently its displacement is small or negligible. The fold, mentioned above, caused a shattering of a part of the Cemetery dolomite, thus presenting a point of easy access to the intrusions of the gabbro.

ECONOMIC GEOLOGY 7/

General Characteristics: The mineral wealth of the district is found in the altered Cemetery dolomite near its contact with the gabbro and diorite intrusions, and also at places where offshoots from the main mass of igneous rock are scattered irregularly in the dolomite. The only ore deposits worthy of serious attention appear to be in the areas of altered sedimentary rocks.

The main Elkhorn ore body is in the form of two shoots which are confined on crests of minor flexures of the sedimentary beds, and which follow the dip of these beds. The shoots have a lenticular cross-section, and are very irregular in longitudinal pattern. They lie adjacent to, or 5 to 10 feet below, the hornstone, and are contained in the dolomite. No doubt this is because the impervious hornstone held the mineralizing solutions at the contact and prevented their escape into overlying strata. Thus the solutions were confined to the crests of the minor folds and the dolomite was replaced by the various minerals found in the mine. The ore body is a typical replacement deposit , and it is quartzose in nature. The silver ores of this nature ran high in silver content and relatively low in lead-zinc content, hence the ores were treated primarily for their silver content. The brecciated chamber deposits which occur in the dolomite at some distance beneath the hornstone-dolomite contact are low in silver and fairly rich in lead and zinc, and for this reason they may more properly be smelted directly. This type of ore is also found in the Sofia ore bodies.

Geologic Relations: The ore deposit occurs in the Cemetery dolomite which is overlain by the altered Elkhorn shale. The dip of these strata ranges from 35 to 50 degrees northeastward. The western limb of the syncline now simulates a monoclinal fold involving all the beds in the Elkhorn district. This monocline is complicated by several lesser folds; two of which contain the ore deposits. These two folds, and the ore they contain, merge together near the 650 mine level and form a broad arch plunging northward.

Outcrops: The surface exposures of the ore deposits south of the mine buildings have not been found, as they were covered by debris left by the pleistocene glaciers. The only place that the outcrop may be seen is in a railroad cut back of the old boiler house, and this was probably the point of discovery. The gossan itself is obscured by rubble (see Plate VI), but the hornstone-dolomite contact is readilly apparent. The rocks have a strike of N 50° W, and a dip of 30° to 50° NE.

Main Ore Shoots: The two main channels of deposition were designated the North and south ore shoots respectively because of their positions relative to the main shaft. Of the two the south was the larger and richer, and had the more regular boundaries. The shoots decreased in size downward, and finally pinched out at about the 1750 level. Above the 350 level, and between the 550 and 650 levels were stringers of ore which connected the two shoots. These stringers appear from the map to have originated from the south ore shoot because they are more strongly developed close to the south shoot. The ore bodies, although irregular in overall size and shape, had a regular roof. This is because the hornstone was not affected by the mineralizing solutions. The elliptical cross section of the ore shoot had a width of from three to six times its thickness. As can be seen from the map (Plate VII) the size of the cross-section of the ore bodies differed greatly along the dip.

North Ore Shoot: This ore shoot was the smaller of the two ore bodies, and had its northern boundary fixed by a minor fold in the hornstone. At the 950 level it divided into two branches. Both branches became lower in value and smaller in size with depth, and the southern branch pinched out completely at the 1250 level. Stoping of the north branch of this ore body ceased at the

Closeup of
Overlying
Elkhorn
Hornstone
(Outcrop of)
(Elkhorn Ore)
(Body)

Distant View
of Outcrop
Showing the
Underlying
Cemetery
Dolomite on
the Left and
the Elkhorn
Hornstone on
the Right.
The Ore Body
(Center) is
Obscured by
Rubble.

