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GEOLOGY AND NOTES ON ORE DEPOSITS OF THE CANYON-NINE MILE CREEKS AREA, SHOSHONE COUNTY, IDAHO

By

Allan Bingham Griggs

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This report is preliminary and has not been edited or reviewed for conformity with U. S. Geological Survey standards and nomenclature.

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General statement

The Coeur d'Alene district in Shoshone County in the panhandle of northern Idaho has yielded a prodigious amount of metal since the beginning of mining there in the early 1880's. By 1944 the gross value of the lead, silver, and zinc, and to a lesser degree, gold, copper, antimony, cadmium, and tungsten produced had passed the $1,000,000,000 mark, and the gross value of the metal produced during the year 1951 amounted to $63,779,925. Periodically, personnel of the U. S. Geological Survey have investigated this important mining area and reported on their findings. The first project was a district-wide study which was described in Professional Paper 62 (Ransome and Calkins, 1908). The next was incorporated into a survey of the mineral deposits of Shoshone County by Umpleby and Jones (1923). In 1935, in cooperation with the Idaho Bureau of Mines and Geology, a detailed re-examination was undertaken which resulted in a report on the Murray area (Shenon, 1938) and a preliminary one on the Silver Belt (Shenon and McConnel, 1939). This project was interrupted, and it was not until after World War II, in 1947, that it was taken up again by the Geological Survey. It is believed that a valuable contribution on the ore deposits and their environment can be made, based upon the great mass of data compiled by the mining companies, and the large amount of additional information that can be obtained from a more detailed study which has the advantage of many miles of underground workings and numerous exposures not heretofore available. As the investigation will continue over a considerable period of time, it was decided that preliminary reports and maps would be issued from time to time as units of work were completed. This paper on the Canyon-Nine Mile Creeks area is one of these reports.

The primary purpose of the initial part of the investigation is the mapping of the areal geology, with which this paper is mainly concerned. The notes on the ore deposits which are included in this report are based upon observations made during the areal mapping, the company maps from which a great amount of data was acquired, and upon literature. They are not intended to be complete, but in order to bring into sharper focus the many problems which need to be studied in greater detail, it seemed advisable to record them while the observations are yet comparatively fresh in the writer's mind. The discussion includes a description of the general setting of the deposits, followed by observations on their relation to the areal geology. Detailed descriptions of individual deposits will be included in the final report on the entire district.

In addition to a surface geological map (pl. 2) and accompanying cross sections (pl. 3), a geological map (pl. 4) showing the underground geology projected to an irregular plane constructed to intersect the principal mine workings also has been prepared. Roughly it coincides with a plane sloping up from an elevation of 3,000 feet on the west to near 4,000 feet on the east side of the map. With so many extensive underground workings near stream level, it was believed advantageous to portray the geology they exposed.

The region dealt with here is contained within the northern half of the Mullan and Vicinity, Idaho, special topographic sheet, which is bounded by meridians 115° 47' and 115° 55' west longitude, and parallels 47° 30' and 47° 33' 45" north latitude. The name, Canyon-Nine Mile Creeks area, has been used rather than that of the special quadrangle, for almost all of the drainage of Nine Mile Creek and a large part of Canyon Creek is within the region. This name is more descriptive and less cumbersome. The boundaries of the area encompass one of the important centers of mining activity in the northeastern corner of the Coeur d'Alene district.

Wallace, the chief city and transportation center of the district, lies two miles south of the southwestern corner of the area at the confluence of Canyon Creek and Nine Mile Creek with the south fork of the Coeur d'Alene River. East-west U. S. Highway 10 goes through Wallace, and branch lines of the Union Pacific R. R. from the west and Northern Pacific R. R. from the east join there. Spurs of these railroads extend up Canyon Creek to Burke and up Nine Mile Creek to the Dayrock mine. Starting from Wallace, two roads traverse the area. One goes up Canyon Creek and continues eastward over Glidden Pass to Thompson Falls, Montana; the other goes up Nine Mile Creek, and continues north beyond the mapped area to Murray, Idaho. Mountain roads take off from these main roads and go to many mines and prospects.

