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LEAD-SILVER DEPOSITS OF THE CLARK FORK DISTRICT BONNER COUNTY, IDAHO

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GEOLOGY OF THE LEAD-SILVER DEPOSITS
OF THE
CLARK FORK DISTRICT, BONNER COUNTY, IDAHO

BY

ALFRED L. ANDERSON

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GEOLOGY OF THE LEAD-SILVER DEPOSITS OF THE CLARK FORK DISTRICT, BONNER COUNTY, IDAHO

By Alfred L. Anderson

ABSTRACT

This report gives the results of a reinvestigation of the lead-silver deposits of the Clark Fork district, Bonner County, Idaho, which since the late twenties have been the most important producers of lead-silver ore in northern Idaho outside of the Coeur d'Alene district, their production up to the end of 1941 having been more than $1,200,000.

The deposits closely resemble those in the Coeur d'Alene district. They are fillings and replacements along minor low-angle thrust and high-angle reverse faults, which genetically are related to the Hope fault, a great transverse earth fracture, which provides the same sort of structural background for this district that the famous Osburn fault does for the Coeur d'Alene district. The deposits are contained in the Wallace and Striped Peak formations, members of the pre-Cambrian Belt series, and are closely associated with faulting and igneous activity that is probably of early Tertiary age.

The mineralization has not been so extensive as in the Coeur d'Alene district, but the deposits, though comparatively small, are rich. Much of the ore is in compact seams and lenses a few inches thick, but stringers of ore and subordinate fractures along which grains of sulfide are disseminated extend across zones that are commonly 2 to 4 feet and exceptionally as much as 8 feet in width. The ore is mainly sulfide ore of the Coeur d'Alene type, consisting dominantly of galena, which is accompanied by lesser quantities of siderite, quartz, and sphalerite and by still smaller quantities of pyrite, arsenopyrite, tetrahedrite, and calcite. Some of the deposits, however, have been substantially enriched by the addition of hypogene silver and antimony minerals, so that much of the ore being mined has a higher silver content than any of that in the Coeur d'Alene district. The hypogene minerals include lead sulfantimonites and sulfarsenites, copper-lead sulfantimonites, and ruby silver. These minerals are absent from only one of the mines, and in one of the mines they form the bulk of the ore that is now being taken out. The high silver content of some of the ore is due in part to the presence of pyrargyrite ($3Ag_2S.Sb_2S_3$).

The deposits apparently were formed at moderate depths and at moderate temperatures. It is believed that the ore will persist to depths appreciably greater than those yet reached in mining. The district has not yet been adequately explored, and undiscovered ore bodies may remain hidden beneath glacial and other surface debris.

INTRODUCTION

PURPOSE AND SCOPE

The Clark Fork district was examined by me in 1927,[1] shortly after the discovery of rich lead-silver ores near the town of Clark Fork, but, as the development was then just getting under way, the deposits were not adequately exposed and little detailed study could be carried on. Since then mining activity has been almost continuous, and the district has become the most important producer of lead-silver ore in northern Idaho outside the Coeur d'Alene district. In 1940, therefore, I was sent back to the district to make a detailed examination of the deposits and thus complete the study begun as a reconnaissance 14 years before. All the lead-silver mines and prospects were reexamined, and those on which much work had been done were mapped in detail. Particular attention was given the structural features that might have bearing on the distribution of the deposits and on the localization of ore within the deposits. This led not only to a reexamination of all the known faults along the zone of the Hope fault but also to a study of the minor faulting that took place during the period of mineralization. Other geologic features were studied that might bear on the genesis of the deposits and on the question of whether the ore would persist with depth. Some study was given, also, to the country rock, in order to determine whether the formational boundaries established during the reconnaissance could in places be made more accurate.

These new studies confirmed most of the conclusions made at the time of the earlier reconnaissance, but they also made for a better understanding of the genesis and structural control of the deposits. It became evident that the Hope fault had played a far more important part in the control of mineralization than had been realized, and that all the ore was confined to minor faults related to the Hope. The new data showed that the Hope fault was a zone rather than a single plane of weakness, and that faulting, igneous intrusion, and mineralization were closely related events.

In both its structural and its mineralogic features the Clark Fork district has been found to be much like the Coeur d'Alene district. The Hope fault has provided the same kind of structural setting for the ore deposits in the Clark Fork district that the Osburn fault has for those in the Coeur d'Alenes. The two districts are also similar in the character of their mineralization, the only difference of note being the presence of considerable

[1] Anderson, A. L., Geology and ore deposits of the Clark Fork district, Idaho: Idaho Bur. Mines and Geology Bull. 12, 1930, 132 pps.

amounts of sulfantimonites of lead and silver, added during a late stage of hypogene enrichment, a stage that is but meagerly represented in the Coeur d'Alene district. Consequently, the Clark Fork ore in general is notably richer in silver than most of the ore in the Coeur d'Alene district.

FIELD WORK AND ACKNOWLEDGMENTS

The restudy was begun in the early part of July 1940 and continued without interruption until September 10. With the assistance of Mr. Lawrence C. Cassidy, a student at the University of Idaho School of Mines, all surface and subsurface exposures were examined, and the accessible workings of the three largest mines, as well as of some of the more important prospects, were mapped. A geologic map of the area that includes the known lead-silver deposits was also prepared, aerial photographs obtained from the United States Forest Service at Missoula, Mont., being used as a base. Because of unavoidable delay in completing the manuscript it has been possible to incorporate in the report information obtained during a week's study in August 1941 and again in a two-day study in August 1943. During these last two visits the new developments were reviewed and the underground geologic mapping brought up to date.

Unfailing cooperation was given by all operators and others interested in the development of the district. Special courtesies were received from Mr. Albert M. Nash, president-manager of the Hope Silver-Lead Mines, Inc.; from the Honorable Compton I. White, Member of Congress and president of the Whitedelf Mining and Development Co.; from Mr. Joseph Reed, president-manager of the Lawrence Consolidated Mining Co.; and from Mr. James E. White, who had leased the Whitedelf mine from the Whitedelf Mining and Development Co. Mr. J. H. Eby, mining engineer and geologist of Spokane, Wash., also gave freely of his store of information on the Clark Fork district, and Messrs. A. D. Eberly, E. O. Clagg, Lloyd Reed, and others gave material assistance in one way or another during the field investigation. To all these men the writer tenders his grateful appreciation.

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GEOGRAPHY

LOCATION

The lead-silver deposits are on the north side of the Clark Fork of the Columbia River, in Bonner County, about 35 miles by air line northwest of the Coeur d'Alene mining district and 25 miles by road southeast of Sandpoint, the county seat of Bonner County

FIGURE 2.—Index map showing the location of the Clark Fork district, Idaho.

(see fig. 2). All of them are within 2 miles of the town of Clark Fork, which is in Tps. 55 and 56 N., Rs. 2 and 3 E., Boise meridian, at about 48°10′ north latitude and 116°10′ west longitude. The area here considered is considerably smaller than the one defined as the Clark Fork district in the earlier report. The district is now re-defined as the area, about 24 square miles in extent, that contains the lead-silver deposits around the town of Clark Fork (see pl. 6).

The district is well located with regard to transportation. The main line of the Northern Pacific Railway and United States Highway No. 10–A (oil-surfaced) pass through the town of Clark Fork. Most of the important mines are less than a mile and some of them only a few hundred yards from these routes.

TOPOGRAPHY

The district (see pl. 5) covers only a small part of the steep southwest slope of the Cabinet Mountains proper, which, with summits 6,000 to 7,000 feet above sea level, rise as a southeastward-trending escarpment 4,000 to 5,000 feet above Pend Oreille Lake and the Clark Fork. Between the river and the main range lie three mountains about 2,000 to 3,000 feet lower in altitude, called Howe Mountain, Middle Mountain, and Antelope Mountain. These are separated from the main range by a deep, broad, unevenly-floored trench alined along the course of the Hope fault (pl. 5, *B*). The district includes all of Middle Mountain and parts of its neighbors, together with part of the valley of Lightning Creek and of the flood plain and delta of the Clark Fork.

Howe Mountain, which is separated on the east from Middle Mountain by the fairly broad valley of Lightning Creek, is a steep-sided ridge lying between and partly parallel to the Cabinet escarpment and the Clark Fork (pl. 5, *A*). Its highest point within the mapped area is about 3,000 feet above sea level, or 1,000 feet above the river. Its southeastern base is skirted by Lightning Creek and lies directly across the stream from the town of Clark Fork. Middle and Antelope Mountains, east of Lightning Creek, are separated from each other by Mosquito Creek. Middle Mountain, which is northeast of the town, reaches an altitude of about 3,500 feet, and Antelope Mountain, east of the town, has an altitude slightly above 4,200 feet. Both are roughly circular in outline (pl. 5, *B*) and are bordered in part by nearly precipitous slopes. The west and southwest slopes of all three of these mountains show evidence of deep glacial scour, whereas the opposite slopes are mantled with irregular hillocks of glacial till. Both Middle and Antelope Mountains have bench-like shoulders or spurs that form part of the floor of an old

A. HOWE MOUNTAIN.

Clark Fork delta and Pend Oreille Lake on the left; Cabinet Mountains and intervening trenchlike depression on the right. Town of Clark Fork in left foreground. View from summit of Antelope Mountain, looking west.

B. MIDDLE MOUNTAIN IN THE CENTER, ANTELOPE MOUNTAIN ON THE RIGHT, AND CABINET MOUNTAINS ON THE LEFT.

Part of the trenchlike depression along the course of the Hope fault which extends along the base of the Cabinet escarpment. View from summit of Howe Mountain, looking east.

MOUNTAINS IN THE CLARK FORK DISTRICT.

valley surface 1,000 feet above the present valley bottoms. Extensive remnants of the old valley floor are well preserved north and east of Antelope Mountain and are partly visible in plate 5, *B*.

The town of Clark Fork is on an alluvial fan laid down by Lightning Creek on the flood plain and delta of the Clark Fork River (pl. 5, *A*). In emerging from the Cabinet Mountains, Lightning Creek flows over a broad aggraded valley floor in a braided channel choked with gravel and boulders. The fan deposited by Lightning Creek has crowded Mosquito Creek against the north and west bases of Antelope Mountain. As the lower valley floors have been built up by deposition of stream and river sediments and raised above their original levels, the boundaries between valley floors and steep valley sides are generally sharp.

CLIMATE AND VEGETATION

Although the district is well within the northern Rocky Mountains, its climate is not especially rigorous. The summers are warm but seldom hot, and the winters are not often severely cold. Most of the annual precipitation, which averages about 30 to 35 inches, falls between the beginning of September and the end of June. Snow accumulates to great depth on the higher slopes and lingers until late in the spring, but at Clark Fork the snowfall is moderate and never seriously interferes with mining operations. Little of the snow that falls before December lasts through the winter, and the lower slopes are largely free from snow by late March or early April. With the rapid melting of snows on the higher mountains in late May and June, Lightning Creek and the Clark Fork River become flooded, but later in the summer the water recedes rapidly to low levels.

Because of the considerable precipitation, the countryside supports a rather luxuriant vegetation where slopes are not too steep (see pl. 5). The region was once heavily forested, but much of the original growth of white pine, cedar, hemlock, larch, and fir has been logged off or destroyed by fire. A dense cover of second growth and underbrush remains, which proves a serious handicap to prospecting and impedes travel off the roads and trails. Ample timber for mining purposes is available.

GEOLOGY

Except for a few dikes of diabase and porphyry, the district is underlain by sedimentary strata belonging to the Belt series (pre-Cambrian), which are covered in places by Pleistocene glacial deposits and Recent alluvium. As in the Coeur d'Alene district, the Belt strata have been folded and complexly faulted, the most impressive structural feature being a great transverse earth fracture known as the Hope fault. As bordering subsidiary fractures have provided openings for the intrusion of the igneous dikes and the circulation of ore-bearing solutions, the Hope fault is also the most important element of the local geology from an economic standpoint. Especial emphasis, therefore, is placed on the Hope and the associated subsidiary faults.

STRATIGRAPHY

Of the six formations that represent the Belt series in the Coeur d'Alene district, only three, the Prichard, Wallace, and Striped Peak, are present in the Clark Fork district. The others, the Burke, Revett, and St. Regis (equivalents of the last two grouped as the Blacktail formation by Sampson in the Pend Oreille district)[2], are exposed a little west of the district, but as these formations contain none of the lead-silver deposits of the district they will not be described. The Wallace and Striped Peak formations, on the other hand, which contain all the deposits known at the present time, will be described in some detail, and as the Hope fault has brought the Wallace and Striped Peak formations against the Prichard, a brief description of the Prichard formation is included. The Pleistocene glacial deposits and the Recent stream deposits, grouped together as Quaternary, will receive only brief description.

BELT SERIES

PRICHARD FORMATION

The only exposure of the Prichard formation in the district is in the Cabinet escarpment just northeast of the Hope fault, where, because of the very steep frontal slope of the mountain, the formation tends to stand out in clifflike ledges.

Much of the formation consists of light-gray argillaceous sandstone interbedded with nearly pure quartzite and fairly dark-colored shale. The proportion of shaly material increases toward the top of the formation, the upper 1,500 feet being made up largely of the grayish-blue laminated shale that is typical of the upper part of the Prichard in the Coeur d'Alene district. These particularly shaly rocks appear in the upper part of the escarpment, where they conformably overlie several thousand feet of the locally cliff-forming siliceous beds. Most of the outcrops have a dark rusty color, quite unlike the colors seen in the weathered outcrops of other members of the Belt series.

[2] Sampson, Edward, Geology and silver ore deposits of the Pend Oreille district, Idaho: Idaho Bur. Mines and Geology Pamph. 31, p. 7, 1928.

WALLACE FORMATION

Except in a small block along the lower northwest slope of Middle Mountain, all the exposures of the Wallace formation lie west of Lightning Creek. The formation is the country rock of all but the northwest third of Howe Mountain, and it also probably underlies much of the glacially mantled surface between Howe Mountain and the base of the Cabinet Mountains. It is altogether more than 6,000 feet thick. Although the Wallace formation was formerly presumed to underlie the lower western slopes of Middle and Antelope Mountains, the rocks there are now known to belong to the Striped Peak formation.

The Wallace formation is very heterogeneous, but, as it is the only formation containing any considerable amount of limy material, it is rather easy to identify, especially where it is weathered. It is made up of thin-bedded, greenish, partly calcareous shale and argillite, of bluish and dark-grayish banded argillite, of light-gray, yellowish-weathering calcareous quartzite, of pale-green and grayish-white quartzite, and of thin beds of impure limestone. Beds almost identical in character recur at many horizons, and rocks of different kinds grade into one another. Sun cracks and ripple marks occur abundantly throughout the formation. The most distinctive feature of the formation is the way in which it weathers. Weathering of the calcareous members produces peculiar cellular forms recognizable even in small fragments, and most of the rock in the formation assumes upon weathering a brownish-yellow color that is highly characteristic.

The rock forming most of the southeast end of Howe Mountain is largely quartzitic, but interspersed with the more massive beds of quartzite are beds of shale and shaly quartzite a few feet to 20 feet or more in thickness. As a whole the formation is fairly competent, and locally it apparently fractures more readily than it folds.

STRIPED PEAK FORMATION

The Striped Peak formation composes most of Middle Mountain and all of Antelope Mountain; consequently it underlies more of the mapped area than any other formation. It is more widespread near Clark Fork than was formerly supposed. The formation is now known to contain some limy members, which, however, are neither so numerous nor so conspicuous as those in the Wallace formation. During the earlier reconnaissance all rocks containing carbonate of lime were grouped with the Wallace, and the somewhat calcareous strata in the lower western slope of Middle and Antelope Mountains, which are now recognized as Striped Peak, were consequently mapped as Wallace. The only beds of the Wallace formation east of Lightning Creek are in the faulted block at the northwest edge of Middle Mountain.

The Striped Peak formation, which consists mainly of sandy and argillaceous materials, has little resemblance to any other division of the Belt series except certain parts of the St. Regis formation, exposed just west of the district. On the lower slopes of Middle Mountain, the formation includes several hundred feet of thin-bedded blackish and bluish-gray shale, somewhat like the shale in the upper part of the Prichard formation. Some of this shale is in beds as thin as paper. The shale is interbedded with more massive beds of banded greenish argillite and with beds of pale-greenish argillaceous quartzite. These rocks grade upward into a great thickness of reddish sandstone and shale alternating with greenish shale, argillite, and quartzite, partly of dull-green and partly of olive-drab hue. The layers of reddish beds range in thickness from a few feet to several hundred feet, and the layers of greenish or olive-drab beds are 50 to 200 feet thick. Calcareous beds are present but are not so conspicuous as on Antelope Mountain, where there are some beds of impure massive limestone several feet thick. The rocks on Antelope Mountain seem to include less of the paper-thin shale and considerably more of the reddish beds than those of Middle Mountain; the upper half of Antelope Mountain has a decidedly reddish tint. On the spur close to the town of Clark Fork, the reddish beds are not so numerous nor so conspicuous as the greenish beds.

Reddish and olive-drab beds are especially characteristic of the formation, but where these are absent the laminated shales are diagnostic. The calcareous beds weather somewhat like those in the Wallace formation, but as they are comparatively few they do not markedly affect the general appearance of the weathered outcrops.

QUATERNARY DEPOSITS

GLACIAL DEPOSITS (PLEISTOCENE)

The glacial deposits include irregular mantles of till, terraces of stratified outwash, and sheets of ponded clay silts. The most widely distributed of these deposits is the till, which conceals much of the bedrock on the northeast slope of Howe Mountain and the lower country across to the base of the Cabinet Mountains, and which also masks much of the bedrock of the foothill country northeast and east of Middle and Antelope Mountains. Isolated patches also occur here and there on Howe, Middle, and Antelope Mountains. Much of that on the mountain slopes forms a thin irregular veneer, but that in the lower country close to the base of the Cabinet Mountains is many feet thick. The till is entirely unsorted, consisting of small to large rounded and angular boulders in a more or less clayey matrix.

Much of the stratified outwash remains as a terrace along the Clark Fork, particularly southeast of the town, but minor patches are scattered in other parts of the district. The largest remnant is a terrace, a hundred feet or more in height, that skirts the south and southwest base of Antelope Mountain, extending almost to the town of Clark Fork. Smaller remnants lie on the southeast tip of Howe Mountain just above Lightning Creek and others on the lower western slope of Middle Mountain. The material on Middle Mountain consists in part of ponded clays. It is capped by till, which extends for some distance up the mountain slope. Detailed study is likely to prove that the deposits belong to more than one cycle of Pleistocene glaciation.

ALLUVIUM (RECENT)

Deposits made by the present streams cover a considerable part of the district. Alluvium forms a relatively broad strip along the Clark Fork and much narrower ones along Lightning Creek and its tributaries, Spring and Cascade Creeks. Alluvium also covers the floor of the lower valley of Mosquito Creek.

The alluvium along the Clark Fork is composed of the finer flood-plain and delta materials, mostly sand and silt. That along Lightning Creek and its tributaries is coarser, consisting preponderantly of gravel mixed with sand and boulders, and is largely of torrential origin. The town of Clark Fork is built upon a coarse bouldery fan deposited by Lightning Creek. The relation between the alluvial flats and the abrupt valley walls suggests that the alluvium has accumulated to depths of some hundreds of feet, especially along the river.

IGNEOUS ROCKS

The few dikes of diabase and porphyry in the district are members of a "porphyry belt" that stretches in a west-northwesterly direction along the general course of the Hope fault. Clark Fork is apparently near the southeast end of the belt, which may be traced westward for at least 25 miles. The dikes apparently occupy associated fractures on both sides of the Hope fault but are most numerous on the northeast side. They are exposed along the lower steep frontal slope of the Cabinet Mountains, particularly northwest of the district, where they extend to and beyond the Pack River and the town of Hope, and in the hills within and alongside the Purcell Trench. Southeastward, toward the Clark Fork district, the dikes appear to decrease in number and variety, and a few miles southeast of the district they finally disappear.

In the Clark Fork district these dike rocks are closely associated with faulting and mineralization. They are the only igneous rocks in the region that possess this relationship and are therefore the only ones that need be considered in this report. The dikes are much younger than the Purcell sills (pre-Cambrian), intruded into the Prichard formation northwest of the district; they are younger, indeed, than the bodies of granitic rock, batholiths and stocks, emplaced during late Jurassic or Cretaceous time.[3] The nearest of these bodies, which consists of granodiorite, is at the edge of the valley of Lightning Creek, just north of the map area. The next nearest are no closer than Pack River, several miles northwest of Hope. The dikes are not genetically and structurally related to the batholitic masses, as believed at the time of the reconnaissance, but are independent injections from a younger magmatic source. For reasons presently to be given, the dikes of the "porphyry belt" are believed to have been intruded during early Tertiary time.

EARLY TERTIARY (?) DIKES

Diabase.—Only two diabasic dikes were observed within the district, one in the underground workings at the Hope mine and the other at the Lawrence mine. Both are intruded along premineral faults, and both have been more or less extensively altered by the mineralizing solutions and are locally cut by stringers of ore.

The diabase is medium-grained and is dark gray to black where unaltered. In thin section it is seen to consist mainly of labradorite and augite, mixed with magnetite, ilmenite, and apatite. The grains of labradorite and augite are similar in size, but the labradorite tends to show better developed crystal form, laths of labradorite being cemented and partly enclosed by augite. Large skeleton crystals of magnetite and ilmenite (?) cut through and apparently replace those of augite and labradorite. Some grains of ilmenite and apatite are about as large as those of pyroxene and plagioclase.

Where it is altered, the diabase is light gray to pale green, and thin sections reveal much sericite, chlorite, and calcite. Where the alteration has been exceptionally intense, the rock is thoroughly bleached, the original minerals have been almost completely destroyed, and the primary texture has been almost obliterated.

[3] Anderson, A. L., Geology and ore deposits of the Clark Fork district, Idaho: Idaho Bur. Mines and Geology Bull. 12, pp. 24-30, 1930.

The diabase is identical with that which the writer[4] has studied along the "porphyry belt" in Kootenai County, Idaho, and somewhat similar to that in the Coeur d'Alene district described by Calkins.[5]

Porphyritic dikes.—The porphyritic dikes that were observed within the district extend along the frontal slope of the Cabinet Mountains east of Lightning Creek. They have the composition of diorite, granite porphyry, and granophyre. The porphyritic dikes west-northwest of the district, between Hope and Sandpoint, range in composition from quartz diorite porphyry to granite porphyry. They are accompanied by nonporphyritic dikes having the composition of gabbro, diorite, and monzonite. As all of these dikes have been fully described in the reconnaissance report, only a brief summary description of the porphyry dikes need be given here. These are conspicuously porphyritic, with phenocrysts of andesine, orthoclase, quartz, hornblende, and biotite. Their groundmasses are fine grained and grayish to pinkish and consist for the most part of microspherulitic intergrowths of orthoclase and quartz, which enclose accessory grains and crystals of magnetite, apatite, sphene, allanite, and zircon. The microspherulitic intergrowths appear to be lacking only in the quartz diorite porphyry. Differences in composition are expressed mainly by differing proportions of orthoclase to andesine, the former predominating in the granite porphyries, the latter in the quartz diorite and granodiorite porphyries. Hornblende is the more abundant in the more calcic porphyries and biotite in the granite porphyry, and quartz is more abundant in the granite porphyry than in the others.