Closeup of
Underlying,
Blocky
Cemetery
Dolomite

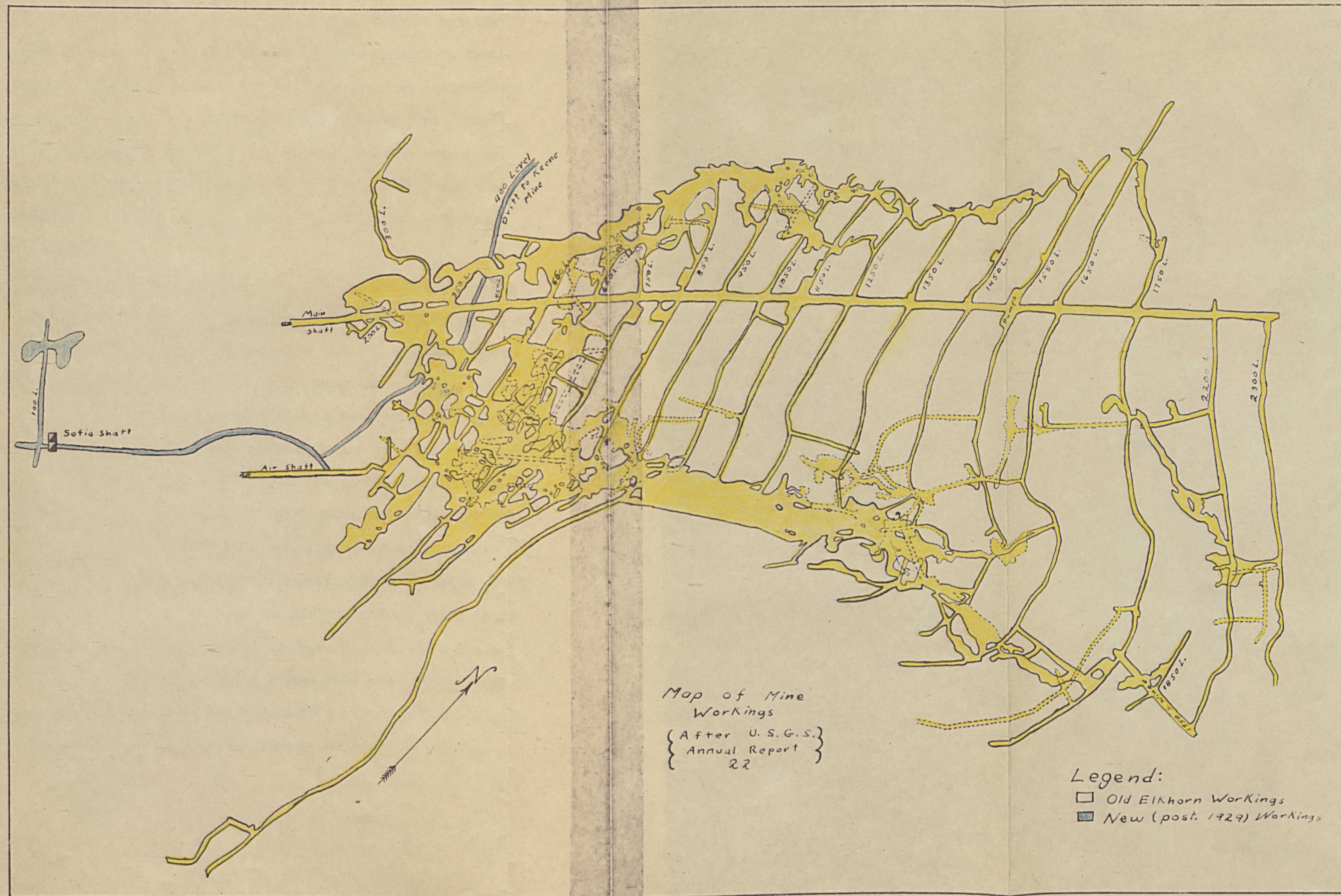
1750 level because of the low silver content of the ore. Weed (7:482) suggests the possibility of a connection between the two ore bodies in the zone between the 1750 north and the 2200 south ore bodies. The mine map (Plate VII) shows transverse ore bodies in this locality.

South Ore Shoot: This important ore body which produced about two-thirds of the mine output, was connected locally to the north ore shoot as mentioned before. It also was limited by the minor folds of the hornstone on both its north and south sides. The ore shoot was continuous and uniform in cross-section and dip from the surface to the 1450 level. From the 1450 to the 2200 level it became smaller and eventually pinched out.

