Geology and Mineral Deposits of the St. Regis–Superior Area Mineral County, Montana

By ARTHUR B. CAMPBELL

CONTRIBUTIONS TO ECONOMIC GEOLOGY

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A reconnaissance study of the geology and mineral deposits of a part of northwestern Montana

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By Arthur B. Campbell

ABSTRACT

The St. Regis-Superior area occupies about 300 square miles in northwestern Montana and includes parts of the Squaw Peak Range and Coeur d'Alene Mountains of the northern Rocky Mountains physiographic province. Nearly 50,000 feet of metasedimentary rocks of the Precambrian Belt series, chiefly varieties of quartzite and argillite, underlies most of the area. The Belt series is informally subdivided with reference to the top of the Wallace formation into lower and upper parts. In this area, the lower part of the Belt series is divided into the Prichard, Burke and Revett, St. Regis, and Wallace formations, in order of decreasing age, and the upper part of the Belt series or the Missoula group is divided into the Spruce, Lupine, Sloway, and Bouchard formations, and an unnamed feldspathic quartzite at Rock Rabbit Ridge, also from oldest to youngest. Formations in the lower part of the Belt series are correlated with formations of the same names in the Coeur d'Alene district, and formations in the upper part of the Belt series are tentatively correlated in part with formations of the Missoula group in the vicinity of Missoula, Mont. Paleozoic quartzite, shale, limestone, and dolomite crop out in several localities in the southeastern part of the area. The limestone unit contains fragments of a single species of *Glossopleura* of early Middle Cambrian age which, together with lithologic similarities, has been used to correlate at least the quartzite, shale, and limestone part of this Paleozoic sequence with the Flathead sandstone, Gordon shale, and Damnation limestone sequence known elsewhere in northwestern Montana. Several small diabasic dikes and sills are present in the area, generally associated with northwestward-trending faults.

The major faults generally trend northwestward and are considered to be part of the Lewis and Clark structural line. The Osburn fault, the major element of the Lewis and Clark line through the Coeur d'Alene district and western Mineral County, has been traced to the east edge of the St. Regis-Superior area, thus extending the mapped length of the fault to about 100 miles. Evidence indicates that this major fault has diminished in intensity in this area and that most of the stress has been relieved along the Boyd Mountain fault that apparently splits from the Osburn fault a few miles west of St. Regis. Stratigraphic and structural evidence indicates a strike-slip right-lateral movement of about 3 miles along the Osburn fault. Horizontal stratigraphic separation along the Boyd Mountain fault indicates a right-lateral movement of about 13 miles.

Low-grade regional metamorphism of the sedimentary rocks in the area has caused the recrystallization of quartz grains and the formation of sericite. Argillite and quartzite have been converted to phyllite and foliated quartzite by dynamic metamorphism in a large area north of the central part of the Osburn fault. Some of the shear zones contain a large amount of introduced carbonate minerals.

From 1901 through 1953 this area has produced 8,086,827 pounds of zinc, 7,932,958 pounds of lead, 2,053,715 pounds of copper, 584,168 fine ounces of silver, and 588 fine ounces of gold. The lead, zinc, and silver have come chiefly from veins in highly foliated rocks near the Osburn fault zone. The attitudes of these veins are controlled in large part by the cleavage. The principal ore minerals are galena, sphalerite, tetrahedrite, and boulangerite, and the gangue minerals are quartz, carbonate minerals, and barite. Most of the copper has come from the Amador vein where chalcopyrite and bornite are the principal ore minerals, and the gangue minerals are pyrite, quartz, and carbonate minerals. The Amador vein occurs in a belt of copper deposits that extends westward into the Coeur d'Alene district. These copper deposits may be genetically associated with diorite dikes and sills lying within the same belt.

Fluorspar has been found in three closely spaced prospects along a northward-trending zone of brecciation and small-scale folding in Dry Creek valley. Incomplete production records show that 781 tons of fluorspar has been shipped from 2 of these prospects.

INTRODUCTION

PRESENT WORK

The St. Regis-Superior area was studied during the summers of 1953 and 1954 as a part of geologic investigations by the U.S. Geologic Survey in and near the Coeur d'Alene district. The object of the present work was primarily threefold: to ascertain the main structural features in the area, with particular attention to the Osburn fault zone; to investigate the mineral deposits; and to determine the stratigraphic relations of the rocks.

The desire to cover as large an area as possible in the available time, but to acquire more than a cursory knowledge of the geology of the area, dictated a somewhat flexible approach to the field mapping. Certain aspects of the geology as well as certain localities received a disproportionately greater amount of the total time. For example, more attention was paid to the stratigraphic details of the upper part of the Belt series, the Missoula group, than to the older underlying rocks. This was necessary because of the relative lack of knowledge of the Missoula group and the need for establishing the stratigraphic sequence before attempting to interpret the structural setting.

The map (pl. 28) presents a geologic interpretation based on data from a network of widely spaced traverses and a study of aerial photographs. The planimetric base map was prepared in part by the U.S. Geological Survey and in part by the U.S. Forest

Service. Topographic features were used in conjunction with aerial photographs to locate positions for the plotting of field observations.

ACKNOWLEDGMENTS

The writer is grateful to the managements of the Nancy Lee Mining Co., the American Smelting and Refining Co., the Amador Mining Co., and the Little Pittsburg Silver Mining Co. for their generous permission to use maps from their files and production data compiled by the U.S. Bureau of Mines. Mr. Gerald L. Thompson ably assisted the writer during a part of the 1954 field season.

PREVIOUS WORK

The St. Regis–Superior area of Montana has been the subject of only limited geologic investigations in the past. Calkins (Calkins and MacDonald, 1909) made a geologic reconnaissance of northwestern Montana and northern Idaho in 1905 for the purpose of correlating the Precambrian stratigraphic section between the Coeur d'Alene district (Ransom and Calkins, 1908) and areas in western Montana studied by Walcott (1899 and 1906), Weed (1899a, 1899b, and 1900), and Willis (1902). Calkins described a single traverse through the area westward from Missoula, Mont., along the Clark Fork (then Missoula River) to Superior, Mont., and northward to the junction of the Clark Fork and Flathead River.

The physiography of the area, with emphasis on the history of the glacial Lake Missoula, has been studied by Pardee (1910, 1942), who attributed various landforms in the Clark Fork valley to the presence in the Pleistocene of that extensive body of water. A more comprehensive study of the physiography and glacial geology has been presented by Alden (1953). A small part of the area was included by Pardee (1950) in his investigation of intermontane basins and late Cenozoic block faulting in western Montana.

Wallace and Hosterman (1956) devoted the summer of 1952 to a study of the area between the Coeur d'Alene district on the west and the St. Regis–Superior area on the east. Their work contributed greatly to the knowledge of the stratigraphy of the lower part of the Belt series and the structural framework in and near the Osburn fault.

GEOGRAPHY

LOCATION AND ACCESSIBILITY

The area discussed in this report lies wholly within the drainage basin of the Clark Fork (fig. 51). U.S. Highway 10, which parallels the river, bisects the mapped area. Superior, Mont., seat of Mineral County, has a population of about 1,050 and is located near

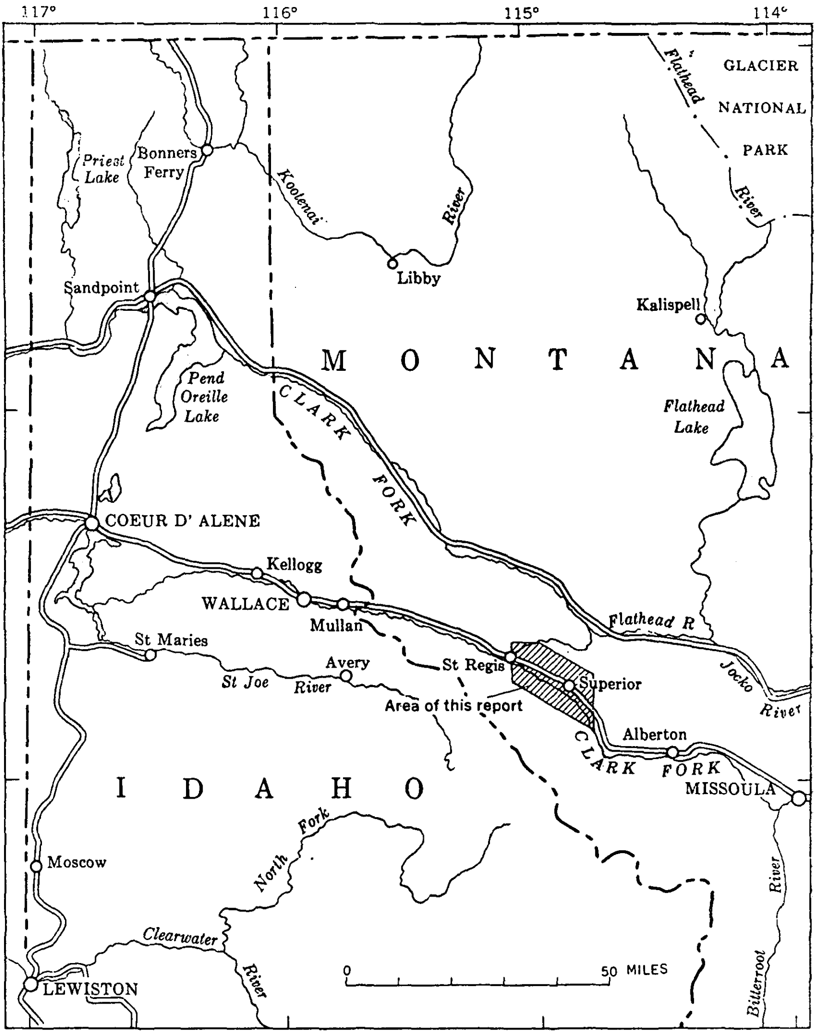

FIGURE 51.—Index map of northern Idaho and northwestern Montana, showing location of St. Regis-Superior area.

the center of the area. In addition to U.S. Highway 10, the region is served by main lines of the Northern Pacific and the Chicago, Milwaukee, St. Paul, & Pacific railroads. Secondary roads follow many of the main valleys and are maintained by the U.S. Forest Service and by the county. Secondary roads servicing mines or logging areas are kept open during the winter, but others are generally impassable from December to June. The area is covered by a network of trails, many of which are practically impassable due to lack of maintenance.

TOPOGRAPHY, CLIMATE, AND VEGETATION

The region is mountainous with a maximum altitude of about 6,700 feet and a minimum of about 2,540 feet. The Squaw Peak Range lies northeast of the Clark Fork and the Coeur d'Alene Mountains lie to the southwest; both are part of the northern Rocky Mountains physiographic province. The erosional cycle is in maturity with a near minimum of ridge or valley flats.

Data concerning temperature and precipitation in the Superior area, which are presented in tables 1 and 2, were furnished by the Weather Bureau, U.S. Department of Commerce. Winters are rarely so severe that mining operations are seriously impeded.

Many of the northward-facing slopes have a thick stand of pines, firs, and other conifers, whereas the southward-facing slopes are commonly grass and brush covered and more sparsely timbered. Lumbering is the leading industry in this area. Adequate timber for mining operations is easily accessible locally.

TABLE 1.—*Records of temperature and precipitation at Superior, Mont., 1949–53*

Year	Temperature, in degrees Fahrenheit, and date					Precipitation (inches)[1]
	Average for year	Highest		Lowest		
		Amount	Date	Amount	Date	
1949	42.7	100	Aug. 5	−28	Jan. 25	16.55
1950	42.9	103	Sept. 3	−31	Jan. 31	23.42
1951	42.8	100	July 17 Aug. 2	−18	Jan. 30	20.03
1952	44.1	101	July 31	−15	Jan. 1	11.34
1953	46.8	105	July 12	13	Feb. 20	18.58

[1] Total for year including snowfall.

TABLE 2.—*Monthly and annual mean maximum and minimum temperatures at Superior, Mont., 1949–53*

[Temperature in degrees Fahrenheit]

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1949	19.2	34.4	46.1	64.3	72.3	74.4	84.1	87.4	75.2	54.5	47.6	33.3	57.7
	−8.0	12.0	20.4	27.5	37.5	41.6	43.5	43.9	39.0	28.2	29.8	16.8	27.7
1950	19.3	38.5	42.9	54.7	63.5	71.2	82.3	83.9	75.4	57.0	41.9	37.6	55.7
	.9	17.9	24.2	28.5	33.2	43.0	46.9	45.4	37.3	35.0	23.6	24.8	30.1
1951	31.3	39.5	43.5	61.6	65.5	71.6	87.7	81.9	71.2	53.3	40.8	29.2	56.4
	12.6	20.3	20.4	26.4	36.5	39.9	45.6	43.5	36.2	33.1	23.3	11.6	29.1
1952	29.0	40.2	44.6	65.2	67.5	72.1	84.1	83.5	79.0	67.4	41.7	34.0	59.0
	10.3	18.4	22.0	26.2	37.9	42.6	43.6	45.3	37.7	26.5	17.8	21.1	29.1
1953	43.3	41.8	49.7	54.9	63.6	69.9	88.6	84.7	79.1	65.1	46.8	39.1	60.6
	28.9	25.0	25.4	29.3	33.6	42.2	44.1	44.3	38.5	28.2	29.4	27.4	33.0

GENERAL GEOLOGY

The area is underlain by about 50,000 feet of metasedimentary rocks of the Precambrian Belt series. This stratigraphic column comprises one of the most complete sections of Belt rocks in northern Idaho and western Montana. The rocks of the Belt series in this area are typically quartzite and argillite, or mixtures of these two rock types, which have been folded, faulted, intruded by diabase dikes and sills, and subjected to very low grade regional metamorphism. Sedimentary features are still fully distinguishable in these rocks, however the term "metasedimentary" is used to emphasize their intermediate position between their sedimentary and metamorphic prototypes.

The terms "quartzite" and "argillite," commonly with modifying adjectives were used during the fieldwork. Wallace and Hosterman (1956, p. 577) found by thin-section examination that many rocks called argillite in the field actually were composed dominantly of silt-sized quartz grains. The problem of classifying such fine-grained, quartzose, low-rank metamorphic rocks is primarily concerned with definitions. The term "argillite," for instance, denotes both mineral composition and grain size to some but implies only a grain size to others. Many of the rocks in the area are slightly metamorphosed equivalents of a quartzose siltstone for which there is no precise name in common usage. The term "quartzose siltsite" has been suggested and has merit.

In this report the term "argillite" is used in the sense suggested by Twenhofel (1937, p. 95), the equivalent of siltstone or claystone after incipient metamorphism. The term "quartzite" as used here refers to the low-rank metamorphic equivalent of a quartz sandstone and is used with modifiers to denote a deviation from this restriction, for example, sericitic quartzite. This method of using only two major rock names and showing variations by use of modifying adjectives has been adopted primarily to coincide with accepted usage by mining geologists in the area. Local dynamic metamorphism has resulted in the formation of phyllite and schist.

Rock-color names used in this report are based on the color classification presented in the "Rock-Color Chart" (Goddard and others, 1951) distributed by the Geological Society of America.

Stromatolites are sparse in the Wallace formation of the lower part of the Belt series and in the Lupine and Bouchard formations of the upper part of the Belt series. These stromatolites represent species of *Collenia* (Richard Rezak, oral communication, 1953) but no specific identifications have been made. Similar forms have been described by Fenton and Fenton (1937, p. 1941–50) and by Rezak (1957, p. 127–154) in the Glacier Park area in Montana. The fossils, where found, are restricted to certain beds that generally contain several simple colonies. However, one example of colonies united laterally was seen. Individual colonies are commonly less than 1 foot in their greatest dimension and are normally calcareous. An individual colony is a biconvex mass consisting of finely crenulated alternating coarse and fine laminae which are subparallel to the upper surface. According to Richard Rezak (oral communication, 1953), these fossils are not useful in this area for precise regional stratigraphic correlations.

Paleozoic rocks, resting unconformably on Precambrian rocks, occur in several isolated patches in the area and consist of a sequence of quartzite, shale, limestone, and dolomite.

PRECAMBRIAN ROCKS

Problems in regional stratigraphic correlation result from lithologic similarities of some formations of the Belt series; the tendency for many of the formations to lose their distinctive characteristics laterally; and the great variation in thickness of formations from place to place. The Wallace formation and its equivalents (Clapp and Deiss, 1931, p. 691–693) offer at least a partial exception, for they retain many of their characteristics throughout much of northern Idaho and northwestern Montana. The Wallace is easily distinguishable from the overlying and underlying formations because it is calcareous and dolomitic. Owing to this individuality, the Wallace has frequently been used in stratigraphic studies as a reference formation for older and younger Belt series rocks. On this basis, the Belt series in the St. Regis–Superior area is here subdivided with reference to the upper contact of the Wallace into a lower part, including all rocks below the upper contact of the Wallace, and an upper part, the Missoula group, including all Belt rocks younger than the Wallace formation.

LOWER PART OF THE BELT SERIES

The rocks of the lower part of the Belt series were subdivided by Calkins (Ransome and Calkins, 1908, p. 29–44) in the Coeur d'Alene district into the following formations in order of decreasing age: Prichard, Burke, Revett quartzite, St. Regis, and Wallace formations. With few exceptions, these stratigraphic units have been used successfully in subsequent work in northern Idaho and adjacent parts of Montana. Several of these formations contain units that are typical of the other formations; contacts are gradational; and lateral sedimentary facies changes can be abrupt. Wallace and Hosterman (1956, p. 580) and the writer found that the Burke formation could not be adequately distinguished from the Revett quartzite in western Montana, so these formations were mapped as a single unit referred to here as the Burke and Revett formations.

PRICHARD FORMATION

The Prichard is the oldest unit of the Belt series exposed in this area. The bottom of the formation is not exposed in the St. Regis–Superior area, although eastward in the Philipsburg quadrangle, Montana, it rests conformably on the Neihart quartzite (Calkins and Emmons, 1915, p. 3). Wallace and Hosterman (1956, p. 579) reported a thickness of nearly 17,000 feet of Prichard exposed along the Clark Fork near the north border of the area discussed in this report. About 4,000 feet of the upper part of the formation is exposed along the north edge of the area included in plate 28, where the contact with the overlying Burke and Revett formations is in part normal and in part a fault contact. In the nearly continuous exposures of the formation along the river, the beds dip from 40° to 65° SW. and form part of the southwest limb of a major northwestward-trending anticline.