The porphyries within the district are less calcic and less conspicuously porphyritic than those elsewhere along the "porphyry belt." The granophyres in particular contain only a few phenocrysts of sericitized feldspar in a white or light-gray groundmass consisting almost entirely of microspherulitic orthoclase and quartz. These dikes are much more altered than the others (apparently by hydrothermal end-stage solutions), and if they ever contained biotite it has been completely replaced by muscovite. An exceptional rock in which the groundmass is not microspherulitic forms a small dike just east of the map area. In this rock phenocrysts of feldspar (largely andesine) and quartz are embedded in a microgranular groundmass of orthoclase and quartz.

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[4] Anderson, A. L., Geology and Metalliferous deposits of Kootenai County, Idaho: Idaho Bur. Mines and Geology Pamph. 53, p. 25, 1940.

[5] Ransome, F. L., and Calkins, F. C., The geology and ore deposits of the Coeur d'Alene district, Idaho: U. S. Geol. Survey Prof. Paper 62, pp. 52-53, 1908. Shenon, P. J., Geology and ore deposits near Murray, Idaho: Idaho Bur. Mines and Geology Pamph. 47, pp. 9-10, 1938 (includes revised descriptions by Calkins).

Age of the dikes.—If, as appears probable, the microspherulitic groundmasses that typify so many of the porphyritic dikes constitute proof of rapid cooling or chilling of the consolidating magma, the dikes must have been intruded into cold rocks comparatively near the surface, and, as the dikes show evidence of as rapid chilling against the granitic rock of the batholithic masses near Pack River and in the Purcell Trench as against sedimentary rocks, they must have been intruded after at least the upper parts of the batholiths had grown cold and presumably after they had been exposed by erosion. Probably, therefore, the dikes were not derived from the same magma as the granitic rock but from magma that was generated later and emplaced at a much higher level in the earth's crust. As the granitic and porphyritic rocks are probably not related, the porphyritic rocks cannot be so old as late Jurassic or Cretaceous, at which time the batholithic masses were emplaced. Further difference of age is indicated by the lack of association between the porphyritic dikes and the Mesozoic structural features.

On the other hand, the dikes show a most intimate structural relationship with the Hope fault. Not only are they concentrated along the Hope fault zone, but they also appear to occupy subsidiary fractures developed at the same time as the main fault. As the Hope fault zone transgresses and is entirely independent of the Mesozoic structures, it is inferred that the faulting along the Hope is a product of the Laramide orogeny (late Cretaceous or early Tertiary). The intimately associated intrusives are probably local manifestations of the widespread igneous activity that occurred through the Rocky Mountain region in early Tertiary time. The dikes have the same structural relationships, and hence presumably the same age, as those of the "porphyry belt" in Kootenai County, which the writer has assigned to the early Tertiary.[6]

STRUCTURE

The structural features of the district are broad open folds, striking nearly north, and the complicated Hope fault zone, whose general strike is about west-northwest. The folding and faulting are believed to be widely separated in time and unrelated in origin. The folding apparently preceded the emplacement of the batholithic masses, which occurred in late Jurassic or Cretaceous time, and was caused by compressive stresses associated with crustal shortening. The zone of transverse faulting, on the other hand, which cuts across the folded strata as well as the batholith, apparently developed in response to horizontal shearing stresses,

[6] Anderson, A. L., op. cit. (Pamph. 53), pp. 21-25.

associated probably with the Laramide disturbance of late Cretaceous or early Tertiary time.

Some faults are associated in origin with the folding and the emplacement of the batholithic rocks, but none of these faults have been recognized within the Clark Fork district as here defined. The early folding is noticeable locally, but the most outstanding structural feature of the district is the great transverse zone of faulting dominated by the Hope fault, an earth fracture of major magnitude recognized and named some years ago by Calkins.[7]

FOLDS (MESOZOIC)

Throughout the Clark Fork district the Belt strata dip toward the east, forming part of the west limb of an open syncline several miles in breadth. The Hope fault cuts directly across the fold, and its northeast side has moved southeastward, the displacement being several miles in relation to the southwest side. Northeast of the fault the beds strike N. 20°–30° E. and dip 15°–20° SE., the dip decreasing toward the east. Southwest of the fault the beds strike N. 20°–30° W. and dip 10°–25° NE. Because of local faulting, the strike of the beds is somewhat different on Howe, Middle, and Antelope Mountains, but the general synclinal structure has not been materially modified.

FAULTS (EARLY TERTIARY)

The Hope fault is accompanied by a great many smaller faults, which apparently were formed at about the same time as the Hope fault and more or less directly in response to the same stresses. These smaller faults are essential components of the transverse zone of faulting dominated by the Hope fault and are generally within a mile or two of the Hope fault itself. This complicated zone of faulting is several miles wide and has been traced for fully 50 miles. The zone may be somewhat broader and may contain more associated faults in the Clark Fork district than in other places along its course. Most of the faults that border the Hope are not parallel to it but diverge from it at small to fairly wide angles.

The Hope fault and many of the associated faults are shown on the geologic map of the district (pl. 6). Some of the associated faults were projected to the surface from underground workings; others were recognized from their topographic expression and from sharp differences in the strike and dip of the

[7] Calkins, F. C., and MacDonald, D. F., A geological reconnaissance in northern Idaho and northwestern Montana, with notes on the economic geology: U. S. Geol. Survey Bull. 384, pp. 52-55, 1909.

beds on their two sides. Because of the glacial deposits that mantle much of the district, the faults hidden from view may be more numerous than those that have been found. Only faults of appreciable displacement have been mapped; countless other fractures of little or no displacement were omitted. For faults visible in underground workings it was generally possible to determine the kind and direction of movement, but these could rarely be determined for those mapped from surface showings alone. For many of the faults not seen underground even the direction of dip was uncertain.

HOPE FAULT

Although the Hope fault has been traced west-northwestward from the district for at least 30 miles and east-southeastward for at least 20 miles, its full extent remains unknown. It closely follows the Clark Fork River downstream to within a few miles of the Idaho line; then, as the river pursues a more westerly course to Pend Oreille Lake, the fault continues along the prominent trench that separates Howe, Middle, and Antelope Mountains from the Cabinet Mountains. Near the town of Hope it passes into an arm of Pend Oreille Lake, but near Sandpoint it emerges from the lake and from beneath the alluvial floor of the Purcell Trench, west of which it may be traced through a deep notch that extends across the Selkirk Mountains. Except where it is concealed beneath the lake waters and the alluvium of the Purcell Trench, this fault is strongly reflected in the topography, particularly by the long abrupt escarpment that forms the southwest border of the Cabinet Mountains and by the great linear trench that extends eastward along the base of the mountains from the town of Hope to a point several miles east of the Montana line. Both the escarpment and the trench along its base are prominent features near the town of Clark Fork (pl. 5).

Where the fault crosses the district its trend is about N. 55°–60° W. Subsidiary fractures indicate that the fault dips to the southwest at a very high angle, probably greater than 70° and perhaps close to vertical. The fault has not been exposed underground, but its trace on the surface is marked in places by a steep-walled erosional trench with walls as much as 100 yards apart. Presumably there is a fault zone of corresponding width in which the rock is thoroughly crushed and in great part reduced to gouge. In places the rocks bordering this zone show evidence of considerable drag.

As already pointed out, the Prichard strata on the north side of the fault abut against the Wallace and Striped Peak on the south, which necessitates a stratigraphic throw of not less than

18,000 feet. The actual displacement, however, is several times as great as that. To restore the synclinal structure cut off and displaced by the fault, the rocks on the northeast side would have to be shifted northwestward in relation to those on the southwest side for a horizontal distance of 12 miles. The Hope fault is therefore a transverse strike-slip fault of the first order of magnitude.

Most of the displacement probably took place during early Tertiary time; since then there has been additional movement, but mainly in a vertical rather than in a horizontal direction. An old erosion surface formed since the early faulting and preserved on the mountain summits now stands 1,500 feet higher on the Cabinet Mountains than on the Coeur d'Alene Mountains, directly to the south.

ASSOCIATED FAULTS

The smaller faults alongside the Hope fault include low-angle thrust faults, high-angle reverse faults, high-angle normal faults, two sets of high-angle strike-slip faults, and a few that have not been classified. These faults were not active quite simultaneously, but they are all believed to have resulted from the same stresses.

Low-angle thrust faults.—Low-angle thrust faults apparently were formed more easily in the weak shaly beds of the Striped Peak formation than in the more competent beds of the Wallace; consequently most of them are on Middle and Antelope Mountains. The only one observed in the Wallace formation is in the block of Wallace strata near the northwest border of Middle Mountain. These faults are very inconspicuous, and were they not exposed in mine workings and in road cuts they might well be overlooked altogether. But, small though they are, they are economically among the most important in the district, for some of the principal lead-silver ore bodies extend along them.

Most of these faults strike north-northeast to northeast, but a few strike northwest. Their dips are mostly 10° to 30° to the southeast or northeast. Neither the strike nor the dip of any one of them is uniform. A fault may be rather sinuous in strike and may also flatten and steepen on the dip, rarely maintaining a constant direction or dip for more than 20 feet. Some of these local variations in attitude may mark the places where the fault crosses beds of different degrees of competency—passing, for example, from quartzite to laminated shale and back again. Although these faults have been called "bedded," they actually cut the bedding of the strata at a considerable angle.

Most of the faults may be traced for several hundred feet and a few for a thousand feet or more. They have caused little displacement, some perhaps a few inches, others a few feet—nowhere enough to produce appreciable offsets in the strata. On many faults the displacement appears to have been localized along a single fracture, emphasized by a thin seam of gouge or a massive seam of ore, but on some the displacement has been distributed along several parallel fractures, the two most prominent of which form the hanging wall and footwall of a zone of shattered rock usually 2 to 3 feet but locally as much as 6 feet wide. In every case the main fracture is bordered by subsidiary fractures, so that the faults are delineated as fault zones rather than as fault fissures. In general the rock of the fault zone is considerably broken, but relatively little gouge has been produced even in the weakest shales, which probably explains why these low-angle thrusts have served so well as channels for the circulation of ore-bearing solutions and have been so favorable to the localization of ore. The movement along these faults has created considerable drag, especially in the weak shales and on the hanging walls. The small drag folds indicate that the hanging wall has been thrust over the footwall and that the thrusting movement has been directed from the southeast. Where drag folds are lacking, the thickening of the ore bodies along the flatter parts of the fault zone and their pinching along the steeper parts afford evidence of the direction of movement.

These are the oldest of the faults associated with the Hope fault. In some places they are cut and offset by normal faults, in other places by strike-slip faults.

High-angle reverse faults.—The high-angle reverse faults appear to prefer the more competent beds of the Wallace formation, and most of those recognized so far cut the Wallace strata on Howe Mountain. Though of much greater throw, they resemble the low-angle thrusts in lacking surface expression and have been observed only in mine workings. They share with the low-angle thrusts the distinction of being the principal ore localizers in the district.

The high-angle reverse faults have about the same trend as most of the low-angle thrusts. The most important one, the Pearl, strikes N. 35°–45° E. and dips 65°–70° SE. Some of the others dip more steeply southeast, and at least one reverses its dip to steeply northwest. They vary somewhat in strike and dip, but far less than the low-angle thrusts.

Some of the faults are only a few hundred feet long, but others may be traced for several thousand feet. On the whole these faults are much more prominent than the low-angle thrusts. They not only are longer but also give evidence of somewhat greater movement. The displacement on the smaller ones is only a few inches; that on the larger is probably some tens of feet. Because of the greater amount of movement, much more gouge has been formed on these faults than on the flat overthrusts, and the disturbed zone, with a multitude of longitudinal and oblique fissures, is in places as much as 40 feet across. Much of the movement apparently has been localized along the footwall of the fault zone, but here and there some has also taken place along hanging-wall fractures. Generally the rock along the footwall is considerably crushed and several inches of it are reduced to gouge, but, despite the relatively abundant gouge, the high-angle faults have not been impervious to the passage of ore-bearing solutions. Drag along many of the faults, particularly in the footwall, shows that the hanging wall has been shoved upward with respect to the footwall, but grooves on some of the slickensided fault surfaces indicate that the movement may have been diagonal rather than directly upward. The fact that ore shoots are localized along the less steeply dipping parts of the fault zones also indicates reverse movement.

In the one place where the low-angle and high-angle reverse faults have been found together, the high-angle faults cut and offset the others, but as both are cut by strike-slip and other faults, there may be no great age difference between them. Their general correspondence in strike and their relation to the local stresses also suggest that they were formed almost at the same time.

High-angle normal faults.—The high-angle normal faults are not restricted to any particular kind of rock, although the most prominent examples are apparently in the Striped Peak formation on Middle and Antelope Mountains. The magnitude of these faults may be about the same as that of the more prominent of the high-angle reverse faults. They ordinarily are not expressed in the topography, but some of them are revealed by the presence of dikes, for these are the faults along which the porphyritic dikes were intruded. Most of them strike about N. 35° W., but at least one strikes about N. 50° W. and another N. 20° W. All of them would, if extended, join or intersect the Hope fault at an acute angle. All dip southwest at angles ranging from 50° to 70°.

One of the greater of these faults is exposed underground in the Hope mine, where, because it contains a diabase dike, it is known as the "dike fault." Another, also occupied by a diabase dike, has been uncovered at the Lawrence mine, and still another, partly filled with sulfides, on the old Ralph property. The dike fault may be traced for more than a thousand feet underground and for a still greater distance on the surface, where its position is marked by a band of especially luxuriant vegetation. The fault strikes about N. 35°–40° W. and dips 45°–55° SW. The dike is frozen to the hanging wall, but considerable movement has taken place along the footwall, beneath which the rock is extensively fractured, several inches of it being reduced to gouge. The fault zone contains a much larger proportion of gouge than those along the reverse faults, but not a greater thickness of mashed and fractured rock. In places the shattering is intensified where branch faults come into the footwall from the southeast at an acute angle. The rock bordering the dike fault shows considerable drag, and the drag folds indicate that the hanging wall has moved straight down the dip with respect to the footwall. Grooves also indicate movement in a vertical direction. A low-angle thrust fault cut by the dike fault has been dropped about 80 feet. A dike-filled fault at the Lawrence mine locally strikes N. 50° W. and dips 70° SW. It is exposed in a single crosscut, where it appears to resemble the one exposed in the Hope mine, and it has cut and displaced a low-angle thrust fault. A mineral-filled fault on the old Ralph property strikes N. 20° W. and dips 55°–70° SW. It is less prominent than the others, and in the workings it shows simply as a narrow breccia vein incompletely filled with siderite and sulfides.

The fact that these normal faults permitted the injection of magma suggests that they are tensional faults or reflect the tensional components of a shearing stress. Apparently most and perhaps all of the dikes exposed between Hope and Pack River extend in a northwesterly direction along faults of this kind and trend.

As these high-angle normal faults cut and offset the low-angle thrust faults, they are younger. Whether or not they are younger than the high-angle reverse faults cannot be determined by such direct evidence.

Strike-slip faults.—The two sets of strike-slip faults are sharply contrasted in magnitude and trend. One set consists of minor faults, all of which trend in the northwest quadrant; the other consists of much greater faults, all of which trend in the northeast quadrant.

Faults of the first set have been recognized only underground, being especially noticeable at the Hope mine. These faults have about the same strike and dip as the Hope fault, to which they seem to be subsidiary. The known displacement on most of these faults is generally but a few inches, or at the most a few feet. As shown by striations and grooves on slickensided surfaces and by offsets, the displacement is, as for the Hope fault, everywhere horizontal, the northeast side having moved relatively southeastward. At the Hope mine, these faults have caused repeated offsets of the low-angle thrust fault, but the offsets have nowhere been sufficient to interfere with the mining of the ore localized along the main low-angle thrust. In some places slickensided and grooved surfaces on the ore show that some of the movement was postmineral, but, as some of these slips also contain ore minerals, much of the displacement probably took place before the mineralization.

The strike-slip faults of northeasterly strike are much more prominently expressed in the topography than any faults yet described except the Hope. Their outcrops are marked by alined gulches, valleys, and saddles, eroded along wide zones of fracturing and crushing, a fact suggesting that these faults are of greater magnitude than the high-angle reverse and normal faults. These strike-slip faults are not restricted to any one formation, being as prominent in the Wallace rocks on Howe Mountain as in the Striped Peak rocks on Middle and Antelope Mountains. Some of them have been examined underground in mine workings, others have been identified from surface relations.

Among the larger of these faults are the Pugh fault at the Whitedelf mine, the Norquist fault at the Hope mine, and several faults on and between Middle and Antelope Mountains. All of these strike about N. 70° E. and are nearly vertical. Their attitude therefore does not conform with that of any other group of faults, but their relation to the Hope fault and to the northwestward-striking strike-slip faults may be significant, for if they were extended they would meet the Hope fault nearly at right angles, as if they were complementary to it.

The Pugh and Norquist faults are marked by zones of intensely crushed and mashed rock, which are for the most part 10 to 15 feet wide but are locally 40 feet wide, with considerably more gougy material than there is along any of the high-angle normal or reverse faults. The fault zones are structurally complex, being made up of numerous fractures diverse in trend, some of which appear to be tensional fractures that extend obliquely across the fault zone. The Pugh fault has displaced the Pearl high-angle reverse fault about 110 feet measured in a horizontal direction, with the offset northeastward on the northwest side. The Norquist, which is supposed to be a continuation of the Pugh, has offset the low-angle thrust at the Hope mine, but the offset segment has not been uncovered on the upper levels but may be on the lowest where the displacement locally is but a few feet. These two faults are apparently not so large as the others of the group; though visibly reflected in the topography, they are not so prominently expressed as the others on Middle and Antelope Mountains, and they have smaller stratigraphic displacement.

Those with the more prominent topographic expression show marked horizontal stratigraphic offsets, with the apparent displacement invariably to the right on the far side of the fault if the offsets are viewed along the strike of the beds. The fault along Mosquito Creek appears to have offset certain of the red beds of the Striped Peak formation on Middle Mountain about half a mile in relation to the same beds on Antelope Mountain. Other faults on Middle Mountain show considerably smaller stratigraphic offsets, but the displacement is invariably to the right in the sense just defined.

Another large fault that probably belongs with this set has brought the beds of the Wallace and Striped Peak together near the northwest tip of Middle Mountain. This fault has a northeasterly trend and is marked by a prominent saddle where it crosses a ridge. It is also revealed in a long road cut that skirts the lower west side of Middle Mountain. There the disturbed zone is more than 100 yards wide and is made up in considerable part of crushed gougy rock. The stratigraphic throw may be several thousand feet. Beds on either side of the zone of faulted rock show large-scale drag, with indications of a prominent strike-slip component of movement. This fault is apparently by far the greatest of those in the northeastward-striking group.

The faults of this group are definitely younger than the low-angle thrust and high-angle reverse faults, which they displace. Their relation to the high-angle normal faults of northwest trend is not entirely clear, but they seem to be at least in part somewhat younger. Air photographs suggest that the dike fault at the Hope mine does not continue directly across the Norquist fault. The Norquist fault, on the other hand, apparently has not been displaced by the dike fault, for the Norquist has been found in the No. 9 level where its projection from the No. 6 and higher levels indicates it should be. The strike-slip faults are apparently among the youngest in the district.

Other faults.—There are a few minor faults that do not conform in trend with those that have been described. Among them are some northward-trending faults at the Whitedelf mine and several at the old Ralph property. These have displacements of a few inches to a few feet. They may be high-angle normal faults that differ slightly in trend from most of the others because of the influence of other faults nearby.

ORIGIN OF THE FAULTS

As the Hope fault has a horizontal component of movement of some 12 miles, it has been classed as a strike-slip fault of the first order of magnitude and accounted for as a product of horizontal shearing stresses, with the active stress on the south side directed to the west-northwest and that on the north side to the east-southeast. Similar stresses, acting in part less directly, could account for all the other faults in the district.

The early-formed low-angle thrust faults and high-angle reverse faults, with their general north-northeasterly trend and southeasterly dip, have the position and relations that would associate them with the compressive components of the west-northwesterly shearing stress, the low-angle thrusts having been developed in the weak shaly members of the Striped Peak formation and the high-angle reverse faults in the more competent quartzitic beds of the Wallace formation. The low-angle thrusts that strike northwest may have responded to the compressive components of the stress associated with the complementary shearing that acted at about right angles to the main shearing—in association, that is, with the northeastward-striking strike-slip faults.

The high-angle normal faults also fit into the pattern as products of the tensional components of the shearing. Their north-northwest trend and their relation to the Hope fault are precisely those demanded by the shearing stresses, and the fact that the faults are commonly occupied by intrusive rocks tends to confirm the belief that they formed in response to tension.

The two sets of strike-slip faults appear to have formed in direct response to the shearing, for they are alined along the directions of maximum shear. The minor strike-slip faults parallel to the Hope fault are apparently subsidiary slips, which, like the Hope fault, developed in response to the main shearing stresses. The larger strike-slip faults, on the other hand, that strike east-northeast, nearly perpendicular to the Hope fault, are apparently shear faults complementary to the main west-northwest shearing.

Thus all the faults—strike-slip, normal, thrust, and steep reverse—may be interpreted as reflecting the action of the major horizontal shearing stresses, acting locally in a west-northwest direction, together with the subordinate complementary shearing stress directed to the east-northeast. Initial failure apparently occurred in response to the compressional components of the stress, but it was soon followed by failure due to tension and then by failure due to shear. Failure due to shear apparently continued for the longest time and produced the greatest results.

The origin of the stresses responsible for the Hope fault and its associated fractures is not definitely known; the stresses apparently originated far outside the district. As the igneous activity associated with the faulting, and hence the faulting itself, is probably early Tertiary, the faulting probably bears a close relation to the Laramide orogeny, of late Cretaceous or early Tertiary time. It is possible that the zone of complicated faulting reflects the differential transmission of stress through the relatively strong rocks of the region against the trough of weak sedimentary rocks on the east (Laramide or Rocky Mountain geosynclinal trough of sedimentation), which was then undergoing deformation by folding and faulting, with the formation especially of great low-angle overthrusts.

ORE DEPOSITS

HISTORY AND PRODUCTION

Lead-silver ore was first uncovered on Antelope Mountain, but just when was not learned. Records show that some of the ore was shipped in 1903, but the shipments were not impressive and the district did not attract much attention until about 10 years later, when the Lawrence Mining and Milling Co., Ltd., later called the Lawrence Consolidated Mining Co., installed a 50-ton gravity concentrator and began to make small shipments of rich lead concentrates.