In general the ore body was in contact with the hornstone roof, the area between the 1450 and 1550 levels being an exception. At the 1450 level the ore body bifurcated. The northern leg pinched out at the 1550 level, but the southern leg continued to the 1750 level where it either pinched out or became too low grade t o work. Development work revealed a more or less separate ore body rising from the 2200 level and lying intermediate between the main shoots.

Intermediate Ore Bodies: Between the 550 and 650 levels was an ore body which, although it was classed as an intermediate ore body, was actually a part of the connection between the north and south ore shoots. This ore body stopped at about the 750 level, and then the two main shoots became separated. Another intermediate ore body occurred between the 1750 and 2300 levels. Here the ore was not oxidized and it was possible to determine its original character. This may be the possible connection between the two main ore shoots which was mentioned before in this work.

Footwall or Chamber Deposits: Two general types of ore bodies are found; (1) continuous masses following for hundreds of feet down the dip, and (2) more


Main Shaft
Sofia Shaft
Air Shaft
400 Level Drift to Keene Mine
300 L.
200 L.
100 L.
850 L.
950 L.
1050 L.
1150 L.
1250 L.
1350 L.
1450 L.
1550 L.
1650 L.
1750 L.
2200 L.
2300 L.
1850 L.
Pumps
N
Map of Mine Workings
(After U. S. G. S. Annual Report 22)
Legend:
Old Elkhorn Workings
New (post. 1929) Workings

or less isolated, irregularly shaped masses lying in the dolomite beneath the continuous ore. This second type is known as "chamber deposits". These consisted of "highly argentiferous lead ore", and although frequently connecting with the main shoot, occurred directly below it. Weed says (7:485) "In general they occur close to the main ore shoot and with one exception are found above a 2-inch argillaceous band in the dolomite, which has been called the footwall of the deposit." These ore bodies are also replacement deposits in the dolomite.

<u>New Discoveries (Chamber Deposits):</u> It has been shown by the development work in the Sofia mine, and by the exploratory work done by Longmaid, that a series of "chamber deposits" were not discovered by the old Elkhorn Company. Two of these chamber deposits were proven to exist near the contact in the old mine. The presence of other deposits of this type are indicated by surface outcroppings. The existance of these isolated bodies suggests the possibility that further exploration may discover the position and extent of deposits now unknown, and as they presumably exist under both of the prongs of the old mine, the chances of the property becoming valuable are good.

There is also a good chance of discovering more chamber deposits between the Sofia and Elkhorn shafts. Mr. Lewis in his exploratory winze (page 10) has discovered a chamber deposit typical of those discovered in the old mine and in the Sofia. This deposit is about 7 feet wide and 20 feet long; as yet, the bottom has not been reached. The ore is a limestone breccia cemented by galena, similar to the footwall chamber deposits in the main mine.

MINERALOGY

General Characteristics of the Ore in the Main Shoots 7/: The great ore shoots as described, are composed of quartz, argentiferous galena, and sphalerite, with some tetrahedrite and pyrite, in country rock of dolomite. The quartz, when not stained by the oxidation of the metallic sulfide in it, is usually light-gray, clear or glassy, and of medium coarsness, but a dark bluish-gray crypto-crystalline quartz also occurs. The ore bodies are mostly free from included masses of limestone or hornstone. An exception to this occurs in the 1750 stope where quartz cements limestone fragments. The quartzy ore of the hanging wall was more or less oxidized and free milling down to the 1350 level. Between the 1350 and 1750 levels, it is said, that the amount of quartz decreased and galena and tetrahedrite increased. However, the ore between these levels is reported to have contained as much or more silver than the ore abo ve the 1350 level. The important change was an increase in base metal content that rendered free milling impractical (7:483).

Oxidation extended deeper along the hanging wall bodies than in the fooywall chambers. The surface solutions naturally would travel down the mineralized zone beneath the slate contact. Even on the 2300 level the freshly cut quartz bodies showed yellow alteration spots around galena grains, and green staining of copper carbonate occurs on particles of tetrahedrite. The pyrite is rusty and porus quartz is associated with the other minerals. The chamber deposits being more or less isolated would be protected from circulating ground water, and in operations much less oxidation was found in these areas. Alteration in the deeper levels is not as extensive as it is in the upper levels, but it clearly shows that oxidation penetrated deeply. Galena in the upper levels was altered to cerrusite, and the silver content was higher. Selected samples were reported to contain as much as 4185 ounces per ton on the 170 level (7:475). This high value in silver no doubt resulted from supergene enrichment.