The outstanding characteristics of the formation are the medium- to dark-gray color and the limonitic staining on weathered surfaces. Wallace and Hosterman (1956, p. 579) noted the predominance of neutral gray or low chroma colors of the fresh rock. The sequence of Prichard beds exposed in this area is composed of about 10 percent argillite, 5 percent is light-gray, vitreous, fine-grained quartzite, and 85 percent of the unit ranges from very fine grained, sericitic quartzite to quartzose argillite. These rock types are interbedded and no particular concentration of a given lithologic type either laterally or vertically was noted. The fine-grained, sericitic quartzite and quartzose argillite are generally medium gray or slightly greenish gray, and the beds range from a few inches to 3 feet in thickness. In general, the purer quartzite is more vitreous, lighter gray, and somewhat thicker bedded than the more impure beds. The argillite is typically medium dark to dark gray, the beds are less than 6 inches thick, and the argillite is commonly fissile parallel to bedding planes. Cleavage, where present, is more sharply defined in the argillite, and shows a pronounced deflection in dip upon passing from argillite into quartzite. Pyrite is abundant in the more argillaceous beds and oxidation has caused limonitic staining on weathered surfaces. Mud cracks are present though not abundant.

The contact with the overlying Burke and Revett formations is gradational through a zone several hundred feet thick. This contact has been mapped above the uppermost dark-gray argillite in the Prichard, as the Burke and Revett formations do not contain similar beds.

The formation here differs in some respects from the correlative strata exposed in the western part of the Coeur d'Alene district. The Prichard rocks exposed in the area are more homogeneous and lack the striking closely spaced laminations of argillite and arenite so characteristic of much of the Prichard farther west. In the Coeur d'Alene area it was possible to map an upper unit of interbedded, vitreous, light-gray quartzite and quartzose argillite ranging in thickness from 700 to 1,800 feet; however the distinctive vitreous quartzite is not present in the St. Regis–Superior area.

The dominant minerals of the Prichard are quartz and sericite, and accessory minerals are biotite, chlorite, tourmaline, feldspar, pyrite, and limonite. The pyrite grains are commonly concentrated along the bedding planes, although some grains were found disseminated through the rock. A mixture of very fine grained (less than 0.025 mm) quartz and sericite occurs in all lithologic types, either interstitially between larger quartz grains, as in the quartzite, or as the major constituent of the argillite. Tourmaline occurs in minor amounts in Prichard rocks as it is throughout much of the Belt series and, because of its euhedral form, is probably secondary in origin. The few feldspar grains in the thin sections examined have been partly altered to sericite.

BURKE AND REVETT FORMATIONS

The Burke and Revett formations were named and described by Calkins (Ransome and Calkins, 1908, p. 32–36) in the Coeur d'Alene district. The Revett formation in its type section near Burke, Idaho, is chiefly a vitreous thick bedded quartzite, but it changes laterally outside the Coeur d'Alene district to an impure thin- to medium-bedded quartzite. This impure quartzite facies of the Revett is so similar to the Burke formation in this area that the two formations were mapped as a single unit.

Many exposures of these formations are within or adjacent to the Osburn fault zone of shearing and folding, where exposures tend to be discontinuous. Examples of these outcrops occur near stream level in the valleys of Fourmile, Sloway, and Keystone Creeks, where the unit crops out north and south of the Osburn fault. The Burke and Revett unit may also be seen in the Little Pittsburg and Nancy Lee mines. The lower contact is poorly exposed near the county road in sec. 9, T. 18 N., R. 26 W. The upper contact may be seen most conveniently either northeast of the Osburn fault in Pardee Creek (secs. 2 and 3, T. 17 N., R. 26 W.), where the beds are overturned or near the Ninemile Divide Road at the head of Flat Creek, where it has not been affected by the shearing associated with the Osburn fault.

A complete section of the Burke and Revett formations is not exposed so a measured thickness cannot be given. A thickness of about 4,500 feet is indicated, however, along the north edge of the mapped area. This thickness may include some duplication by faulting that was not detected in the limited exposures in that area. Wallace and Hosterman (1956, p. 581) reported a minimum of 3,000 feet of Burke and Revett in a complete but unmeasured section west of the St. Regis–Superior area.

The lithology of these predominantly arenaceous formations ranges from fine-grained, argillaceous quartzite near the lower contact to fine-grained, subvitreous to vitreous quartzite higher in the section. In general, purer quartzite beds occur near the top of the section just as they do in the Coeur d'Alene district; however, in this area there is more interbedded impure quartzite in the upper part of the formations. These rocks are generally medium to light gray or greenish gray but the more vitreous quartzite is lighter in color. Some light-purple tints were seen in the vitreous quartzite near the Ninemile Divide Road at the headwaters of Flat Creek. Bedding thicknesses range from a few inches in the more argillaceous beds to 5 feet or more in the vitreous quartzite. Concentrations of sericite are along many bedding planes throughout the section. Ripple marks and mud cracks are locally conspicuous but are not abundant, and crossbedding is apparent in some of the more massively bedded quartzite.

The bulk of the rock is composed of quartz and sericite, and minor amounts of carbonate minerals, chlorite, tourmaline, feldspar, and zircon. In the thin sections examined, quartz constitutes 60 to 90 percent of the rocks and has an average grain size of 0.05 mm. These grains are generally equidimensional and angular with interlocking borders. Undulatory extinction of individual grains of quartz is particularly evident in thin sections from specimens that came from in and near the Osburn shear zone. Some of these grains also show varying degrees of preferential elongation parallel to the planes of foliation. Argillitic quartzite contains as much as 40 percent sericite occurring mainly as fine-grained interstitial material; however, some replacement of quartz by sericite was noted. Sericite grains show a high degree of parallel alinement in the planes of foliation and many thin sections show nearly simultaneous extinction of the sericite upon rotation of the microscope stage. Minor amounts of brown and green tourmaline were seen in many thin sections as small scattered grains whose unabraded automorphic outline and preference for orientation in foliation planes indicate a metasomatic origin.

Much of the rock of the Burke and Revett formations exposed in the area has been greatly altered from the typical rocks described above. Intense shearing and sericitic alteration have converted many of the rocks into foliated sericitic quartzite in the wide zone of disturbance along the Osburn and other parallel faults. Locally, where shearing was abnormally intense, the rock has been changed to a quartz sericite schist. Carbonate minerals have been introduced into the sheared and shattered quartzite and argillite near the Osburn fault. In places the carbonate mineral content is as high as 20 percent of the total volume, and the rock will effervesce moderately in cold dilute hydrochloric acid. Several differential thermal analyses of these rocks, using a portable differential thermal analysis apparatus, indicate the presence of ferrodolomite or ankerite. Owing to the presence of carbonate minerals, much of the Burke and Revett near the Osburn fault has previously been mistaken for the younger Wallace formation that contains similar appearing dolomitic quartzite beds. Regional stratigraphic relations, however, and the lack of other typical Wallace formation lithologic characteristics have clarified this identification.

ST. REGIS FORMATION

The St. Regis formation in the St. Regis–Superior area is composed of 1,900 to 2,200 feet of thin-bedded quartzose argillite and a few beds of light-gray sericitic quartzite. Beds of fissile, greenish-gray, sericite-rich, argillite are diagnostic of this formation. As in the underlying Burke and Revett formations, the St. Regis in the zone of the Osburn fault contains secondary carbonate minerals. Much of the intensely foliated St. Regis in the Little Pittsburg mine will effervesce freely in cold dilute acid.

The dominant color of the St. Regis rocks south of the Osburn fault and in the area on the north adjacent to the fault zone is a greenish gray that ranges from a dusty-yellow green to a medium light gray. Such gray and green rocks crop out along the Pardee Creek road south of the fault. North of the Osburn fault both greenish-gray and purplish-gray are present. Rocks with purple hues, typical of the formation in the Coeur d'Alene district, are exposed along the ridge west of the junction of the Flat Creek road with Ninemile Divide Road in sec. 31, T. 18 N., R. 25 W.

The contact of the St. Regis formation (Ransome and Calkins, 1908, p. 36–39) with the underlying Burke and Revett is gradational through a transition zone 100 to 200 feet thick, and it is difficult to set more than an arbitrary boundary even where continuous exposures exist. This contact was mapped where the dominant rocks change upward from light-gray quartzite to pale-green quartzose argillite. Mapping this contact close to the Osburn fault is further complicated by pronounced cleavage that obliterates bedding planes and his produced foliated sericitic quartzite and even phyllite.

The upper St. Regis rocks are slightly dolomitic near the contact with the overlying Wallace formation and weather yellowish brown on the surface. The upper contact in this area is placed where the thin-bedded greenish-gray argillite and quartzose argillite of the St. Regis give way to the interbedded medium- to dark-gray argillite, and dolomitic quartzite, of the Wallace formation. Where exposures are good, such as northeast of the Osburn fault along the Pardee Creek road, this contact may be seen as a pronounced change in lithologic types through a transition zone 50 to 100 feet thick. Beds of argillite similar to the St. Regis lithologic types may be found in the lower several hundred feet of the Wallace, making it difficult to place this contact in areas of sporadic outcrops.

Wallace and Hosterman (1956, p. 582) discussed the pronounced sedimentary facies changes that occur in the St. Regis formation in the Coeur d'Alene area of Idaho and in northwestern Montana. Absence of known time equivalents in the Belt series precludes positive interpretation of such facies changes. Consequently regional correlation of the St. Regis formation is based more on relative position in the rock column than on a comparison of local physical characteristics.

Microscopic examination emphasizes the mineralogic similarity of the St. Regis to the underlying formations. Quartz and sericite are the major components, the relative percentages of which vary with different rock types. Nearly all the quartz grains in the thin sections examined were less than 0.06 mm in size, had sutured borders, and showed poorly defined preferential elongation in intensely sheared rocks. Parting planes of the more fissile argillite are seen in thin section as distinct bands of sericite, separating more arenaceous layers. Fine-grained chlorite is present in significant quantities in the green rocks and occurs disseminated through the rock or, particularly in the foliated rocks near the Osburn fault, as clusters of grains clearly visible in hand specimens and frequently associated with pyrite. Fine-grained dolomite occurs in amounts as much as 40 percent by volume in some of the upper beds and is clearly distinguishable from the coarser grained secondary carbonate minerals which occur in poor defined clusters in the rocks near the Osburn fault. A few grains of tourmaline were found in the sections studied. Opaque minerals in these rocks are generally small euhedral magnetite crystals or less commonly pyrite cubes. Very fine grained hematite is present in the purple rock and it probably causes the red and purple coloration.

WALLACE FORMATION

The Wallace formation defined by Calkins (Ransome and Calkins, 1908, p. 39–43) in the Coeur d'Alene district maintains many of its gross characteristic features throughout large areas, although in detail it is the most heterogeneous formation of the lower Belt series. This congruity makes the formation a useful reference from which to work out stratigraphic relations of formations both younger and older. Exposures of this formation are extensive throughout northwestern Montana and northern Idaho.

The formation is composed of quartzite, argillite, limestone, and dolomite, and a wide range of mixtures of these rock types. The most diagnostic characteristic of the formation as a whole is the nearly ubiquitous presence of calcite, ferrodolomite, or low-iron ankerite, or mixtures of these minerals. Much of the rock has a thin yellowish- or reddish-brown coating derived from the weathering of the ferruginous carbonate minerals.

The reported thickness of the Wallace varies greatly among described localities in Idaho and Montana. This variation may be due partly to differences of opinion concerning the location of the upper contact and partly to a variable thickening of the section by small-scale crumpling typical of this formation. Such pronounced differences as a thickness of 4,000 feet in the Coeur d'Alene district (Ransome and Calkins, 1908, p. 40) and 17,000 feet northeast of Libby, Mont., (Gibson, 1948, p. 13), however, probably represent diversities in the original thickness of the unit. Because of folding and faulting, it was impossible to find a complete section of Wallace in the St. Regis–Superior area, but a thickness of about 10,000 feet is exposed in the Dry Creek valley where the lowermost part of the formation is not exposed. The stratigraphically lowest rocks seen at this locality resemble those found near the lower contact in adjacent areas, so that about 10,500 feet of Wallace is estimated as the total thickness in this vicinity.

The Wallace has been subdivided into local mappable units by Wagner (1949, p. 12–13) in the vicinity of Avery, Idaho; by Shenon and McConnel (1939, p. 5) in the Silver Belt area of the Coeur d'Alene mining district; and by Griggs (1952, p. 42–49) in the vicinity of Wallace, Idaho. Two general lithologic units were suggested by the reconnaissance mapping in the St. Regis–Superior area, although more detailed work would most certainly result in refinements of this crude subdivision. The upper unit received more attention than the lower because this area afforded an excellent opportunity to study the upper contact of the Wallace formation.

The lower unit of the Wallace is best exposed in Pardee and

Flat Creek valleys. Intense deformation in this area, however, has caused a pronounced foliation in the rock, which has obliterated the bedding in many places. The upper part of this lower unit is well exposed in the massive cliffs north of the highway immediately west of Superior and in the Dry Creek valley between Ann Arbor Gulch and Wilson Gulch.

The lower unit is composed of 6,000 or more feet of thin-bedded, dark-gray argillite or phyllite interbedded with thin-bedded, subvitreous, light-gray quartzite, all dolomitic. The lower 500 to 700 feet of this lower unit contains many 3- to 12-inch beds of light-gray, dolomitic quartzite interbedded with the argillite. Above this part the formation becomes more argillaceous, and argillite or silver-gray phyllite predominates over quartzite. But in the upper half of this unit, as in the lower part, the quartzite beds increase in abundance and are dominant in certain zones. Siliceous or argillaceous limestone and dolomite beds appear throughout the section but are particularly evident in the upper half of the lower unit. Nearly white to light-gray colors predominate in the dolomitic quartzite whereas the limestone and argillite are medium to dark gray. Weathered surfaces of the carbonate-rich rocks are etched and often have irregular rounded projections of more siliceous material. Calcite segregations, or molar-tooth structure, were observed on some weathered dolomitic rock surfaces. Beds of light-colored dolomitic quartzite and siliceous limestone are as much as 30 inches thick and generally form prominent outcrops. Minor crenulations of bedding planes are common and mud cracks, graded bedding, small-scale scour and fill, and ripple marks are abundant in some beds. Several shades of reddish to yellowish brown are typical of weathered surfaces throughout this part of the section.

The contact of the lower and upper units is fairly sharp and is evident even in the soil that changes from a yellowish brown below the contact to a grayish brown above the contact. Slightly less than 4,000 feet of the upper unit was measured in a stratigraphic section on the north side of Sheep Mountain. Three consistent lithologic types, interbedded with one another in varying amounts, make up the entire upper unit. An estimated 65 to 70 percent of the strata is a thin-bedded, light-gray, slightly sericitic quartzite, some of which is dolomitic. The average carbonate content of this quartzite is much less than that of the lower unit. Quartzite beds are commonly 1 to 3 inches thick and a few beds are as much as 12 inches thick. Black argillite in beds that range in thickness from paper-thin to 2 inches accounts for 10 to 15 percent of the total thickness of the upper unit. This argillite interbedded with the light-gray quartzite forms a conspicuously banded rock typical of the upper part of the Wallace. Bedding planes in this banded rock are irregular, and beds of both rock types may pinch or swell along strike, forming a somewhat anastomosing pattern in outcrops. Graded bedding and pronounced mud cracks are common in this rock.

Scattered laterally and vertically throughout this upper unit are zones of rocks ranging in composition from medium- to dark-gray, silty, dolomitic limestone to very limy siltstone. Rocks of these types comprise 20 to 25 percent of the upper unit. These limy zones, normally extremely thin bedded, are composed of interbedded laminae of limy and silty material that are difficult to detect on fresh surfaces. The thin bedding is apparent, however, on the hackly weathered surfaces that form from differential weathering. Such features as crinkling of beds, molar-tooth structures, and calcareous stromatolites are characteristic of these rocks. The varying amounts of carbonate in these thin-bedded rocks produces a pronounced irregular laminated brown and black coloration on weathered surfaces. A large part of the upper unit is exposed in road cuts immediately east of Superior, Mont., along U.S. Highway 10. The rocks in these unweathered exposures, however, do not show the pronounced hackly appearance typical of the etched surfaces in the normal outcrop. All but the lower 300 to 400 feet of this upper unit is exposed on the north side of Sheep Mountain.

The contact between the Wallace formation and the overlying Spruce formation is marked by a distinct lithologic change from the interbedded quartzite, argillite, and carbonate rocks of the upper unit of the Wallace. The basal Spruce strata are composed of very thin and evenly bedded, light-green, quartzose argillite alternating with medium-green, very fine grained quartzite, also very thin bedded. This lower part of the Spruce is slightly dolomitic and, where weathered, has a thin powdery limonitic coating that is a lighter color and more pronounced on the argillite than on the quartzite.

Microscopic examination of rocks from the Wallace formation indicates that their mineralogy is similar to the underlying formations except for a significant increase in primary carbonate minerals. Quartz, carbonate minerals, and sericite, all very fine grained, occur as dominant constituents but in varying amounts in all rock types. The accessory minerals are tourmaline, chlorite, feldspar, zircon, magnetite, pyrite, and limonite. Judging from the mild effervescence in cold dilute acid of many hundreds of rocks in the field, the results of differential thermal analyses, and the limonitic staining on weathered surfaces, dolomite or ferrodolomite is the dominant carbonate mineral. A mixture of calcite and dolomite is indicated in many specimens for, although the rock effervesced freely with cold dilute acid, a differential thermal analysis revealed the double endothermic reaction typical of dolomite.

UPPER PART OF THE BELT SERIES (MISSOULA GROUP)

The Precambrian rocks lying conformably above the Wallace formation were described by Clapp and Deiss (1931, p. 677–683) in the vicinity of Missoula, Mont., where they named these rocks the Missoula group. They divided the Missoula group into 5 formations and estimated its total thickness to be about 18,000 feet. Recent geologic investigations by the U.S. Geological Survey in the Missoula, Mont., area indicated that parts of this group are not recognizable outside the immediate vicinity, and that previously unrecognized complex structure affects the rocks at the type localities. Because the subdivision of the type section is currently being revised (Willis Nelson, oral communication, 1954) and because of the unmapped interval of 40 to 50 miles between the Superior and Missoula areas, rocks of the Missoula group in the St. Regis–Superior area were subdivided and named independently of the formations in the type area.