No other discoveries were made until 1923, when the small but rich Elsie K vein was uncovered on the lower western slope of Middle Mountain and began to be worked in the Elsie K mine, later renamed the Hope. Shipments of rich hand-sorted lead-silver ore began almost immediately, but the new mine, though it proved profitable from the surface, was almost as little noticed as the Lawrence mine had been 20 years before. Not until 3 years later, when the uprooting of a tree near the southeast end of Howe Mountain uncovered a body of rich lead-silver ore, was general interest aroused. The discovery of ore by the uprooting of a tree during a storm received widespread publicity, and the Whitedelf soon became one of the most talked-about mines in the State, but this new discovery proved disappointing with depth. In the meantime, however, work had begun on the Pearl vein, which had been disclosed a short time previously in a newly opened road cut. The Pearl vein proved to be one of the most important finds ever made in the district. It was soon supplying shipments of rich ore from the very surface, and was destined to become the source of practically the entire production from the Whitedelf mine. Production increased rapidly during the next several years at both the Whitedelf and Hope mines, and the Clark Fork district soon outranked all the others in the northern part of Idaho except the Coeur d'Alene. These discoveries prompted considerable prospecting, and some strikes were made, but none of them compared with those at the Lawrence, Hope, and Whitedelf mines. The later history of the district has centered in the activities of these three mines.

Since 1913 the work at the Lawrence mine has been intermittent, but some concentrates have been shipped in each year except 1921, 1924, 1928, 1930, 1933, and 1936. During the last few years the mine has been worked by leasers. Shipments from the Elsie K had totaled 14 carloads by the time of the reconnaissance study in 1927. In 1928 one or two carloads were shipped each month. Most of the shipments were made by leasers, who later purchased the mine from the owner and organized the Hope Mining Co. Production continued to increase through 1929 to 1931. In 1931 the property was equipped with a mill, but work was suspended in 1932 and the mine remained idle through 1933. Some development work was carried on later, and in 1935 the mine was taken over by the Hope Silver-Lead Mines, Inc. The new management continued operations on a greatly increased scale, generally producing 2 to 3 carloads of concentrates monthly.

The Whitedelf mine began to ship hand-sorted ore in July 1926, and in less than 18 months had sent 95 carloads to the smelter. The Whitedelf Mining and Development Co. had been organized in March 1926, but most of the early shipments were made by leasers. Production was curtailed considerably during 1928 and 1929, when deeper levels of the mine were being opened. In 1929 the property was equipped with a 75-ton flotation concentrator, and since then mostly concentrates have been sent to the smelter. Because of the low price of metals the mine was closed in 1933, and it was not fully reopened until 1937. Development was then resumed, and the company continued operations until early 1940, when the mine was taken over by leasers, who concentrated their attention upon a newly discovered shoot of rich silver ore in a faulted segment of the Pearl vein. This discovery again served to stimulate interest in the district.

The production from the three mines is given in the table following:

Production of the Clark Fork district, 1913-43, in terms of gross metal content

[By G. E. Woodward, Bureau of Mines, U. S. Department of the Interior]

Year	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)
1913	4, 746	0. 26	4, 877	111	510, 579	
1914	324	. 21	1, 326	40	121, 914	
1915	457	. 08	1, 455	74	163, 308	
1916	454		943	160	111, 225	
1917	762	. 08	2, 254	159	197, 271	
1918	772		2, 195		199, 753	
1919	144		518		56. 514	
1922	107		1, 675		163, 932	
1923	67		941		88, 630	
1925	224		6, 080		200, 163	
1926	1, 322	. 95	45, 760	893	1, 013, 625	
1927	3, 028	. 20	116, 661	209	2, 202, 084	
1928	2, 483		74, 461	564	1, 460, 661	
1929	11, 811	2. 80	88, 709	916	1, 815, 688	
1930	19, 182		85, 960	2, 487	1, 984, 390	
1931	21, 516		89, 550	2, 794	2, 147, 692	
1932	11, 997		53, 137	1, 267	1, 204, 302	
1933	6, 455	. 60	24, 219	810	646, 213	
1934	6, 700	. 50	22, 348	450	665, 495	
1935	4, 764	. 80	12, 713	226	393, 221	
1936	10, 250	2. 80	37, 162		1, 168, 358	
1937	23, 808	14. 00	52, 246		1, 696, 704	
1938	12, 591	4. 00	47, 320		1, 346, 668	
1939	12, 135	4. 00	48, 355	1, 597	1, 232, 797	
1940	12, 759	3. 00	63, 279	2, 400	1, 195, 176	
1941	9, 616	1. 00	58, 747	3, 171	841, 867	
1942	12, 077	2. 00	47, 737	1, 914	812, 620	700, 000
1943	11, 166		14, 019		607, 002	74, 300
Total	201, 717	37. 28	1, 004, 647	20, 242	24, 247, 852	774, 300

CHARACTER

The lead-silver deposits are much like those in the Coeur d'Alene district, but on the whole they have a somewhat higher proportion of silver and antimony because of a late local hypogene enrichment. Fundamentally, however, they are galena-siderite fillings and replacements along zones of fractured and fissured rock. In addition to argentiferous galena, the deposits enriched in antimony and silver contain lead sulfantimonites in various proportions and minor quantities of silver sulfantimonites. The importance of the enrichment is reflected in the ratio of silver to lead in the different deposits. Those that were not enriched contain about 0.20 ounce of silver to one percent of lead; those that were enriched contain 0.50 to one or more ounces of silver to each percent of lead. The enriched deposits contain appreciable amounts of antimony, enough in places to be recovered as a byproduct. Some zinc is contained in the ore but generally not enough to be recoverable. The amount of copper is negligible.

Much of the ore is massive and contained in compact seams and stringers. The structural relations suggest that the ore was formed at moderate depth; the mineralogic features indicate deposition at moderate to fairly low temperatures. The deposits differ from those of the Coeur d'Alene district mainly in size rather than in character.

GEOGRAPHIC AND GEOLOGIC DISTRIBUTION

All the productive mines are within a mile of the town of Clark Fork, the Whitedelf being near the southeast end of Howe Mountain, the Hope on the lower western slope of Middle Mountain, almost directly across Lightning Creek from the Whitedelf, and the Lawrence on the lower northwest slope of Antelope Mountain. Some of the other deposits are near the crest of Antelope Mountain and on the long ridge that extends toward the edge of town, but most of them are on the lower slopes, facing Lightning and Mosquito Creeks, and fall within a semicircle of 2 miles radius with its center in the town of Clark Fork. The most distant are at the north end of Middle Mountain, the nearest on the lower slopes at the edge of town.

The deposits on Howe Mountain and those at the north end of Middle Mountain are contained in the Wallace formation; all the others are in the Striped Peak formation. The distribution of the ore appears to have little relation to the kind of rock; ore deposition depends chiefly on the presence of favorable structural openings, especially of minor faults related to the Hope fault. These seem to be especially well developed in the vicinity of the town of Clark Fork.

STRUCTURAL RELATIONS

All of the faults exposed underground show evidence of more or less intense hydrothermal alteration or mineralization, but bodies of commercial ore have been found only along the low-angle thrust faults and the high-angle reverse faults. Faults of both these kinds contain less gouge than the other faults in the district, and it is apparently for this reason that they have provided especially favorable openings for the circulation of the ore-bearing solutions. The normal and strike-slip faults, with their thick gouges, have inhibited extensive mineralization, and along them only small and widely scattered bodies of ore have been found. The ore at the Lawrence and Hope mines is all on low-angle thrust faults, although at the Hope mine a little ore has been uncovered locally along the dike fault and stringers of ore have been found along the Norquist. At the Whitedelf mine the ore is on a steep reverse fault, the Pearl. Several other high-angle reverse faults also contain or have contained a little ore. Ore has been stoped from two small shoots along the Pugh strike-slip fault, but all the deposits found elsewhere, except those on Howe Mountain, are on low-angle thrusts.

The structural relations and characteristics of the various controlling faults have already been given. Additional details will be included in the descriptions of individual properties.

MINERALOGY[8]

GENERAL FEATURES

Except for the added assemblage of complex lead and silver sulfosalts, the ore minerals in the Clark Fork district are those that characterize most of the lead deposits in the Coeur d'Alene district. It is thus convenient to separate the minerals into two groups, the earlier one representing the Coeur d'Alene type of mineralization and the later one consisting of the minerals formed by hypogene enrichment. Some of the minerals tentatively identified in the later group are rare, and their local abundance is one of the most interesting features of the Clark Fork mineralization.

Supergene minerals are of little consequence in the district, because weathering has had time to accomplish little since the Pleistocene glaciers stripped away the former oxidized outcrops. Today the sulfides appear at or just below the surface and are only partly altered to anglesite and cerussite (sulfate and carbonate of lead, respectively) and only partly encased in limonitic and manganese oxides formed by the decomposition of the associated manganiferous siderite.

EARLY MINERALS (COEUR D'ALENE TYPE)

The early minerals include galena, sphalerite, pyrite, arsenopyrite, tetrahedrite, bournonite (?), siderite, quartz, calcite, barite, and possibly rhodochrosite, but only the galena, sphalerite, siderite, and quartz are readily distinguished, some of the others being visible only under the microscope.

Galena.—Galena is the most abundant of the early minerals and, except in certain shoots along the Pearl vein where sulfantimonites predominate, is the principal ore mineral, being the source of most of the lead and of an appreciable part of the silver. The silver-lead ratio in the early assemblage ores of the district as a whole is probably not far from that in the Lawrence mine, where the ore has not received additions of the lead and silver sulfantimonites. There the galena concentrate carries 14 to 15 ounces of silver to the ton, or about 0.20 ounce of silver to each percent of lead. As these concentrates contain less than 0.01 percent of copper and rarely more than 0.15 percent of antimony, a few micro-

[8] The specific identity of some of the sulfosalt minerals is in doubt.

scopic grains of tetrahedrite can hardly account for the presence of all the silver, and the galena must therefore be argentiferous.

Most of the galena shows the effects of rather intense deformation, associated particularly with the movements that reopened the early fillings and permitted the admission of the younger mineral-bearing solutions. Although originally most of it was coarsely cubic, much of it now is mashed or granulated and shows a pronounced gneissic structure. Some, however, has been changed to fine-grained "steel" galena. This deformation is generally most pronounced along the borders of the galena bodies, but where the structural movement has been particularly intense it has affected all the galena. Where the deformation has been relatively slight, as at the Lawrence mine, the mashed zone is only about half an inch wide and passes abruptly into coarsely crystalline cubic galena in which the cleavage is curved or bent. At the Hope and Whitedelf mines the younger sulfantimonites have in large part been introduced along the zones of flowage.

Excepting calcite, the galena appears to be the youngest of the early minerals. It commonly encloses scattered irregular grains of pyrite and even more widely scattered remnants of microscopic grains of arsenopyrite and tetrahedrite. It also cements brecciated masses and grains of sphalerite, and in places it forms tiny veinlets that cut the sphalerite. Where it has been deposited in openings it may form a crust on sphalerite or, if sphalerite is absent, on siderite. Much of it shows a marked tendency to replace siderite, but where siderite is absent or has been largely replaced, seams, ramifying veinlets, and irregular bodies of galena may penetrate and replace earlier quartz or altered country rock.

Sphalerite.—Sphalerite is present in small but variable quantity in all the deposits. Some shipments from the Lawrence mine have contained only traces of zinc, but others have contained 1 to 3 percent, and one contained enough to incur a smelting penalty. The ore of the Hope mine contains a somewhat higher proportion of sphalerite. Shipments from the intermediate and upper levels have contained 2.5 to 5 percent of zinc; those from the lower levels commonly contained a little more than 5 percent, and exceptionally as much as 10 percent. But, although the proportion of sphalerite increases downward in general, it may be far from uniform on a given level; different ore shoots differ widely in their content of sphalerite, the mineral being almost absent from some shoots and relatively abundant in others. The sphalerite at the Whitedelf mine shows a similar distribution, though on the whole it is less abundant than at the Hope mine. Much of the ore that was first shipped contained a trace to 1 percent of zinc, but with increasing depth the zinc content has ranged upward to 3 percent, and in some of the late shipments the concentrates have contained as much as 5 percent and one as much as 9.5 percent of zinc.

Much of the sphalerite has a reddish-brown color that makes it easy to distinguish from the pale-brownish or buff siderite and the other minerals. The hue of the sphalerite tends to be reddish at the Hope mine and brownish at the Whitedelf. It is extensively brecciated and has locally been crushed to a powder, which coats the surface of the ore. Part of it is confined to small lenses, pods, and bunches, less than an inch to several inches long and a fraction of an inch to an inch wide. Much of it forms scattered granules or small veinlets in the wall rock.

The sphalerite is older than the galena but apparently younger than the pyrite, arsenopyrite, quartz, and siderite. Like the galena it encloses scattered remnants of pyrite and less commonly of arsenopyrite and penetrates and replaces siderite, quartz, and the altered country rock. That which penetrates and replaces the siderite and altered country rock generally forms irregular ramifying veinlets. Where it has been deposited in openings it forms a layer next to the walls, commonly on a base of siderite or quartz crystals. It is confined to the edges of massive ore seams usually as brecciated grains cemented with galena and as wall-rock stringers cut off sharply and penetrated by bands and stringers of galena. Where the ore consists dominantly of massive galena, the sphalerite is mostly restricted to stringers in the bordering wall rock. When the later hypogene antimony-bearing and silver-bearing solutions moved along the deformational zones at the margins of the ore bodies much of the brecciated sphalerite became cemented with sulfantimonites and sulfarsenites, partly because these sulfosalts replaced the galena that originally had cemented the shattered grains of sphalerite.

Tetrahedrite.—Tetrahedrite is present in variable but small quantity in all of the ore, generally as microscopic grains within the galena, less commonly as larger, irregular grains associated with galena and sphalerite. It seems somewhat more abundant in the ore at the Whitedelf mine than elsewhere, but even there it is recognized only under the microscope. The tetrahedrite is presumably argentiferous, and the galena may have acquired a part of its silver content by replacing tetrahedrite. However, such a process can hardly account for more than a very small part of the silver, for, as much of the ore contains no more than .01 percent of copper, the proportion of tetrahedrite in the ores is now and probably always was very small. A little tetrahedrite occurs in fractures in the sphalerite. The mineral is therefore younger than the sphalerite but older than the galena.

Bournonite (?).—Bournonite ($Cu_2S.2PbS.Sb_2S_3$) forms widely scattered microscopic grains and irregular masses in the ore at the Hope and Whitedelf mines. Its appearance and reactions are much like those of tetrahedrite, from which it may be distinguished by the rather conspicuous polarization colors that it displays in reflected polarized light. The mineral apparently occurs in both the younger group and the older group of minerals. Only the older bournonite will be described at this point.

The older generation of bournonite forms minute masses enclosed in galena and narrow margins on and tiny veinlets in tetrahedrite also enclosed in galena. These narrow rims of bournonite and tiny veinlets in the tetrahedrite indicate that the bournonite probably was formed during replacement of tetrahedrite by galena, the tetrahedrite contributing the copper, antimony, and some of the sulfur and the lead-bearing solutions contributing the lead and perhaps a part of the sulfur. Its position in the sequence is therefore between tetrahedrite and galena. The younger generation of bournonite, as will be shown later, replaces lead sulfosalts as well as galena.

Pyrite.—Small remnant grains of pyrite are invariably present in the marginal parts of the ore bodies, and scattered crystals of it occur in the bordering wall rock. It is not conspicuous except in some of the fissure and breccia zones that were not impregnated with galena. Locally it is fairly abundant in the fractured rock bordering some of the ore bodies.

The crystals and grains of pyrite are generally minute, but pyritohedral faces can usually be distinguished even on the smaller crystals. Crystal outlines are absent only where the mineral has been partly replaced by sphalerite, galena, and some of the lead sulfantimonites. It forms a few massive granular aggregates, but they are small and relatively inconspicuous. Much of the pyrite in the wall rock is in rather sparsely disseminated crystals. In the zones of brecciated rock not filled with ore the pyrite tends to form thin crystalline crusts on breccia fragments, much of it being in thin patches on the surface of the altered rock.

As pyrite has been engulfed in sphalerite and galena and locally replaced by them, it is clearly older than either; but it is younger than siderite, for minute pyritohedrons encrust crystal faces of siderite and are alined along cleavage planes in siderite. In places pyrite and quartz are closely associated, and one or both fill fractures in siderite or form veinlets replacing siderite. So little pyrite is enclosed in galena as to suggest that the pyrite in the main masses of ore was replaced by the younger ore minerals.

Arsenopyrite.—Arsenopyrite has been identified along all of the mineralized faults, but only in minute grains and crystals, which as a rule are sparsely disseminated, so that the mineral can ordinarily be detected only under the microscope. It usually occurs in the silicified walls bordering the ore seams, rarely as inclusions in the sphalerite and galena. Enough of it is associated with the ore, however, to have an appreciable effect on smelter returns. Ore from the Lawrence mine contains as much as 0.1 percent of arsenic and ore from the Hope mine 1.0 to 1.5 percent. At the Whitedelf mine the arsenic content has averaged about 0.5 percent, but it has been somewhat higher in late shipments, which included ore that was rich in lead sulfantimonites. As this ore appears to show no increase in arsenopyrite, its increase in arsenic is thought to reflect the presence of lead sulfarsenites. At only one place, in the drift along the dike fault on the No. 3 level of the Hope mine, is arsenopyrite visible to the unaided eye, but that is because the microscopic grains are so abundant and so closely spaced as to impart a distinctly grayish metallic color to the altered shale.

Much of the arsenopyrite forms minute rhombic crystals, but some of the crystals enclosed in sphalerite and galena have indented borders and rather irregular outlines. The crystals apparently were not so easily replaced as those of pyrite. Most of the arsenopyrite, like the closely associated pyrite, impregnated the bordering walls of the ore seams, lying alongside them rather than within them. The association of the arsenopyrite with equally minute crystals of pyrite in the wall rock suggests that both were deposited at about the same time and in advance of the other sulfides.

Siderite.—Siderite is an ever-present but generally not an abundant mineral, being conspicuous in only a few places. It is, however, the most abundant gangue mineral, apart from altered wall rock broken with the ore in mining. In the breccia vein at the old Ralph property it happens to be the most abundant mineral, but elsewhere it is subordinate to the ore minerals, probably because much of that which may have been deposited has been largely replaced by ore. Nowhere is it entirely wanting, although it is somewhat spotty in its distribution and recognizable in some places only under the microscope.

The siderite has a pale buff color that sets it apart from the other minerals. It is manganiferous and yields a black gossan when oxidized. It exhibits a marked tendency to form regular crystals; perfect rhombohedra not uncommonly impregnate the sericitized wall rock and form crusts on rock fragments in breccias. In places these crusts are covered or partly covered with sulfides. The siderite also occurs in more massive form, particularly in stringers and irregular veinlets in the fractured wall rock and in thin sheets along the walls of the ore seams. These sheets have generally been so brecciated by faulting movements and then so extensively replaced by ore minerals that remnants of siderite are strewn along the marginal parts of the ore seams, forming small, bleblike inclusions, small discontinuous pods and interrupted layers, or mere isolated grains. Siderite is therefore most conspicuous in veinlets and small bunches in the wall rock, beyond the reach of the sulfides.

The extensive replacement of the siderite by sulfides shows it to be an early mineral; it is, in fact the earliest mineral in all deposits except one. In this exceptional instance it forms a layer on quartz, whereas elswhere the veinlets and scattered crystals of siderite in the country rock are penetrated and replaced by quartz as well as by sulfides.

Rhodochrosite.—Rhodochrosite occurs very sparsely in some of the minor slips that cross the ore bodies of the Hope mine. It forms little stringers of no great persistence, which attract attention only because of their pinkish color. As the rhodochrosite was not observed in contact with the ore, its position in the depositional sequence remains in doubt. Unlike the siderite, it is not closely associated with the galena or earlier minerals, and it may be younger than any of these; it may even have been deposited during the subsequent silver-antimony metalizing stage.

Quartz.—Quartz is considerably less abundant than siderite, being indeed scarcely noticeable except in some of the lead-silver sulfantimonite ore along the southwestern segment of the Pearl vein, in the Whitedelf mine. There, however, the quartz appears to be associated with the younger group of minerals. The early-stage quartz, which alone is to be considered here, is more easily distinguished in thin sections and polished sections than in hand specimens, although here and there small stringers and masses in the fractured wall rock and small crystals and grains within the ore itself are visible to the naked eye. White crystals of quartz form drusy crusts on breccia fragments of wall rock, and isolated crystals are enclosed in the sulfides. White granular quartz forms veinlets or small irregular masses, usually along fractures in the wall rock.

The early quartz is not all of the same age. In the breccia vein at the old Ralph property it commonly encrusts fragments of country rock and is encrusted in turn with siderite crystals, whereas elsewhere it has been deposited on siderite crystals or occurs in stringers or masses that cut the siderite. The younger quartz, also, replaces siderite as well as country rock. For the most part, however, the quartz is older than the sulfides, for remnant grains and crystals of it are enclosed in the sulfides and masses and stringers are cut and replaced by ore. Deposition of quartz apparently just preceded and in part accompanied the deposition of the early sulfides.

Barite.—Barite is exceedingly rare, having been noted in only two places, one in a specimen from a narrow vein on the east slope of Antelope Mountain, the other in a single thin section of the silicified wall rock in the Whitedelf mine. In the first case the barite forms a filling less than an inch thick between walls of coarse white comb quartz; in the second it forms microscopic crystals in or near seams or stringers of quartz. Its relations prove that it is younger than the quartz, but there is nothing to indicate its age with respect to the sulfides. As it is closely associated with quartz, it, like the quartz, may have been deposited before the sulfides.

Calcite.—Calcite, though it generally escapes notice, is more or less widely distributed through the district, chiefly in microscopic stringers that cut the sulfides. Some, however, is visible to the naked eye; in the breccia vein at the Ralph mine tiny flat rhombohedrons of calcite encrust the sulfides, and in some of the ore at the Lawrence mine there are crystalline crusts as much as a fourth of an inch thick in open fractures in the galena. Elsewhere the mineral was recognized only microscopically as fracture fillings in the sulfides. The relations described show that calcite is the youngest of the early-stage minerals, having apparently been deposited just after the last of the galena. Crystalline crusts may be supergene.

LATE HYPOGENE MINERALS

The deposits on Antelope Mountain, which include those of the Lawrence mine, apparently received no additions of late hypogene minerals; the silver-antimony enrichment is confined to the deposits on Middle and Howe Mountains. Hypogene minerals make up a fourth of the ore substance at the Hope mine and almost all of the ore in the deeper levels of the Whitedelf mine and in the offset segment of the Pearl vein to the southwest. Small amounts of these late minerals have also been observed in nearby lightly mineralized faults, including the Pugh, the Norquist, and the dike fault.

Because of the enrichment, the ore at the Hope mine contains about two to three times as much silver and 10 to 20 times as much antimony as the unenriched ore at the Lawrence mine. The ore of the Whitedelf mine is even more enriched; most of it contains 4 to 6 and part of it 10 to 15 times as much silver as the

Lawrence ore and generally 10 to 40 and exceptionally 90 times as much antimony. As indicated by smelter returns, the Lawrence concentrates generally contain less than 0.1 percent but exceptionally as much as 0.3 percent of antimony; the concentrates and ore at the Hope contain 1 to 2 percent (maximum 2.29 percent) of antimony. The concentrates from the upper levels of the Whitedelf mine contain 1 to 4 percent of antimony, and those from the lower levels and the shoot in the southwest segment of the Pearl vein contain 2.5 to 9.6 percent. The concentrates from the Lawrence mine contain about 15 ounces of silver to the ton, those from the Hope 30 to 45 ounces, and those from the Whitedelf 60 to 80 ounces, except in the deeper ore, where returns of 100 ounces are common and as much as 200 ounces per ton has been recorded.