In general the structure of the ore consists of interlocking grains without banding or crustification; rarely there is a banding due to the replacement of limestone fragments by dark-colored jaspery quartz, and the dark-colored variety stands out in strong contrast. In one place where pyrite occurs lying against the slate, the ore shows a well marked banding parallel to the bedding planes of the slate.

Occurrence of ore in the Sofia Workings: The ore deposits now being worked from the Sofia shaft are described as "brecciated chamber deposits", the deposits being made up of limestone fragments withethe interstices between the fragments filled with galena. Some secondary alteration occurs (Plate VIII). The chamber deposits of the old mine apparently were similar in character to those of the Sofia. Weed and others believed that the breccias were developed mechanically by faulting, folding , or other earth forces, and that the ore minerals were deposited in the mechanically created openings. Dr. Perry suggests that the ore breccias may be "replacement breccias" caused by the ore minerals replacing the dolomite, and leaving residual cores of unreplaced dolomite which takes on the appearance of isolated rock fragments. Exzmples of replacement bressias composed of angular fragments of the replaced material within the replacing material are commonplace. The chambers may have been localized along feeder fissures now obscured because of the extent of the replacement phenomenon.

Ore Minerals of the Elkhorn Mine: A complete list of minerals present in the ore bodies cannot be made from observation at the present time, because the ore is gone and the main ore stopes are inaccessable. The following descriptions are taken mainly from Weed (7:459 -- 7:469).

PLATE 7a

Polished surface of specimen of ore from Sofia workings, showing encroachment of secondary Lead Carbonate (s) on Galena (g). The dotted area (d) is dolomite gangue.

This encroachment is typical in the formation of ores by replacement. The black Triangles are cleavage faces of Galena.

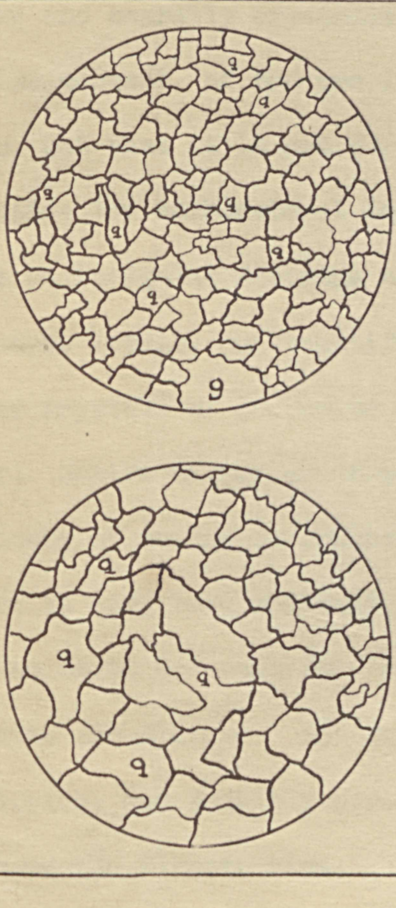


Plate 7b

Thin section of gangue from Sofia workings showing relation of c lcite (c), quartz (q), and galena (g). (crossed nicols)

Galena: Argentiferous galena is perhaps the most important ore mineral in the Elkhorn mine and other mines in this district. It occurs massive, medium granular, and by itself; but it is commonly associated with sphalerite. The large footwall orebodies of the mine consist mainly of this mineral.

Bournonite: "Weed states that, "this antimonial sulphide of copper and lead occurs sparingly in the quartzose ores of the Elkhorn mine". It closely resembles the more common tetrahedrite.

Tetrahedrite: According to Weed, "This mineral occurs abundantly in the Elkhorn mine, where it is highly argentiferous". It is probably one of the parent minerals of the native silver and silver-rich quartzose ores of the upper parts of the mine.