The Missoula group in the St. Regis–Superior area was divided by the writer into five formations, which partly correlate lithologically with the type section. Lithologic similarities between the two areas are more pronounced in the upper half of the section than in the lower. The total estimated thickness of the Missoula group in this area is about 16,000 feet as follows:

	Feet
Unnamed feldspathic quartzite of Rock Rabbit Ridge (youngest)	700+
Bouchard formation	4,000+
Sloway formation	5,000±
Lupine quartzite	3,000±
Spruce formation (oldest)	3,500±
Total	16,200±

SPRUCE FORMATION

The distinctive thin-bedded argillite and impure quartzite unit that conformably overlies the Wallace formation is here named the Spruce formation from exposures at its type locality on Spruce Ridge (secs. 32, 33, and 34, T. 17 N., R. 27 W.) and the adjacent north slope of Sheep Mountain (secs. 5 and 6, T. 16 N., R. 27 W.). A poorly exposed section of the Spruce in Cedar Creek valley near the south edge of the mapped area is probably virtually complete and undisturbed, and there the formation has been estimated to be 3,500 feet thick. The lower 1,500 feet of the formation was measured on the north side of Sheep Mountain, partly along Spruce Ridge, where a fault of unknown magnitude has displaced the remainder of the formation. A section measured on the west side of Blacktail Mountain included the upper 800 feet of the formation. More easily accessible exposures of most of the formation are immediately north of U.S. Highway 10 between Johnson Creek and First Creek and, of the lower part of the formation, southeast of the mapped area along the road south of the settlement of Quartz, Mont.

The formation is composed of three units that have some diagnostic characteristics, but none of these units is a well-defined entity. The transition from one unit to another is so gradational and the differences are so slight that it would be difficult to place a contact between them.

As previously mentioned, the contact of the Spruce formation with the underlying Wallace is placed at the base of the grayish yellow-green, quartzose argillite interlaminated with light dusky yellow-green, very fine grained, argillitic quartzite. The rock has thin (1/8 to 1/2 inch), regular beds that are not crinkled like many of the beds in the Wallace. Rocks of this type are dominant within the lower 600 to 700 feet of the formation. The lowermost 200 to 300 feet of this unit is slightly dolomitic and is light yellowish brown on weathered surfaces.

The impure, greenish-gray quartzite becomes thicker bedded (1/2 to 3 inches) and more prevalent above the lower unit and is the dominant rock type in the middle unit that is about 2,000 feet thick. Within the middle unit thin beds of greenish-gray argillite are interlaminated with the quartzite but these beds are not as abundant as in the lower unit. Pale purplish-gray quartzite, ranging from impure to vitreous, occurs in many zones in this part of the formation. An outstanding feature of the Spruce rocks, and especially of the middle unit, is the widespread occurrence of small euhedral magnetite crystals. Many beds contain sufficient amounts of magnetite to deflect a compass needle.

The upper unit of the Spruce, 700 to 800 feet thick, is similar to the lower unit, for the rocks are slightly dolomitic and weather to a reddish brown. This part of the Spruce formation closely resembles certain zones in the Wallace; however the absence of dark-gray argillite and the regularity of the bedding in the Spruce distinguishes the two formations. In the upper few hundred feet many 3- to 6-inch beds of dolomitic, light-gray quartzite occur, and a few 6- to 8-inch beds of siliceous limestone that contain a network of thin calcite veinlets are particularly diagnostic of this unit. The amount of carbonate-free quartzite increases again in the upper

300 feet, and this quartzite is in contact with the overlying Lupine quartzite. The lower part of the Lupine quartzite has thin interbeds of grayish-purple argillite. The contact between the Spruce and the Lupine is placed at the base of these purplish rocks.

The stratigraphic equivalents of the Spruce formation show many lithologic variations throughout northwestern Montana and northern Idaho. The most outstanding variations among several described localities are a change of the dominant color and differences in thickness. The rocks overlying the Wallace formation in the Coeur d'Alene district were named the Striped Peak formation by Calkins (Ransome and Calkins, 1908, p. 44) who described them as a 1,000-foot sequence of shale and quartzitic sandstone, mostly reddish purple and green. There the top of the formation has been removed by erosion. The Miller Peak formation (Clapp and Deiss, 1931, p. 678–679) in the Missoula, Mont., area has been correlated with the Striped Peak and is here tentatively considered as a partial stratigraphic equivalent of the Spruce formation on the basis of the stratigraphic position of both formations in relation to the Wallace formation. At its type section, the Miller Peak is 2,900 feet thick and consists predominantly of reddish-purple argillite, very different from the Spruce rocks. Willis Nelson (oral communication, 1954) stated that the current modification of the subdivision of the Missoula group in the vicinity of Missoula, Mont., will redefine the Miller Peak to include rocks more similar to those in the Spruce formation.

It is apparent from a regional study of the Spruce formation and equivalents that these rocks show pronounced sedimentary facies variations laterally. Differences in lithology and total formation thicknesses of the Spruce, Striped Peak, and Miller Peak in their type localities have been pointed out. Similar lithologic variations are also apparent in other nearby localities. Sampson (1928, p. 7) described the Striped Peak formation in the Pend Oreille district of Idaho as including 9,000 feet of rock; more than twice the thickness reported elsewhere. Although Sampson used the name Striped Peak, the rocks he described are lithologically much more similar to the rocks in the Spruce formation than to those in the Striped Peak. Anderson (1930, p. 18–19) mapped the Striped Peak in the Clark Fork district, Idaho, and pointed out that the formation changes from a green olive drab in the western part of the mapped area to predominantly red in the eastern part. He reported a thickness of 4,000 feet in an area where the top of the formation has been removed by erosion. Gibson (1948, p. 16) reported 2,000 feet of interbedded red and green shale, argillite, sandstone, and quartzite in the Striped Peak formation near Libby, Mont. The writer had a brief opportunity to see the rocks in the Libby area, and was impressed with the possibility that an unknown amount of thin-bedded, greenish argillite and quartzite, similar to the Striped Peak of the Pend Oreille area and to the Spruce formation of the St. Regis–Superior area, had been included by Gibson in the upper part of the Wallace formation. This may partly explain the exceptionally thick section of Wallace and the relatively thin section of Striped Peak that he reported in that area.

Microscopic examination of thin sections of Spruce formation rocks emphasizes their characteristic feature of being thinly interbedded quartzite and argillite. The argillite laminae are composed of an extremely fine grained mixture of quartz and sericite, and the arenaceous layers consist of silt- and fine sand-size quartz grains in a finer grained matrix of quartz and cericite. A few grains of chlorite are identifiable and probably much more exists in the fine-grained matrix. Some thin sections contain small amounts of brown biotite and a few small tourmaline grains. Carbonate minerals, chiefly ferrodolomite and calcite, are major constituents only in some of the uppermost and lowermost beds.

LUPINE QUARTZITE

The Lupine quartzite is here named from exposures along Lupine Creek, a tributary to Trout Creek, near the south edge of the mapped area (sec. 33, T. 16 N., R. 26 W.). The outstanding overall characteristics of this formation are the abundance of vitreous to subvitreous quartzite, and the reddish or purplish tints in many of the rocks throughout the section. These quartzitic rocks are resistant to weathering and form bold outcrops and prominent talus at many places in the southern half of the mapped area. Quartzite beds range in thickness from a few inches to as much as 5 feet and commonly contain thin reddish-purple laminae. Dusky red-purple argillite occurs sparsely throughout the section as very thin beds or as argillaceous partings in the predominantly light-brownish-gray quartzite. Many of the quartzite beds are slightly feldspathic, and the feldspar grains appear as small white specks on weathered surfaces. Long thin lenses of pinkish ferrodolomitic quartzite occur sporadically within the quartzite beds throughout the formation and are conspicuous on exposed surfaces where they weather to a dark brown. These dolomitic lenses are diagnostic of the Lupine, for they were not found in any other formation.

A partial type section of the Lupine was measured and described on the west side of Blacktail Mountain (sec. 34, T. 17 N., R. 27 W. and sec. 4, T. 16 N., R. 27 W.). The 2,750 feet of the formation measured in that section probably represents all but about the upper 300 feet of the formation. The type section for the upper 300 feet is in sec. 18, T. 16 N., R. 26 W. Thus, a thickness of about 3,000 feet is estimated for the Lupine formation. Following is a generalized description of the section studied on Blacktail Mountain:

	Feet
Upper contact not present but believed to be not more than 300 feet stratigraphically higher (top). Eroded.	
Quartzite, medium- to thick-bedded, vitreous, equigranular, medium-grained, light brownish-gray to grayish-red purple, Muscovite-rich, dark-purple argillite commonly on bedding planes. Some beds are feldspathic. Weathered rocks have pale-lavender tint	450
Quartzite, thin- to medium-bedded, subvitreous, grayish red-purple to light brownish-gray containing many thin, pink or purple laminae. Brown-weathering, grayish-pink, dolomitic quartzite lenses 1 to 3 in. thick and 3 to 6 in. long are common. Quartzite more vitreous near top	540
Quartzite, medium- to thick-bedded, fine-grained, subvitreous, light-brownish-gray. Many beds slightly feldspathic. Thin purple laminations and grayish-pink dolomitic lenses are common. Some very thin, red-purple argillite interbeds. Forms massive outcrops and large blocky talus. Specular hematite common along fractures. Few ripple marks and some low-angle crossbedding present	1,150
Quartzite, thin- to medium-bedded, brownish-gray, slightly sericitic. Thin purple laminae decreasing toward top of interval. Rock weathers to pale-purple tint. Some beds near top contain long thin lenses of grayish-pink dolomitic quartzite	360
Quartzite, thin-bedded, subvitreous, light-brown; containing dusky red-purple argillaceous laminae and partings. A few quartzite beds are slightly dolomitic. Many mud cracks and ripple marks (botton)	250
Total thickness	2,750+

The best known exposure of the uppermost 300 feet of the Lupine is on the north side of Cedar Creek valley near its junction with Bear Gulch. There 2- to 4-foot beds of subviterous purplish-gray quartzite separated by bright reddish-purple argillaceous partings crop out along the valley bottom. A few isolated stromatolites occur in several of the quartzite beds in road cuts at this locality. These quartzite beds probably are about equivalent stratigraphically to the uppermost beds of the measured section on Blacktail Mountain. About 300 feet stratigraphically above these rocks, 2-foot beds of subvitreous quartzite are overlain by 1- to 6-inch beds of slightly sericitic, light-brown quartzite and mud-cracked reddish-purple argillite as partings, which are the lowermost beds of the overlying Sloway formation.

The contact between the Lupine and Sloway formations has been placed as nearly as possible above the uppermost zone of medium-bedded, vitreous to subvitreous quartzite. Placement of this contact in areas of few exposures is somewhat uncertain because some beds in the lower thousand feet of the Sloway formation closely resemble upper Lupine rocks. The presence of the thin dolomitic lenses in the upper beds of the Lupine and their absence in the lower beds of the Sloway is also a criterion of this contact. In some areas a light grayish-green banded argillite occurs at the base of the Sloway but it is discontinuous. The Lupine-Sloway contact is generally gradational and difficult to determine, especially in areas of discontinuous exposures.

The Lupine is lithologically similar to the Hellgate formation (Clapp and Deiss, 1931, p. 679) near Missoula, Mont., and is probably correlative in part with it.

The rocks of the Lupine are composed chiefly of well-sorted quartz grains and varying amounts of fine-grained feldspar and sericite. Hematite and carbonate minerals occur as accessory minerals. Quartz grains that reach a maximum of 0.1 mm are subangular to subrounded and many show secondary quartz overgrowths. Minute crystals of hematite commonly coat original quartz grains and impart the reddish color to the rock. A carbonate mineral, probably ferrodolomite, constitutes as much as 10 percent in the grayish-pink lenses of carbonate-bearing quartzite found throughout the section.

SLOWAY FORMATION

The stratigraphic unit that conformably overlies the Lupine quartzite is here named the Sloway formation from the massive exposures of the unit in secs. 14, 15, and 16, T. 17 N., R. 27 W., near the mouth of Sloway Gulch. The Sloway formation is the most heterogeneous formation of the Missoula group. The formation comprises rock types ranging in composition from claystone to vitreous, coarse-grained quartzite, all typically having red or green colors of a higher chroma than the rocks in the other formations. No complete stratigraphic section of the Sloway was found but a total thickness of about 5,000 feet is estimated on the basis of several partial sections in secs. 7 and 18, T. 16 N., R. 26 W., in secs. 29, 33, and 34, T. 17 N., R. 26 W., and in secs. 3, 4, 10, 11, 14, and 23, T. 16 N., R. 26 W. These partial sections constitute the type section of the Sloway formation.

The lower part of the formation is composed chiefly of thin-bedded, light-brown, impure quartzite interbedded with very thin bedded, reddish-purple argillite. Vitreous to subvitreous, medium- to thick-bedded quartzite becomes more prevalent higher in the section although some argillite beds are present. Above this quartzitic zone, in the upper half of the formation, the rocks are more argillaceous and vivid red or green argillites, claystones, and impure quartzites are common. Lithologic evidence and relative stratigraphic position, indicate that the Sloway probably is at least a partial stratigraphic correlative of the McNamara formation described by Clapp and Deiss (1931, p. 680–681) in the type area of the Missoula group. The lithologic simliarities between the two formations are especially apparent in their upper parts.

The lower contact is gradational and is marked by a decrease in thickness of bedding and an increase in amount of reddish-purple argillite from the underlying Lupine quartzite. In general, the lower part of the Sloway is composed of a thick sequence of 1- to 6-inch beds of slightly sericitic, light-brown quartzite interbedded with beds of reddish-purple argillite generally less than 1 inch thick. A few beds or a sequence of beds in the lower part of the formation are grayish green or a mottled grayish green and reddish purple. These colors change along strike so they are not dependable as stratigraphic markers. The relative amounts of red and green rocks change both vertically and laterally throughout the formation. Mud cracks are more common in the red and purple beds than in the green ones, and salt casts were found only in the reddish-purple argillite. This lower part of the formation is best exposed on the ridge dividing Cougar Creek and Trout Creek drainage basins between the Campground and Verde Creek faults.

Above the lower zone of thin-bedded quartzite, but presumably below the middle of the formation, is a zone made up of many 1- to 3-foot beds of vitreous, pale-pink or white, quartzite interbedded with micaceous quartzite and siliceous argillite. Many of the vitreous quartzite beds are coarse grained and have a sugary equigranular texture. A few beds of calcareous sandstone occur throughout this interval. The argillite beds are less than 6 inches thick and commonly contain small, poorly defined segregations of quartz and mica. Mud cracks are numerous in the argillite and ripple marks are numerous in the quartzite. This quartzitic part of the formation is partly exposed at the mouth of Sloway Gulch, across the Clark Fork from the mouth of Pardee Creek, and in a railroad cut near the mouth of Thompson Creek.

The upper half of the Sloway is composed chiefly of quartzose to micaceous argillite, generally a conspicuous reddish purple or green. Thinly interlaminated light- and dark-grayish-green argillite zones, similar to certain zones in the Spruce formation, are common in this upper unit. Micaceous quartzite beds with thin purple laminae are also present. Dense, fine-grained, green or reddish-purple argillite, which breaks with a conchoidal fracture, is also characteristic of this part of the section. Scour and fill, mud cracks, and ripple marks are numerous. Thin flakes of argillite, probably the result of subaerial mudcurling during deposition, are commonly present in quartzitic beds that overlie argillite. The formation becomes more quartzitic in the upermost 300 to 400 feet and grades gradually into the gray micaceous quartzite of the overlying Bouchard formation. The upper half of the Sloway is exposed along the south side of the Clark Fork valley between Cedar and Trout Creeks, and some of the upper bright reddish-purple argillite crops out in a Chicago, Milwaukee, St. Paul and Pacific railroad cut near the southeast corner of the area in sec. 9, T. 15 N., R. 25 W.

As in the underlying formations, the chief mineral constituents of the Sloway rocks are quartz and sericite. The notable accessory minerals are chlorite, biotite, tourmaline, feldspar, magnetite, hematite, and limonite. Much of the argillite is so extremely fine grained that no microscopic mineral identification was possible. Many of the quartz grains in the coarser quartzite are rounded and coated by minute euhedral hematite grains. Biotite is significantly more abundant than in the lower part of the Belt series, although present in only small amounts.

BOUCHARD FORMATION

The unit composed principally of interbedded micaceous quartzite and quartzose argillite that conformably overlies the Sloway formation is here named the Bouchard formation from its exposures near Bouchard Lake (sec. 23, T. 17 N., R. 27 W.). The type section of the formation is in secs. 24 and 25, T. 16 N., R. 26 W.

The Bouchard formation is lithologically similar to the lower 4,170 feet of the Garnet Range formation of the Missoula group type section (Clapp and Deiss, 1931, p. 681–683). Part of the Garnet Range formation seems to be repeated by faulting in the type section, and the formation will be redefined during current studies in that area.

The stratigraphic column of the Bouchard formation in the vicinity of Bouchard Lake was measured and studied in detail. The gradational lower contact described in the section on the Sloway formation is exposed in that column but the uppermost part of the column has been removed by faulting. This partial stratigraphic section is about 4,000 feet thick and probably includes most of the formation.

The Bouchard underwent a period of pre-Middle Cambrian erosion, for its estimated thickness is different from place to place. For example, only about 3,000 feet of Bouchard rocks have been preserved near the mouth of Trout Creek where the formation is unconformably overlain by Middle Cambrian rocks. The top of the Bouchard was not seen in contact with the presumably overlying feldspathic quartzite of Precambrian age, at Rock Rabbit Ridge, so no original thickness can be estimated. The unconformable contact between the Bouchard and a vitreous quartzite of Middle Cambrian age is exposed in several places in the southeastern part of the mapped area.

Additional extensive exposures of the formation may be seen in the valleys of Dry, Thompson, Cedar, and Trout Creeks. A stratigraphic section including both the lower contact and upper unconformable contact is partly exposed on the ridge due south of the mouth of Trout Creek. A particularly good exposure of the lower contact occurs along the abandoned Trout Creek road in the southeast corner of sec. 22, T. 16 N., R. 26 W.

The Bouchard is easily recognized and is exceptionally homogeneous throughout the entire section. The outstanding characteristics of the formation are its micaceous nature and the predominant greenish-gray colors of low chroma. Medium- to thick-bedded, greenish-gray or olive-gray, subvitreous quartzite, generally micaceous, is predominant, but some dark olive-gray to olive-black micaceous argillite and olive-gray quartzose argillite are interbedded with the quartzite throughout the formation. The argillite and quartzose argillite are particularly in evidence in the lowermost and uppermost parts of the formation. Most of the rocks weather to a buff, olive gray, or reddish brown. An exception to the nearly ubiquitous drab-colored rock are several separate 6- to 12-inch beds of vitreous, white quartzite about 1,000 feet above the lower contact. Thin interbeds of dark-gray fissile shale were found near the mouth of Verde Creek about 200 feet stratigraphically below the contact of the Bouchard and the Cambrian quartzite. A bed containing many individual calcareous stromatolites is exposed just above the lower contact in a road cut of the abandoned Trout Creek road in the southwest corner of sec. 23, T. 16 N., R 26 W.