Field work and acknowledgments

The present study of the Coeur d'Alene district began in 1947. However, the work in this area was not begun until the middle of the summer of 1948. From then until the fall of 1950 an equivalent of a year and a half was spent mapping the surface and underground geology.

More than a third of this time was spent mapping mine workings. In all, over 35 miles of them were traversed. For the most part these were the larger crosscuts, and the ore deposits were usually studied on one level only. All work on the maps and reports was in recess for the first six months of 1951.

The wholehearted cooperation received from the mining companies of the district during the present study has been most helpful and provided a very pleasant association. Among those to which the project is particularly indebted for furnishing maps and data for this phase of the work and allowing access to mine workings are H. L. Day, President and General Manager, Rollin Farmin, Superintendent, and F. M. Galbraith, Chief Geologist, Day Mines, Incorporated; J. E. Berg, General Manager, Federal Mining and Smelting Company; Keith Whiting, Chief Geologist, Western Division, American Smelting and Refining Company, and L. E. Hanley, President and Manager, and R. E. Sorenson, Chief Engineer and Geologist, Hecla Mining Company. Many additional geologists and engineers on the staffs of these mining companies also were helpful in assisting and in giving advice. The owners or managers of a number of other properties were likewise courteous and helpful in allowing access and furnishing data. Thanks is also due to the U. S. Bureau of Mines for furnishing production figures for the mines of the area.

To S. Warren Hobbs, the project chief under whom this work was done, and to co-worker Robert E. Wallace, special thanks are due for advice and guidance. Much credit is also due Henry C. Rainey III, James A. Noel and Ben Bowyer, who assisted in the mapping of the area. Thanks are due to

Charles Milton for making the photomicrographs. The writer is deeply indebted to Professor Charles F. Park, Jr. for his encouragement and advice.

Climate and vegetation

The records of the United States Weather Bureau for a 22-year period show the mean annual precipitation at Wallace to have been 38.5 inches, and at the Burke substation on Canyon Creek just beyond the east edge of the map to have been 44 inches. The elevation at Wallace is 2,770 feet, and at the Burke substation, 4,082 feet. An indication can be gained from this of the greater amount of precipitation at higher elevations. At the Burke substation much of this falls as snow, whereas at Wallace it is considerably less.

Most of the precipitation comes between October and April, and much of the area is mantled with snow for from 4 to 5 months.

The maximum range in temperatures for the same period at Burke substation was from a low of -21° F. to a high of 95° F. Such extremes are rare, and the mean average at the Burke substation was 40.4° F., showing that the climate is not rigorous even though the area is located in the northern Rocky Mountains.

At least 75 percent of the area is covered by timber and brush. The remainder consists of the flatlands within the narrow valleys, of scree covered slopes and of rock outcrops. The trees are firs, pines or other conifers. Most of those that were useful for mining or lumbering have been logged off. Part of the logged off country has grown back to brush, but most is covered by a second growth, some of which has matured sufficiently to be suitable for mining timbers.

Physical features

The area drained by Canyon and Nine Mile Creeks lies within the Coeur d'Alene Mountains, a part of the northern Rocky Mountain physiographic province. The main crest of the range lies a few miles to the east. Sharp ridges, running west from it in general, separate the drainages of Canyon and Nine Mile Creeks from each other and from the drainages to the north and south. The streams have cut narrow, deep and steep sided valleys, maturely dissecting the region. The ridge crests show a rather uniform elevation (see pl. 6A) of plus or minus 6,000 feet, which indicates that the area was formerly one of low relief. Here and there these ridge crests rise to summits somewhat above the general level. Sunset (elev. 6,423 feet) and Goose Peaks (elev. 6,363 feet)(see pl. 8A) near the north edge of the map, and Tiger (elev. 6,626 feet) and Custer (elev. 6,423 feet) Peaks, capping the ridge just northwest of Burke are examples. The low points, somewhat below 3,000 feet, are along Canyon and Nine Mile Creeks at the south and Beaver Creek at the north, making the maximum relief about 3,500 feet.