Sphalerite: Pale to dark-brown resinous sphalerite occurred intermixed with galena, pyrite, and other minerals of the Elkhorn mine. It was generally massive and coarsely crystalline. Old descriptions of the mine indicate that the zinc content of the ore increased in the lower levels of the main ore shoots, but that it is not particularly plentiful in the chamber deposits.

Cerrusite: The carbonate of lead, cerrusite, apparently was always present with galena as irregular coatings and replacements of galena by oxidation, even in the deeper levels, and beautiful stellated clusters of thin snowy-white tabular crystals of cerrusite were described.

Silver: Native silver occurred as branching fern-like clusters of crystals and sheets or scales in cracks, coating surfaces of less altered material. It appears to have been abundant in in the thoroughly oxidized upper levels, which no doubt accounts for the high silver content of the shallow ores.

Malachite and Azurite: The green and blue carbonates of copper, malachite and azurite, and possibly aurichalcite, were present sparringly in the ore bodies of the Elkhorn mine.

Smithsonite: Zinc carbonate was found on dolomite fragments of oxidized parts of ore bodies. It formed gray crusts 1 mm. thick with a drusy surface, covered with a second crust of pale apple-green botryoidal material showing both radial and concentric structure.

Pyrrhotite: The magnetic sulphide of iron is said to have occurred in the Elkhorn mine as a massive coating around cubes of pyrite in the white dolomite of the bottom levels of the mine.

Pyrolusite: This occurred in small masses, and as dendritic markings on the yellow, partially oxidized dolomite of the Elkhorn mine.

Gangue Minerals of the Elkhorn Mine: Quartz; This mineral was abundant and almost always present in the ore bodies of the Elkhorn mine. It formed in both the hanging wall and footwall ore bodies, although apparently was less plentiful in the chamber deposits. It occurred in every form from coarsely crystalline to extremely fine crystalline textures; locally it developed coarse comb structures filling open spaces, however, groups of large crystals were rarely found.

Calcite: This mineral occurred abundantly as crystalline coatings of well-shaped rhombohedrons in drusy cavities in the lead zinc ore, throughout the Elkhorn mine. It also occurred occasionally in stalactitic forms in small cavities and water courses. Much of this calcite may have resulted from supergene alterations.

Dolomite: This, since it is the host rock to the ore bodies, was always present. It formed the white "marble" footwall in the Elkhorn mine. Specimens now available show a mozaic of uniform grains without well shaped crystals.

Writers Observations on Minerals now to be Seen: The most important minerals of the Sofia mine are galena and cerrusite. The galena occurs disseminated through the dolomite. It is similar to the galena in the Elkhorn mine, being massive and medium granular. There is, however, little or no sphalerite associated with it. It may be possible that the Sofia galena contains some silver, but it is more probable that the silver occurs in the cerrusite, which is always found surrounding the galena. This cerrusite occurs as a secondary replacement of the galena an is encroaching upon the galena. It is, here, a massive form of the mineral with a greasy luster (Plate IX)

Pyrolusite occurs in the Sofia workings as dendrites of manganese in the Cemetery dolomite. These dendrites are very dainty, and are similar in appearance to leaves pressed between the pages of a book.

Azurite and malachite are rarely found in the Sofia as blue and green stains.

The quartz which is occasionally found in the Sofia ore is massive, milky quartz. Once in a great while some minute crystals of the mineral are found in the Sofia workings.

Dolomite forms the containing walls of the Sofia and Elkhorn "chamber deposits", as well as the gangue in which the minerals occur. There are no well-shaped crystals but in general the dolomite is uniform in texture and composition.