Most of the sulfantimonite and sulfarsenite that make up the additions to the ore form lead-gray to steel-gray granular masses, which may easily be mistaken for tetrahedrite, except in some places where they form fibrous and divergent groups. The minerals occur for the most part as irregular veinlets and masses in the galena, especially in deformational zones near and along the margins of the ore seams. Stringers of them also penetrate and replace fractured siderite, and masses of them cement the marginal sphalerite, apparently by replacing the galena that previously had cemented the sphalerite. Deposition has not, however, been effected by replacement alone; independent stringers of sulfosalts have been observed along some fault zones that contain but little galena. Some of the ore in the southwest segment of the Pearl vein is made up of curved laths and needles of the sulfosalts that penetrate and lie between crystals of quartz.

The late hypogene minerals that may readily be recognized include quartz and pyrargyrite. The others are so much alike that they can be distinguished individually only with difficulty. The minerals identified include semseyite(?) ($9PbS.4Sb_2S_3$), jordanite(?) ($4PbS.As_2S_3$), and bournonite(?) ($Cu_2S.2PbS.Sb_2S_3$). This group of minerals is negative to most etch reagents. All of them react with aqua regia, and all but bournonite respond readily to nitric acid. Most other reagents are negative. The various sulfosalts and their distinctive tests and relationships are discussed in detail in another report.[9]

Quartz.—Quartz apparently belonging to the late stage of metalization was observed only with the ore in the southwest seg-

9 Anderson, A. L., Lead-silver mineralization in the Clark Fork district, Bonner County, Idaho: Econ. Geology, vol. 41, No. 2, March-April, pp. 112-122, 1946.

ment of the Pearl vein, where it forms rather loosely meshed, partly interlocking crystals cemented and in part penetrated by needles and laths of the complex sulfosalts. It forms a very subordinate part of the ore shoot as a whole, and it seems to be absent from all the other deposits in the district.

Semseyite (?).—Semseyite was observed in some of the polished sections of ore from the Pearl vein.

Jordanite (?).—Jordanite was identified in some of the ore from the Hope mine.

Bournonite (?).—Bournonite reappears with the younger minerals in the ore at the Hope and Whitedelf mines, being microscopically visible when the associated minerals have been etched by nitric acid. It then appears distinctly as grayish veinlets and stringers cutting and replacing galena and the various lead sulfosalts.

The presence of late bournonite is apparently responsible for raising the copper content of the ore at both the Hope and Whitedelf mines. In the latter mine most of the ore shipped between 1939 and 1941 inclusive contained 0.01 to as much as 0.5 and some of it as much as 0.8 percent of copper, whereas the ore shipped earlier contained less than 0.01 percent of copper. The increase came when the ore notably rich in the sulfosalts was mined. The ore at the Hope mine likewise has fluctuated between 0.01 and 0.1 to 0.2 percent. The ore at the Lawrence mine, on the other hand, has never carried more than 0.01 percent of copper, and that probably represents, roughly, the percentage of copper in the ore deposited throughout the district during the early stage of metalization, any higher percentage being due to enrichment during the later hypogene stage.

Pyrargyrite.—Pyrargyrite ($3Ag_2S.Sb_2S_3$) has thus far been observed only at the Whitedelf mine and there only in the ore shoot in the southwest segment of the Pearl vein, which was being mined in 1940 and early 1941. It may be present on the deeper levels of the mine (inaccessible in 1940), for the silver content of the ore mined from those levels was unusually high. Pyrargyrite is fairly abundant in the ore shoot in the southwest segment of the Pearl vein, where scattered grains and irregular stringers of it are plainly visible, particularly along fractures that cut the lead sulfosalts and galena. In polished sections it is easily detected without etching as grains and veinlets that cut and replace the sulfosalts and galena. It tends to be distributed along fractures that cut across both sulfosalts and galena and may have been the last mineral to enrich the ore shoots. As pyrargyrite, like the other sulfosalts, appears to increase with depth and has no apparent relation to the surface or ground-water table, it is probably a product of hypogene rather than supergene enrichment.

The presence of pyrargyrite probably has had much to do with the high silver content of the ore in which it occurs. In much of the Whitedelf ore the silver-lead ratio has been about 1:1 (one ounce of silver to each percent of lead), but in the shoot that contains the pyrargyrite the ratio is commonly 2:1 to 3:1 and goes as high as 6:1. The last two shipments of concentrates in 1941 carried 210.5 and 237.5 ounces of silver per ton and 38.6 and 36.6 percent of lead, respectively. The lead content of these two shipments was considerably below the average for the mine, whereas the antimony content (9.6 and 8.4 percent) was considerably above the average, being indeed the highest ever recorded for the mine. The relatively low lead content and the relatively high antimony and silver content suggest that the ore consisted largely of the lead sulfantimonites.

PARAGENESIS

As many data on mineral succession have been included in the descriptions of the individual minerals, little more than a summary of the paragenesis need be given here. The order in which the minerals were deposited during the first period of metalization is particularly well defined, for wherever the minerals were not deposited as successive crusts in open spaces minor faulting contemporaneous with ore deposition fractured and crushed the earlier minerals, which were then cemented and partly replaced by later minerals. After the major structural break that separated the two periods of metalization, the mineralization-faulting was not so prominent, and the order in which the various sulfosalts were then deposited is not so easily interpreted and has not been entirely worked out.

In all but one of the deposits mineralization was initiated by deposition of siderite in fractures, accompained by replacement of the bordering country rock. The only known exception to the rule occurred in the breccia vein at the old Ralph property, where the first mineral deposited was quartz, which was followed by siderite. In most of the deposits a period of minor faulting occurred next, before other minerals were introduced. Much of the siderite that had been deposited was more or less extensively brecciated by this faulting, after which quartz was introduced closely followed by sulfides, all of which replaced the siderite except where the siderite had only partly filled open spaces and had not been disturbed by the faulting; in that case the quartz and sulfides were deposited on the surface of the siderite crystals. A minor structural break also intervened between the deposition of quartz and that of the sulfides, for much of the quartz is cut by healed fractures filled with sulfides, by which the quartz is partly replaced. Some quartz, however, continued to be deposited with the sulfides, which enclose widely scattered crystals of quartz. Barite was locally deposited on the quartz, perhaps before the sulfides.

The first sulfide deposited was either pyrite or arsenopyrite; there is no decisive evidence as to which came first. Again structural adjustments interrupted the process, and both minerals, particularly the pyrite, were fractured. Both minerals were then cemented and partly replaced by the sulfides that followed, first sphalerite and then galena. Rather marked movement also occurred after the deposition of the sphalerite, much of which was shattered before any other sulfides were added. Tetrahedrite was deposited immediately after sphalerite, but much of it was subsequently replaced by galena, locally with an intervening reaction rim of bournonite. Very minor fracturing of the galena and other minerals permitted the introduction of a little calcite. Whether the rhodochrosite was introduced at this point or during the succeeding silver-antimony stage has not been determined, but it appears likely that the deposition of calcite brought the early mineralization to a close. Further faulting served merely to shatter the sphalerite and to deform the galena by flowage, giving much of it a prominent banded or gneissic structure or changing it to fine-grained "steel galena."

Renewed mineralization, which occurred after the deposits on Howe and Middle Mountains had been reopened by vigorous movements, began in at least one place with the deposition of quartz, but generally it began with the deposition of the various complex sulfantimonites and sulfarsenites, which filled fractures and replaced galena. As most of the sulfosalts are intimately associated, they may in part have formed contemporaneously. However, some sulfantimonites and sulfarsenites replace other sulfantimonites and sulfarsenites.

DISTRIBUTION OF THE ORE

Much of the ore comes from compact seams and lenses composed almost entirely of massive sulfides, but some occurs in stringers or forms disseminated grains. The seams and lenses generally lie along the more prominent fractures or fissures of the fault zone, ordinarily along one of the walls, with the stringers and the disseminated grains in the fractured rock alongside. The main ore seams are generally separated from the walls by gouge of variable thickness, which permits the ore to be easily detached from the country rock. The compactness of the ore and the ease with which it can be separated from the waste facilitated hand sorting in the early days, when attention was directed only to the main seams and lenses, so that the ore could be cheaply mined and concentrated without the expense of milling.

In each of the bodies on the low-angle overthrusts, much of the ore is concentrated in thin, compact high-grade seams, commonly no more than a few inches wide, along the better-defined wall of the fault zone, which is usually the footwall; but some of the ore forms grains and stringers in the fractured rock above, and in places the stringers join another but smaller seam along the hanging wall. At the Hope mine the width of the main ore seam has averaged about 4 inches and has rarely exceeded 7 inches. During the early operations the seam was mined profitably wherever it was more than 2 inches thick. No attention was then paid to the stringers, but when the mill was placed in operation the stringers as well as the main seam were stoped, and all the ore was saved. In some parts of the mine the stringers have increased the thickness of the high-grade ore to 2 feet or more and have provided stoping widths of 4 and even 6 feet. At the Lawrence mine, also, much of the ore has been mined from a footwall seam that is mostly 2 to 4 inches and locally as much as 8 inches thick. Ore has also been mined from hanging-wall seams and from stringers and disseminated ore in the fractured rock between the hanging-wall and footwall seams, giving stoping widths of 2 to 4 feet. Most of the other low-angle thrust faults possess more or less similar characteristics. In some, however, the ore is in small bunches or pockets or in numerous small stringers in the fractured and brecciated country rock.

Although the ore seams in all these thrusts are remarkably persistent, they are not uniform in thickness; they pinch to knife-edge thinness and swell to bodies several inches thick. To be minable, an ore shoot must be at least 10 feet long. Some shoots have been mined for several hundred feet on the strike and for considerably greater distances on the dip. Some seams instead of pinching break up into thinner rather widely spaced stringers; the splitting as well as the pinching mostly occurs at places that show an increase in the quantity of gouge along the fault zone.

The ore in the steep reverse faults also is largely confined to compact seams or thin lenticular veins; but as much of the faulting movement has taken place on several planes rather than a single plane, there may be several prominent seams, rather than only one, along the fault zone. All of the early work at the Whitedelf mine was done on the Pearl vein, which occupied a prominent footwall fissure that contained 2 to 29 inches of massive sulfides on the Norquist tunnel level. At one place some feet above the level, the vein bulged to 7 feet 10 inches of massive ore, but in general the thickness of the vein either above or below the tunnel level rarely exceeded 24 inches. In places stringers and disseminated sulfides formed milling ore, but such ore remained unmined until after the mill had been put in operation. Search for milling ore then led to the discovery of other seams along the fault zone. Three were uncovered above the Norquist tunnel level, two of them with 3 feet of high-grade ore and one with much disseminated ore. Two or possibly three seams of compact ore were exposed on the two lowest levels, the one along the footwall apparently being the largest. In the offset segment of the Pearl vein the ore body along the James E. White tunnel was made up of compact masses, bunches, and small connected lenses, which in places made 3 feet of high-grade ore. In much of the fault zone, bordering stringers and minor seams provided stoping widths as much as 6 feet or more. The ore seams along the Pearl vein are not continuous. In places they divide into stringers, particularly where the gouge increases in abundance; elsewhere the ore spreads outward into oblique fractures or ends altogether.

In the lightly mineralized normal faults, including the dike fault at the Hope mine and some strike-slip faults such as the Pugh and the Norquist, the sulfides occur sparingly in small bunches, disseminations, and stringers. These are in gouge, but the sulfides are generally not much crushed, and ramifying nets of stringers remain intact. In only a few exposures are the stringers and other small bodies concentrated into compact seams and lenses, and in only a few places has stoping been attempted.

ORE SHOOTS

The localization of ore shoots is entirely structural, showing no relation whatever to the chemical composition of the enclosing rock. The ore was deposited where openings permitted the circulation of the mineralizing solutions, and such openings were available where the walls of the fractures had separated during the faulting. In both the low-angle thrust faults and the high-angle reverse faults openings developed wherever there was a local flattening of the dip. In the low-angle thrusts the lenticular ore shoots dip less steeply than the less highly mineralized parts of the fault zone, indicating clearly that the hanging wall had been lifted away from the footwall, thereby providing space for the circulation of the ore solutions. Where the dip increases, on the other hand, the amount of gouge increases and the ore pinches, because the walls had been forced together and the rock ground to gouge as one wall rubbed against the other. Similar relations are observed on the high-angle reverse faults. Gouge impeded the circulation of ore solutions along the more steeply dipping parts, where rubbing occurred, whereas wider openings facilitated the flow along the less steeply dipping parts, where the walls were lifted apart. Consequently, the ore pinches as the dip increases and thickens as the dip decreases. On strike-slip faults, also, the ore bodies pinch along the strike at places where the mainly horizontal movement caused the walls to rub together and widen where that movement forced the walls apart.

Other structural controls have aided in the localization of ore shoots. The most important of these is the union of ore seams. At the Hope mine, for example, some of the best ore shoots have been found where more steeply dipping seams along the footwall of the thrust zone have curved upward to join the hanging-wall seam. Similarly, some of the widest shoots have been found in places where steeply dipping seams of ore have entered the thrust zone from below the footwall and have added their ore to that already in the thrust zone. In such places the best ore has been found where the seams have come close together and the one from below has flattened and become parallel to the one just above. Some of the entering seams may occupy diagonal fractures, which connect one thrust with another in a closely spaced overlapping series of thrusts. Along the steep reverse faults, such as the Pearl vein, some of the widest ore bodies have been localized by the union of mineralized fissures within the thrust zone, particularly by the union of lateral fissures that join the main fissure at an acute angle. The greatly increased shattering associated with the intersection of the low-angle thrusts and high-angle reverse faults with the crosscutting high-angle normal and strike-slip faults also has favored increased porosity and the localization of some of the larger bodies of ore. Some of the best ore shoots along the low-angle thrust at the Hope mine were near the dike fault, the air-raise fault, and the Norquist fault, and some of the best ore at the Whitedelf was near the intersection of the Pugh fault with the Pearl fault. Union of stringers has also given rise to wider seams and lenses of ore on some of the other low-angle thrusts. In general, the structural controls are much the same throughout the district.

Recurrent faulting, with consequent reopening of the mineralized faults, during the period of mineralization has also been an important factor in the distribution of ore and the localization of ore shoots, for the deposits that were not disturbed after the early mineral deposition were not enriched by the younger mineralizing solutions. Late addition of silver has very materially enhanced the grade of the ore at both the Hope and Whitedelf mines and has had much to do with delineating the ore shoots.

Stoping has been more continuous on upper than on lower levels, which suggests that the ore shoots may decrease in stope length with increasing depth. The ore seams at the Hope mine pinch and swell, so that they form lenticular shoots 12 to 100 feet or more in length, but above the No. 3 level the shoots were so spaced that the stopes are continuous for a horizontal distance of more than 600 feet southwest of the dike fault. Below the No. 3 level the ore shoots appear to be fewer and more widely separated. Similar conditions appear to prevail at the Lawrence mine, where the main stoping has been carried along the vein for 250 feet on the tunnel level, but scattered pillars of lean ore indicate that the individual shoots, though closely spaced, are rarely more than 40 feet long on the strike. The workings below the tunnel level explore only a small part of the vein, but, as these workings were not accessible, it could not be learned at first hand whether the ore shoots decrease in size or become more widely spaced with increasing depth. The controlling thrust fault is long, and other shoots, some of them as persistent and as highly mineralized as the one in the main part of the mine, have been uncovered. At the Whitedelf mine the ore was almost continuous from the portal of the Norquist tunnel to the Pugh fault, a distance of 530 feet, and was stoped from the level 100 feet below the Norquist tunnel level to the surface. Below the 100-foot level, however, the ore shoot split into two branches, separated by several hundred feet of barren fissure. Each of these branches appears to decrease in stope length with increasing depth, and on the 400-foot level the one near the shaft is about 80 feet long and the other about 130 feet long. On the lower levels the ore in the shoots tends to form thin lenses about 40 feet long, joined by mere seams of ore or separated by barren zones that are generally a good deal less than 40 feet long. In the southwest segment of the Pearl vein, the ore shoot exposed in the James E. White tunnel was about 130 feet long.

The ore shoots, both those on the low-angle thrust faults and those on the high-angle reverse faults, plunge more or less steeply to the northeast.

MINERAL ZONING

The deposits in the district show some tendency toward both horizontal and vertical zoning, part of which may be accounted for on thermal and part on structural grounds. The horizontal zoning is not especially well displayed within any single deposit except the Whitedelf, but it becomes apparent when the deposits are considered collectively. Sphalerite, for example, is somewhat more plentiful at the Hope and Whitedelf mines than at the Lawrence; galena, on the other hand, is proportionately more abundant at the Hope mine than at the Whitedelf and most abundant at the Lawrence. Where it is relatively scarce, the fact is largely due to its having been in part replaced by the lead sulfosalts.

The sulfosalts contain less lead and more silver and antimony than galena, and they are most abundant at the Whitedelf mine, less so at the Hope, and absent at the Lawrence. The concentrates at the Lawrence mine are therefore higher in lead than the concentrates at the Hope mine, which in turn are higher in lead than those at the Whitedelf, and, conversely, the amount of antimony and silver is greatest at the Whitedelf and least at the Lawrence. This decrease in silver and antimony and the corresponding increase in lead away from the Whitedelf may be explained on structural grounds. At the Lawrence mine the ore has been little disturbed by faulting movements during or after mineralization, and except for a thin casing of gouge on one side of the main seam it is frozen to the walls. At the Hope mine, on the other hand, the ore has been considerably disturbed by faulting concurrent with and subsequent to mineralization, so that all the minerals except those deposited last are much fractured; the ore as a whole is considerably shattered and is much more encased with gouge than the ore at the Lawrence. At the Whitedelf mine disturbance during and after mineralization has been even more marked than at the Hope mine; the Pearl fault was more active than the mineralized fault at the Hope mine, which, however, was considerably more active than the one at the Lawrence. Apparently the deposits at the Whitedelf and Hope mines were reopened by the intramineralization movements just in time to receive the solutions bearing silver and antimony, and, as the disturbance at the Whitedelf mine was the more marked, the reopening at the Whitedelf was the more complete and the channels formed were the more favorable for the circulation of the ore solutions; the Whitedelf deposits consequently received more of the sulfosalts, and the unreopened Lawrence deposits received none at all.

Vertical zoning seems to be shown in each of the deposits, though at the Lawrence mine the inaccessibility of the lower workings made it impracticable to gather much evidence bearing on this point. At both the Hope and Whitedelf mines sphalerite

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appears to become somewhat more abundant with increasing depth, whereas galena tends to become somewhat less abundant, largely because of an increase in sulfosalts. There is a corresponding decrease downward in the percentage of lead, particularly at the Whitedelf, where the sulfosalts are most abundant. The material gain in silver and antimony with depth at the Whitedelf mine may be explained on the supposition that these two elements were largely deposited by replacement of galena before the solutions that carried them reached what are now the upper levels of the mine. When it was visited, the mine showed considerable promise of becoming chiefly a silver mine rather than a lead mine; the last shipments contained 35 to 40 percent of lead and more than 200 ounces of silver, whereas ore mined nearer the surface had contained 60 percent of lead and 60 ounces of silver.

WALL-ROCK ALTERATION

The rock in and along the mineralized fault zones has lost its original blackish, reddish, or dark-greenish colors, all of it now having a pale-greenish cast. The change is generally more pronounced along the more highly mineralized fault zones, but it may be observed in various degrees of intensity along all the fault zones that permitted circulation of mineral-bearing solutions. It is natural to infer that the bleaching was caused by the action of the mineralizing solutions, and this inference is confirmed by microscopic study.

Under the microscope the bleached rock shows abundant tiny flakes of sericite; it also generally shows irregular veinlets, masses, and embedded crystals of siderite, here and there a small crystal of tourmaline, and, especially near the ore seams, much quartz and some disseminated crystals of pyrite and arsenopyrite. The bleaching appears to be largely associated with the formation of sericite, which is distributed to the very borders of the zones of alteration. The sericite has replaced much of the quartz and calcite of the original rock, and in places it has replaced the rock altogether. The sericite has a pale-greenish tint, which accounts for the greenish cast of the altered rock.

Other minerals, in turn, partly replace the sericite. Siderite cuts the sericitized rock and encloses fragments of it, and where the mineral is abundant it has largely replaced the sericite. Quartz has not only replaced some sericite but also penetrates and replaces siderite. Some of it is in veinlets, but some of it forms irregular fine-grained masses, which penetrate and replace rock that contains much sericite and siderite. Scattered crystals of pyrite and arsenopyrite may accompany the quartz, particularly the quartz of the silicified zones bordering some of the ore seams. In places along the Pearl vein where sulfantimonites and sulfarsenites are abundant, the fine-grained quartz that generally occurs along the mineralized zones has been permeated by coarser-grained quartz, apparently added during the late silver and antimony metalization.

The alteration has not progressed uniformly; it is especially intense and widespread in certain places and in certain rocks. It appears to reflect more or less directly the intensity of mineralization. Sericite is the most widespread of the secondary minerals but is most abundant near mineralized fractures. Siderite is confined mostly to the rocks close to the mineralized fractures. Secondary quartz is even less widely distributed; it appears to be confined, like pyrite, to the immediate vicinity of the ore. Most of this quartz was deposited just before the early sulfides, but locally some quartz was deposited during the later stage of mineralization.

GENESIS

The localization of the dikes of diabase and prophyry and the lead-silver deposits along the zone of structural weakness controlled by the Hope fault indicates a close relationship between faulting, intrusion, and mineralization. As intrusion and mineralization took place while faulting was still in progress the faulting must have reached to a relatively deep magma reservoir and provided avenues of escape for portions of a differentiating magma and later for mineralizing solutions.

The escape of the mineralizing solution from the magmatic source was not continuous; it was repeatedly interrupted by structural adjustments, some of them small, some of them rather large. When the solutions first reached the levels at which the ore is now found, they apparently were rich in potash. They reacted strongly with the country rock in and along the zones of faulting, extracting lime and silica and enriching the rock in potash, which combined in sericite as the main product of reaction. The mineralizing process may then have been temporarily interrupted by renewed faulting. The solutions that rose subsequently differed in composition from the earlier ones; they carried iron carbonate, which was deposited as siderite in fractures and replaced some of the sericitized country rock. The mineralization was again interrupted by minor faulting movements, during which a little quartz was deposited in fractures and impregnated the bordering walls. Then, in close succession, pyrite and arsenopyrite, sphalerite, tetrahedrite, bournonite(?), galena, and calcite were deposited in similar fashion. With the deposition of galena and the slightly later calcite, the early cycle of mineralization came to a close.

Mineralization did not everywhere end, however, with the deposition of the galena and associated minerals. Recurrent faulting of somewhat greater intensity reopened the channel ways leading to some of the lead deposits, again permitting movement of ore-bearing solutions. These later solutions, however, were very different from the earlier; for, although they locally carried a little silica, they also carried much silver and antimony and perhaps some lead, together with minor quantities of arsenic and copper, possibly dissolved from the tetrahedrite and arsenopyrite at depth. In the deposits that were reopened there were deposited, largely by replacement of the galena, various complex sulfantimonites and sulfarsenites of lead and sulfantimonites of copper and lead and of silver alone. Some minor faulting continued after the second mineralization, but no more minerals were deposited. The rhodochrosite, which occurs sparingly in the district, may have been deposited at the close of this later period of mineralization.