The rocks are mineralogically similar to those of the other rocks of the Belt series. Quartz and sericite constitute the bulk of the minerals, and feldspar occurs in minor amount. Some chlorite was found, but probably much more is present in the extremely fine grained interstitial material which makes up a large percentage of the impure quartzite and siliceous argillite.

FELDSPATHIC QUARTZITE OF ROCK RABBIT RIDGE

A thick-bedded vitreous quartzite probably deposited conformably on the Bouchard formation in Precambrian time is here designated the feldspathic quartzite of Rock Rabbit Ridge. The only known outcrops of this quartzite form massive cliffs on Rock Rabbit Ridge along the north side of Dry Creek valley opposite its confluence with Dry Fork valley (sec. 27, T. 17 N., R. 27 W.). These exposures of vitreous quartzite are limited to a small block bounded by faults and alluvium so that no conformable contact with any other formation is exposed. About 700 feet of quartzite occurs in this structurally isolated block. Elsewhere in the area the formation is absent, for Middle Cambrian rocks rest directly on the Bouchard formation. The significance of this unconformable relationship will be discussed in the following section.

The feldspathic quartzite is composed of medium- to coarse-grained, pink, white, or reddish-purple, vitreous quartzite in beds ranging from 1 to 8 feet in thickness. Color banding and thin cross-laminae are common. Some vitreous quartzite beds have a small amount of sericite on bedding planes and many slightly feldspathic beds contain sericite as an alteration product. Quartz grains are well rounded and are cemented by oriented quartz overgrowths. Very small euhedral to subhedral hematite grains coat the original quartz grains and are enclosed by the quartz overgrowths.

Rocks similar to the feldspathic quartzite at Rock Rabbit Ridge occur in several zones in the Sloway formation, but none of these zones approaches a thickness of 700 feet. The Middle Cambrian quartzite that crops out a few miles east of the Rock Rabbit Ridge exposure is similar lithologically but is only about 150 feet thick and is not feldspathic.

The Sheep Mountain formation of Clapp and Deiss (1931, p. 683) is the youngest formation of the Belt series in the Missoula, Mont., area, and is similar lithologically to the feldspathic quartzite of Rock Rabbit Ridge. The type section of the Sheep Mountain formation is 2,300 feet thick and rests conformably on the Garnet Range formation, which probably is partly equivalent to the Bouchard formation. On the basis of lithologic similarities and probable relative stratigraphic position, the feldspathic quartzite is considered as equivalent to the Sheep Mountain formation of Clapp and Deiss.

PALEOZOIC ROCKS

Paleozoic rocks in the vicinity of Lozeau, Mont., (pl. 28) were first noted by Calkins (Calkins and MacDonald, 1909, p. 90) as a result of reconnaissance work. During the present work, a sequence of Paleozoic quartzite, shale, limestone, and dolomite was found in the area described by Calkins. Parts of this sequence were also found in several other localities in the southeastern part of the mapped area.

The most complete section of these rocks is exposed in Lime Ridge immediately south of the mouth of Deep Creek in the southeastern part of the area. The contact with the underlying rocks of the Belt series is not exposed there, but the quartzite, which is the lowest unit in the Paleozoic section and which crops out at the base of the west end of this ridge, unconformably overlies the Bouchard formation in nearby localities. This lowest Paleozoic unit is composed of about 150 feet of medium- to coarse-grained vitreous quartzite that is pink, red, white, or tan, or mottled combinations of these colors. The beds range from 6 inches to 3 feet in thickness and are commonly crossbedded. The quartz grains range from medium- to coarse-sand size, and although most grains have sutured borders. some have subrounded grains with secondary overgrowths. No feldspar was observed in the thin sections studied. A pebble bed composed of quartz pebbles as much as one-half inch in diameter in a finer grained matrix is present at the base of this quartzite in exposures both at Chimney Rock, on the ridge between Trout and Cedar Creeks, and on the ridge between Trout and Cougar Creeks.

Overlying this quartzite is an olive-green, fissile, micaceous shale that contains lenses of thin greenish-gray or brown sandstone. A thin layer of reddish-purple argillaceous material generally is present between these lenses and the overlying green shale. The contact between the shale and the underlying quartzite is poorly exposed, but on the knob between the mouths of Verde and Cougar Creeks it appears gradational through 40 to 50 feet of interbedded shale and quartzite. Markings believed to be worm castings were found in this shale unit, which is estimated to be 80 to 100 feet thick.

The contact between the shale and the overlying limestone is not exposed. The limestone unit is about 175 feet thick, but only parts of it are well exposed in prominent cliffs on the west end of Lime Ridge, on both sides of the mouth of Verde Creek, and at Chimney Rock. The dominant rock of this unit is a very finely crystalline, dark-gray, thin-bedded limestone that is distinctively mottled by irregular lenses and streaks of yellowish-brown dolomitic limestone. Pieces of dark-gray oolitic limestone occur as float, but such rock was not seen in place. The upper half of the unit forms the cliffs and talus on the west end of Lime Ridge. Several specimens of faunal-bearing limestone were collected from the talus. These specimens contained broken remains of trilobites that were identified by Allison R. Palmer (written communication, 1954), U.S. Geological Survey, as "a single species of *Glossopleura*, a common characteristic and regionally widespread guide to rocks of early Middle Cambrian age."

Stratigraphically above the limestone unit on Lime Ridge is a thin, poorly exposed zone of very thin bedded, light-brown, dolomitic sandstone which has local films of glauconite on some bedding planes. This zone is in turn overlain by about 400 feet of medium-gray, very finely crystalline dolomite, which is distinctively mottled in places by a lighter gray dolomite, and a dark-gray to grayish-black, medium-crystalline dolomite. The only rocks found which could be younger than the dolomite were several float fragments of black shale that contain pink dolomite lenses. No outcrop of this shale was found. The Lime Ridge section is the only locality in the mapped area that contains rocks younger than the mottled gray limestone.

In the Flathead Range of northwestern Montana, Deiss (1939, p. 34–39) described the Middle Cambrian rocks, from oldest to youngest, as the Flathead sandstone, Gordon shale, and Damnation limestone. The Damnation limestone is the only limestone unit in northwestern Montana from which the trilobite *Glossopleura* has been previously described (A. R. Palmer, written communication, 1954). Thus, the mottled limestone unit that contains *Glossopleura* in the St. Regis–Superior area is probably equivalent to the lower part of the Damnation limestone. Furthermore, the underlying shale and quartzite in the St. Regis–Superior area are probably equivalent respectively to the Gordon shale and Flathead sandstone as used by Deiss. Knowledge of the rocks above the limestone unit in this area is too scant to permit correlation with units in other areas.

The limestone unit in Lime Ridge is nearly identical lithologically to much of the Meagher limestone in west-central and southwestern Montana. Each of these Middle Cambrian limestone units is underlain by a lithologically similar sequence of quartzite and shale. Lithology and relative stratigraphic position indicate that the limestone unit in the St. Regis–Superior area is correlative with the Meagher formation. Faunal evidence in these two limestone units, however, indicates that the limestone on Lime Ridge is older than the Meagher (A. R. Palmer, written communication, 1954), and supports Hanson's (1952, p. 13) suggestion of a Cambrian sea transgressing to the east in this region.

PRECAMBRIAN-CAMBRIAN UNCONFORMITY

The unconformable relation of the Bouchard formation and the Flathead(?) quartzite is not apparent locally, as the angularity between beds of the two formations is slight. When the entire mapped area is considered, however, there is evidence of a great hiatus between the two formations, during which erosion and deformation were active.

The principal line of evidence is the presence of the 700-foot thick block of feldspathic quartzite at Rock Rabbit Ridge believed to be the youngest Precambrian rock of the area, in a place only 6 miles from an exposure of the Bouchard formation that is immediately overlain by the Flathead(?) quartzite of Cambrian age. This block of feldspathic quartzite, now isolated by faults, is the solitary remnant in this area of a Precambrian formation that was almost completely removed prior to the advance of the Middle Cambrian sea. This block of quartzite was folded or more likely was faulted into a position where it was protected from the extensive erosion that removed it elsewhere in the vicinity. The Flathead(?) quartzite was seen in contact only with the Bouchard formation; nowhere does the Flathead(?) overlie the feldspathic quartzite of Rock Rabbit Ridge.

Another indication of this erosional interval is the bevelling of the Bouchard formation prior to Middle Cambrian time. In its type locality, the Bouchard formation has a measured thickness of about 4,000 feet, plus an unknown thickness at the top of the section that has been displaced by faulting. Yet a few miles to the east, only about 3,000 feet of the Bouchard is present where it is overlain by the Flathead(?) quartzite.

Erosional bevelling of Precambrian formations is even more apparent on a regional scale. Figure 52 illustrates this bevelling along

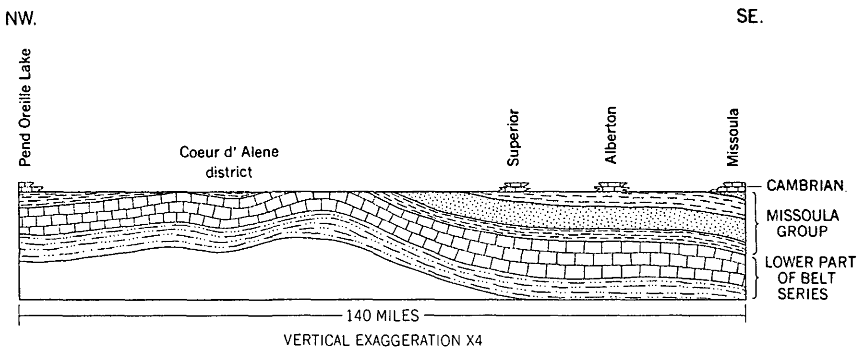

FIGURE 52.—Diagrammatic section showing Precambrian-Cambrian unconformity in northwestern Montana and northern Idaho.

a line from Missoula, Mont., through the St. Regis–Superior area, to Lake Pend Oreille, Idaho. The vertical-scale exaggeration necessary for clarity in the illustration creates a false impression of the degree of angularity between the Precambrian and Cambrian rocks.

Near Missoula, Mont., the Flathead(?) is in contact with the Sheep Mountain formation of Clapp and Deiss, the youngest formation of the Belt series in that area. Near both Alberton and Superior, the Flathead(?) quartzite immediately overlies the Bouchard formation. Farther west in the vicinity of Pend Oreille

Lake, Sampson (1928, p. 8–9) reported a Cambrian quartzite (the Gold Creek quartzite) lithologically similar to the Flathead(?) in contact with the Striped Peak formation. The angular discordance between the Precambrian and the Cambrian beds at these locations is so slight that it was not detected. Deiss (1939, p. 48), however, described the unconformity at several places in northwestern Montana where the angle of discordance is as much as 11°. Middle Cambrian strata have been reported at several other localities in this region and at each locality the Precambrian–Cambrian contact is much lower stratigraphically than it is in the St. Regis-Superior area. These localities are as follows: In the Swamp Creek valley area southeast of Libby, Mont., (Calkins and MacDonald, 1909, p. 82–83, and Gale, 1934, p. 174–179); in the Clark Fork valley in the vicinity of Noxon and Heron, Mont., (Campbell, and others, 1937, p. 411–421, and Gibson, 1948, p. 19–20); and on the east shore of Pend Oreille Lake (Calkins and MacDonald, 1909, p. 60–63).

The unconformity lies about 17,000 feet above the upper contact of the Wallace formation in the Missoula area and about 9,000 feet above the same contact in the Pend Oreille area. This difference suggests the possibility of the removal of as much as 8,000 feet of the Belt series before Middle Cambrian time. Deiss (1933, p. 34) estimated that 18,000 to 19,000 feet of rocks of the Belt series was eroded from other areas in northwestern Montana during this erosional interval. Nondeposition of part of the Missoula group or lateral variations in its thickness may account for some of the variation in the stratigraphic position of this unconformity.

TERTIARY AND QUATERNARY DEPOSITS

Tertiary and Quaternary deposits of unconsolidated or partly lithified gravel, sand, silt, and clay overlie the older rocks in parts of all the major valleys. For purposes of description these sediments can be classified according to origin and mode of occurrence as terrace gravels, lacustrine deposits, valley alluvium, and landslide deposits. These deposits were not studied in adequate detail to separate them on the geologic map, so that with one exception they are shown as undifferentiated. The exception is the deposits of partly lithified gravel, sand, and silt that were mapped as a separate unit in several small areas. These deposits were formed under conditions different from the other terrace deposits and were mapped separately chiefly to emphasize their existence and the locations of their exposures.

TERRACE GRAVELS

Terrace gravels are present at several altitudes from a few feet above the Clark Fork level up to nearly 2,400 feet higher on the divide between Flat and Siegel Creeks. Most of the gravels are on well-defined terraces at several different heights above the river that now occupies a narrow gorge. Alden (1953, p. 52) described a series of terraces near Lozeau where the river has cut through about 50 feet of bedrock. The 4 main terrace levels at that location are 50, 150, 450 and 650 feet respectively above the river level. The 650-foot terrace is about 3,400 feet above sea level. Many of the lower level terraces are very extensive and are used as grazing land and cultivated fields. The terrace deposits are composed chiefly of coarse gravel, commonly capped by fertile silt.

The terraces southwest of St. Regis, present as high as 3,700 feet above sea level or 1,000 feet above the river level, have been extensively dissected and in places all that remains are gravel-capped ridges. These gravel deposits coalesce downslope with the lower, younger, and better defined terraces. Other patches of well-rounded gravels on spurs between the tributary valleys of the Clark Fork have been included with the undifferentiated valley deposits on the map. Notable examples of these spur deposits occur up Thompson Creek valley where water-worn gravels cap spurs that extend to the top of the water shed on each side of the valley. Dissection and creep of the gravels have obliterated most topographic expression of terraces on these spurs. Many more such occurrences than are shown on the map undoubtedly exist in areas not traversed. The highest gravel deposit seen is on the divide between Flat and Siegel Creeks in the northeastern part of the mapped area. Many small well-rounded pebbles form a thin discontinuous cover over the small area examined.

The ages of the different gravel deposits represent a long time interval. The gravels on the divide between Flat and Siegel Creeks may be related to the Miocene peneplane which Pardee (1950, p. 368) described at an altitude of 4,000 to 4,500 feet in this area. The extensive valley-cutting stage is attributed to the Pliocene and Pleistocene by both Pardee (1950, p. 366) and Alden (1953, p. 52). Although the extensive terraces along the Clark Fork valley are probably Pleistocene, some of the higher level gravels capping the tributary divides may be Pliocene in age.

CONGLOMERATE AND RELATED DEPOSITS

Alden (1953, p. 32) described the occurrence of "a peculiar deposit, whose age and mode of origin are not well understood" in the Clark Fork valley near the town of St. Regis. This and similar deposits consisting of conglomerate, sandstone, shale, and stratified unconsolidated material were seen by the writer at three localities: near the mouth of Little Joe Creek, at the mouth of Cold Creek, and northwest of the mouth of Marble Creek.

The deposits are exposed only in cuts in terraces near or at the present river level where they are capped by unconsolidated gravels. Both sorting and stratification are variable from bed to bed within a single exposure. In general, the deposit at the mouth of Little Joe Creek contains more pronounced bedding and is better sorted than the similar deposits in the other two localities. The degree of lithification varies within a single exposure from friable to compactly indurated. The bulk of the deposit consists of conglomeratic beds. These beds are composed chiefly of very well rounded and polished cobbles and boulders of Missoula group rocks, but they also contain large angular rock fragments from the Wallace formation. Interstitial material is composed of sandstone and mudstone.

Beds in these deposits near the mouths of Cold Creek and Little Joe Creek have primary dips of as much as 30°NE. The amount and direction of dip suggest that they were formed from alluvial material flushed out of the tributary valleys. The Clark Fork may be actively cutting down through the deposits or has just breached them, for several exposures are present near water level.

Alden (1953, p. 32) was uncertain of the age of the deposit for he states that it "in part at least, may be of Pleistocene age, or it may be of Tertiary age or older." Geomorphic evidence throughout the surrounding region indicates major uplift about the end of the Miocene and extensive valley deepening during the Pliocene and Pleistocene epochs (Pardee, 1950, p. 366). Thus it is probable that these deposits so close to the bottom of the valley are Pleistocene in age and may be related to glacial Lake Missoula.

GLACIAL LAKE MISSOULA DEPOSITS

The Clark Fork valley in the area of this report was flooded during part of the Pleistocene epoch by an extensive lake. The history of this glacial Lake Missoula has been discussed by Pardee (1910; 1942), Alden (1953, p. 154–160), and Bretz and others (1956). The water level of the lake was reported to have reached a maximum altitude of 4,150 to 4,200 feet. It occupied an area of about 3,000 square miles and had a total volume of more than 500 cubic miles. The lake may have filled and at least partly emptied several times during its history.

Several poorly defined wave-cut benches mark the elevations of stillstands of the lake level at several places on the walls of the Clark Fork valley. The best examples of these benches occur on the east-facing valley wall in sec. 7, T. 17 N., R. 27 W., but even there they are obvious only from a great distance when the sun is in a favorable position to cast accentuating shadows on them.

Fine silt and clay deposits that probably were deposited in this lake were found in several localities on some of the terrace levels. Patches of erratic cobbles and boulders, generally of rocks from the Missoula group were found at several localities at an altitude of 4,000 feet or more and probably have been ice rafted on the lake. A large angular erratic boulder of the Wallace formation is resting on a small terrace on the spur between Dry and Thompson Creeks where it is difficult to attribute its position to anything other than ice rafting.

VALLEY ALLUVIUM

Very little Recent alluvium exists along the Clark Fork for it is now downcutting within a narrow inner gorge bounded by gravel terraces. Most of the tributary streams, however, are flanked by alluvial deposits along their lower courses.

LANDSLIDE DEPOSITS

A landslide which completely blocked the valley occurred in the Dry Creek valley about 1 mile southwest of its junction with the Dry Fork valley. There a large block, loosened along the Dry Creek fault, slumped into the valley bottom and filled this part of the valley with large blocky rubble to a depth of nearly 300 feet. The slide has been breached by the stream at about the midpoint of this valley.

IGNEOUS ROCKS

The igneous rocks in the area are dikes and sills of dark greenish-gray, fine- to medium-grained diabase closely associated with the northwestward-trending system of faults. No dike or sill could be traced for more than a few hundred feet along strike and their widths ranged from 1 to 100 feet; most are less than 30 feet wide. No examples of the large through-going dikes and sills comparable to those both north and south of the mapped area were found. Many small igneous bodies undoubtedly were not seen during the mapping because of their ease of weathering in comparison to that of the enclosing country rock. The sedimentary rocks in contact with the dikes and sills often appear slightly chloritized, and some biotite and a few grains of ottrelite have formed in the wallrock near some of the larger bodies. The age of intrusion of the igneous rocks is doubtful; the dikes cut all formations of the Belt series except the unnamed feldspathic quartzite at Rock Rabbit Ridge, and some of the dikes occupy fault zones known to be younger than Middle Cambrian in age.