A number of small cirques on the north sides of the ridges bear witness to the mountain glaciation which took place during Pleistocene time. The best developed one, however, is an anomaly, for it faces eastward. It lies near the summit of Tiger Peak and debauches into Gorge Gulch. Unlike many of the well defined cirques in the Coeur d'Alene region, it contains no lakes, but is floored by small meadows and intervening rocky ribs.

Several erosional surfaces are evident on the lower part of the ridge between Canyon and Nine Mile Creeks. The highest caps the ridge between elevations of 3,500 and 4,125 feet. Remnants of a terrace near an elevation of 3,800 feet lie on the Nine Mile Creek side. Part of another terrace is evident on the Canyon Creek side at an elevation of 3,400 feet, just south of the mapped area. All of these are capped by gravels.

SEDIMENTARY ROCKS

The consolidated sedimentary rocks, which underlie approximately 80 percent of the Canyon-Nine Mile Creeks area, all belong to the pre-Cambrian Belt Series. They consist of a thick group of conformable fine-grained sediments, regionally metamorphosed to a minor degree, and ranging in composition from argillite to quartzite with some carbonate-bearing zones. They have undergone a complex structural history of folding and faulting, have been intruded by monzonite stocks and dikes of different compositions, and have been hydrothermally altered in places. Many important lead-zinc-silver ore bodies have been deposited within them. All six subdivisions of the Belt Series named by Calkins (Ransome and Calkins, 1908, pp. 23-25) are represented in this area.

Unconsolidated sediments include terrace deposits, glacial material and alluvium. Remnants of the gravels, some of which probably date back to Tertiary time, cap ridges or occur on terraces along their sides. The glacial material includes both till and fluvio-glacial deposits. The alluvium is confined to the narrow valleys of Canyon, Nine Mile and Beaver Creeks.

Belt Series

General features

The Belt Series comprises a group of conformable, fine-grained sediments of late pre-Cambrian age underlying much of northern Idaho, western Montana and southeastern British Columbia. These sediments have been estimated to have attained a thickness of over 40,000 feet. In the Coeur d'Alene district, however, the total thickness has been calculated as ranging from 21,000 to 27,000 feet with neither the top nor bottom of the section exposed. Here the series consists of argillite, quartzite, and all gradations between these two types, with some zones of carbonate-bearing rocks. So far as is known the Belt Series are unfossiliferous in the Coeur d'Alene district, but fossil algal reefs have been found in the Libby quadrangle to the north (Gibson, 1948, p. 15) and fossil remains of simple life forms have been reported as occurring in Belt rocks at several other places.

In the Coeur d'Alene district the subdivisions of the Belt Series, as described by Calkins, are from oldest to youngest: Prichard, Burke, Revett, St. Regis, Wallace and Striped Peak formations. In the absence of fossil markers, these subdivisions have been made on lithologic features; these hold true and are diagnostic when considered for an entire formation. However, duplications of rock types, in some instances over fairly thick sections, make it difficult to distinguish some formations from others, or at least from parts of formations. This is particularly true of the St. Regis and Striped Peak, which duplicate each other over large thicknesses; to a lesser extent, it is true of parts of the upper Prichard and upper Wallace. The boundaries between some formations are transitional, and no sharp contact can be shown. The transition zone between Burke and Revett is the thickest, where the change from one type of rock to another takes place over several hundred feet. Also, in many places the hydrothermal alteration has been intense enough to mask the identity of the rock.

During this investigation the Prichard and Wallace have been subdivided into upper and lower Prichard, and upper and lower Wallace. Fairly distinctive lithologic characteristics have been found widespread enough to warrant the splitting. The scarceness of any marker beds and the great thickness of the formations warrant any possible refinements which are helpful in unraveling the complex structure.