The absence of any minerals diagnostic of high-temperature origin indicates that the temperatures of the mineralizing solutions while the minerals were being deposited never rose above moderate heights. Sericite, siderite, and quartz in the country rock are commonly associated with mesothermal deposits, and the ore minerals of the early cycle of mineralization in this district are also of species that are deposited at moderate temperatures. During the second metalization the temperatures must have been appreciably lower, for silver and antimony generally become more concentrated as the temperature of the solutions becomes lower, and the complex sulfantimonites and sulfarsenites are commonly regarded as diagnostic of epithermal conditions.

The absence of shearing on the one hand and of intense brecciation on the other indicates that ore deposition took place neither at great depth nor very near the surface. The rather small amount of open space associated with the fissuring and fracturing and the absence of marked banding or crustification and of ore textures that suggest rapid chilling against cold near-surface rocks indicate that the ore was deposited at moderate depths, perhaps a mile or two below the then existing surface. The association of the deposits with hypabyssal intrusive rocks also suggests that the deposits were formed at intermediate depths.

As, for reasons given elsewhere in the report, the faulting and igneous activity are considered to have been affiliated with the

Laramide orogeny, of late Cretaceous or early Tertiary time, the associated mineralization must have taken place at about the same time. The ore deposits, like those in Kootenai County along similar zones of structural weakness and igneous intrusion,[10] are believed to have been formed in the early part of the Tertiary.

OUTLOOK

Although the Clark Fork district resembles the Coeur d'Alene district in its stratigraphic and structural setting and in the character of its mineralization, its deposits are neither so numerous nor so large as those of its more famous neighbor. The excellent grade of much of its ore may partly compensate, however, for the smaller size of the deposits, which, if worked economically and on a scale proportionate to their size, may continue to produce for some years to come. As development has only kept pace with mining, the extent of the reserves is unknown, but the geologic conditions suggest that the roots of the ore bodies may extend some distance below the present workings. The apparent decrease in the size and number of the ore shoots with depth may merely reflect local unfavorable structural conditions; the ore, apart from a slight increase in zinc content, shows no definite mineralogic change such as might be expected near the lower limits of the ore bodies. As the controlling structural features presumably extend to depths far beyond any that will ever be reached in mining, the vertical range of the ore is probably determined by physicochemical conditions, of which temperature is most important; and as the character of the mineralization and the wall-rock alteration suggest that temperatures, at least during the early mineralization, were moderate, it is unlikely that there was any abrupt change to higher, less favorable temperatures, such as would be reflected in an abrupt change in the composition of the ore. The increase in antimony and silver with depth, particularly at the Whitedelf mine, complicates the problem of ore persistence, but as these metals favor less heated solutions than those that carried and deposited the galena and associated minerals their increase in depth apparently adds to the likelihood that the ore will continue to deeper levels than have thus far been reached.

Increasing depth is not likely to be attended, however, by a uniform change of conditions either for the better or for the worse. Ore shoots are largely localized along the less steeply dipping parts of the low-angle thrust faults and the high-angle reverse faults, and there is no apparent reason why the steepen-

[10] Anderson, A. L., Geology and metalliferous deposits of Kootenai County, Idaho: Idaho Bur. Mines and Geology Pamph. No. 53, pp. 21-25, 28-31, 43-44, 1940.

ing of the faults and the pinching of the ore bodies in the deeper parts of some of the mines should not give way to the reverse conditions at still greater depth, unless the greatly increased rock pressure should be unfavorable for deeper-seated thrusting and induce a marked change in the character of the faulting. In view of the moderate depth at which the deposits have been formed, the few hundred feet of development can hardly have disclosed the full vertical extent of the structure favorable to mineralization.

Not enough exploration has been carried on at the several mines to make it certain that all the mineralized fractures have been found, and even the known fractures may contain ore bodies hitherto undiscovered.[11] Some of the branch and parallel thrust zones at the Hope mine deserve more attention than they have received. More work might well be directed, for example, along the dike and Norquist fault zones, particularly where they are joined by branch faults or where they cut the mineralized thrusts. There may be zones of fractured rock in or along these faults that have provided channel ways for the movement of ore-forming solutions and room for the deposition of large ore bodies. At the Whitedelf mine additional exploratory work might be carried out to advantage along the Pearl fault and in the country rock southeast of it, especially from the deeper levels of the mine. At the Lawrence mine a number of well mineralized low-angle thrusts have been uncovered. Most of the present limited development has been confined to one of these faults, but some of the others show promise and seem worth prospecting.

Although all the faults in the district show some evidence of the action of mineralizing solutions, only the faults that were of small throw, and therefore not encumbered with heavy gouge, allowed that free movement of the ore-bearing solutions that favored the formation of large ore deposits. Such conditions were best fulfilled by the low-angle thrusts and the high-angle reverse faults, and it is toward the discovery of such faults that search for new ore bodies should primarily be directed. As these faults are not reflected in the topography and are generally very inconspicuous even where they crop out, and as, moreover, they are largely mantled with glacial debris, they are not easily discovered. Their discovery, like that of the Whitedelf ore body, may have to be more or less accidental, unless geophysical methods of prospecting can be effectively applied to deposits similar in size to those already found. Two areas are especially worthy

[11] Diamond drilling by the U. S. Bureau of Mines since 1943 has proved the persistence of the Pearl vein beneath the valley of Lightning Creek and has disclosed an ore body on the Hope property beneath several hundred feet of gravel fill.

of prospecting—that which contains the present producing mines and that which lies between the mines and the Hope fault. Some of the most likely ground may lie beneath the gravel of Lightning, Mosquito, Cascade, and Spring Creeks.

MINES AND PROSPECTS

WHITEDELF MINE

LOCATION AND PROPERTY

The Whitedelf mine is near the southeast end of Howe Mountain, in sec. 34, T. 56 N., R. 2 E. (pl. 6). The property extends entirely across the ridge, but the principal workings and the mill are on the northeast side, along and just above Spring and Lightning Creeks. Other workings, including the James E. White tunnel, are on the southwest side of the ridge, within a hundred yards of United States Highway No. 10–A. Much of the work done in 1940 was in the James E. White tunnel, but since then the development has been transferred back to the main part of the mine, on the Lightning Creek slope. The mine and mill are about 2 miles by road north-northwest of the railroad station at Clark Fork, or 1¼ miles from the center of town.

The mine is owned by the Whitedelf Mining and Development Co., incorporated in March 1926. The property includes 300 acres of patented land, 80 acres of which is held under lease, a fully equipped mine camp, and a 75-ton flotation concentrator. Development comprises nearly 6,000 feet of underground workings in some eight or nine tunnels, six of which were accessible in 1940 and 1941 (pls. 7 and 8). Most of the work has been carried on from what is known as the Norquist tunnel level, which is connected by a steeply inclined shaft with the 100, 200, and 400 levels, and, by a winze from the northeast end of the 400, with the 500 and 600 levels. Above the Norquist is Anderson tunnel No. 1 (now caved). Most of the ore that has been mined has come from above and below the Norquist tunnel, but a considerable quantity has also come from the James E. White tunnel. Other tunnels near the Norquist are the White tunnel on the Middle vein and the Pugh tunnel on the Pugh vein, but no work has been done in either of them for a long time. The Clagg-Reed tunnel is above the James E. White tunnel, high on the southwest slope of the ridge.

HISTORY AND PRODUCTION

The uprooting of a tree during a storm in 1926 is given credit for the discovery of ore on the Whitedelf property. Test pits had been driven on the Pearl and Pugh fissures as early as 1924 but without disclosing any mineralization of consequence. The ore bared by the uprooting of the tree, though it gave an excellent surface showing, apparently bottomed within a few feet, and work on this vein—the Middle vein—was finally abandoned. The disclosure had, however, prompted work on other fissure zones, including the Pearl, which had been exposed by a road grader not long previously. With comparatively little development, the Pearl vein fulfilled all the hopes that had been so briefly raised by the Middle vein, and it has been the source of practically all the ore that has been taken from the Whitedelf mine. The results of work on other fissure zones, including the Pugh and South veins, have been disappointing.

Mining and shipping of ore from the Pearl vein started almost immediately after the discovery of ore in the Middle vein. As the ore was rich and came to the very surface, little capital outlay was needed; the hand-sorted ore made the mine pay from the surface. When organized in March 1926, the Whitedelf Mining and Development Co. held 160 acres of patented land. Work was pushed rapidly by both company and leasers, and before the end of the year considerable ore had been stoped from above both the Norquist and Anderson tunnel levels. In the summer of 1927 the workings on the Norquist tunnel level were about as extensive as they are today, and by early autumn all the ore except that of milling grade had been stoped to the surface. The mine was then equipped with electric power, and work was started on an inclined shaft about midway between the face and portal of the Norquist tunnel. By the end of the following year the shaft had been sunk about 200 feet below the tunnel level, and drifts had been carried to the northeast and southwest along the Pearl vein on both the 100 and 200 levels. Work was also begun on a 75-ton flotation concentrator, which was completed in the early part of 1929 and placed in operation in July of that year. Mining and development were continued by the company and by leasers through 1929, 1930, 1931, and 1932. During this period the shaft was sunk to the 400-foot level, and drifting was carried northeastward to the present face. In 1933 the mine was closed because of the low price of metals, and except for some work at the mill in 1936 it remained idle until 1937. In that year a search was made for additional ore along and above the Norquist tunnel; some ore was uncovered and some concentrates were shipped. In 1938 the shaft was unwatered, the lower levels were retimbered, and a winze was sunk from the 400 to the 500 and 600 levels. This work continued into early 1940. Some crude ore and considerable quantities of concentrates were shipped from the main level and the lower levels. Early in 1940 the company suspended operation and leased the mine to James E. White.

Until 1938, all the ore that had been mined had come from the segment of the Pearl vein northeast of the Pugh fault. In that year the segment southwest of the Pugh was discovered and exposed in cuts and shafts across the ridge to the southwest slope (pl. 9). Prospecting of this newly discovered segment was continued in 1939, and some high grade ore was uncovered and mined. In 1940 the Clagg-Reed and the James E. White tunnels were started near the crest and the lower southwest slope of the ridge, and work was continued along them. During the early part of 1940 a body of silver-rich ore was opened along the James E. White tunnel, and ore and concentrates valued at more than $84,000 were taken from it and shipped during the next few months. Early in 1941, the ore shoot above the James E. White tunnel having all been stoped out, development was transferred to a crosscut and drift on the 400 level of the main mine, which were driven southwest to undercut this ore shoot at greater depth. When the property was visited in August 1941 the drift had been driven about 800 feet, but it still lacked several hundred feet of reaching the downward projection of ore. Later the ore shoot was undercut and stoped upward almost to the James E. White tunnel level (pl. 10). The mine was idle in the summer of 1943.

Up to the end of 1942, the operators had shipped 82,702 tons of ore, containing 11,301,107 pounds of lead, 16,061 pounds of copper, 658,318 ounces of silver, and 6.65 ounces of gold. The production by years is given below:

Production of the Whitedelf mine, 1926-42, in terms of gross metal content

[By G. E. Woodward, Bureau of Mines, U. S. Department of the Interior]

Year	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds
1926	978	0.95	37,795	893	719,844	
1927	2,518		103,163	209	1,774,019	
1928	2,109		64,636	564	1,204,807	
1929	10,464	1.70	66,082	891	1,112,835	
1930	18,955		81,227	2,383	1,844,969	
1931	15,323		61,635	1,900	1,326,270	
1932	9,551		39,736	1,022	820,198	
1933	900		4,574	95	88,295	
1934	70		4,678	100	89,421	
1936	250		1,796		29,936	
1937	2,755		14,480		340,688	
1938	3,465	2.00	26,185		452,041	
1939	3,522	1.00	25,608	519	426,870	
1940	5,136	1.00	46,302	2,400	505,115	
1941	5,006		50,477	3,171	460,431	
1942	1,700		29,944	1,914	105,368	
Total	82,702	6.65	658,318	16,061	11,301,107	

STRATIGRAPHIC AND STRUCTURAL RELATIONS

All of the mineralized fracture and fissure zones at the Whitedelf mine are contained in the Wallace formation, here represented by partly calcareous quartzite that weathers buff but is grayish and greenish when fresh, by shaly quartzite, and by laminated siliceous shale. The country rock as a whole is dominantly quartzitic, the shaly members being rather widely separated and rarely more than 20 to 30 feet thick. In most of the underground exposures the strike of the beds is about N. 25° W. and the dip 25° NE., but locally the strike may range from N. 5° W. to N. 35° W. and the dip from 15° NE. to 35° NE. Wide departures from the average are mostly the result of the drag of the beds along or against faults.

The most significant features of the local geology are the faults. Most of these cut sharply across the bedding, and they deviate but little in passing from quartzite to shale. The distribution and structural relations of the more important faults are shown in plate 9. Included are the Pearl, Middle, and South faults, all apparently high-angle reverse faults, and the Pugh fault, an important high-angle strike-slip fault. The Pugh fault displaces the Pearl, but because of the lack of observable intersections its relations to the other faults have not been determined. All these faults have been mineralized, but, as pointed out earlier, only the Pearl has yielded much ore.

The Pearl is the most persistent of the high-angle reverse faults and has been traced entirely across the lower southeast end of Howe Mountain and even across to the other side of Lightning Creek. Its general trend is about N. 35°–40° E., but because of minor undulations the strike ranges from N. 30° E. to N. 45° E. The dip, which is everywhere to the southeast, usually ranges between 60° and 75°, though it locally attains 80°. The only serious break in the continuity of the Pearl fault occurs where it has been displaced by the Pugh.

The Pearl fault is not a single fissure but a broad zone of fissured and fractured rock 10 to 40 feet wide. Much of the movement has taken place along the footwall, and consequently the lower part of the fault zone resembles a gouge-filled fissure. In places, however, there has been appreciable movement along hanging-wall fractures and along fractures in the broken rock between the hanging-wall and footwall zones. The fissures thus formed are not all well defined. Some die out along the strike, the movement on them being taken up by parallel overlapping fissures, and other split up into gouge-coated fractures of lesser prominence. Only the footwall fissure appears to persist. In many places it is joined by lateral fissures extending to it from the hanging-wall side. Branches also curve outward into the walls and then bend back to rejoin the main fissure. Numerous minor fractures also extend obliquely outward, but only for a short distance. Generally the disturbance extends beyond the fracture zone and is reflected in a prominent thrust drag in the beds, particularly along the footwall side. In general the fault zone contains much gouge; drifts along it remain open only when strongly timbered. The fracture zone tends to be wide where its dip is low and narrow where its dip is high, and it is narrower, as a rule, in shales or shaly quartzites than in more massive rocks.

The Middle fault is not nearly so conspicuous as the Pearl fault zone, and it does not appear to be very long. As its strike is about N. 55° E., the Middle fault would meet or intersect the Pearl fault if it persisted far enough, but it dies out, or at least becomes so inconspicuous as to be unrecognizable, before reaching the Pearl fault. It dips about 80° NW. The disturbed zone is ordinarily no more than 4 feet wide and the main fissuring no more than a few inches wide. The displacement on the Middle fault has apparently been very much less than that on the Pearl fault.

The South fault is somewhat more prominent than the Middle fault but much less so than the Pearl fault. It has been traced underground for more than a hundred feet and may extend over the ridge to the Miller ground just east of the James E. White tunnel. It apparently does not continue far in the other direction, for it is not revealed in surface cuts nor in the long crosscut driven south from the Norquist tunnel. It is parallel to the Pearl fault and lies a few hundred feet southeast of it. Along the short adit drift the strike is N. 50° E. and the dip 70° SE., but both strike and dip are somewhat variable. The fault has at least one clearly defined wall, but the drift has not revealed the entire fault zone. At some places on the Miller ground the fracture zone measures as much as 12 feet wide. Drag in the bordering wall rock indicates that the fault is a high-angle reverse fault.

The Pugh fault is much more conspicuous than the Pearl fault and probably has a considerably larger throw, for it offsets the Pearl fault 110 feet horizontally. Its general trend is about N. 70° E., but in crossing the Pearl fault zone it has been refracted, so that locally it strikes about due east. In most places it dips about 85° S., but in some places it is vertical or even dips steeply to the north. The fault zone is widest where it changes direction in crossing the Pearl fault, being there about 40 feet across. As the fault resumes its normal course the zone of fractured rock narrows and in most places does not exceed 10 or 15 feet. The various fractures making up the fault zone differ widely in strike and dip, some of them extending along the zone and others cutting obliquely across it. The movement along the fault has produced an enormous amount of gouge as well as of less finely pulverized rock and has also produced intricate drag folds in the rock within as well as alongside the fault zone.

Many lesser faults are exposed in the Whitedelf mine, most of which cut and offset the Pearl and Middle faults. Most of them strike about N. 5° W., dip 65°–70° W., and displace the other faults 2 to 4 feet in a horizontal direction. The displacement is invariably to the south on the west side of the fault. Some of the movement has been premineral and some postmineral.

OCCURRENCE AND DISTRIBUTION OF ORE

Every fault in the Whitedelf mine contains some ore, but apparently none except the Pearl was structurally suited for deposition of ore in any considerable amount. Although the Pearl fault is a broad complex zone of fissuring and fracturing, much of the ore on the Norquist and upper levels formed a vein of massive sulfides along the footwall fissure; in the Norquist tunnel this vein was 2 to 29 inches thick. The vein was mined to the surface between a point near the portal of the tunnel and the Pugh fault and also for a short distance in the offset segment on the other side of that fault. In one place above the Norquist level the ore swelled into a mass 7 feet 10 inches wide, but elsewhere the thickness of the vein rarely exceeded 24 inches and was for the most part considerably less. Its average width along the Norquist tunnel was only about 9 inches. In places, especially where the gouge increased in abundance, the ore broke up into stringers. Stringers also extended outward along fractures, and in places there was considerable disseminated ore. Some of the other fissures, also, along the fault zone contained seams of ore. At one place above the Norquist tunnel there were three separate seams. A seam on the footwall and one on the hanging wall each contained 3 feet of high-grade ore; the third, in the space between, consisted mainly of disseminated ore. Between the Norquist level and the 400, only the footwall seam apparently contained much ore; below the 400, however, ore seams were found along both the footwall and hanging-wall of the fracture zone. In the James E. White tunnel, on the southwest side of the ridge, the distribution of the ore was much like that in the Norquist tunnel. The ore tended to form compact seams and masses and to occur in bunches and lenses as much as 12 inches thick. There were also additional seams and stringers, which, added to the main body of ore, formed as much as 3 feet of high-grade and as much as 6 feet of milling ore. The ore was concentrated along footwall and hanging-wall fractures, which locally seemed to be fairly closely spaced.

The distribution of the ore shoots along the Pearl fault is shown in plate 10. The largest shoot was uncovered along the Norquist tunnel level and was stoped continuously to the Pugh fault and upward to the surface. The shoot extended downward to the 100 level with little change, but below that level it split into two branches separated by several hundred feet of barren fissure. One branch lies close to the intersection of the Pearl with the Pugh fault; the other lies at some distance to the northeast. Both plunge steeply to the northeast and appear to decrease in stope length with increasing depth. Below the 100 level the ore body is said to have been more lenticular than above, tending to form relatively thin lenses, rarely more than 40 feet long, separated by thin seams of ore or barren zones 10 to 20 feet long. In some places on the 400 level the lenses are said to have been as much as 3 feet thick. As the winze from the 400 to the 500 and 600 levels was filled with water, first-hand information on the characteristics of the shoots below the 400 was not to be had.

The shoot on the southwest side of the Pugh fault was stoped on the Norquist level for only a short distance. The height to which the stope extended was not learned. The shoot also was cut on the 400 level, when the drift was about 100 feet long, and was stoped to a height of about 130 feet. Like the main ore shoot on the northeast side of the Pugh fault, this shoot plunges steeply northeast.

The ore shoot in the James E. White tunnel had a stope length of about 130 feet and was stoped upward for 200 feet, apparently to the top of the commercial ore. In the Clagg-Reed tunnel above, the ore occurred in compact but very small seams or lenses and the shoots were small. The ore shoot has since been undercut on the 400 level and the ore stoped upward about 215 feet, almost to the James E. White tunnel level (pl. 10). The stope was inaccessible in August 1943.

Although the junctions of seams and the greatly increased fracturing close to the Pugh fault have tended to cause local increases in the amount and thickness of the ore in the ore shoots, the position of every shoot has been controlled by the angle of dip of the guiding fissure or fracture. The ore shoots occur where there is a local flattening of the dip, and they terminate, laterally and above and below, where the dip increases. As pointed out earlier, upward movement of the hanging wall has separated the walls along the less steeply dipping parts of the reverse faults and has brought them tightly together along the more steeply dipping parts. The gouge produced where the walls have been rubbed together formed an effective seal, which directed the ore-bearing solutions into the more open parts of the fault zone. Above the 100-foot level the fissure that contains the ore dips 60°–70° SE. The splitting of the main ore shoot below the 100 level occurs at a place where the dip locally increases to 75° or 80°. The ore shoot in the James E. White tunnel, also, appears where the dip decreases from 75° or more to 60° and 70° and ends where the dip again increases.

As much as 3 feet of ore appeared in the Middle fault where it was exposed by the uprooting of a tree, but the ore pinched abruptly on both strike and dip, and very little extended to the tunnels below. In the upper tunnel the mineralized zone was mostly less than 6 inches wide, though in places it attained a width of 2 feet. Ore was stoped to the surface but only for a very short length. In the main tunnel below, the mineral-bearing seam was less than an inch thick. The fault dips very steeply and may dip somewhat more steeply below than above. Much of the mineralization is near fault intersections, the premineral offsets by the northward-trending faults providing additional openings for ore. The ore in the Middle fault is not so compact as that in the Pearl.

An ore shoot about 20 feet long, containing as much as 30 inches of better than milling-grade ore, was uncovered in the tunnel or drift on the South fault. One carload of this ore was shipped. The ore shoot dips about 70° SE. and may be in a part of the zone fissure that does not dip as steeply as the remainder.

Although the Pugh fault has not generally been regarded as a mineralized fault, it shows the effects of rather extensive hydrothermal alteration, and in places it contains scattered sulfides, mostly pyrite but locally galena and sphalerite in addition. Some stoping was done on two small shoots in the zone of most intense fracturing, where the Pugh fault changes its course in crossing the Pearl. One shoot is about 60 or 70 feet from the end of the Pearl fault on the Norquist tunnel; the other is 60 or 80 feet beyond. The ore shoots were 20 and 25 feet long, respectively, and 2 to 7 feet wide. The ore was disseminated but of milling grade. The fact that there were also thin unbroken stringers cutting the gouge indicated that the ore was not drag picked up from the Pearl fault.

MINERALOGY

The ore at the Whitedelf mine has been known especially for its high silver content. Much of the ore mined in the early days carried about 1 ounce of silver to each percent of lead, and the silver content has increased with depth, some of the more recent shipments having contained as much as 6 ounces of silver to each percent of lead. This mine illustrates better than any other the enrichment in silver by late hypogene solutions.