The only fresh dike rocks were found south of the Boyd Mountain fault zone. These rocks are dark greenish gray, fine- to medium-grained diabase. Both augite and pigeonite were seen in some thin sections, but augite was the only pyroxene in others. The pyroxenes are generally light brown to colorless and have distinct cleavage. In a few sections in which the plagioclase has not been completely altered, it was identified as andesine (An_{40} to An_{50}). Skeletal crystals of ilmenite or intergrowths of ilmenite and magnetite are abundant in all thin sections studied. Primary brown hornblende and biotite occur in very minor amount. Small areas of micro-pegmatite were seen in some thin sections and account for most of the quartz and orthoclase in the unaltered rock.

Alteration of these rocks has been widespread and variable in degree. The alteration processes have uralitized the pyroxenes and have decomposed the plagioclase to an extremely fine grained material that is probably saussurite. Many rocks also show chloritic alteration. The dikes have been more intensely altered in the vicinity of the Osburn and Boyd Mountain faults. The major mineral constituents in this area are saussurite(?), uralite, chlorite, and quartz. Minor amounts of biotite and calcite are also common and a poorly defined bluish-green alkali amphibole occurs in a few of the thin sections studied.

STRUCTURAL FEATURES

The major faults of the St. Regis–Superior area are a part of the Lewis and Clark line, described by Billingsley and Lock (1939, p. 36) as "a northwest tear fault zone of continental scale." One of the salient features of this part of the Lewis and Clark line is the high degree of parallelism of the major Osburn, Boyd Mountain, and Siegel faults all of which strike generally N. 60° W. and dip steeply to the south.

Differences in the complexity of folding north and south of the Osburn fault in several localities have been noted by several workers. Wallace and Hosterman (1956, p. 588) pointed out that in western Mineral County, Mont., overturned folds are common north of the fault, but are the exception on the south side. A similar pattern exists in the St. Regis–Superior area where tight overturned isoclinal folds are north of the fault in the area including the headwaters of Pardee, Keystone, and Flat Creeks, whereas south of the Boyd Mountain fault, a probable split off the Osburn fault, folds are open and broad.

FAULTS

The main structural features in the area are the persistent, steeply dipping faults that trend northwestward and have large displacements. Some of these faults, such as the Gladue, Boyd Mountain, and Osburn, are the southeastward extensions of faults mapped by

Wallace and Hosterman (1956) in western Mineral County. The Verde Creek and Campground faults, which also have large displacements, strike slightly more to the north than the main fault system and are truncated at a low angle by it. A few minor, northward-trending faults mapped in the southeastern part of the area seem to be younger than the major period of faulting. The Dry Creek fault, the only westward striking fault found in the area, is probably also younger than the main northwestward-trending faults. Many of the minor faults, especially those in areas immediately north and south of the Osburn fault, appear to be high-angle faults in an echelon pattern associated with strike-slip movement along both the Osburn and Boyd Mountain faults.

OSBURN FAULT

Location.—The Osborn fault is one of the major faults in the northern Rocky Mountains area. This fault has been traced continuously from near the city of Coeur d'Alene, Idaho, eastward to the east boundary of the area shown in plate 28, about 100 miles. Regional tectonic maps suggest that the Osburn fault extends northwestward beyond the city of Coeur d'Alene, but the evidence is extremely tenuous. An eastward extension of the fault may account for one of the several shear zones near Missoula, Mont. Anderson (1948, p. 96) suggests that the Osburn fault may extend as far southeast as Deer Lodge, Mont.

The Osburn fault through this area is a zone of intense shearing several hundred feet wide whose position is indicated by a series of alined topographic depressions in transverse ridges. Typical examples of these topographic saddles are the depressions in the ridges between Keystone and Sloway Creeks and between Pardee and Flat Creeks. Float of foliated sericitic quartzite, generally slightly dolomitic, and light-colored soil with a high sericite content occur along the fault zone in the western part of the area where quartzite of the Burke and Revett formations is present in both walls. To the east in areas where the less competent Wallace formation is present in both walls of the fault, the width of the fault zone appears to narrow, and the rock in the float shows less evidence of shearing.

The only known exposures of the fault are in several workings of the Nancy Lee mine, sec. 31, T. 18 N., R. 26 W (pl. 30). There the fault zone, about 250 feet wide, contains several 1- and 2-foot gouge seams separated by sheared and folded rocks. The movement along the fault has been along a zone of multiple shears rather than along a single plane, and it seems probable that this zone is braided in gross pattern. It appears from these exposures that the fault zone dips 80° to 85° SW.

Displacement.—Although the Osburn fault has been traced for 100 miles and has been examined in detail at many places within that distance, the direction and amount of movement along the fault have remained in controversy. Much of the evidence gained in recent geologic work in the Coeur d'Alene district, Idaho, has strengthened the concept of a net strike-slip movement of several miles with the south side offset relatively westward. Wallace and Hosterman (1956, p. 591) interpreted some of the folding along the fault as drag folding that would indicate a strike slip with the south wall moved westward at least one-half mile. The same writers (Wallace and Hosterman, 1956, p. 591) suggested a strike slip of about 16 miles with the south side moved westward based on a study of the structural discontinuity along opposite sides of the fault. V. C. Fryklund (oral communication, 1955) has concluded from a study of vein mineralogy in the Coeur d'Alene district that a similar movement of about 16 miles is necessary to match areas of similar ore-mineral zoning north and south of the Osburn fault.

The offset along the Osburn fault appears to be less in the St. Regis–Superior area where a normal horizontal displacement of about 3 miles is indicated by the faulted segments of the St. Regis formation in the Pardee Creek–Flat Creek area. A final stage, if not all of this movement, involved a strike slip with the south side offset relatively westward. This conclusion is based on the interpretation of very high angle drag folds in the Little Pittsburg and Nancy Lee mines.

Age.—It is impossible to assign a specific age to the Osburn fault, for it seems likely that it has had a complex history of repeated movements. Although the earliest recorded movement was post-Belt, Eardley (1951, p. 287) and Paul Billingsley (oral communication, 1953) have suggested that the fault may be part of a large deep-seated zone of crustal weakness, the Lewis and Clark line, which possibly has been active since Belt time. Major movement since Middle Cambrian is indicated by down-faulted blocks of Middle Cambrian rocks along elements of the main northwestward-trending fault system of which the Osburn is a part. Pardee (1950, p. 399–400) described physiographic evidence which he interpreted as indicating late Cenozoic block faulting along the Osburn in the area described by Wallace and Hosterman (1956), but no evidence of such late movement was recognized by the writer in the St. Regis–Superior area.

BOYD MOUNTAIN FAULT

The Boyd Mountain fault has accounted for the largest displacement along the St. Regis–Superior part of the Lewis and Clark line.

The surface trace of the Boyd Mountain fault is located almost entirely within the valley of the Clark Fork in the mapped area. Valley fill masks most of the surface expression of the fault, but several exposures along its strike supply sufficient evidence to establish its location. The position of much of the main valley seems to be structurally controlled by this fault. A lineament that may be the extension of the Boyd Mountain fault can be traced east of the mapped area to Nemote Creek and perhaps as far as Alberton, Mont.

Wallace and Hosterman (1956), who named the fault, recognized the possibility that the Boyd Mountain fault in the area northwest of St. Regis is either the southernmost element of the Osburn fault zone, or a large fault that diverged from this zone. They do not show any connection between the Osburn and Boyd Mountain faults on their map, but R. E. Wallace (oral communication, 1954) believes that such a connection could probably be proven by detailed geologic mapping in the area between St. Regis and Henderson, Mont.

The Boyd Mountain fault strikes N. 50–60° W. and dips deeply to the south. The direction and amplitude of movement along the fault cannot be determined satisfactorily with the data at hand. Apparent displacement varies from place to place along the trace of the fault. The maximum stratigraphic displacement attributed to this fault alone is about 10,000 feet at the mouth of Pardee Creek, where the Sloway formation is faulted against the Wallace. A minimum stratigraphic displacement is present northwest of St. Regis where Wallace and Hosterman (1956) found Burke and Revett formations in both walls. Such anomalous displacements can be explained by differential vertical movement, by strike-slip movement cutting previously deformed rocks, or by a combination of both.

The Wallace-Spruce contact in the north block intersects the fault near the mouth of Johnson Creek, whereas this same contact in the south block is almost 13 miles to the northwest where the projection of the contact across the valley fill would intersect the Boyd Mountain fault in the vicinity of St. Regis. If most of the movement were strike slip, and if this offset represents the true amount of movement, it is apparent that a much greater amount of the displacement along the Lewis and Clark line took place along the Boyd Mountain rather than along the Osburn fault. Movement accompanying the intersecting Campground, Verde Creek, and other faults, however, also contributed to this total stratigraphic offset. It is noteworthy that the postulated combined horizontal offset of the Osburn and Boyd Mountain faults east of their probable point of intersection is of the same order of magnitude as that attributed to the Osburn fault alone in the Coeur d'Alene district.

SIEGEL FAULT

The Siegel fault is the northernmost element of the system of major northwestward-trending faults. The position of the fault is defined by a remarkably straight alinement of topographic depressions and structurally controlled stream channels. The St. Regis formation is in fault contact with Burke and Revett rocks where the fault crosses the county road in sec. 1, T. 18 N., R. 27 W. The fault at that point is also indicated by a perpetual spring, by drag folding in the St. Regis rocks, and by several massive quartz veins. A shear zone in which Prichard rocks are present in both walls was seen about 2 miles east of the mapped area along the projected strike of the Siegel fault.

The topographic expression of the fault indicates that the fault plane is vertical or perhaps dipping very steeply southward. The strike of the fault is N. 65° W. and does not appear to vary more than a few degrees along its mapped length. Apparent stratigraphic displacement along the fault varies from place to place. East of the mapped area Prichard rocks are in both walls. Where the fault crosses the Clark Fork the lower part of the St. Regis formation is in contact with the lower part of the Burke and Revett formations, which indicates a stratigraphic throw of about 3,000 feet. These relations could result from rotational dip-slip movement along the fault, however, it is more probable that it was caused by strike-slip movement similar to that along the paralleling Osburn fault.

The Siegel fault is probably the eastern extension of the Tamarack Creek fault described by Wallace and Hosterman (1956, p. 594). The fault continues eastward beyond the mapped area in the vicinity of the headwaters of Siegel Creek and a lineament on the aerial photographs indicates that it continues eastward into the Ninemile Creek valley. This fault may be the same as that traced by Pardee (1950, pl. 1 and fig. 20, p. 392) along the north wall of the Ninemile Creek valley, eastward to the junction of the Blackfoot River and Clark Fork near Missoula, Mont. The shear zone north and northeast of Missoula reported by Wallace and Hosterman (1956, p. 589) is probably along the Siegel fault extension rather than the Osborn fault. The Siegel fault represents one of the major through-going structural elements of the region and is distinctive because of its parallelism with the Osborn fault along its entire known trace.

GLADUE FAULT

The Gladue fault can be traced from near the mouth of Tamarack Creek in the northwestern part of the map southeastward to the vicinity of Pardee Creek. This fault is evident from anomalous contacts between the Burke and Revett formations and the Wallace formation where it crosses the Sloway Gulch road and between the Burke and Revett formations and the St. Regis formation in the area north of the village of Keystone. A shear zone that is associated with local folding of Wallace rocks may be seen where the Gladue fault crosses the Pardee Creek road. Shearing and dike intrusion immediately north of the Osburn fault in the Flat Creek valley may indicate a continuation of the Gladue fault. These indications of faulting are near the Osburn fault and may be related only to it; therefore the Gladue fault has been mapped only as far east as the Pardee Creek valley.

This fault is possible the eastward extension of a zone of faulting that Wallace and Hosterman (1956) mapped near the mouth of Tamarack Creek, however the connecting part between Tamarack Creek and Sloway Gulch has been observed only as a lineament on aerial photographs.

The straight alinement of topographic depressions along the fault suggests that the fault plane is vertical, or nearly so, and has a strike of about N. 55° W. The maximum stratigraphic displacement occurs in Sloway Gulch where Burke and Revett rocks are in contact with the lower part of the Wallace formation. The overturned Keystone syncline in the northeast block is truncated by the fault, and the lack of a similar fold in the southwest block suggests that the movement was mainly strike slip rather than dip slip. The concept of such strike-slip faulting does not seem valid, however, if the fault terminates in the Pardee Creek valley as shown on the geologic map (pl. 28). Evidence is not conclusive in regard to the type and amount of movement along this fault.

VERDE CREEK FAULT

The Verde Creek fault trends about N. 45° W. and is truncated by the Boyd Mountain fault at a low angle. The Verde Creek fault was traced from near the mouth of Thompson Creek southwestward through the valleys of Cedar, Trout, and Verde Creeks to the east edge of the mapped area where it is covered by valley-fill material. A pronounced lineament appearing on the aerial photographs continues on strike with this fault for some distance eastward and may represent its continuation. The fault is nowhere well exposed; however, its approximate location is well defined by stratigraphic discontinuities and topographic depressions. Diabase dikes have been intruded along the fault at several places near the southeast corner of the mapped area.

The stratigraphic relations of the two blocks of the fault indicate a rotational movement along the fault plane. In the vicinity of

Thompson and Cedar Creeks the northeast block is upthrown relative to the southwest block, yet near the mouth of Verde Creek the opposite relation is present. The fulcrum of rotation is located in the Trout Creek valley where the stratigraphic displacement is at a minimum and opposite directions of throw are indicated along the fault to the northwest and to the southeast.

CAMPGROUND FAULT

The Campground fault is parallel to and about 1 mile southwest of the Verde Creek fault. The fault is exposed in Cedar Creek valley where a 75-foot zone of intense shearing occurring in a road cut on the northwest side of the valley separates Cambrian shale from Lupine quartzite. The presence of the fault elsewhere is indicated by topographic depressions, pronounced stratigraphic discontinuities, and exposures of diabase dikes along the fault near Thompson Creek and between Verde and Sunrise Creeks. The fault was traced from the mouth of Sunrise Creek in the southeast corner of the mapped area northwestward to a point near Murphy Creek where it is truncated by the Dry Creek fault. A possible faulted segment of the Campground fault intersects the north side of the Dry Creek fault where feldspathic quartzite is faulted against the Sloway formation. The northward projection of this faulted segment under the valley-fill material probably accounts for the stratigraphic discontinuity between the Sloway formation exposures at the mouth of Sloway Gulch and the outcrops of Wallace formation in the middle of the valley between the mouths of Cold Creek and Fourmile Creek.

The relation of this fault to topography indicates that its attitude southeast from the vicinity of Thompson Creek is nearly vertical, and that it dips steeply to the north in the area northwest of Thompson Creek. Stratigraphic displacement along the entire length of the fault indicates the northeast side has been downthrown. Net displacement is not known, but the stratigraphic throw is between 4,000 and 5,000 feet.

DRY CREEK FAULT

The nearly vertical Dry Creek fault strikes generally in a westerly direction and transects the Dry Creek valley near its confluence with the Dry Fork valley. West of the valley bottom the fault plane angles up the north valley wall and is last identifiable in a saddle in the ridge between Dry and Marble Creeks. Westward beyond this point the Wallace formation is present in both walls, and the identity of the fault is lost. Along the north valley wall the fault is clearly marked by a series of notches which have formed along the fault plane on spur ridges into the main valley. Formation changes on each side of the fault are apparent, and the cuts for a road to a small copper prospect in sec. 28, T. 17 N., R. 27 W. have exposed a zone of intense shearing along the trace of the fault. East of the Dry Creek valley the fault is easily traced because of formational differences on opposite walls and topographic depressions to a point where the Bouchard formation appears in both walls at Murphy Creek, and exposures are too poor to permit location of the fault.

The apparent stratigraphic displacement is misleading because the fault cuts across a previously faulted and folded terrane. Normal movement along the fault plane is evident from the over-all stratigraphic relations and from the probable offset of the northeastward-dipping Campground fault along the Dry Creek fault.

The Dry Creek fault is particularly noteworthy for it represents a later stage of movement than the dominant northwestward-trending fault system and seems to be the only representative in this area of that later period of deformation. Nowhere else in the area has any member of the northwestward-trending fault system unquestionably been offset by a westward-striking fault.

OTHER FAULTS

Many additional faults are shown on the geologic map but are not named and discussed in detail because of limited knowledge of their position and relationship or because of their relatively small size. In some cases such faults were crossed by only one mapping traverse and could not be properly evaluated. Within the major structural blocks of the area many of these unnamed faults are similar in attitude to one another, and apparently were formed by the same stresses.

Northeast of the Osburn fault several shear zones were seen in road cuts and mine workings where they tended to parallel the strike of the Gladue fault and would, if projected, intersect both the Osburn and the Siegel faults at low angles. The faults mapped in that area represent only the most pronounced breaks within a wide belt of rocks which have been intensely affected by shearing.

A group of northwestward-trending faults were mapped in the area between the Osburn and Boyd Mountain faults. The faults were recognized between Flat and Pardee Creeks mainly by the offsetting of the St. Regis formation. Faults with a similar strike were found within the Wallace formation in the vicinity of Johnson and Lozo Creeks, but could not be traced far. This group of faults intersects the Boyd Mountain fault on the south at a low angle.

The area southwest of the Boyd Mountain fault contains numerous minor faults of different attitudes. Many of these follow the regional structural grain and have a northwesterly strike. Exceptions exist, however, particularly near the southeast corner of the mapped area where several northward-striking faults were found north and south of the Campground fault. The southeast corner of the map shows a complexly faulted area in which both Cambrian and Precambrian rocks have been affected. This small area downfaulted between the major Boyd Mountain and Verde Creek faults is composed of tilted fault blocks in which rocks of the Lupine quartzite, the Sloway and Bouchard formations, and Cambrian units are exposed.

FOLDS

Tight complex folds are characteristic of parts of the area north of the Boyd Mountain fault, whereas open folds are typical of the area south of the fault. The orientation of the folds is also different in the two parts of the area. Northeast of the Boyd Mountain fault the traces of the axial planes strike northwestward parallel to the major faults, whereas southwest of the fault the traces of the axial planes generally strike northward or northeastward. Only a few small overturned folds were seen in the area south of the fault, however to the north overturned strata are much more common. The Little Pittsburg syncline and part of the Keystone syncline are the only major overturned folds in the area; both trend northwestward and have an overturned north limb.