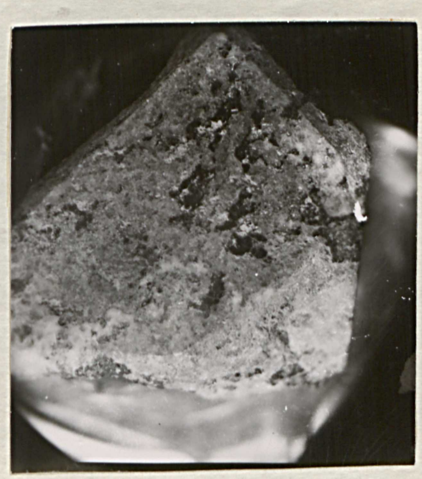
Plate IX A and IX B are illustrative of various specimens of Sofia ore. Figure C shows how the galena and pyrolusite appear in the hand specimen. Figure B shows the galena in a polished surface, with a ring of cerrusite around each grain of galena. Figure A is a photomicograph illustrating how the cerussite actually encroaches upon the galena. Figure D is a picture of a very vuggy speciman showing minute cerrusite crystals lining cavities. Figure E is a photograph of a speciman of high-grade ore from the Sofia mine. This photograph shows spots of cerrusite occurring with quartz and limonite in dolomite.

A) Photomicograph of polished section showing encroachment of Cerrusite on Galena X20.

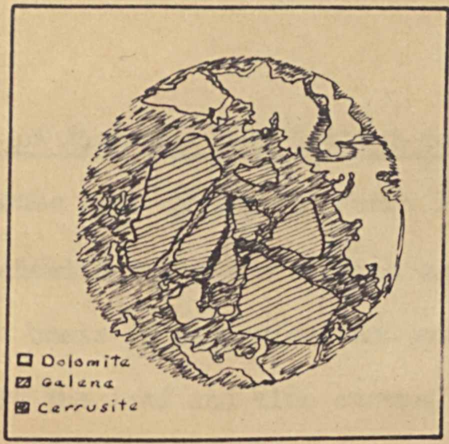
B) Polished section showing Galena (dark) in Dolomite. Natural size.

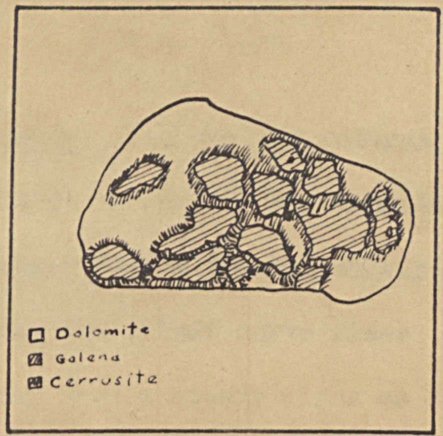
C) Hand speciman showing Dolomite with Galena in upper part and manganese dendrites in lower part. 1/3 natural size.

Cerrusite crystals on drusy quartz, lining cavities. X$1\frac{1}{2}$. Figure D.



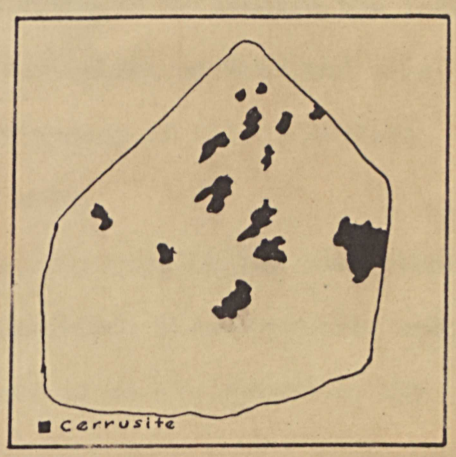
Massive cerrusite with quartz and limonite. X$1\frac{1}{2}$. Figure E


Dolomite
Galena
Cerrusite


Dolomite
Galena
Cerrusite


Dolomite
Galena
Manganese


Shaded areas are cavities


Cerrusite

Relation of Zinc and Lead Content to Silver Content: From smelter returns on shipments made during the years 1945 through 1949 the writer has compiled a graph showing the ratio of lead and zinc to silver (Plate X). The silver was used as a basis of comparison and consequently the the silver curve rises regularly. The lead and zinc curves, although they show a steady rises as the silver rises, fluctuate noticeably between the highest and lowest silver values. However, these fluctuations in the lead zinc curves seem to parallel each other roughly. That is as zinc cont increases or decreases, lead content reacts the same way.