The chief minerals are galena and various sulfantimonites and sulfarsenites; these are accompanied by such minerals as sphalerite, pyrite, tetrahedrite, and arsenopyrite, but the sphalerite and pyrite occur in negligible quantity, and the tetrahedrite and arsenopyrite are visible only under the microscope. The gangue minerals include siderite and quartz, but neither is conspicuous. In most parts of the mine, especially in the upper levels, galena stands out as the most abundant mineral, but close inspection generally reveals a more or less generous admixture of masses and grains of sulfantimonites and sulfarsenites. Along and above the Norquist level the sulfosalts made up a tenth to a fourth of the ore, but the proportion seemed to increase with depth, and in some of the ore from the 500 and 600 levels galena was subordinate rather than predominant; there some of the ore consisted almost entirely of the sulfosalts. Galena was subordinate, also, in the ore shoot exposed in the James E. White tunnel, where it appeared only in small bunches and stringers, generally alongside of the main bodies of lead sulfantimonites and related sulfosalts. Pyrargyrite was the only one of the sulfosalts that could be recognized megascopically.

Much of the ore along the Pearl fault has been shattered by postmineral movement, and in places a large part of it has been mashed and ground up in the gouge. Slickensided surfaces along and across the ore are common.

The ore along the Middle fault consists mainly of galena, which is mixed with brecciated siderite and sprinkled with granules of reddish sphalerite and crystals of pyrite. In the lower tunnel the fault zone contained only scattered grains of galena and here and there a little pyrite. The ore in the South vein is chiefly galena. The Pugh fault zone contains scattered grains of pyrite, but the minerals in the two small shoots included galena, sphalerite, and small quantities of the sulfosalts.

HOPE MINE

LOCATION AND PROPERTY

The Hope mine is on the lower western slope of Middle Mountain, almost directly across from the Whitedelf mine, in secs. 26 and 36, T. 56 N., R. 2 E. The mill and main operating level are just above Lightning Creek, about 2 miles by road due north of the railroad station at Clark Fork, or about 1¼ miles from the center of town (pl. 6).

The mine is now owned by Hope Silver-Lead Mines, Inc. The property includes a considerable acreage of patented farm land, 14 unpatented mining claims, a complete mine plant, and a 150-ton flotation concentrator. In 1941 the development comprised more than 9,000 feet of underground workings on nine levels (pl. 11). The levels above the No. 3 (the present haulage level) have been abandoned and are no longer accessible. The levels below are connected with the No. 3 by two inclined shafts or winzes, one going to the bottom of the mine and the other to the No. 6 level. The levels are spaced at intervals of about 150 feet measured on the incline, the slope of which is about 22°. Several tunnels that formerly connected with the two upper levels are now only partly open. Their portals are at and just above the road that skirts Middle Mountain several hundred feet above the creek.

HISTORY AND PRODUCTION

The discovery of ore at the Hope (then called the Elsie K) in 1923 was not nearly so spectacular as the discovery of ore at the Whitedelf 3 years later. A sack of ore dug from an old cut along the road that circles the lower slope of Middle Mountain attracted the attention of Purdy and Jensen, leasers from the Coeur d'Alene district, who thereupon obtained an operating lease from the owner of the homestead on which the ore had been found. These men began work along the roadway, and within a short time they were making carload shipments of high-grade hand-sorted ore. By 1927, the vein on which the discovery was made had been opened by more than 600 feet of drifts from short crosscuts driven at the level of the road. Much of the ore had then been stoped above the road level, and preparations were under way to drive the No. 3 tunnel from near the level of the creek. In the meantime the leasers had negotiated for purchase of the mine, and before long they had paid for the mine from earnings. Wishing to mine on a larger scale, the new owners organized the Hope Mining Co., which was incorporated November 19, 1927, and continued the deeper development and the shipments of hand-sorted ore. In 1931 a mill was erected on the property. Except for the few months between August 1932 and May 1933, the mine remained in almost continuous operation until 1935, but much of the work done was development work. By 1933 much of the ore above the No. 3 level had been stoped, and work had started at lower levels.

In 1935 the mine was taken over by the Hope Silver-Lead Mines, Inc., incorporated September 23, 1935. Some of the older workings were reopened and some ore of milling grade recovered from them, but much of the work was carried on at levels below the No. 3. A second winze was sunk on the vein at a point nearer the portal, after which the use of the old winze for hoisting purposes was abandoned. By 1940 all the known ore above the No. 6 level had been stoped, and in that year work was begun on the No. 7 level. In 1941 the winze was deepened and work started on the No. 8 and No. 9 levels. Work continued on these lower levels until March 1944, when because of a manpower shortage the mill was forced to shut down from lack of ore. Work was then started on a vertical 750-foot 2½ compartment shaft to open up the ore body on the Pearl vein which had been discovered through the activities of the United States Bureau of Mines in its exploratory diamond-drill work in the valley of Lightning Creek.

The production by years is given in the table following.

Production of the Hope (Elsie K) mine, 1925-43, in terms of gross metal content

[By G. E. Woodward, Bureau of Mines, U. S. Department of the Interior]

Year	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)
1925	122		5,663		148,976	
1926	161		7,043		193,954	
1927	294	0.20	12,289		321,679	
1928	374		9,825		255,854	
1929	1,000		21,273	25	602,297	
1930	227		4,733	104	139,421	
1931	6,122		27,207	870	715,500	
1932	2,420		12,979	245	353,392	
1933	5,514	.60	19,229	664	497,112	
1934	6,562	.50	17,670	350	482,367	
1935	4,735	.80	12,440	226	366,253	
1936	10,000	2.80	35,366		1,138,422	
1937	21,000	14.00	36,979		1,284,500	
1938	9,000	2.00	20,073		802,850	
1939	8,574	3.00	22,236	1,078	745,462	
1940	7,547	2.00	16,274		593,461	
1941	4,500	1.00	7,236		256,100	
1942	10,320	2.00	17,128		638,122	700,000
1943	11,120		13,593		542,121	74,300
Total	109,592	28.90	319,236	3,562	10,077,843	774,300

STRATIGRAPHIC AND STRUCTURAL RELATIONS

The ore at the Hope mine is contained in faults that cut the Striped Peak formation, which locally is represented by dark-gray, almost black laminated shale together with more massive and lighter-colored siliceous shale and quartzite. Along the mineralized zones the rock has been considerably altered, and the color has been changed to light gray or pale green, but despite the bleaching the strata are easily recognized as Striped Peak by their closely spaced partings. Higher on the slope are the alternating reddish and greenish sandstones, shales, and argillites that make up the more conspicuous and even more diagnostic members of the formation. Exposed in the mine is a diabase dike 4 to 40 feet wide intruded along one of the faults. This dike has been considerably altered by hydrothermal solutions, which have largely changed its original dark-gray to black color to light gray and pale greenish gray, much like that of the altered shale.

The beds have a northerly trend and rather low to moderate easterly dips. Near the portal of the No. 3 tunnel the bedding strikes N. 5°–10° E. and mostly dips 5°–12° E., though in places the dip steepens to 20°. Through most of the mine, however, the strike is N. 20°–25° W., increasing to N. 30° W. or more near faults, and the dip is usually 5° to 15° E., though it is locally as much as 30° E. Minor flexing of the beds is plainly visible in places, and at some points the bedding is horizontal. Small drag folds appear along some of the faults.

The stratified rocks have been cut by numerous faults, some of moderate throw but others of negligible throw. These faults include low-angle thrusts—or zones of closely spaced overlapping thrusts—a high-angle normal fault, and many high-angle strike-slip faults, two of which are prominent. The main thrust contains the Elsie K vein. The high-angle normal fault, which contains the diabase dike, has been designated the dike fault. One of the major strike-slip faults exposed in the far south end of the workings on the fourth, fifth, sixth and ninth levels is known as the Norquist. It has been regarded by some observers as a continuation of the Pugh fault on the Whitedelf property. A smaller fault between the Norquist fault and the dike fault has been called the air-raise fault. Many faults of lesser magnitude have been recognized but not named. The thrust faults are cut and displaced by all the other faults, with offsets of a few inches to many feet, apparently always to the northwest on the southwest side of the fault. All the faults except some of the very small ones are premineral, but all show evidence of postmineral movement. Few of them fail to show the effects of hydrothermal alteration, and most of them contain at least a few stringers of ore.

The low-angle thrusts have a northeasterly trend, which diverges rather widely from that of the Striped Peak strata. Northeast of the dike fault the thrusts generally strike N. 10°–20° E., but in places they strike due north. The dip is usually eastward at angles of 18° to 22°, but the inclination may rise to 26° or decrease to 10°. At one place on the No. 6 level the dip is practically flat or is even slightly to the northwest. Southwest of the dike fault the strike averages about N. 30° E., but it ranges from about due north to about due east. The average dip is somewhat steeper than it is northeast of the dike fault—about 20° or 25° SE.; it is also more variable, ranging from 15° to 35° SE. These marked local variations in the strike and dip show up well on the geologic map of the underground workings. (See pl. 12.)

Northeast of the dike fault only one zone of thrusting has been uncovered, but between the dike and the Norquist faults there are three overlapping thrusts, apparently linked to one another by diagonal branches. These relations are most evident on the No. 4 level, where two thrust faults are exposed at the south winze. The lower fault is followed southeast by the drift to a point midway between the air-raise fault and the Norquist fault, where it passes into the left wall (pl. 12). A short distance ahead a third thrust enters the drift from the right and is followed to the Norquist fault. These thrust faults are somewhat divergent in trend, and the third, which is also exposed on the No. 3 and No. 5 levels, strikes more nearly north than the others.

The displacement along the faults is small—a few inches to a few feet. In many places the beds show striking evidence of drag, and the drag relations indicate that the movement was directly up the dip, the stress having been applied from a southeasterly direction. The fracture zones along the thrusts are generally 2 to 3 feet wide but locally are as much as 6 feet wide. Ordinarily one wall is more distinct than the other and is marked by a fairly thick sheet of gouge. Fractures extend upward in places for considerable distances into the wall, and some steeply dipping fractures join the thrusts from the under side.

The dike fault strikes N. 35°–40° W. and dips 45°–55° SW. It is marked by considerable gouge and shattered ground. The dike lies along the hanging wall of the fault and in most places is frozen tightly to the wall. The fault apparently continued active after the intrusion of the dike. The movement was along the under side of the dike, for beneath it there is a fracture zone as much as 20 feet wide. The displacement of the low-angle thrust fault could be interpreted either as a horizontal movement of 240 feet or as a vertical movement of 80 feet, but grooves indicate that the displacement has been in a vertical direction. Drag folds show that the hanging wall of the dike fault moved down relative to the footwall. Much of the displacement along the fault probably took place before mineralization, for the dike zone everywhere shows strong evidence of hydrothermal action. In places the stringers of ore in the gougy matrix along the fault zone have not been disturbed, but the presence of crushed sulfides in some of the gouge gives evidence of moderate movement since mineralization.

The Norquist fault, which cuts the low-angle thrusts in the southwest part of the mine, strikes N. 70°–80° E. and dips 75°–80° SE. It thus draws closer to the dike fault as the mine gains depth, and the two faults should intersect not far ahead of the face of the No. 7 level. The Norquist fault has produced a zone of heavy broken ground as much as 15 feet wide. The rock along it has been much softened by hydrothermal alteration and will not stand without support. Small, somewhat broken masses of sulfides have been found in the soft gouge of the fault zone. The amount of displacement on this fault is unknown. Crosscuts to the east and west on the southwest side of the fault on the No. 3 level have not uncovered the displaced segments of the thrusts, although diamond drilling in each crosscut has revealed lightly mineralized fractures some distance out in the country rock. If the Norquist fault is a continuation of the Pugh fault, then the thrusts should be offset to the southwest, perhaps as much as 100 feet. The continuation apparently has been found on the No. 9 level (pl. 12), but the displacement is much less than 100 feet.

The air-raise fault is less conspicuous than either of the other two. It strikes about N. 65° W. and dips 60°–80° SW. On the upper levels it appears to have split into two branches separated by 15 to 40 feet of more or less broken rock. On lower levels there is but a single fissured zone. The fault has displaced the low-angle thrusts on the several levels of the mine 10 to 40 feet horizontally and perhaps 3 to 14 feet vertically. The displacement apparently decreases with depth. The fault has the same strike as the great Hope fault, as do also the many minor strike-slip faults exposed here and there throughout the mine. Although the air-raise fault contains no ore and shows little evidence of hydrothermal alteration, it may be premineral, for there is a little ore in faults of similar strike and dip that are exposed on the No. 6 and No. 7 levels northeast of the dike fault.

Northeast of the dike fault there are several well-marked faults that strike N. 70°–80° W. and dip 60°–80° SW. These may be branches of the dike fault, or they may be earlier faults cut off by it. The most prominent one is exposed in long drifts on the No. 4 and No. 5 levels, where it may be traced outward directly from the dike fault. The zone of disturbed rock is locally as much as 10 feet across. At one place the wall rock shows a drag that indicates a reverse movement, but the relations are not wholly clear. The rock along the fault has been bleached and contains some ore—enough in one place to have prompted the driving of a small stope. Faults of similar trend may be seen elsewhere in the workings, but they are not so conspicuous nor so persistent as the one just described, and they have not been traced from one level to another. Some of them are mere slips and are not mapped. Those on the No. 6 and No. 7 levels displace the low-angle thrust fault to the northwest on the southwest side of the faults. Some but not all of these faults are bordered by hydrothermally altered rock.

OCCURRENCE AND DISTRIBUTION OF ORE

Although much of the faulting has been premineral, the only considerable bodies of ore have been found along the low-angle thrusts, the others having apparently been too much clogged with gouge. Much of the ore in the overthrusts forms narrow, compact, high-grade seams a fraction of an inch to 5 or 6 inches wide, sharply separated from one of the walls by slickensides and thin sheets of gouge. In the upper stopes the average width of the ore seam was about 4 inches, and the minimum thickness that permitted profitable recovery and concentration by hand sorting was 2 inches. The seam showed some tendency to pinch and swell and to form lenticular shoots a dozen to a hundred feet long, but these lenses were so closely spaced that the ore southwest of the dike fault was mined continuously, for about 600 feet on the strike, from the No. 3 level to the surface. Some of the best ore in the upper workings was near the dike fault; there the ore was 6 to 7 inches thick. This unusual thickness apparently was caused by movement along the normal fault that had increased the distance between the walls of the older overthrust, thus facilitating the circulation of ore-bearing solutions. Another favorable zone for mineralization was between the air-raise and Norquist faults, where the high-grade ore measured 6 to 32 inches in thickness, though not all of it was in a single compact seam. Stringers in the fractured rock bordering the ore seams increased the stoping width of the mill feed. The stoping ore commonly attained a thickness of 3 or 4 feet, and at one place on the No. 6 level northeast of the dike fault, where the thrust was notably flat, it was 6 feet thick. In August 1941 milling ore as much as 2 feet thick, containing some high-grade seams, had been uncovered on the No. 8 and No. 9 levels. The main body of ore on the No. 9 level proved to be close to the Norquist fault (pl. 12).

The size and distribution of the ore shoots are indicated by the outlines of the stoped areas shown on the mine map (pl. 11). The stopes, and therefore the ore shoots, appear to become somewhat smaller, more widely separated, and more lenticular with increasing depth. The ore shoots occur where there was a local flattening of the dip of the thrust plane, which, as just pointed out, favors the separation of the walls and thus provides the space needed for the circulation of the ore-bearing solutions and the deposition of ore. Conversely, pinching occurs where there is a steepening of the dip and an increase in the amount of gouge. In some places the quantity of ore has increased where more steeply dipping seams along the footwall of the thrust zone have joined the hanging-wall seam, or where steeply dipping seams have come into the footwall from below, perhaps along diagonal fractures. These fractures, after joining the thrust zone, have continued parallel with, and close to, the footwall seam along the main thrust. In places the footwall seams have swelled out into some of the largest and richest shoots. Character of country rock, also, may have played a part in localizing the favorable structural zones, for in entering the weak laminated shales the thrust zones have flattened to conform more closely with the bedding, and consequently have widened out. Most of the stopes in the upper part of the mine are in these laminated shales, though most of those at depth are in more massive rock. Perhaps this change in the character of the rock has had something to do with the smaller size of the shoots in the deeper levels; but that decrease may have been partly due to the fact that the thrust faults steepen downward, particularly in the more massive beds.

As the ore has been considerably disturbed by recurrent faulting both parallel to and across the ore seams, it is more or less broken and is easily detached from the country rock, a condition that has greatly facilitated both hand sorting and the driving of drifts and stopes. On the No. 6 level, however, the slips and cross faults have handicapped mining because of their large number and close spacing, and one of the shoots below that level was abandoned, at least temporarily, because of heavy ground. The ore body near the southwest end of the No. 6 level is not far from the Norquist and air-raise faults, and the one near the northeast end is near and in line with the oblique west-northwest faults that extend out from the dike fault. The increased shattering may be associated with the closer spacing and nearness of these larger faults.

Small bunches and stringers of ore minerals have been uncovered along the Norquist fault, and some ore has been found along the dike fault. Nets of ramifying stringers that cross broad zones of gougy rock have been found along the dike fault; locally these stringers are grouped in zones a dozen feet across. On the No. 3 level a lens of ore several inches thick was found along the footwall of the dike fault in the drift, and additional stringers were found in the fractured rock alongside, but on the No. 4 and No. 5 levels no ore worth stoping was found.

MINERALOGY

The ore at the Hope mine has not been so generously enriched in silver as the ore at the Whitedelf, but there is otherwise little difference except in the number and relative proportions of the late hypogene minerals. Galena is the most abundant and most widely distributed of the ore minerals in the Hope mine, but it is invariably accompanied by considerable quantities of some of the lead sulfantimonites, by minor quantities of sphalerite and pyrite, and by microscopic grains of tetrahedrite. Lead sulfantimonites are visible throughout the mine; in places they make up fully a third of the ore. They seem to be at least as abundant on the lower levels of the mine as on the higher levels, but their abundance differs considerably in different shoots. The lead sulfantimonites also make up a large part of the ore minerals scattered along the Norquist fault, the dike fault, and other mineralized faults. Sphalerite appears to become somewhat more abundant in the lower levels of the mine, where it forms 5 to 10 percent of the ore, but even there it is generally so scarce that it is penalized rather than paid for. It is distributed rather sporadically, some ore shoots containing very little and others a good deal. Pyrite and arsenopyrite are fairly abundant along parts of the dike fault and in some of the minor faults in which no galena was deposited, but otherwise they occur largely as microscopic grains, visible in polished sections of the ore and in thin sections of the bordering wall rock. There is enough arsenopyrite in the ore to make the concentrates shipped to the smelter contain 1 to 1.5 percent of arsenic.

The gangue minerals include minor quantities of siderite and quartz and in places a little rhodochrosite. Much of the siderite forms small bleblike inclusions in the sulfides and discontinuous seams between the ore minerals and the wall rock. Some occurs, also, in stringers and irregular masses along fractures in the wall rock. The quartz is not readily seen except in polished sections and thin sections, where it is found to be closely associated with the sulfides. The rhodochrosite is confined to a few small stringers along some of the minor cross slips on the No. 6 level and to widely scattered stringers along the Norquist and dike faults.

SUGGESTIONS FOR PROSPECTING

As shown by the geologic map of the Hope workings (pl. 12), the mineralized thrust fault did not end near the face of the No. 3 and No. 4 levels in the northeast part of the mine, but was lost when the drifts were driven into the foot wall. Unless the drifts are continued on the thrust, it cannot be known whether the end limits of the commercial ore bodies have been reached. The map shows, also, that ore bodies on two distinct thrust zones have been worked in the southwestern part of the mine but have been only partly explored. Additional crosscuts judiciously spaced and driven into both the hanging and footwalls would not only explore both of the thrusts but might even lead to the discovery of others. For example, a layer of sulfides is visible in the roof of the drift on the No. 4 level, at the point where the drift crosses the older of the two winzes in the southern part of the mine, and this layer may represent a mineralized thrust that is not exposed elsewhere. If the layer is persistent it would be reached by crosscuts driven into the hanging wall from any of the main drifts in the southwestern part of the mine. Only by adequate crosscutting can it ever be determined whether the thrust faults in the mine make up a complex system or a series of relatively short but overlapping fractures. The rather extensively faulted ground on and below the No. 6 level also deserves further attention, for the faulting at that locality suggests nearness to the Norquist and dike faults.

Because of the generally small size of the ore bodies, the lower limit of mining is likely to be determined by increased mining costs rather than disappearance of ore with depth. Although sphalerite seems to become more abundant on the lower levels (Nos. 7, 8, and 9) than on the higher levels, it probably does not herald any abrupt change in the character of the ore. The ore bodies that had just been exposed on the No. 8 and No. 9 levels in August 1941 contained a greater proportion of sphalerite than those on the higher levels, but they were as large as the higher ore bodies and richer in the lead-antimony minerals —two facts that augur well for continuation of good ore to greater depth.

LAWRENCE MINE

LOCATION AND PROPERTY

The Lawrence mine is on the lower northwest slope of Antelope Mountain, in sec. 1, T. 55 N., R. 2 E., about a mile due east of the town of Clark Fork, or 2 miles by road from the railroad station. The mill and portal of the main tunnel are just above Mosquito Creek; other workings are scattered well up the slope of Antelope Mountain.

The mine is owned by the Lawrence Consolidated Mining Co. The property includes 12 unpatented claims, complete mining equipment, and a 50-ton gravity concentrator (rolls, tables, and jigs) operated by a small Pelton wheel, water for which is flumed from Mosquito Creek. Development comprises more than 5,500 feet of underground workings, divided between 8 or 9 tunnels but extending in greater part from the tunnel shown in plate 13. This tunnel, a 900-foot crosscut, extends diagonally across the vein about midway between the portal and the face. In the drift just northwest of the intersection of the crosscut and the vein, an inclined shaft has been sunk 180 feet, and drifts have been carried along the vein on the 150-foot level. Stopes extend from the bottom level to the surface.

HISTORY AND PRODUCTION

As pointed out earlier, the mine made its first shipments of ore in 1903, but there was little activity between that year and 1913, when the Lawrence Mining and Milling Co. installed the present 50-ton gravity concentrator. The company operated the mine and mill continuously, or nearly so, for the next 6 years. Since then the mine has been operated only intermittently, much of the work being done by leasers, mostly in tunnels above and to the side of the main tunnel. The Lawrence Consolidated Mining Co. was incorporated in 1923.

The production of the mine by years is given in the table following. Shipments from 1913 to 1942 amounted to 9,358 tons of ore containing 1.63 ounces of gold, 26,211 ounces of silver, 619 pounds of copper, and 2,806,471 pounds of lead. According to company records, 13.2 tons shipped in 1903 contained 211 ounces of silver and 19,669 pounds of lead, and 23.4 tons shipped in 1912 contained 274 ounces of silver and 33,599 pounds of lead.