The Keystone syncline located along the headwaters of Sloway, Keystone, Pardee, and Flat Creeks is well defined in over-all pattern as a southeastward-plunging fold, but locally small-scale folding and faulting made the structure complex, especially near the axis of the syncline. The fold axis has been offset by a northwestward-trending fault that passes through the headwater areas of both Pardee Creek and Sloway Gulch. Between this fault and the Gladue fault in the Sloway Gulch area, the north limb of the fold is overturned and Wallace rocks underlie those of the St. Regis formation. Northeast of the fault, however, the north limb is normal and dips fairly consistently to the southwest. The south limb, which dips northeast in the vicinity of Flat Creek, is nearly vertical or locally slightly overturned to the southwest in the Keystone-Pardee Creeks area.

The tight nose of the Pardee anticline is well exposed near the intersection of the Osburn fault and Flat Creek. This anticline has been cut by the Osburn fault and evidence that the south limb was offset and differentially tilted along a series of subsidiary faults may be seen in a study of the St. Regis formation outcrop pattern near the mouth of Pardee Creek. Tight folds, some overturned, locally modify both the Keystone syncline and the Pardee anticline and are too numerous to be shown at the scale of the geologic map.

Another noteworthy fold in this area north of the Boyd Mountain fault is the Little Pittsburg syncline that extends west from Sloway Gulch into the Fourmile Creek valley. The syncline is overturned to the south and the St. Regis formation dips under the Burke and Revett formations in the north limb. This relation is evident both in underground workings and on the surface at the Little Pittsburg mine. The fold plunges to the southeast in the Sloway Gulch area where it is truncated by a fault.

A broad open syncline with a northeastward-trending axis is indicated by the stratigraphic distribution southwest of the Boyd Mountain fault. This large downwarp is best defined by the trace of the contact between the Wallace and Spruce formations that inscribes a broad arc from the mouth of Cold Creek, southward through the Dry Creek and Cedar Creek valleys, then eastward where it is shown just south of the southeast corner of the map. The attitude of the rocks within the block between the Verde Creek and Campground faults also reflects a broad syncline modified by faulting and smaller scale folding. One of these folds, a broad anticlinal arch, is well exposed on the northward-facing valley wall between Murphy and Thompson Creeks where it may be seen from U.S. Highway 10.

Many smaller folds exist throughout the area; some are shown by fold axis symbols on the map, but many are local and have not been shown.

CLEAVAGE

Cleavage of two types occurs in many rocks in the mapped area. One type is parallel or subparallel to the axial planes of folds, and is genetically related to the folding. The other type seems to be related to the later faulting and generally is more sharply defined locally than the axial-plane type. The relation of the axial-plane cleavage to bedding planes may be used in determining the position and shape of the folds involved, whereas the cleavage related to faulting cannot be used in this manner. Thus it is desirable, but not always possible, to distinguish between the two types of cleavage.

Axial-plane cleavage has formed locally at many places in the mapped area, but perhaps the most interesting and best defined occurrences are in the Wallace formation near the headwater areas of Sloway, Pardee, and Flat Creeks. There the alternating argillite and quartzite strata have been folded into the Keystone syncline. Cleavage has formed in both rock types, but cleavage planes are much more abundant in the argillite beds than in the quartzite beds. The relation of the cleavage to bedding varies from one rock type to another; the acute angle of intersection between cleavage and bedding planes is smaller in the more argillaceous rocks. This variation in attitude is generally not present in the cleavage related to the later faulting. The cleavage planes in the quartzite beds often have a flattened S shape where viewed in a vertical plane normal to the axial plane. Shenon and McConnel (1940, p. 442) have pointed out that the tops of such S-shaped cleavage planes are bent toward the axial plane of the anticline. The cleavage in the argillaceous layers is especially useful, for its attitude closely approximates the attitude of the axial plane of the fold, and the intersection of the cleavage and bedding planes is about parallel to the plunge of the fold axis. The relation of this type of cleavage to bedding is useful in determining beds that are overturned; the general rule applied is that beds which dip steeper than cleavage, and in the same direction, are overturned.

A. B. Griggs (1952) recognized two varieties of cleavage related to shearing in an area northwest of Mullan, Idaho: first, a local cleavage restricted to definite zones of faulting, and secondly, a regional cleavage which may show no relation to earlier structures. Although both of these types of shear foliation are in the St. Regis–Superior area, the regional variety is worthy of special note. This regional cleavage is most pronounced in the area between Pardee and Sloway Creeks from near the Osburn fault northward nearly to the divide enclosed within the large loop of the Clark Fork. The degree of cleavage development varies locally, but in general the rocks have undergone moderate to intense cleavage with accompanying sericitic alteration and phyllitization. Even the more quartzitic Burke and Revett rocks are intensely foliated and highly sericitic. The cleavage has a pronounced orientation in strike direction between about N. 40° to 70° W. and dips steeply either northeast or southwest. The overall pattern of this area of deformation is elongate parallel to the strike of the cleavage and parallel to the trend of the major faults. Cleavage of this type is of economic importance because it is a favorable locus for mineral deposits.

Wallace and Hosterman (1956, p. 600) have used the term "puckers" to describe the small Z-shaped crenulations formed in foliated rocks that have been crossed by small secondary shear zones. Commonly 2 and rarely 3 sets of puckers are superimposed on the dominant cleavage planes in the intensely deformed area described above and indicate several distinct periods of structural adjustment. Invariably the movement along the incipient shear that causes the Z-fold is normal.

MINERAL DEPOSITS

Most of the mineral deposits in this area, particularly the lead and zinc deposits, are located in and north of the Osburn fault zone. The mineral assemblage in these veins is similar to that in many of the veins of the Coeur d'Alene district to the west, and a continuous belt of similar deposits, which lies adjacent to the Osburn fault, extends from the Coeur d'Alene district into this area. A small amount of silver has been produced from one argentiferous tetrahedrite deposit that lies immediately south of the Osburn fault zone. A belt of copper deposits, which also can be traced continuously from the Coeur d'Alene area (Wallace and Hosterman, 1956, p. 609), lies along the south edge of the area. Several deposits of fluorspar near the southwest corner of the area lie within a northward-trending zone of folding and brecciation, and, with one minor exception, are entirely separate from known sulfide mineral deposits.

The following paragraphs discuss the lead and zinc, silver and lead, copper, and fluorite deposits as separate groups. Only the mines which were accessible to the writer, or those inaccessible mines for which adequate maps and reports could be obtained from companies, will be described. The deposits included in the following discussion have accounted for all but 110 tons of the total 248,345 recorded tons of ore produced in the area from 1901 through 1953.

LEAD AND ZINC DEPOSITS

The lead and zinc deposits, which account for most of the area's total mineral production, occur in fissure-replacement veins. They are grouped together in the vicinity of the Osburn and parallel faults between the valleys of Sloway Gulch and Flat Creek. These veins all strike from N. 50° W. to west and dip steeply. The veins are narrow and are persistent in strike and dip, although productive ore shoots within them are generally short in strike length compared to their dip length. This is especially true of the ore shoots in the Iron Mountain mine, the major producer of the area. Galena and sphalerite are the most common ore minerals, and boulangerite, chalcopyrite, and argentiferous tetrahedrite are present in some veins. The gangue is generally quartz and sheared country rock, although barite is present in at least two veins, and some siderite and ankerite have been reported.

Total production figures for this area from 1901 through 1953, according to the records of the U.S. Bureau of Mines, list 7,932,958 pounds of lead and 8,086,827 pounds of zinc.

IRON MOUNTAIN MINE

The main portal (1600 level) and surface buildings of the Iron Mountain mine are in the SW¼ sec. 12, T. 17 N., R. 26 W. The mine is easily accessible by the graded Flat Creek road and is about 3.5 miles northeast of Superior, Mont.

Plate 29 shows the extent of the workings, which is large in comparison to other mines in the area. Only the 700 and 1600 adit levels were partly accessible in 1954. All passages to the shaft on the 700 level (pl. 29) were caved and most of the accessible stoped area was deemed unsafe for examination. All of the area north of the shaft on the 1600 level (pl. 29) was virtually inaccessible because of oxygen depletion in the air. The American Smelting and Refining Co., present owner of the mine, generously allowed the writer access to the maps, cross sections, and reports in their files. Although incomplete, they supply at least a general knowledge of the geology in areas long inaccessible. Much of the following discussion is based on data obtained from this source.

All of the accessible parts of the mine are in the Wallace formation, and, according to reports, this is true of the entire mine. The St. Regis–Wallace contact is a short distance southwest of the 1600 level portal. The mine is on the southwest limb of the Keystone syncline; this fold has been modified locally by minor folding that is evident both on the surface and underground. Bedding can seldom be detected underground because of the phyllitization of the argillite, although a few quartzite beds remain distinguishable. The predominant feature of the rocks on the 700 and the 1600 levels is a ubiquitously well-defined cleavage that strikes N. 40° to 70° W. and generally dips from 45° NE. to vertical, although sometimes it dips steeply southwest. Bedding, where found, is generally parallel in strike to this cleavage, and has the same or slightly smaller angle of dip. Small secondary shear zones cross this cleavage; they generally dip at a slight angle to the southwest and form small Z-folds or puckers. Several sets of joints also are superimposed on the predominant cleavage. Many northwestward-striking zones of intense shear cleavage are present on both mapped levels, but no fault of major displacement was seen.

The bulk of the ore has come from 2 ore shoots, 1 on each of 2 parallel veins. These veins, which have been named the "Lead" vein and the "Zinc" vein because of their different predominant metallic content, are 30 to 50 feet apart. They strike N. 50° to 70° W. and dip 75° to 85° NE., nearly parallel to the predominant shear cleavage. Below the 1300 level the Lead vein swings sharply north on the east end, where it forms the so-called Hook vein. This bend in the vein is well illustrated by the shape of the drifts on the 1850 and 2000 levels (pl. 29).

In addition to the 2 main veins, 2 smaller parallel veins have been cut on the 1600 level. One is 170 feet into the hanging wall of the Lead vein and has been stopped up from this level about 60 feet for a length of more than 60 feet. The other vein is about 80 feet in the footwall of the Zinc vein and has been mined from 1 small stope from the 1600 level taildrift. These 2 veins may be the extensions of 2 veins similarly located with respect to the main veins on the 700 level. The McDonald vein in the hanging wall of the Lead vein has been mined along about 50 feet of strike length, but the stope was inaccessible in 1954. Little is known of the extent or metal content of these veins.

The ore shoots of the Lead and Zinc veins are remarkably elongate down dip. Although records are incomplete, it seems that they have been mined sporadically from the surface down to the 2000 level in stopes whose lengths range from 30 to 200 feet. It is reported that the veins range from 2 to 15 feet in width, but widths appear to average 3 to 5 feet. Both ore shoots rake to the northwest; the Lead vein about 15°, and the Zinc vein about 10°. Galena, boulangerite, and sphalerite are the ore minerals in both veins but occur in different proportions in each. Chalcopyrite is found in minor amounts. The gangue is sheared country rock and some vein quartz. Minor amounts of siderite occur in parts of the mine. No silver mineral has been reported, so apparently the silver occurs in argentiferous galena. Above the 1000 level, the silver to lead ratio averaged 2 ounces to 1 percent, whereas below that level it averaged 1.6 ounces to 1 percent.

A lead-antimony sulfosalt in the Zinc vein, and possibly in the Lead vein, is unique in the veins of this area. Shannon (1920, p. 594) identified the mineral as boulangerite and described its occurrence as a "constant constituent of the zinc ore in a vein mined at the Iron Mountain mine—occurring in all of the ore as small disseminated grains and fibers in fine granular sphalerite, and as bunches of coarse fibers with coarse dark-brown sphalerite in white quartz." Geologists of the American Smelting and Refining Co. (oral communication, 1955) estimate that one-third of the lead produced from the mine occurred in boulangerite.

Table 3 is the recorded production from the mine.

NANCY LEE MINE

The Nancy Lee mine property is located in secs. 31 and 32, T. 18 N., R. 26 W. and in secs. 5 and 6, T. 17 N., R. 26 W. Access to the

TABLE 3.—*Production record for the Iron Mountain mine, 1901 through 1953. No production recorded except in the years indicated* [1]

Year	Ore milled or shipped to smelter (short tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)
1909	104		926		16,640	60,570
1910	553		7,983		92,523	1,686
1911	57		2,490		28,979	14,954
1913	10,580	2	34,186		415,073	78,999
1914	8,486		37,763		441,240	100,538
1915	50,100		123,094		1,521,353	405,508
1916	39,400		74,607		1,296,388	3,663,730
1917	399		5,212		80,815	232,464
1918	38		427		4,500	23,968
1920	88		3,288		43,848	
1921	26		1,782		18,226	
1922	203	1	8,020		99,525	
1923	19		925		11,595	
1924	12		311		4,000	
1925	4,835		11,406		86,643	330,000
1926	10,111		24,061		356,240	954,415
1927	424	1	10,130		144,492	165,376
1928	370	1	5,377	613	71,890	146,926
1929	424	1	6,526	580	85,021	159,909
1930	359	1	4,590	391	68,866	136,513
1935	1		78		1,266	
1947	60		333	57	6,335	380
1948	150		449	79	4,357	1,120
1949	5,110	4	2,703	515	132,310	128,160
1950	2,000	2	3,324	300	30,966	83,469
1951	456		2,194	508	16,238	27,575
1952	7,947	6	8,880	1,132	175,889	504,427
1953	4,824		8,290	1,099	130,523	314,397
Total	147,136	19	389,355	5,274	5,385,741	7,535,084

[1] Furnished by the U.S. Bur. Mines, Div. Mineral Industries. Published by permission.

mine site is gained from U.S. Highway 10 via the Keystone Creek road to a point just south of the settlement of Keystone, then northwest on the Mill Gulch road to the mine, about 4 miles from the main highway. This is the only mine which was in operation during the fieldwork for this report.

Plate 30 is a composite map showing the location of all known underground workings at the property. This mine has produced ore from veins in and near the Osburn fault zone. The workings are in heavy ground which is difficult to keep open. As a result, most of the mine was inaccessible in 1953 and 1954. Except for a brief examination of the 640 level in 1952, the writer has not seen any other parts of the mine that have been productive. Through the cooperation of Nancy Lee Mines, Inc., owners of the property, permission has been granted to use geologic maps furnished by them. These maps have been modified somewhat by the writer on the basis of knowledge gained during the regional mapping. Plate 30 is a geologic map of the 525 and 640 levels. Much of the following discussion of the geology of the mine is based on the maps and other information supplied by Nancy Lee Mines, Inc.

In the past the mine has been considered to be in the Wallace formation, because of the high carbonate content of the wallrocks. Areal mapping, however, has shown that these rocks belong to the

Burke and Revett formations, and that the carbonate minerals are secondary rather than primary. Most of the rocks that were seen by the writer in the accessible parts of the mine are foliated sericitic quartzite and siliceous phyllite, all dolomitic. No true limestone or dolomite was seen. Much of the lithologic variation underground is the result of the difference in shearing intensity along the branches of the Osburn fault.

The structural setting is complex, for all the mine workings are in or near the Osburn fault zone. Underground mapping has shown that the rocks of the area have been subjected to intense folding along axes that strike generally N. 50° W., and shearing that strikes about the same direction. The Osburn fault as seen in the mine is a wide imbricate shear zone striking generally N. 50° to 70° W. and dipping steeply southwest. It consists of many 1- to 3-foot gouge seams that are separated by zones of sheared and crumpled rock as much as several tens of feet wide. The anastomosing nature of the fault strands is shown on plate 30. Nearly horizontal slickensides and steeply plunging drag folds indicate a late strike-slip movement on the fault.

Several veins have been explored on the property, but only the King and Queen veins, which are cut in the main mine workings, have produced a significant amount of ore. The Queen vein, or "copper vein," was explored and worked from the Jeldness shaft, a 300-foot shaft on a 60° incline, and the Ivanhoe tunnel. This vein, in which argentiferous tetrahedrite apparently was the predominant ore mineral, was 2 to 4 feet wide, striking slightly north of east, and dipping 30° N. at the surface and 50° N. in the lower levels. It was mined from the surface down to the Ivanhoe tunnel (245 level) for a stope length of about 200 feet. The copper-rich ores, which were shipped prior to 1919 (table 4), came from stopes in this vein. The vein is reported to have contained parts that were rich in galena. Gangue consisted of altered quartzite, quartz, and a little siderite. No positive extension of this vein has been proven below the Ivanhoe tunnel (245 level).

The King vein, or lead vein, is reported to be well exposed on the 245 level where it appears as a 15-foot zone of fissures filled with siderite and quartz. At that point the vein strikes slightly north of west and dips 75° S. It also contains minor amounts of galena, sphalerite and chalcopyrite on that level. The vein apparently terminates to the west against the Osburn fault. This vein appears to be the one which has been cut on the 525 and 640 levels where it has been displaced after mineralization along several branches of the Osburn fault zone in a most complex manner as is shown in the generalized cross section *A–A'* on plate 30. Some low-grade sideritic parts of the vein on these levels are in the form of saddle reefs in drag folds near the Osburn fault, but these have been sliced by subsequent movement along the fault. The higher grade lead-zinc parts of the vein also have a saddle-reef relation in places but most generally occur as banded replacement deposits along the foliation of the country rocks.

An unknown amount of ore is reported to have been produced from the Keystone workings, which are north of the main mine area, before 1905. Some tetrahedrite and galena were found on the old dump which indicates a possible similarity to the Queen vein ore.

Table 4 indicates a fairly impressive production record, but the high cost of mining such a discontinuous ore body in very heavy ground has resulted in a low net profit. The amount of stoping is small in relation to the amount of development and exploration, and there are no reasons to expect that more favorable conditions will be found by additional exploration.

TABLE 4.—*Production record for the Nancy Lee mine, 1901 through 1953. No production recorded except in the years indicated* [1]

Year	Ore milled or shipped to smelter (short tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)
1909	29	1	388	2,000	5,294	------------
1910	386	1	5,576	30,573	72,066	------------
1911	63	1	811	1,933	22,150	------------
1912	750	16	8,700	47,018	127,956	------------
1913	1,090	25	15,097	67,474	280,022	------------
1914	122	3	3,547	18,287	58,682	------------
1915	174	5	3,166	20,620	34,311	------------
1916	296	11	5,933	49,805	78,728	------------
1917	790	11	6,736	46,066	107,042	------------
1918	349	8	2,736	29,452	16,390	------------
1928	23	------------	184	56	6,396	3,215
1936	10	4	------------	------------	------------	------------
1944	1,303	3	2,275	1,774	117,892	53,803
1945	1,811	1	971	1,466	49,224	4,280
1946	11,763	23	20,868	39,764	560,729	200,199
1947	5,000	20	12,818	10,196	101,315	22,405
1948	12,000	58	31,877	49,088	299,510	66,002
1949	5,500	34	15,414	27,134	68,619	70,485
1950	1,200	25	9,267	10,240	32,092	6,980
1951	6,060	57	17,933	21,014	215,128	19,977
1952	1,635	20	7,027	11,455	110,142	11,937
1953	1,680	13	5,448	9,543	111,027	46,587
Total	52,034	340	176,772	494,958	2,474,715	505,870

[1] Furnished by the U.S. Bureau of Mines, Div. Mineral Industries. Published by permission.