In general, workers in the surrounding country have used the same subdivisions for the Belt Series. Some whose work has been more nearly reconnaissance have lumped some formations together. Others have had to group formations because of the disappearance of distinguishing features. A table showing these discrepancies and correlating the formations of the Belt Series in the neighboring region to those of the Coeur d'Alene district follows.

This table points up some marked changes in thickness and indicates some losses of characteristic lithology. To the north and east the Burke, Revett and St. Regis formations lose their individual identity and become an undivided group of predominantly quartzitic rocks. Collectively they are called the Ravalli formation. To the north and northwest in the Clark Fork and Pend Oreille districts the same formations also lose some of their identifying characteristics. The purplish hues so characteristic of the St. Regis continue down into the Revett, and the massive white quartzite of the Revett has graded into a heterogeneous section of quartzitic rock. This group of rocks also becomes notably thicker to the northwest, north, and northeast. A comparison of the Avery, Coeur d'Alene, Trout Creek and Libby sections shows a progressive thickening of the Wallace formation from south to north. Even so, the sections do indicate that similar environments remained fairly constant for a widespread region over long periods of time.

Some changes have been noticed in the Coeur d'Alene area. The most marked is the thickening and coarsening of the sediments in the Burke, Revett and St. Regis formations in going from east to west. In the eastern part of the district the upper Prichard is 1,800 feet thick, whereas about 25 miles to the west in the Pine Creek area it is only 600 to 800 feet thick (Forrester and Nelson, p. 6). Near the Montana border the St. Regis formation is thicker south of the Osburn fault than it is to the north; most of this thickening is within the upper argillaceous part.

The greater thickness of the Striped Peak formation in the neighboring regions indicates that a considerable amount of the Belt Series has been eroded away in the Coeur d'Alene district. Whether it amounted to the maximum of 30,000 feet of upper Belt sediments that overlies the equivalent of the Wallace in parts of western Montana is highly doubtful, as no evidence of such has been found in the adjacent areas. A possibility exists that the region may have been capped by Cambrian rock, as small remnants of Cambrian limestone occur in down faulted blocks in the Pend Oreille and Clark Fork districts to the north and northwest.

Shallow water features

Shallow water features are common throughout the upper half of the Belt Series in the Coeur d'Alene district. The contact between upper and lower Prichard marks the break between sediments deposited wholly under water and those deposited in an area which was awash or exposed to the sun and air at intervals. A good balance between deposition and subsidence must have been maintained over a long period of time to have had shallow water features so prevalent throughout 10,000 feet plus of sediments in a basin many thousands of square miles in extent. The quartzitic beds exhibit cross lamination, ripple marks and pseudo-conglomerates, whereas mud cracks, mud breccias and rain pits are characteristic of the argillaceous rocks.

The cross laminated layers, or perhaps more properly, continuous inclined bedded strata, are most abundant in the upper Burke and the Revett, and are restricted to the purer quartzites (see pl. 11A). Such beds are a foot or more in thickness. The inclined layers, which range from a fraction to an inch plus in thickness, are sharply truncated at the top, are usually slightly curved at the bottom, and show good partings. These partings commonly occur along very thin laminae containing concentrations of heavy minerals. Calculations based on 20 observations show that originally the inclined layers dipped around 30 degrees, the majority towards the northeast. These are far too few observations, however, on which to base any conclusions on current directions. The persistence and uniformity of these beds and the other layers associated with them are good evidence that they all were deposited under water.

Both oscillatory and current ripple marks have been observed, with the former much more abundant. Interference ripples, where one set has been imposed on another, are not uncommon. The ripple marks are usually found capping the impure quartzite strata. For this reason they are most characteristic of the upper Prichard, Burke, St. Regis, lower Wallace and Striped Peak formations. Their wave length is usually from 1 to 3 inches.