Production of the Lawrence mine, 1913-43, in terms of gross metal content

[By G. E. Woodward, Bureau of Mines, U. S. Department of the Interior]

Year	Ore (short tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)
1913	4,746	0.26	4,877	111	510,579	
1914	324	.21	1,326	40	121,914	
1915	457	.08	1,455	74	163,308	
1916	454		943	160	111,225	
1917	762	.08	2,254	159	197,271	
1918	772		2,195		199,753	
1919	144		518		56,514	
1922	94		1,458		146,695	
1923	36		535		51,506	
1925	102		417		51,187	
1926	183		922		99,827	
1927	216		1,209		106,386	
1929	333	1.00	1,167		95,584	
1931	71		708	24	105,922	
1932	21		390		28,852	
1933	41		416	51	60,806	
1934	68				93,707	
1935	29		273		26,968	
1937	51		747		70,278	
1938	126		1,062		91,777	
1939	39		511		60,465	
1940	76		703		96,600	
1941	110		1,034		125,336	
1942	57		665		69,130	
1943	46		426		64,881	
Total	9,358	1.63	26,211	619	2,806,471	

STRATIGRAPHIC AND STRUCTURAL RELATIONS

The country rock of the Lawrence mine belongs to the Striped Peak formation. It includes thin-bedded to fairly massive grayish to greenish argillaceous and calcareous quartzite and shale, together with some highly bleached but originally reddish sandstone and shale. The beds strike N. 3° W. to N. 12° W., and they dip 12°–22° NE., except along zones of faulting, where drag may locally increase or decrease the dip. Although their variations in strike and dip are small, the beds have been disturbed by several kinds of faults, chiefly by minor low-angle thrusts but also by high-angle normal, strike-slip, and reverse faults. All the faults cut the bedding at fairly large angles.

The low-angle thrust faults, of which there are at least seven on the property, have all been more or less extensively mineralized. Most of them strike about N. 40° E. and dip about 20° SE., but at least one strikes N. 55° W. and dips 20°–28° NE. (fig. 3). The northeasterly strikes vary considerably, however, within short distances, ranging from N. 25° E. to N. 55° E., and they are associated with dips of 13° to 25° SE. (See pl. 13.) The zone of fracturing associated with the thrusts is commonly 2 to 4 feet wide but may locally be as much as 8 feet wide. It appears to be widest where the dip is lowest and to narrow as the dip increases. Most of the fracturing is on the hanging-wall side of a footwall fissure. Some of the thrust faults are known to be several hundred feet long. The subordinate as well as the main fractures contain ore, a good deal of which has been deposited by replacement of the bordering rock.

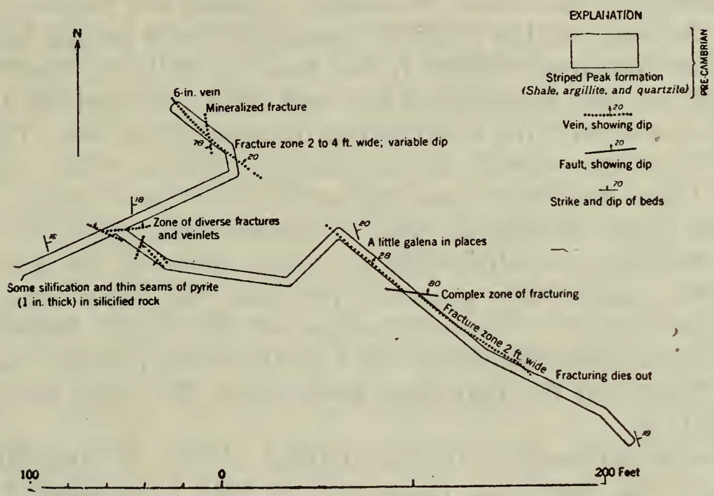

FIGURE 3.—Geologic map of vein of northwest trend at Lawrence mine.

The distribution of the steep faults is shown in plate 13. These faults cut the overthrusts, offsetting them several feet in places. They have a general easterly trend and dip either north or south. A high-angle normal fault containing a diabase dike about 6 feet wide is exposed in a drift east of the main workings. The fault strikes N. 50° W. and dips 70° SW. Its wall rocks have been considerably fractured and somewhat altered. The vein followed by the drift ends against the dike but is known to continue beyond the dike, on which it has been offset an undetermined but probably no great distance.

OCCURRENCE AND DISTRIBUTION OF ORE

The low-angle thrust faults are mineralized for great lengths, but the ore in them is restricted to relatively short but numerous lenticular shoots along the recurring flatter parts of the fault zones. In these shoots the ore is largely concentrated in a sheet, an inch to several inches wide, along one or both of the walls, and numerous veinlets and stringers and some disseminated ore are found in the fractured rock between the walls. In the principal thrust zone, exposed in the main part of the mine, the bands of ore measured 2 to 4 inches where they were seen, but locally they may have been wider. As shown in plate 13, the ore has been stoped for 250 feet on the strike and at least 300 feet on the dip. In one of the openings on the same thrust, several hundred feet northeast of the main workings, the ore measured 12 inches, 8 inches of it consisting entirely of massive sulfides. Ore was stoped for 60 feet on the strike, and up to the surface 20 feet above. In another opening still farther northeast, the band on the footwall measured 4 to 6 inches, but, because of numerous veinlets in the hanging wall, the total thickness of ore was commonly 2 feet and locally as much as 4 feet. Ore was followed for a horizontal distance of 55 feet. The ore body is on the segment of the thrust northeast of the diabase dike. Other workings above the main tunnel have stopes about 60 feet long. Surface as well as underground exposures show that the thrust is mineralized for many hundred feet and that the cross faults have generally produced but minor offsets in the main thrust. The continuation of the thrust beyond the cross fault in the southwest part of the mine (pl. 13) has not been found, but the fault may have raised the thrust above the tunnel level.

Another mineralized thrust, striking N. 35° E. and dipping 16°–18° SE., had been penetrated in 1941 by a short tunnel about 500 or 600 feet up the slope from the portal of the main tunnel. It shows as much as 8 feet of fractured rock, with ore distributed in small stringers, pods, and veinlets along the fractures. The ore exposed appears to be low-grade mill feed. Three other closely spaced mineralized thrust faults had been uncovered in the new road to the portal of the short tunnel just mentioned. These faults strike N. 35°–40° E. and dip southeast at low angles. The ore is contained in narrow seams and stringers.

A thrust fault that strikes N. 55° W. has received considerable attention. It lies several hundred feet above the one in the main workings and at some distance to the northeast. These two faults should intersect east of the present workings, probably near the base of the slope. The northwesterly-striking fault has been exposed in several tunnels, including the one shown in figure 3, and in a long series of cuts on the northeast side of the gulch extending out toward the main valley of Mosquito Creek. As shown in this tunnel (fig. 3) and in a tunnel and stope about 60 feet above, the ore occurs in stringers along a fracture zone 2 to 4 feet wide. The cuts show that the fault is not persistently mineralized but contains only scattered lenses of ore. Along the upper tunnel ore has been stoped upward about 25 feet.

The ore in all the thrusts has been little affected by postmineral movement except along cross faults, and there is rarely more than a thin selvage of gouge. Walls stand remarkably well, needing little support except in the vicinity of cross faults.

MINERALOGY

As the ore of the Lawrence mine has not been enriched with late hypogene silver and antimony, it consists predominantly of massive galena, accompanied by generally inconsequential amounts of sphalerite, tetrahedrite, pyrite, arsenopyrite, siderite, quartz, and calcite. Statements as to the silver, antimony, arsenic, and lead in the ore have been given on pages 64-65, 68, and 70-71. The 14 ounces of silver per ton of concentrate is apparently divided between argentiferous galena and scattered microscopic grains of tetrahedrite. Sphalerite is not readily detected in the ore, but in places the zinc content ranges between 1 and 3 percent. The zinc appears to be distributed very irregularly. Pyrite is not readily visible except in the more lightly mineralized zones, but microscopic remnants of it are enclosed in the galena. Neither siderite nor quartz is conspicuous, and both may in places be absent; outcrops, however, are rather heavily stained with iron and manganese oxides. Calcite locally forms crystalline crusts that line openings in the ore.

OUTLOOK

Although the ore shoots are relatively small, there are many of them, and they occur along several of the thrust faults. Altogether there are seven known mineralized thrusts, most of which have been but little explored. Because of the locally widespread mineralization, the property may be worthy of more development than it has received.

LITTLE SENATOR

The Little Senator property is on the steep lower northwest slope of Antelope Mountain, just southwest of the Lawrence, in sec. 1, T. 55 N., R. 3 E., a mile due east of Clark Fork. The property comprises the Little Senator group of four claims, on which there are three short tunnels and several cuts. Most of the recent work has been in a 230-foot adit drift near the foot of the mountain. There is a 180-foot drift on the slope about 200 feet higher and a 40-foot adit well up the gulch, but no work seems to have been done in them recently. Each adit is on a separate mineralized zone. Most of the cuts are alined along the outcrop of the mineralized zone exposed in the lowest adit.

Five or six mineralized faults are said to cross the Little Senator group; some of them are extensions of those on the Lawrence group. Those prospected on the Little Senator group include two mineralized low-angle thrusts and one high-angle fault, all in the shaly and siliceous beds of the Striped Peak formation, which locally strike N. 5° E. and dip 10° SE.

The mineralized thrust in the lower adit strikes N. 40°–45° E. and dips 20°–25° SE. The displacement along it has apparently been but a few inches. In places the fracturing virtually disappears, but in several places the fracture zone is as much as 3 feet wide, and in one place it contains 4 inches of massive sulfides. Along much of the drift, however, mineralization is represented by mere bleaching of the country rock. Most of the visible ore is exposed in a number of cuts that extend diagonally southwest up the slope for a distance of several hundred feet. These cuts commonly show 1 to 2 inches, and locally 4 inches, of massive ore extending along one of the walls of the fault zone.

The thrust in the middle adit strikes N. 5° W. to N. 20° E. and dips 5°–12° E. At the face of the adit the thrust is cut off by a fault, marked by a broad zone of gouge, that strikes about N. 30° W. A winze inclined about 30° SW. has been sunk on the fault. Much gouge has run into the adit despite heavy timbering. Near the fault the thrust contains 1 to 2 inches of massive sulfides, and scattered stringers appear near the portal. At some places between the fault and portal the main sulfide seam is roughly paralleled, at a distance of 2 or 3 feet, by a second discontinuous seam. The fracture zone does not anywhere appear to be more than 3 or 4 feet wide. Movement has been sufficient to produce thin bands of gouge on some fractures. In a cut 100 feet to the southwest the fractured rock is stained with manganese oxides.

A high-angle fault, which strikes N. 50° W., is exposed in the 40-foot adit far up the gulch. It contains 2 to 3 feet of mashed rock and coarse-grained calcite bordered by less extensively fractured rock.

Except in the steep fissure up the gulch, the ore consists of cubic galena, partly oxidized to anglesite in the outcrops. Neither pyrite nor sphalerite appears to be present in the specimens of galena that were collected for study. The presence of limonitic oxides, in part darkened by manganese oxides, suggests the presence of some primary siderite.

RED CLIFF

The Red Cliff mine is in sec. 6, T. 55 N., R. 3 E., on the north side of Antelope Mountain, 1½ miles due east of Clark Fork. The slopes there rise precipitously to the summit several hundred feet above and fall steeply to the bottom of Mosquito Creek valley, perhaps a thousand feet below. The mine is reached by trail from the Mosquito Creek road. Development comprises two adit drifts, one about 60 feet above the other. The lower is 96 feet long, and crosscuts from it extend 67 feet to the west and 28 feet to the east. The upper tunnel is 90 feet long and has a shallow winze at the end of a 30-foot crosscut.

The drifts extend along a mineralized low-angle thrust in the Striped Peak formation. The beds strike about N. 30° E. and dip 14° SE.; the thrust strikes N. 20° E. and dips 20° SE. The rocks in the cliffs just above the mine are thin-bedded reddish sandstone and shale, but the rock in the mine is laminated grayish shale, which is more or less bleached, being nearly white where most intensely altered by the mineralizing solutions. Other faults also have been uncovered underground. One, exposed in the far end of the lower adit, strikes N. 55° W., and dips 70° SW.; it is normal and has displaced the thrust fault 4 feet vertically. Another fault exposed in the winze from the east crosscut on the same level strikes N. 30° E. and dips 65° SE. This is a reverse fault, which also has cut the thrust, though the offset has not been exposed. The rock adjacent to it has been considerably fractured and bleached and has been lightly mineralized.

The thrust zone is 4 to 6 feet wide. Both walls are sharply delineated by narrow bands of gouge. Much of the ore is next to the gouge on each side, but some occurs in fractures, parallel and diagonal to the walls, in the rock between. In the lower adit there are two narrow ore seams, which are generally about 4 feet apart but which in places join and increase in thickness. At the face a seam along the hanging wall dipping 5° is joined by a seam dipping 25° that extends from the footwall and also by a seam of ore along a diagonal fracture. The ore seams are generally no more than an inch or two thick, and only a little stoping has been done, principally along a shoot about 40 feet long.

The ore seams consist of massive sulfides, dominantly of galena, but there are minor stringers of sphalerite in the bordering rock. Some calcite is visible in the ore, but neither quartz nor siderite, although siderite at least is probably present, for the shallow, oxidized parts of the deposit are iron stained. High silver values are reported by the owners of the property. An assay report dated September 27, 1939, showed 46 percent of lead and 63.3 ounces of silver per ton, and another, dated January 8, 1940, showed 65 percent of lead and 84 ounces of silver. No late hypogene sulfosalts were observed in polished sections.

RALPH

The Ralph property is on the lower north slope of Antelope Mountain, near the northeast corner of sec. 1, T. 55 N., R 2 E., about half a mile east of the Lawrence mine. It is developed by two tunnels, one about 100 feet vertically above the other. The lower has 262 feet of workings, including a 130-foot crosscut, from which a 34-foot drift extends to the southwest and an 85-foot drift to the northeast about 27 feet from the face. There is also a drift extending 88 feet northeast from a point 56 feet from the portal, and a drift extends 30 feet westward from a point 6 feet farther out. The upper tunnel is about 65 feet long but is blocked a short distance from the portal by an open winze.

Several mineralized faults have been exposed in the workings, but only the main one has been much prospected. All are in the laminated blackish and dark-gray shales of the Striped Peak formation. The beds strike a little west of north and dip about 15° E., but otherwise the formation has been little disturbed except by the faults, most of which are of small throw. Drag on some of the faults indicates that they are reverse faults, but the most prominent one is apparently normal. This fault strikes about N. 20° W. and dips 55°–70° SW.; the others strike N. 10° W. to N. 5° E. and dip 65°–90° W. All of them are slightly mineralized, but only the normal fault has invited much attention.

The vein along the normal fault is as much as 2 feet wide in the upper tunnel and 1 to 4 feet wide along the drifts in the lower tunnel. Much of it may be described as a breccia vein with 6 to 12 inches of gouge on the hanging wall. The filling consists largely of a rubble of little-altered fragments of country rock, partly cemented with quartz and siderite, accompanied in places by a little pyrite, sphalerite, and galena. The minerals show banding by crustification, and drusy surfaces in unfilled openings. As the siderite is far more abundant than all the other minerals combined, the vein may be classed as a sideritic breccia vein. No commercial ore has been uncovered.

Breccia veins 2 to 12 inches wide, with quartz as the only cementing material, are exposed in the lower workings.

ANTELOPE

The Antelope property, on the long spur that extends eastward from the town of Clark Fork to Antelope Mountain, includes three claims along the crest and upper north slope of the spur. It is owned by the Whitedelf Mining and Development Co. Development consists of a number of open cuts and trenches and a 15-foot tunnel alined along the otherwise concealed outcrops of two mineralized zones. This tunnel and seven of the cuts, which follow the lower zone, are spaced at intervals of 30 to 200 feet in an easterly direction along the upper slope of the spur; the others, which follow the upper zone, are near the crest and are alined in a northeasterly direction. The mineralized zones are apparently localized along low-angle thrusts of little displacement. In most places the cuts have not penetrated the oxidized parts of the outcrops, so that structural and mineralogical relations are rather obscure.

The most westerly of the cuts on the lower zone, a 50-foot trench, exposes limy quartzites of the Striped Peak formation, slightly stained in one place with iron and manganese oxide. The beds strike N. 6° E. and dip about 20° E.; the strike and dip of the thrust have not been closely determined. In the second cut, a 60-foot trench about 36 feet from the first, the thrust zone is exposed for about 50 feet, and there appears to strike about N. 55°–60° E. and to dip 15° SE. It is mostly 8 to 12 inches wide, but locally its width is as much as 24 inches. It consists of black, iron-stained and manganese-stained rock, which at one spot shows a little partly oxidized pyrite and siderite disseminated in silicified shaly quartzite. The third cut, about 70 feet east of the second, apparently missed the thrust and exposes only weathered quartzite, which strikes N. 25° E. and dips 10° SE. In the fourth cut, 210 feet farther east, about 8 inches of black limonitic and manganese-stained rock is exposed, and about the same width of iron-stained and manganese-stained rock is also shown in the fifth cut, 30 feet beyond. The tunnel, which lies 30 feet beyond the fifth cut, exposes about 2 feet of fractured rock, stained with oxides of iron and manganese, beneath a 2-inch layer of gouge. Two additional cuts, one 40 feet east and the other 80 feet east of the tunnel, afford similar exposures of the thrust zone.

The upper mineralized zone is exposed in the main cut near the crest. It shows the same black manganese staining as the one below and appears to strike N. 60° E. and to dip 15° SE. The country rock strikes N. 7° W. and dips 17° E. A number of other cuts are alined in a northeasterly direction, but no manganese-stained rock is shown in any of them.

No sulfides other than the partly oxidized pyrite have been found, nor have oxidation structures been observed that might suggest the presence of galena below the shallow oxidized zone. The limonitic iron and the black manganese oxides appear to have been largely formed by oxidation of rather scanty siderite deposited in the fractured rock along the thrusts.

PIER AND CADY

The Pier and Cady property, originally the Whitcomb, is on the lower south slope of Middle Mountain, in sec. 35, T. 56 N., R. 2 E., about half a mile north of the town of Clark Fork. The development on the property includes three tunnels, only one of which was open in 1940. The work was begun in 1926 or 1927, and in 1927, when the property was first examined, the lengths of the tunnels totaled 365 feet. Some work was done in 1928, but during most of the time since then the property has been idle. The tunnel open in 1940 was the intermediate tunnel, a 137-foot adit drift with a 45-foot crosscut near the face. The lower tunnel, which had a length of 225 feet in 1927, had then been closed off and converted to a reservoir for storing water. The output from the property has been negligible. In 1937 some leasers shipped 3,208 pounds of ore, which netted $27.83.

A low-angle thrust and a high-angle fault have been exposed in the workings. Both cut laminated black and dark-gray shales of the Striped Peak formation. In the mine the beds generally strike N. 25°–30° E. and dip 10°–20° SE., but drag has modified the strike and dip along the faults. The low-angle thrust strikes N. 25°–30° E. and dips 25°–30° SE., having in large part the same strike as the beds but a steeper dip. The high-angle fault, which strikes about N. 55° E. and dips 60° NW., is much more conspicuous than the thrust. Its gouge is so heavy that drifts along it do not remain open unless heavily timbered. This fault is marked on the surface by a straight, sharp gulley. The low-angle thrust lies east of and close to the high-angle fault, which it approaches in the far end of the workings. The zone of fractured rock along the thrust is mostly 2 to 3 feet wide but is locally as much as 6 feet wide.

The only significant bodies of ore lie on the low-angle thrust. The drifts were started along a 6-inch seam of massive galena, but the seam split into half a dozen branches too small to be minable distributed over a zone about 5 feet wide. Near the portal of the intermediate adit is a compact seam of sulfides about an inch thick, but a short distance inward this seam, also, breaks up into thin, rather widely spaced stringers. Small thin lenses appear here and there along the drift, but these too repeatedly break up into stringers, especially along the more gougy parts of the thrust zone. Near the face there are two minor seams about 6 feet apart, joined by thin stringers of ore. The rock along the high-angle fault has been somewhat bleached, and in places it is cut by thin seams and stringers of sulfides.

The ore consists mainly of galena, but it also contains tetrahedrite, sphalerite, pyrite, arsenopyrite, siderite, quartz, and sulfantimonites. The ore shipped in 1937 carried 24.8 ounces of silver to the ton, 37.38 percent of lead, 0.6 percent of zinc, 0.26 percent of arsenic, and 0.2 percent of antimony.

BLAIR AND COLLINS

The Blair and Collins property is on the lower northwest slope of Middle Mountain, near the junction of Cascade and Lightning Creeks, in sec. 26, T. 56 N., R. 2 E. It lies about 2½ miles by air or 3 miles by road north of Clark Fork. No work appears to have been done on the property since 1927, and most of the short tunnels that had been driven on the slope were only partly accessible in 1940.

Mineralization is confined to a low-angle thrust fault that strikes about N. 20° W. and dips 25°–30° NE. The fault cuts limy beds of the Wallace formation, which locally strike about N. 10° W. and dip about 25° NE. The Wallace formation has here been brought against the Striped Peak formation along one of the major northeastward-striking strike-slip faults, which is only a short distance south of the low-angle thrust.

The thrusting has produced a brecciated zone 2 to 3 feet wide, along either the foot or the hanging wall of which, in places, there is a vein of massive galena ½ to 2 inches thick, accompanied by minor stringers of galena in the fractured rock between the walls. In some parts of the thrust zone the ore tends to form small pockets or lenses rather than continuous seams, and here and there it consists of stringers in the brecciated rock. As the thrust lies parallel to the mountain slope and is generally within a short distance of the surface, the ore is somewhat oxidized. The galena, however, has been little changed except for incipient alteration to anglesite, though it as well as the bordering rock is rather heavily stained with black manganese oxides. Neither pyrite nor sphalerite was noted in the partly oxidized ore.

MILLER

The Miller property is on the lower southwest slope of Howe Mountain, about 400 feet east of the portal of the James E. White tunnel, in sec. 34, T. 56 N., R. 2 E. It contains two open cuts and two tunnels, which are, respectively, about 40 feet and 145 feet long. Most of the work on the property was done in 1927 and shortly thereafter. Some small shipments of hand-sorted ore were made.

The property covers the southwestward extension of the South vein of the Whitedelf property. This vein extends along a high-angle reverse fault, which cuts thin-bedded shales and massive quartzites of the Wallace formation, well exposed in cliffs near the portals of the tunnels. The beds strike N. 30° W. and dip 30° NE., except within and immediately along the fault zone. The fault, which has not offset the beds more than a foot or two, strikes N. 30°–50° E. in the upper tunnel and N. 50°–55° E. in the lower. Its dip is generally about 80° SE., but in places it decreases to 75°, and in the lower tunnel it increases to 90°. In the cut above the upper tunnel the fault zone, there about 12 feet wide, is limited on the footwall by a prominent fracture and contains several minor fractures extending toward and along the hanging wall. The beds between the fractures are considerably crumpled, but the entire displacement across the disturbed zone probably does not exceed 2 feet. In the tunnel just below the cut the footwall and hanging wall are marked by well-defined slips 4 to 6 feet apart, between which lies a block of moderately folded and fractured country rock. In the lower tunnel the disturbed zone is 2 to 3 feet wide and shows a little gouge along fractures cutting and bordering the more or less crumpled beds.