LITTLE ANACONDA GROUP (VELVET ADIT)

The Little Anaconda property is near the headwaters of Pardee Creek in sec. 35, T. 18 N., R. 26 W. Of the two adits and a surface shaft only the lower or Velvet adit (fig. 53) was accessible in 1954.

The workings are all within the lower unit of the Wallace formation, and the country rock is typically a fissile medium- to dark-gray argillite or phyllite with a few interbedded quartzite beds, all of which are dolomitic. Both the bedding and the predominant

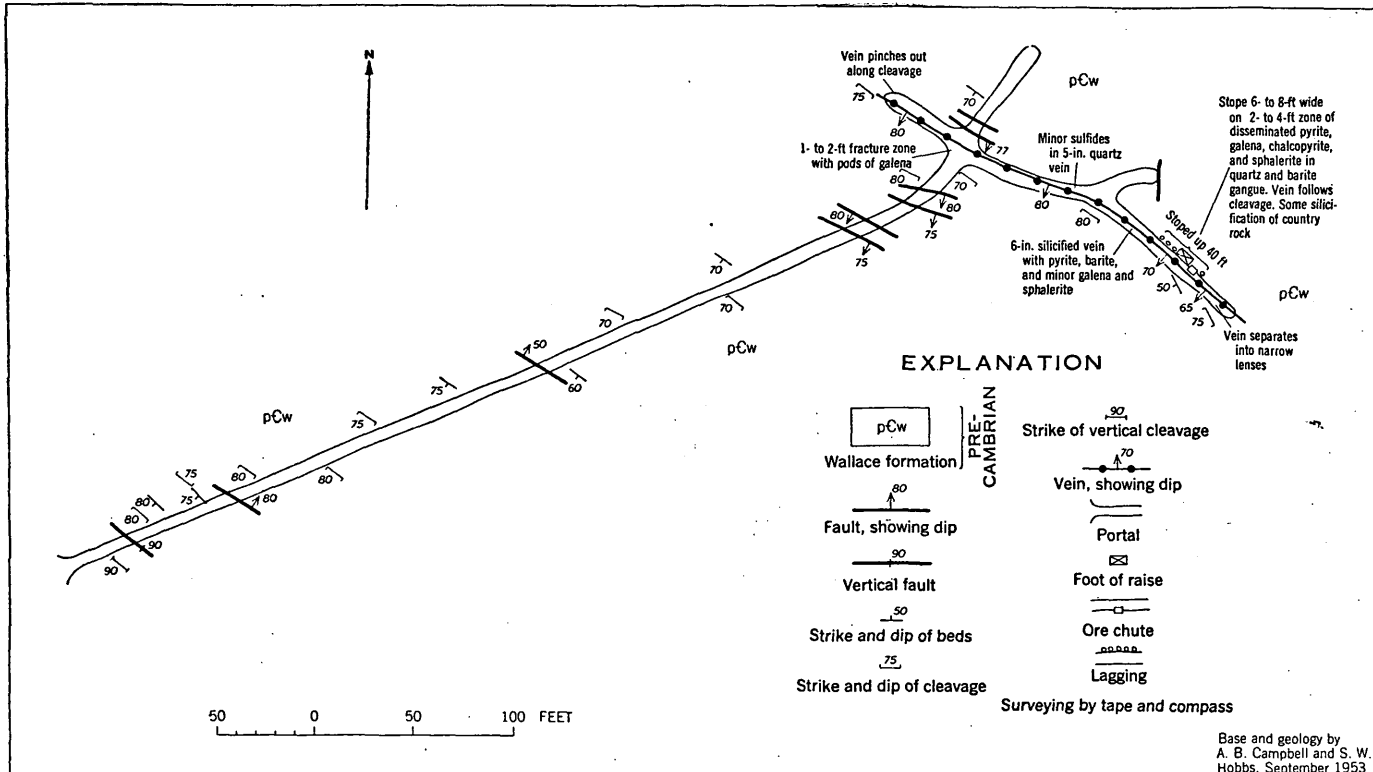

FIGURE 53.—Geologic map of the Velvet adit of the Little Anaconda group, Iron Mountain mining district, Mineral County, Mont.

cleavage generally strike N. 50° to 60° W. and dip steeply to the southwest. The vein consists of discontinuous pods and veinlets of ore minerals in a zone of shearing parallel to the cleavage and is accompanied by silicification of the country rock. The only stope on the vein is near the southeast end of the drift where a short part of the vein was mined above the drift level an estimated 40 feet. The vein is 2 to 4 feet wide in the back of the stope, and is composed of pyrite, galena, sphalerite, and chalcopyrite in a gangue of quartz, barite, and minor amounts of calcite. These vein minerals occur as replacements along cleavage planes in the silicified country rock. Table 5 shows the recorded production figures from this property.

TABLE 5.—*Production record for the Little Anaconda group, 1901 through 1953. No production recorded except in the years indicated* [1]

Year	Ore milled or shipped to smelter (short tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)
1942	94	--------	265	--------	12,779	22,802
1952	44	--------	427	172	5,485	464
Total	138	--------	692	172	18,264	23,266

[1] Furnished by the U.S. Bur. Mines Div. Mineral Industries. Published by permission.

UPPER KEESEY PROSPECT

Near the headwaters of Sloway Gulch are several adits of which only the upper one, known as the Upper Keesey prospect, is accessible. The portal is adjacent to and on the same level as the Forest Service road in sec. 19, T. 18 N., R. 26 W. In addition to the adit, the workings (fig. 54) include an inclined winze, a small sublevel at the foot of the winze, and two inaccessible raises. The country rock is phyllite of the Wallace formation, in which a few quartzite beds are fairly well preserved, but, in general, the bedding has been obliterated. The predominant cleavage strikes N. 45° to 55° W. and dips 45° to 80° NE. and bedding planes, where seen, are generally parallel in strike to this cleavage but dip a few degrees less. The cleavage surfaces commonly have many small-scale plications or puckers.

The vein, which has been cut 315 feet from the portal, is controlled by the attitude of the predominant set of cleavage planes. From the winze collar southeastward the vein is only a few inches wide. It is made up mostly of quartz throughout its exposed length, but contains a few small pods of galena, chalcopyrite, sphal-

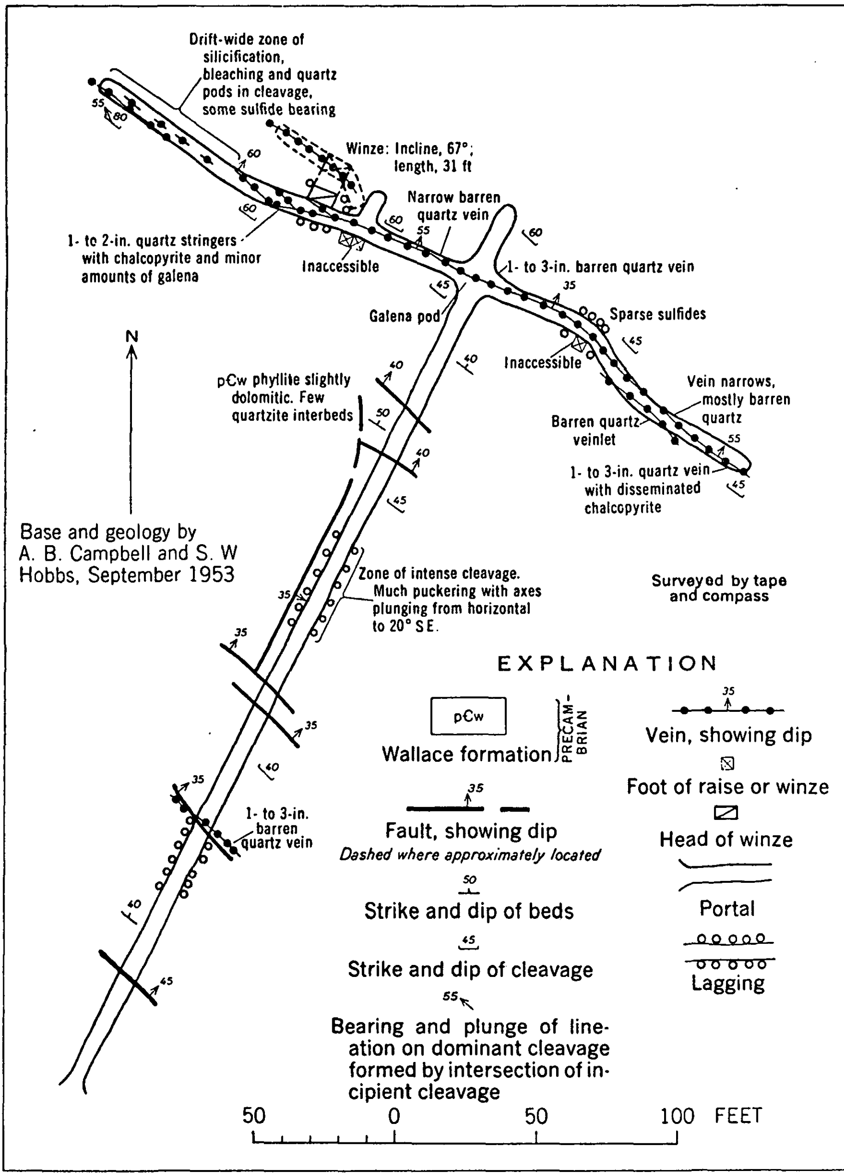

FIGURE 54.—Geological map of the Upper Keesey prospect, Keystone mining district, Mineral County, Mont.

erite, and pyrite. A small amount of barite occurs as a gangue mineral in addition to the quartz. Northwestward from the winze the vein splits into many irregular pods and stringers of quartz in a zone of intense cleavage. A few of these quartz pods contain sulfide minerals, but most are barren. The vein shows no increase in width or tenor on the sublevel at the bottom of the winze. No production from this prospect has been recorded.

DEADWOOD GULCH PROSPECT

The Deadwood Gulch prospect is near the headwaters of Sloway Gulch in sec. 20, T. 18 N., R. 26 W. The workings (fig. 55) consist of a lower adit, which was only partly accessible at the time of mapping, an upper adit about 220 feet above the lower one, and a shallow prospect shaft 38 feet above the upper adit. It appears that a raise was driven from the face of the upper adit level to the shaft, but this has caved and is obscured by rubble in the shaft bottom. The bedrock exposed throughout the workings is phyllite of the Wallace formation. Bedding planes have generally been completely obliterated by a pronounced cleavage that strikes generally west and dips from vertical to 70° S. A complex structural history is indicated by two sets of "puckers" superimposed on the main cleavage. One set of puckers is nearly parallel to the cleavage in strike and is about horizontal; the other set strikes northwestward and plunges 30° to 40° SE. The mine workings are in the overturned northward-dipping limb of a syncline. Some poorly defined bedding surfaces in the upper adit, however, locally appear to dip south. Remnants of beds, where preserved at all, generally consist of thin quartzite layers that have been rotated spatially by many small displacements along many slip planes. The attitudes of such remnants of beds are so erratic that they do not contribute to the knowledge of the shape of the larger scale fold of which they are a part.

The vein, which has been exposed in both the upper adit level and the shaft, occurs in a narrow zone of shearing parallel to the foliation of the phyllite. Quartz is the predominant vein mineral, and varying amounts of galena, chalcopyrite, and sphalerite accompany it locally. The vein width ranges from less than 1 to about 10 inches, and in places consists only of small discontinuous pods of quartz along the narrow shear. Two small right-lateral faults intersect the vein in the upper adit level, and have caused from 12 to 18 inches north-south horizontal separation of the vein. Another northwestward-striking fault has cut off the vein near the face of the upper adit and in the southeast corner of the shaft. No attempt has been made in either place to locate the faulted segment. The lower adit level is northwest of the projection of the vein and is barren with the exception of abundant irregular quartz pods in the planes of foliation. An unknown amount of the east end of this lower level was not accessible because of caving. There has been no recorded production from this property.

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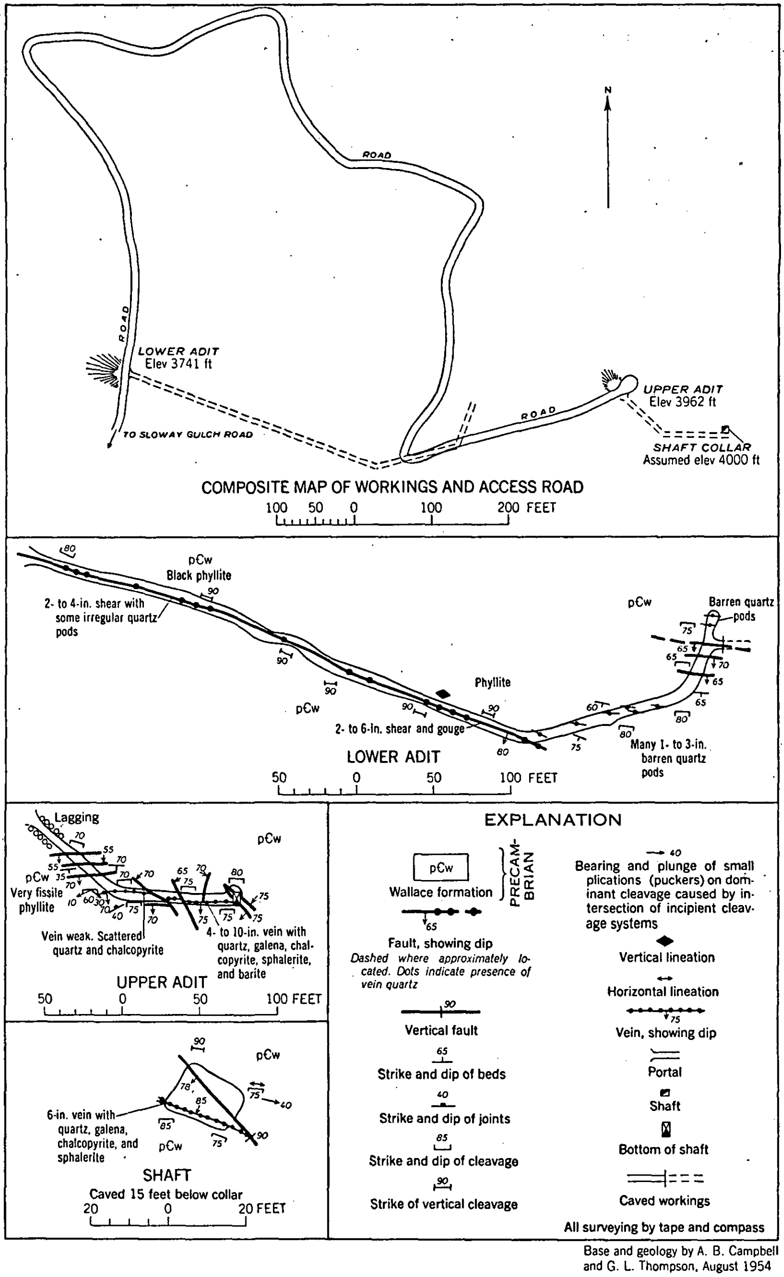

FIGURE 55.—Composite and geologic maps of workings at the Deadwood Gulch prospect, Keystone mining district, Mineral County, Mont.

SILVER AND LEAD DEPOSITS

In this area, the only vein that has been mined chiefly for its silver content is in the Little Pittsburg mine. This mine has produced only a small amount of ore, and a description of the deposit is included here in a separate category only to emphasize the existence of this type of vein near the lead and zinc deposits but separated from them by the Osburn fault.

LITTLE PITTSBURG MINE

The Little Pittsburg mine is in sec. 1, T. 17 N., R. 27 W. and sec. 36, T. 18 N., R. 27 W. The property may be reached by traveling 2.5 miles northward on the Sloway Gulch Forest Service road from its junction with U.S. Highway 10. Plate 31 shows most of the workings on the property; however, the Keesey tunnel was the only workings open during this study. The last 750 feet of the Keesey tunnel was rehabilitated during 1951 and 1952 so that geologic studies could be made in an area reported to contain significant reserves of lead, silver, copper, and antimony ore. Costs of this program were shared by the U.S. Government through the Defense Minerals Exploration Administration and by the Little Pittsburg Co. Most of the discussion of the geology of this mine is based on reports of examinations of this property by R. E. Wallace and J. W. Hosterman, of the U.S. Geological Survey, during the progress of the Defense Mineral Exploration Administration work. Most of the Keesey tunnel was inaccessible during the present geologic study because of oxygen depletion and caving.

Although this mine is associated geographically with the lead-zinc mines, it is separated from them by the Osburn fault zone. The mineral suite of argentiferous tetrahedrite, chalcopyrite, stibnite (or boulangerite) and siderite of the deposit also sets it apart from the nearby lead-zinc deposits. No galena or sphalerite was seen in the Keesey tunnel.

The country rock in the Keesey tunnel is fissile phyllite of the St. Regis formation and micaceous quartzite of the Burke and Revett formations, all of which are dolomitic as a result of carbonate alteration. Many outcrops of quartzite above the Keesey tunnel portal are highly foliated. The intense foliation of the rocks in the mine area is undoubtedly the result of adjustments along the Osburn fault that lies a short distance to the north of the mine. In the mine area the rocks are in the overturned north limb of the Little Pittsburg syncline, and the phyllite dips under the quartzite. Bedding in the phyllite is completely destroyed, but the contact between the phyllite and quartzite dips 45° to 50° N.

According to J. W. Hosterman (written communication, 1952), there are four narrow sulfide-bearing veins exposed in the Keesey tunnel level east of the shaft (pl. 31). The mine openings west of the shaft were not accessible to Hosterman. Small pods of one or more of the minerals tetrahedrite, chalcopyrite, pyrite, and stibnite, are in these narrow veins in a gangue of sheared country rock, quartz, and siderite. None of the veins contain sufficient quantities of ore minerals to warrant mining.

The production record from the property is presented in table 6. The ore probably came from stopes in the inaccessible area west of the shaft on the Keesey tunnel level, reported to have been productive in the past, and (or) from the inaccessible lower Little Pittsburg level. The production figures plus assay data show that the ore contained a large amount of lead. Either the small galena-free veins that were exposed in the accessible part of the workings in 1952 are different mineralogically from those from which the ore was taken, or the mineral that was reported to be stibnite, is in reality boulangerite. No figures are available concerning the antimony content of the ore shipped.