The curves show average ounces of silver for a definite range plotted against an arbitrarily spaced distance for that range. (eg. average 5.7 oz. silver on the abscissa against range 5 to 7 oz. silver on the ordinate. The lead and zinc are plotted as percent on the abscissa against the corresponding range in oz. of silver on the ordinate. (eg. 6% lead against 5-6 oz. silver). The small graph in the upper left hand corner shows the result of averaging the returns over a greaterrange. Namely 0-10 oz. silver, 10-15 oz. silver, and greater than 15 oz. The purpose of the curve is to compare the lead-silver and the zinc-silver ratios, and to show variations of lead and zinc with increase in silver content. The curves show ounces of silver plotted against range as compared with percent lead and zinc.

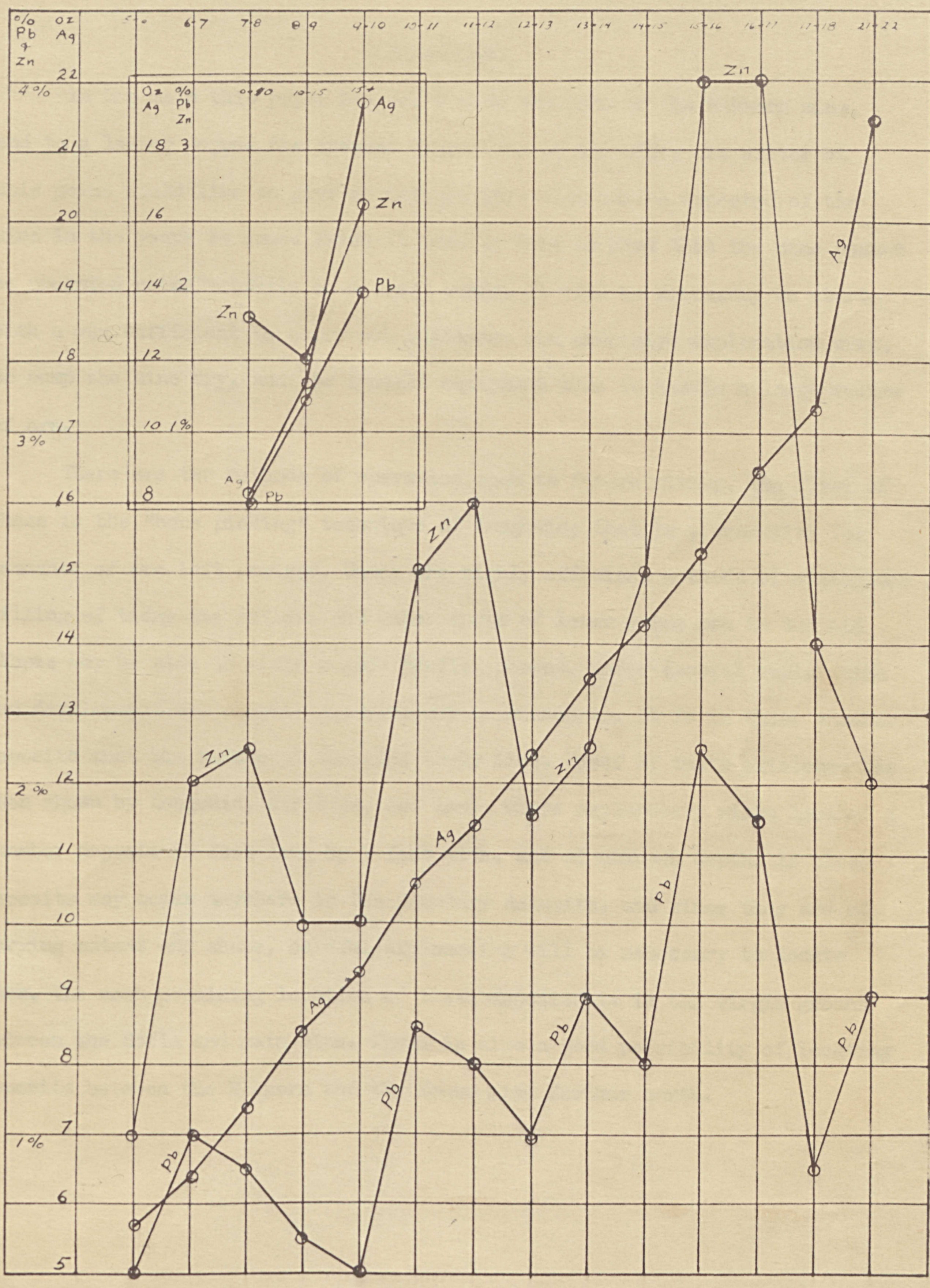
A plausable reason for the zinc and lead curves paralleling each other could be the mutual occurrence of galena and sphalerite. These minerals are nearly found together, and when the galena content of an ore decreases the amount of sphalerite also decreases. As to the overall rise of all three curves; the silver is associated with the other minerals and will also increase in richness as the amount of lead and zinc increases. Supergene enrichment would of course alter this condition.