The fault zone shows evidence of hydrothermal alteration, and some of the fractures contain a little siderite, quartz, pinkish carbonate, sphalerite, and lead sulfantimonites, and possibly a little galena. The ore minerals now visible in the exposures are sparsely and rather irregularly distributed, in part as a network of narrow stringers. There is less evidence of mineralization in the lower tunnel than in the upper, where the dip is not quite so steep. There, in the ore that was stoped, the sulfides formed small pod-like nests, and veinlets that are generally no more than an inch thick.

EBERLY

Considerable prospecting has been done by A. D. Eberly on land of the Daugherty estate, north of the Whitedelf property, on the northeast side of Howe Mountain. The work includes several tunnels and cuts, which have exposed fault zones otherwise concealed by the glacial drift that covers the lower slope of the mountain and the low country to the north. These openings reveal that the country rock represents the Wallace formation, with the same character and attitude as on the southwest side of the ridge. Both reverse and strike-slip faults, conforming in pattern to those on the Whitedelf ground, have been uncovered.

Most of the tunnels and cuts are on a fault that strikes N. 40° E. and dips 70°–75° SE. This fault contains, in places, as much as 12 inches of gouge. Drag in the beds alongside indicates that the hanging wall has moved relatively upward. The fault has been traced for more than 150 yards by cuts, drifts, and tunnels, one of which is 110 feet long. In one of the upper tunnels a drift has been carried along a fault striking N. 70° E. and apparently dipping about 45° S., which appears to end abruptly against the one that strikes N. 40° E. The fault striking N. 70° E. is marked by numerous fractures and badly crushed and gougy ground. Drag in the bordering beds suggests that the movement along it has been diagonally upward from the southwest. This fault is also exposed in a cut about 100 yards to the west, where it shows 1 to 2 feet of gouge along a fracture that dips about 50° S., and there again pronounced drag along the hanging wall indicates a shove from the southwest at a fairly low angle.

Both faults display evidence of hydrothermal action and con tain a little sulfide. In places the reverse fault contains small scattered pods and stringers of lead sulfantimonites and stringers of quartz and carbonate. The second fault contains, in addition, small scattered pods and stringers that contain a little siderite, galena, sphalerite, and lead sulfosalts, stringers of a white carbonate, and stringers of quartz that seems to be older than the quartz-siderite seams. The rock along both fault zones has been somewhat sericitized and silicified and locally chloritized.

OTHER PROPERTIES

A tunnel known as the Clagg-Norquist, at or near the Daugherty-Whitedelf property line, has exposed two faults. A tunnel has been driven along one of the faults, which is somewhat mineralized. This fault, which contains little gouge, strikes about N. 75° W.; in some places it dips steeply south and in other places steeply north. Near the face of the tunnel it appears to be cut off by a fault of variable trend, which strikes about due east to southeast. This second fault dips about 75° N. and shows grooves that are inclined about 35° E. A few stringers containing pyrite, quartz, and a carbonate are scattered along the fault that strikes N. 75° W.

Several minor low-angle thrusts in red beds of the Striped Peak formation have been uncovered on the south slope of Middle Mountain, across from the Lawrence mine, but without revealing significant showings of ore minerals. The faults strike about N. 20° E. and dip about 25° SE.; the bedding locally strikes N. 30° W. and dips 15°–18° NE. One of the short tunnels shows, within a vertical distance of 6 feet, three small low-angle thrusts that contain some small stringers of siderite. Another tunnel has been driven along a fault that strikes N. 45° E. and dips 80° NW. This fault has 8 inches of gouge.

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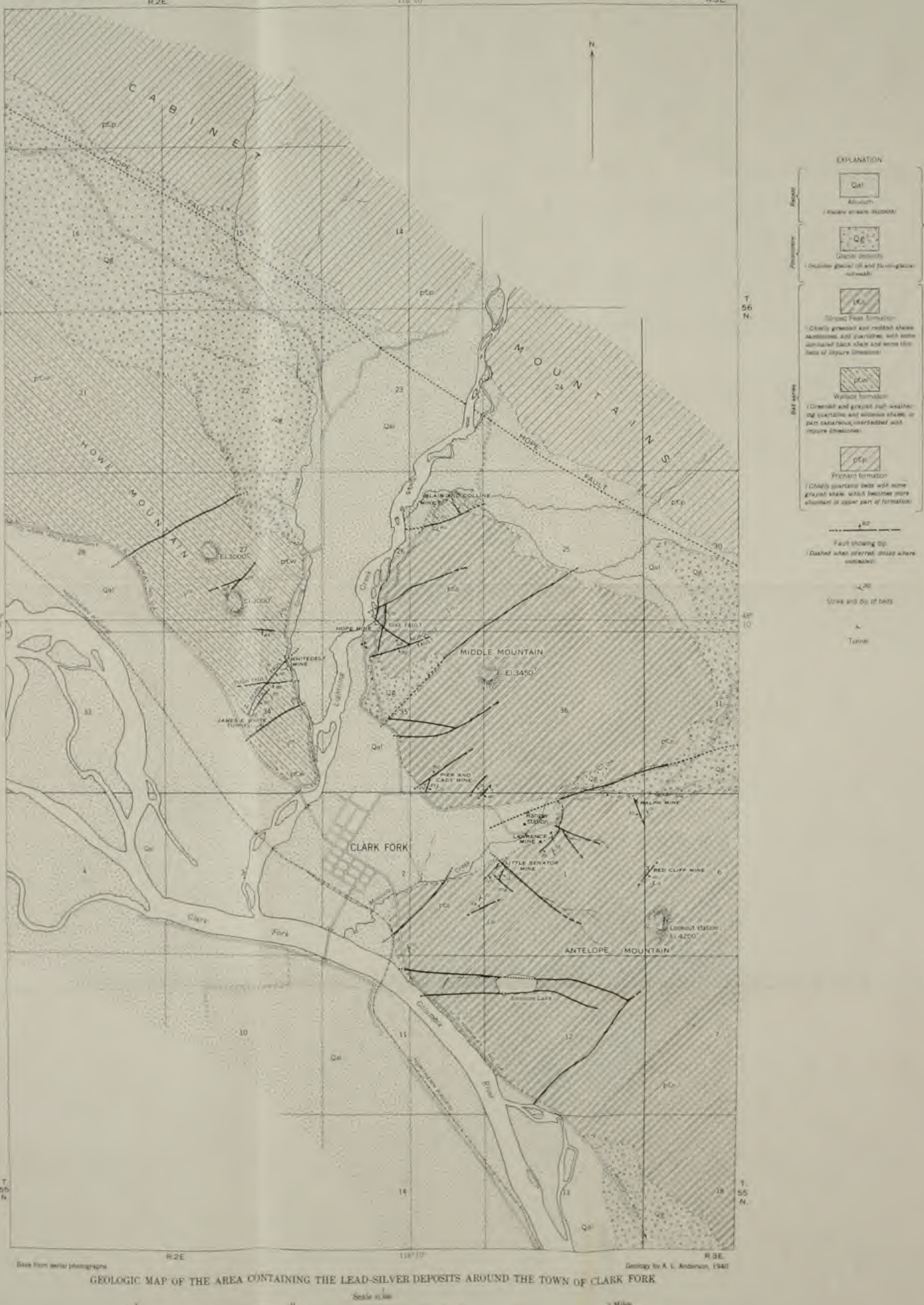
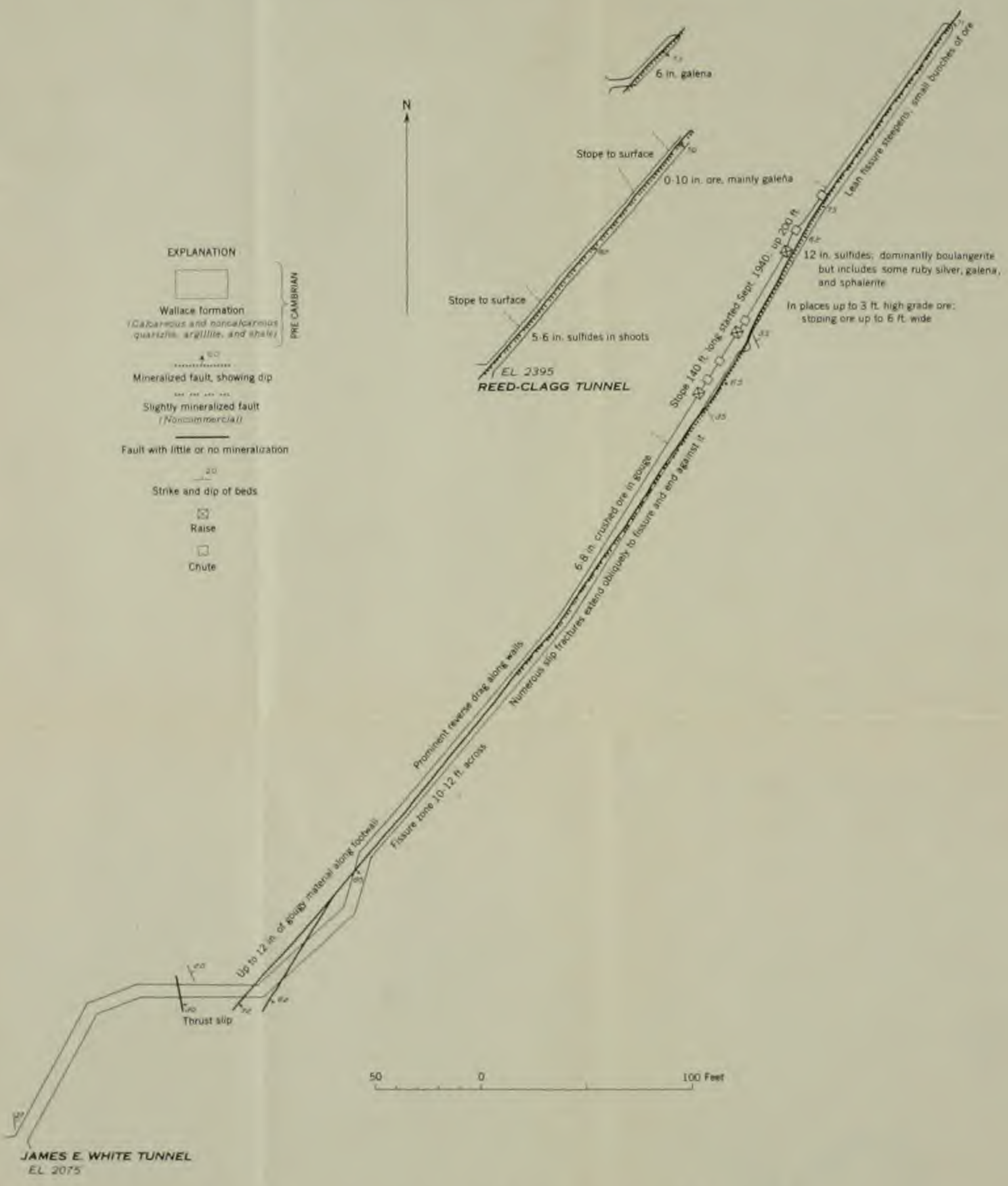
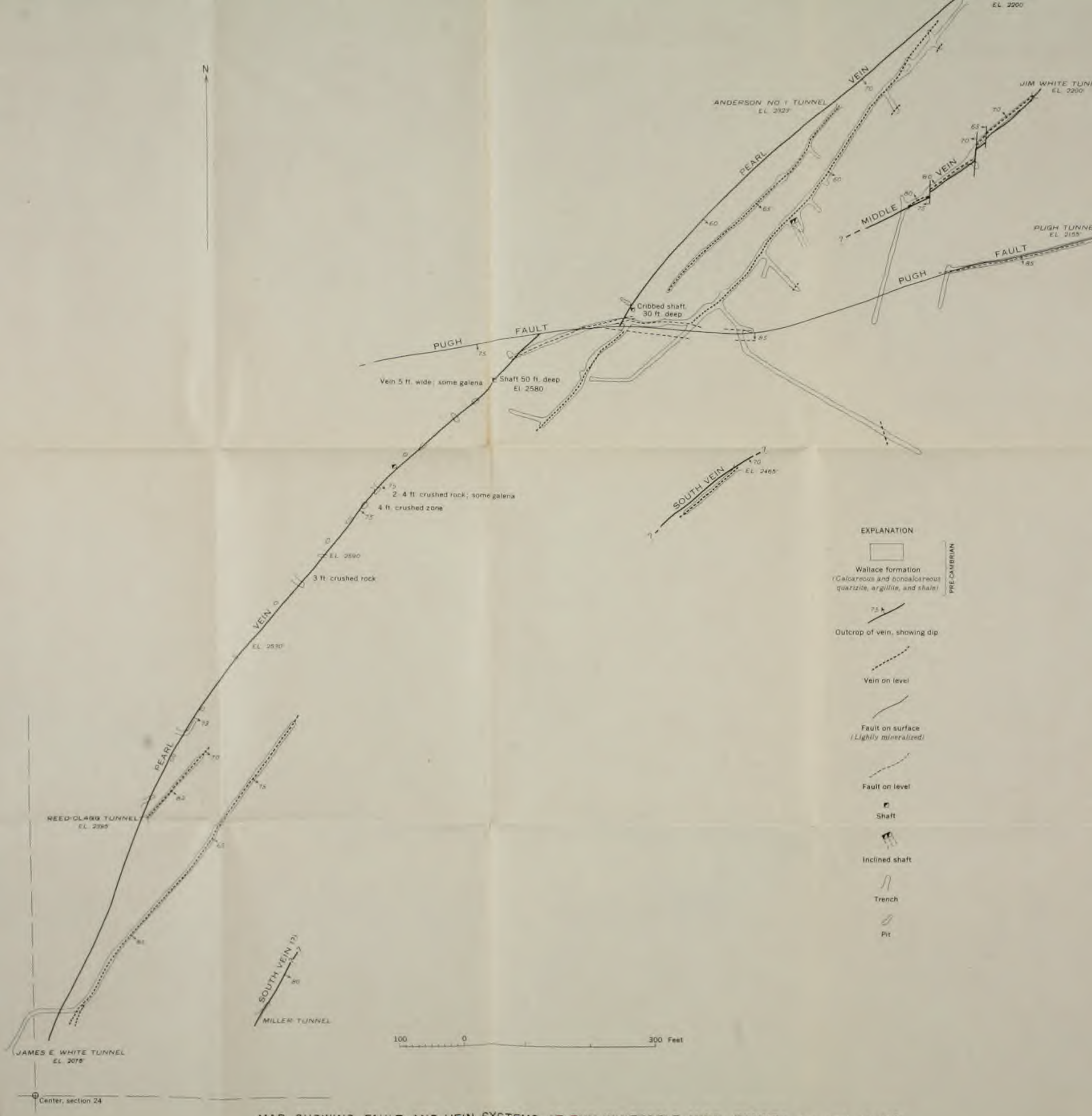


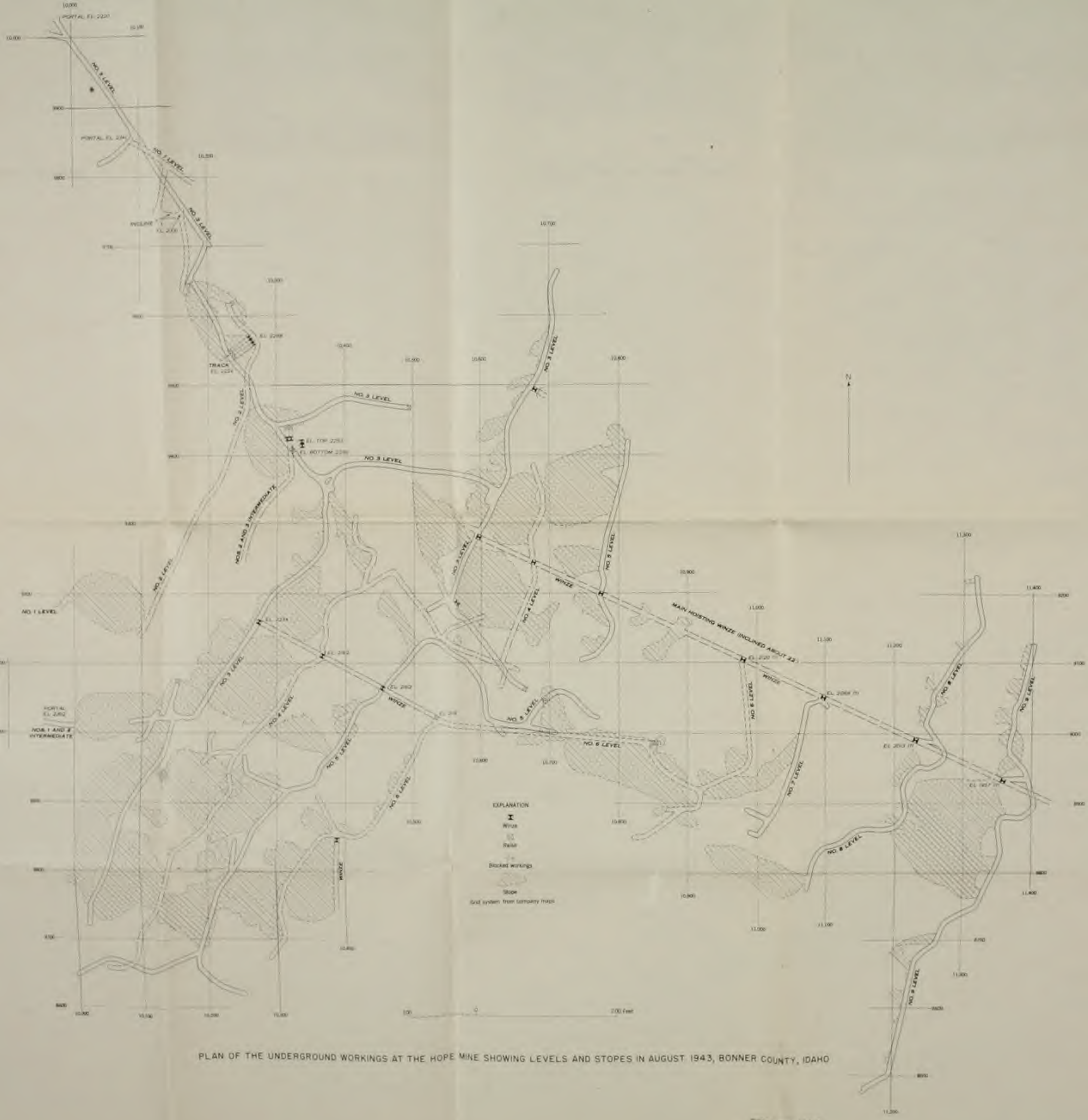
GEOLOGIC MAP OF THE AREA CONTAINING THE LEAD-SILVER DEPOSITS AROUND THE TOWN OF CLARK FORK



PLAN OF WORKINGS ON SOUTHWEST SEGMENT OF THE PEARL VEIN AT WHITEDELF MINE SHOWING GEOLOGY ON LEVELS, BONNER COUNTY, IDAHO

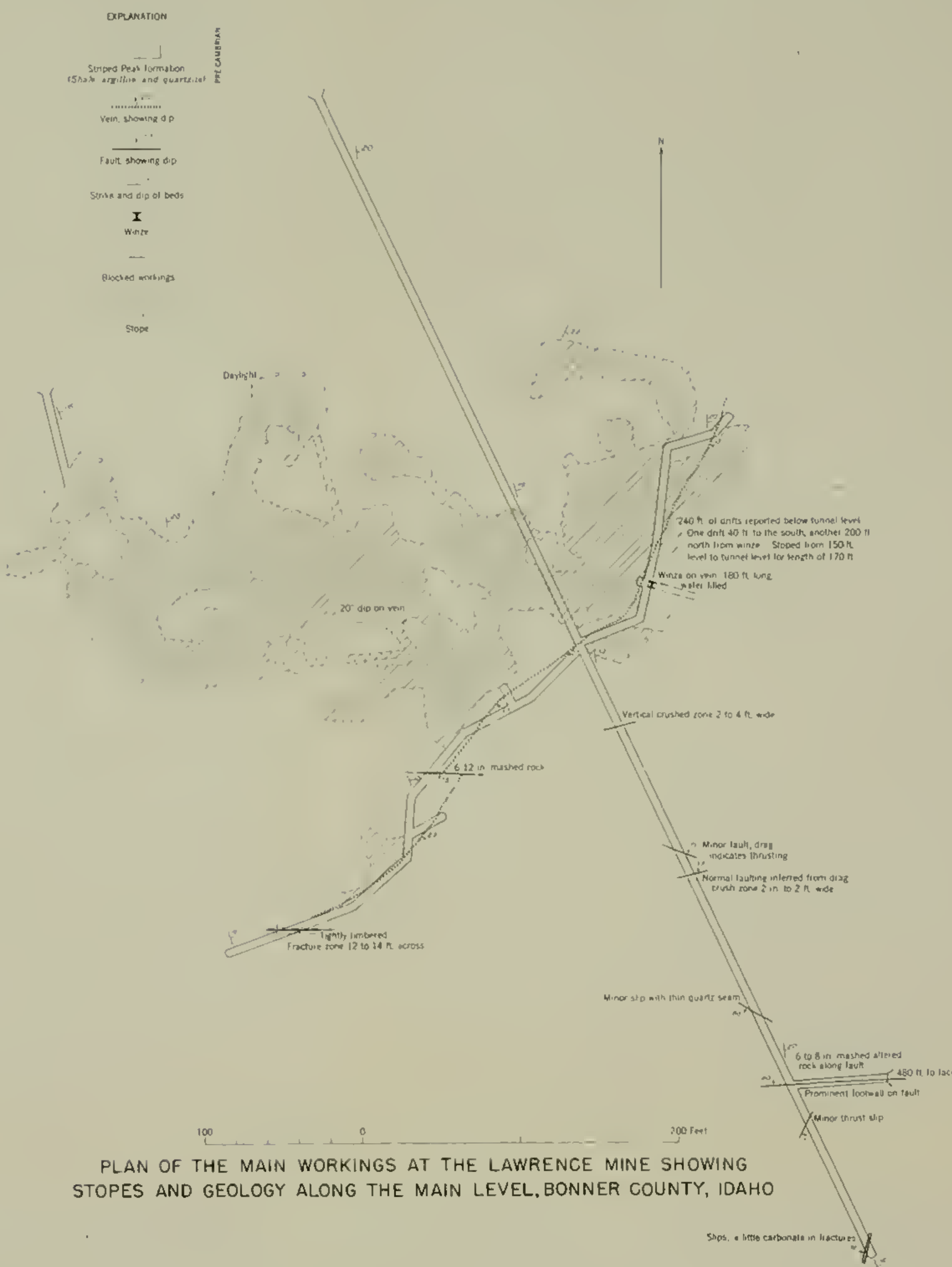


MAP SHOWING FAULT AND VEIN SYSTEMS AT THE WHITEDELF MINE, BONNER COUNTY, IDAHO



PLAN OF THE UNDERGROUND WORKINGS AT THE HOPE MINE SHOWING LEVELS AND STOPES IN AUGUST 1943, BONNER COUNTY, IDAHO

GEOLOGIC MAP OF THE LEVELS AT THE HOPE MINE, BONNER COUNTY, IDAHO



PLAN OF THE MAIN WORKINGS AT THE LAWRENCE MINE SHOWING STOPES AND GEOLOGY ALONG THE MAIN LEVEL, BONNER COUNTY, IDAHO

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