TABLE 6.—*Production record for the Little Pittsburg mine, 1901 through 1953. No production recorded except in the years indicated* [1]

[No zinc produced]

Year	Ore milled or shipped to smelter (short tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds)	Lead (pounds)
1913	17	1	2, 295	2, 356	--------
1932	24	4	2, 461	1, 572	7, 409
1933	20	2	2, 080	955	3, 657
1936	30	1	1, 366	627	4, 318
Total	91	8	8, 202	5, 510	15, 384

[1] Furnished by the U.S. Bur. Mines Div. Mineral Industries. Published by permission.

COPPER DEPOSITS

Several of the lead and zinc veins contain some chalcopyrite and tetrahedrite, but the only primarily copper mine in the area is the Amador mine. This property has produced about 75 percent of the total recorded copper production of 2,046,963 pounds from this area.

AMADOR MINE

The Amador mine is near Cedar Creek in the SE¼ sec. 28, T. 16 N., R. 27 W., about 12 miles southwest of Superior, Mont. The mine is easily accessible via well-maintained county and Forest Service roads.

Ore was produced from the Amador mine from 1913 to 1920, inclusive, then the mine was idle until 1951 when 256 tons of ore was shipped, presumably from the old dump. Also at that time the entire mine was dewatered; costs of the dewatering operation were shared by the Amador Mining Co. and the U.S. Government through an exploration contract with the Defense Minerals Exploration Administration. Old records indicated that a large tonnage of ore was left during former mining operations, and the dewatering was a preliminary step in a proposed development and exploration program. Upon completion of the dewatering, however, it was found that no minable bodies of ore existed and that the vein was noncommercial below and at each end of the one ore shoot that had been productive. The mine was examined and partly mapped by several members of the U.S. Geological Survey during the period when it was dewatered. After geologic examination the mine was allowed to flood again and was not accessible during this study of the Superior area. The following discussion is based mainly on reports by R. E. Wallace, U.S. Geological Survey, at the time the mine was dewatered.

The underground workings at the mine (pl. 32) consist of the main adit level, an 8- by 12-foot vertical shaft which collars in the main adit level, the 60, 200, 400, and 700 levels, and an adit, called the Southeast drift, across the creek from the main mine portal. It should be pointed out that the names given to the levels are not true vertical distances below the collar of the shaft. The 60 level is 59.4 feet, the 200 level is 158.5 feet, the 400 level is 300.0 feet, and the 700 level is 601.5 feet below the collar of the shaft.

The mine is in interbedded, slightly dolomitic argillite and quartzite of the Wallace formation that have a general N. 30° W. strike, and a steep dip to the northeast. A large dike or sill occurs about one-quarter of a mile south of the mine, and the association of the Amador copper vein with this igneous rock is similar to the relation between several other copper deposits and the Wishards or related sills in the area west of the Amador (Wallace and Hosterman, 1956, p. 607). None of these copper deposits have been large producers. Little else is known of the regional setting of this mine, for the geology of the mine area has been connected to the main mapped area by only one reconnaissance traverse.

The vein strikes approximately west and dips 40° to 60° S. It curves southeastward at the east end and splits into several discontinuous weakly mineralized strands that strike on the average about N. 40° W. Widths of the main vein range from a few inches to 8 feet. Quartz-carbonate gangue is present throughout the vein, dolomite or ankerite predominates in the upper levels, and calcite is more common on the 700 level. The ore contains varying amounts of pyrite, chalcopyrite, and bornite, in decreasing order of their relative abundance. Two features seem to have controlled the position of the ore shoots: first, on the 700 level drift the vein weakens greatly where it passes from argillaceous beds into quartzite beds and, second, the vein becomes narrow and lenticular towards the east end where its attitude is more nearly parallel to that of the bedding.

No additional exploration work is deemed feasible under current conditions. The one ore shoot has been completely mined. Exploration at the ends of the shoot on the 200 and 400 levels, and below the shoot on the 700 level has not been favorable. Assays of 11 channel samples of 135 feet of the vein on the 700 level averaged only 0.47 percent copper. Although the vein is persistent on the 700 level, it is evident that the ore shoot does not extend down to that level.

Table 7 is the total recorded production from the Amador mine.

TABLE 7.—*Production record for the Amador mine, 1901 through 1953. No production record except in the years indicated* [1]

[No lead or zinc produced]

Year	Ore milled or shipped to smelter (short tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds)
1913	331		295	67, 355
1914	78		79	21, 058
1915	208	1	67	16, 279
1916	5, 596	4	1, 420	380, 565
1917	21, 263	15	1, 761	443, 805
1918	19, 840	18	1, 942	490, 720
1919	940	3	279	52, 748
1920	258	1	117	28, 548
1951	256	2	218	38, 868
Total	48, 770	44	6, 178	1, 539, 946

[1] Furnished by the U.S. Bur. Mines, Div. Mineral Industries. Published by permission.

FLUORSPAR DEPOSITS

Fluorspar was first discovered in the Dry Creek valley in 1943 about 7 miles southwest of the confluence of Dry Creek and Clark Fork, and the first commercial production in Montana came from this locality in 1948. Three prospects, the Bear Creek, Lime Gulch, and Wilson Gulch prospects, have been developed in the vicinity. C. P. Ross (1950, p. 204–210) reported on the early stages of the exploration of the Bear Creek (formerly Spar) prospect and R. M.

Corn[1] mapped and described all three prospects in 1953 when production was in progress.

All three of these deposits are similar in many respects. The country rock at each is the Wallace formation that here consists of a thick sequence of interbedded light-gray quartzite and medium-gray argillite; all are dolomitic rocks that weather to shades of brown or red. The rock surfaces often have weathered differentially, and thin discontinuous beds or pods of more siliceous material stand out in relief. Much tight folding accompanied by some shearing is evident throughout a belt several hundred feet wide. This belt trends N. 10° to 20° W. and all three deposits are restricted to it. Narrow zones of shearing, which are apparently discontinuous and perhaps have an echelon orientation, have sheeted and brecciated the rocks without much differential movement. Most of the brecciated rock has been cemented by an introduced carbonate mineral, identified by differential thermal analysis as ankerite. This belt of brecciation and carbonate emplacement has been traced north as far as near the mouth of Little Joe Creek. All three fluorspar prospects are located near the south end of this zone, and no fluorite was found elsewhere along its extent.

R. M. Corn reported that the Bear Creek and Wilson Gulch prospects produced a total of 781 tons of handsorted fluorspar between 1948 and 1950. The Lime Gulch prospect did not produce any ore. A grade of 94.6 percent CaF_2 was quoted for 318 tons, but no grade was quoted for the remainder. Small reserves of shipping-grade ore are in sight at both the Bear Creek and Wilson Gulch opencuts, but because of the small size of these ore bodies and the costs of mining, hand sorting, and shipping, a mining operation would be marginal at best. The zone of brecciation is apparently a favorable locus for fluorite deposition. Exploration for additional deposits should most logically be concentrated in this zone, or in similar zones that are reported to occur south of this one.

BEAR CREEK PROSPECT

The Bear Creek (formerly Spar) prospect is in the NW¼ sec. 31, T. 17 N., R. 27 W. near the confluence of Bear and Dry Creeks. Plate 33 shows geologic maps of the surface and underground workings. The surface pit and the two adits west of the pit were open during this study. The adit that trends westward from Bear Creek valley was caved near the portal, and the geology shown on that level is from the report by R. Corn.[2] A shallow shaft was sunk from the surface pit, but has slumped and filled with rubble.

[1] Corn, Russell M., 1953, Fluorite deposits in the Dry Creek district, near Superior, Mineral County, Montana: Thesis, Montana School of Mines, Butte, Mont.

[2] Corn, R. M., 1953, op. cit.

An outstanding feature of this prospect is a large vein of milky quartz that crops out on the nose of the ridge. The outcrop strikes N. 80° W. and is about 150 feet long and 25 feet wide. Similar outcrops have been reported in the Dry Creek valley south of the mapped area, but they were not examined during this work. The west end of the Bear Creek quartz vein has been intensely sheeted in a N. 20° to 40° W. direction and shattered. A pit and shallow shaft there exposed several irregular bodies of fluorite and massive calcite and ankerite. The fluorite and carbonate minerals replaced the quartz and, to a lesser degree, the surrounding country rock. The fresh fluorite is pale blue to green, but upon prolonged exposure these tints fade. Weathering also causes the fluorite to break down into fine-grained cleavage fragments. The main pod, from which most of the ore was mined, ranged from 6 to 8 feet in diameter and was nearly pure fluorite. This pod contained the only sulfide minerals found in any of the 3 fluorspar prospects, and here only 1 small lens of galena, chalcopyrite, and tetrahedrite was seen. According to a miner who worked at the property, the main fluorite pod was mined out at a depth of about 15 feet.

No additional minable bodies were found by the underground exploration. The upper adit (adit *A*, pl. 33) to the west of the pit cut vein quartz in which a few small pods of fluorite were found in the south wall of the adit. The lower adit (adit *B*, pl. 33) to the west of the pit did not show fluorite, but did show small-scale folding and fracturing of the country rock and much introduced quartz and ankerite scattered throughout. Adit C (pl. 33) that was driven from the Bear Creek side has a total of about 600 feet of workings, according to R. Corn, but it did not extend to the area below the main fluorite outcrop. Corn's map of this adit does not indicate the presence of any fluorite.

WILSON GULCH PROSPECT

The Wilson Gulch prospect is in the NW¼ sec. 1, T. 16 N., R. 28 W. in Wilson Gulch about 1.5 miles south of its junction with Dry Creek. The workings at this property consist of several surface trenches on the hillside. Figure 56 is a geologic map of these cuts. The largest cut, the first one observed along the road to the property, is about 60 feet long, 40 feet wide, and 30 feet high. Much of this cut has sloughed in, but Corn[3] reported a "mineralized zone containing about 30 percent fluorite, is exposed for nearly 60 feet and is more than 5 feet wide." This is the only cut that showed a minable quantity of ore.

[3] Corn, R. M., 1953, op. cit.

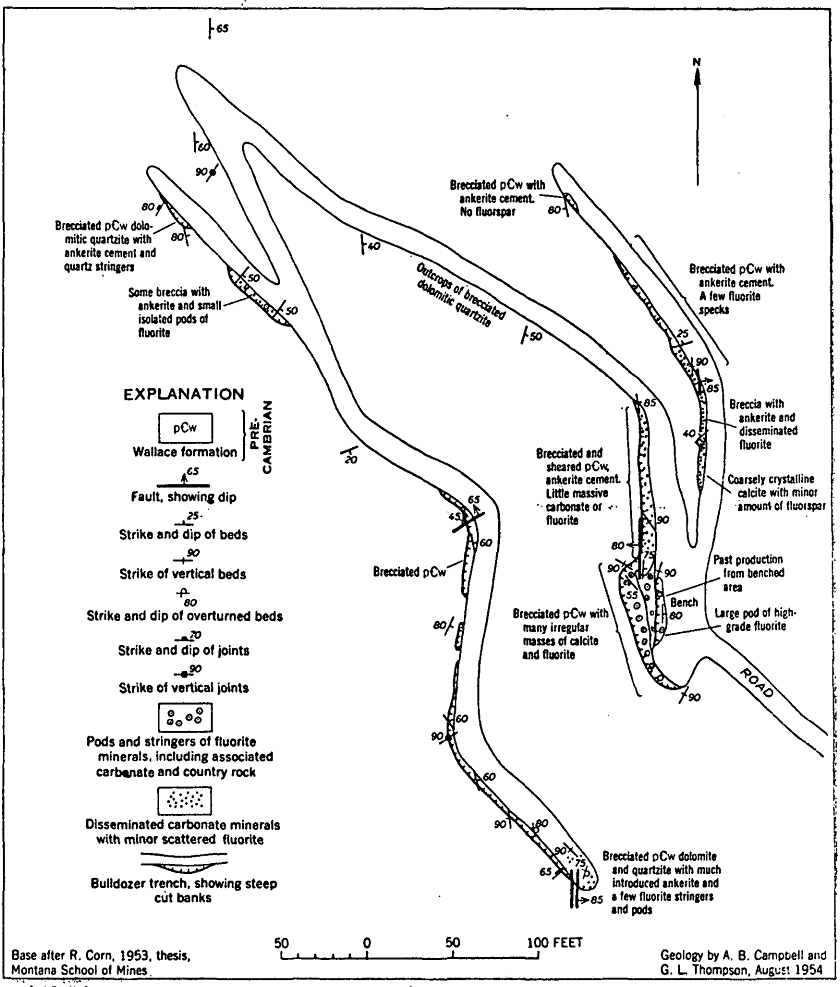

FIGURE 56.—Geologic map of the Wilson Gulch fluorspar prospect, Mineral County, Mont.

The country rock is brecciated and sheeted as at the Bear Creek prospect, although the sheeting is not so closely spaced or evident here. No milky quartz veins are found in association with the fluorite here. The breccia zone is 50 to 75 feet wide and contains much introduced ankerite and sparse fluorite in the vicinity of the prospect trenches. The breccia zone can be traced northward from the Wilson Gulch trenches to the Bear Creek deposit, but very little fluorite was seen in the zone between the two prospects. In the vicinity of the large cut, irregular masses of calcite have replaced the country rock and in turn have been partly replaced by fluorite. Locally the fluorite replacement extends into the surrounding limy or dolomitic rocks. The trenches cut several north-south faults that do not give indication of much differential movement.

LIME GULCH PROSPECT

The Lime Gulch prospect is in the Dry Creek valley about a quarter of a mile west of the mouth of Lime Gulch in the SE¼ sec. 30, T. 17 N., R. 27 W. The workings at this prospect consist of a surface trench that has slumped badly and an adit about 200 feet long. A geologic map of the adit is shown in figure 57.

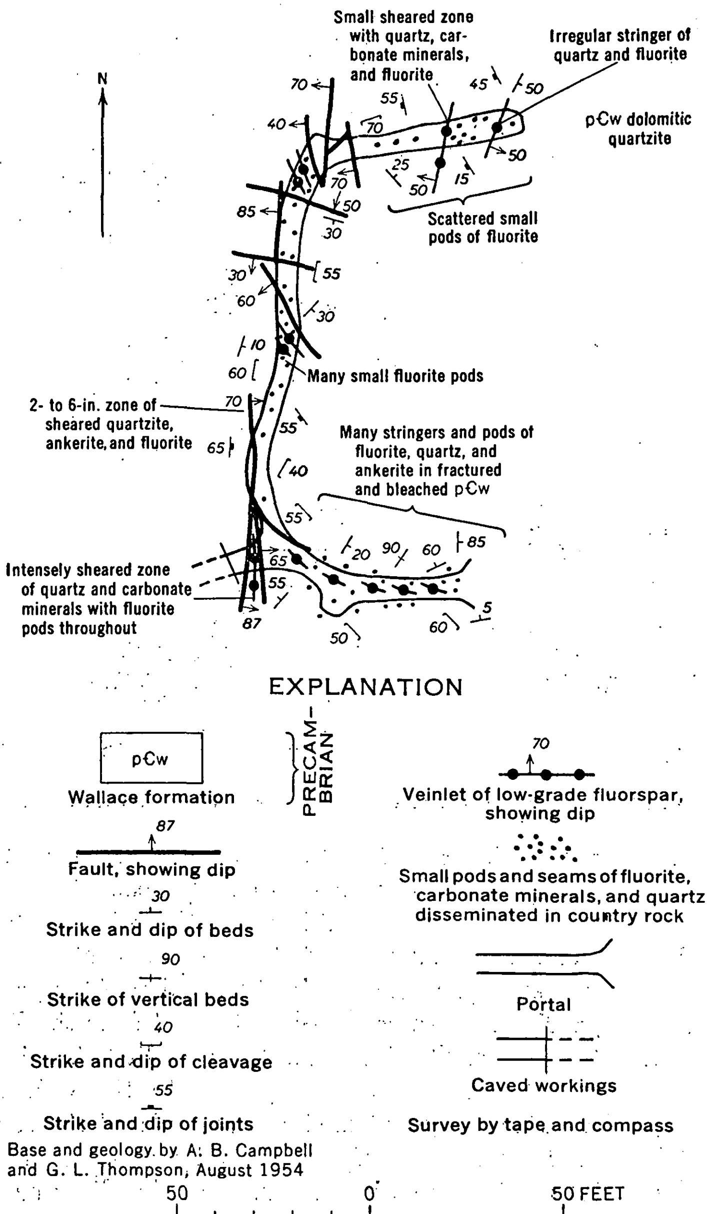

FIGURE 57.—Geologic map of the Lime Gulch fluorspar prospect, Mineral County, Mont.

As at the other two fluorite prospects, quartz, ankerite, and fluorite occur in a breccia zone within the Wallace formation. The fluorite is in veinlets and pods in the quartz and ankerite, but it is not present in minable quantities in the adit or the surface trench. Several small faults that strike northward are postmineralization in age, as indicated by the quartz, ankerite, and fluorite that are crushed along them. A strong northward-trending shear zone is partly exposed in a caved crosscut about 50 feet from the portal.

OTHER DEPOSITS

Several mines and prospects have not been described because either they are now inaccessible, or adequate records concerning their activities were not available to the writer. Notable in this category is the Santa Rita mining group that is immediately north-northwest of the abandoned village of Keystone in the Keystone Creek valley. Large dumps of several adits indicate that much underground work was done in the area between Pack Gulch and Keystone Creek; however, only parts of a few adits are now accessible, and no vein was seen in the accessible parts. The main adit level that was driven northward out of the Keystone Creek valley has caved a short distance from the portal. A geologic sketch map of a part of this adit supplied by the Santa Rita Mining Co. indicates the presence of 2 veins; one about 1,200 feet and the other about 1,875 feet from the portal. From that map it seems that the vein closer to the portal strikes westward and dips southward; the content and size of the vein are unknown. The vein farther from the portal strikes N. 40° W. and dips 50° SW. The extent and size of the vein are not indicated, but the presence of lead and iron in the vein is noted.

Many caved adits were seen in the valleys of Pardee and Sloway Creeks, but such prospects were abandoned long ago, and no records concerning them could be found.

The Nite Owl mine is in sec. 33, T. 18 N., R. 26 W., a short distance northeast of the village of Keystone. This mine, located in foliated quartzite of the Burke and Revett formations, has been operated intermittently for many years. The U.S. Bureau of Mines lists the production for the years 1926, 1927, and 1951 as totaling 193 ounces of silver, 5,178 pounds of lead, and 22,607 pounds of zinc. This metallic content was extracted from 66 tons of ore. The mine was inaccessible when the fieldwork was done but was reopened late in 1954. Whether any ore has been produced since that time is not known.

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