Table for small graph:

Range	Ounces Ag	Percent Pb	Percent Zn
0-10 ounces	8.2	0.5	1.8
10-15 ounces	11.4	1.25	1.54
15 ounces	19.4	2.05	2.6

Table for Main Graph:

Range	Average of	Ave. Oz. Silver	Percent Lead	Percent Zn
5-6	3 samples	5.7	0.6	1.0
6-7	3	6.4	1.0	2.0
7-8	6	7.4	0.9	2.0
8-9	13	8.5	0.7	1.6
9-10	8	9.3	0.6	1.6
10-11	20	10.6	1.3	2.6
11-12	8	11.4	1.2	2.8
12-13	7	12.4	1.0	1.9
13-14	7	13.5	1.4	2.1
14-15	5	14.3	1.4	2.1
15-16	7	15.3	2.1	4.0
16-17	3	16.5	1.9	4.0
17-18	5	17.4	0.9	2.2
18-19	0			
19-20	0			
20-21	0			
21-22	4	21.5	1.2	2.0


% Pb & Zn
oz Ag
6-7
7-8
9-10
10-11
11-12
12-13
13-14
14-15
15-16
16-17
17-18
21-22
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4%
3%
2%
1%
Oz Ag
% Pb Zn
18 3
16
14 2
12
10 1%
8
0-10
10-15
15+
Ag
Zn
Pb

CONCLUSIONS

In the main this paper has dealt with the past of the Elkhorn mine, and to a lesser degree the present operations of the mine. The writer at this point would like to give an insight into what may be expected of the mine in the years to come. First it must be born in mind that the mine cannot be operated satisfactorily on a small scale. It will be necessary to start with a sum sufficient to carry out efficient and extensive exploration work, to pump the mine dry, and to install equipment able to handle a large volume of ore.

There are two methods of operation open to future mining. The first of these is the "bone picking" technique of Longmaid; that is , searching for remnants of ore left unmined. Under the highly efficient methods of mining and milling of tiday the pillars and other spots of lower grade ore in the old stopes may be made to yield a good profit. Second, under careful exploration and development new chamber deposits may be opened up. It is in these chamber deposits that the future of the mine truly lies. Proof of their existance has been shown by Longmaid, Carlston, and Lewis whose exploratory winze located a chamber deposit 20 feet long by 7 feet wide, and of unknown depth. As these deposits may occur anywhere in the Cemetery dolomite, and since they are of varying extent and shape, careful exploration will be necessary to locate them. The most promising location of these deposits is in the virgin ground between the Sofia and main mine. There is also a good possibility of locating deposits between the Elkhorn and the Keene mine farther north.

BIBLIOGRAPHY

(1) Barrell, Joseph Microscopical Petrography of the Elkhorn Mining District, Jefferson County, Montana. U. S. G. S. Annual Report No. 22, Part IId

(2) Hanson, Dr. A. M. Unpublished Manuscript

(3) Peale, A. C. Three Forks Folio, Montana. U. S. G. S. Geologic Atlas

(4) Perry, Dr. E. S. Stratigraphic Control of Ore Bodies in Montana Engineering and Mining Journal, October, 1945, pages 96-97

(5) United States Government Geologic Map of Montana

(6) Weed, W. H. Little Belt Mountains Folio, Montana. U. S. G. S. Geologic Atlas

(7) Weed, W. H. and Barrell, Joseph Geology And Ore Deposits of the Elkhorn Mining District, Jefferson County, Montana. U. S. G. S. Annual Report No. 22