The pseudo-conglomerates, or ovoid structures, have been found capping impure quartzite to fairly pure quartzite beds in the upper Prichard and in the Burke formation. They are irregular in shape, rounded, and flattened parallel to the bedding. They are usually less than an inch thick and two inches plus or minus in other directions. A thin micaceous coating gives their surfaces a sheen, and causes them to part cleanly from the surrounding rock. The manner in which they originated is puzzling. They resemble flow casts (Shrock, 1948, p. 156), but differ in that they are of the same composition as the beds in which they are found. They were undoubtedly formed during the depositional stage. Whether, as Calkins suggested, they were due only to waves rolling up masses of water-soaked sands, which flattened horizontally due to their weight (Ransome and Calkins, 1908, p. 31), is questioned. That wave action plus a bonding agent caused the sandy material to ball up seems more plausible.

Mud cracks may be found in any argillaceous rock from the upper contact of lower Prichard on up the section, but they are particularly abundant in the upper parts of the upper Prichard and St. Regis as well as within a number of zones in the Wallace and Striped Peak (see pl. 12B). The cracks are closely spaced; the irregular polygonal blocks bounded by them usually are not more than an inch or two across. They extend down from a fraction of an inch to several inches, and are filled with lighter colored sandy material (see pl. 17A). Their crenulation is most likely due to compaction during lithification. Where fracture cleavage is well developed, the mud cracks tend to align parallel with the cleavage.

The mud breccias are most common in the upper part of the St. Regis, where they occur in layers usually only a fraction of an inch thick. They consist of accumulations of chips formed from thin layers of mud, which cracked, curled and parted from the underlying sandy material when the surface was exposed to the sun. They lie at random orientations indicating they were washed about with the next flooding. They were not moved far, however, as their outlines are still angular.

Raindrop impressions observed by Calkins (Ransome and Calkins, 1908, p. 31) and casts of salt crystals seen by Gibson (1948, p. 16) are shallow water features that were not seen by the writer. Cross lamination, ripple marks and mud cracks together with gradational bedding are of great assistance in determining tops and bottoms of beds.

Mineralogy

Mineralogically, the rocks of the Belt Series consist primarily of quartz and sericite, except for those containing appreciable amounts of carbonate minerals. The quartz content ranges from somewhat less than 25 percent in the most argillaceous varieties to over 95 percent in the purest quartzite, with sericite making up most of the rest of the rock. The quartz grains are angular to subangular; this is true even of these within the coarser grained quartzites. They range in size from 0.01 mm.

in the argillite to a maximum of 0.5 mm. in the quartzite, with the average sizes for these end members being about 0.02 and 0.25 mm. The sericite has an elongate flaky habit. Most of it is very small, 0.05 mm. or less in length and averaging about 0.02 mm. A scattering of much longer flakes, however, is observed in many of the thin sections; most of these are from 0.1 to 0.2 mm. in length and are probably in part secondary. In the argillaceous rocks the sericite with the small quartz grains forms a felted mass, which makes a matrix in the less pure quartzites, and occurs interstitially in the purer quartzites.

Feldspar grains are present in the quartzitic rocks, where they usually make up about one or two percent, at most five percent. They are somewhat rounded, and are similar in size to the associated quartz grains. They consist of both plagioclase, which is mostly oligoclase, and potash feldspar, which is mostly microcline.

Black opaque grains are sparsely scattered throughout the rocks. They range from magnetite to ilmenite in composition. Many, where altered, are partially or entirely replaced by leucoxene, or, in the case of some in weathered rock, are rimmed by a rusty red staining. Irregular grains and octahedra, which are larger than the associated quartz grains, must be secondary. Tourmaline, zircon, and to a much lesser extent rutile, occur in minor amounts scattered within the rock. In some quartzite beds these heavy minerals are concentrated within very thin dark laminae. A rosette of tourmaline which was observed in one thin section is undoubtedly secondary, and this is also probably true for many of the larger well developed tourmaline prisms. Magnetite octahedra are more numerous in the purple and pink tinted quartzites.

Pyrite and to some extent pyrrhotite are characteristic of the Prichard formation. In the upper Prichard pyrite occurs as cubes or shapeless blobs up to 5 mm. across. In the lower Prichard, however, the greatest amount occurs concentrated along thin laminae in grains a millimeter plus or minus in size. In some places pyrrhotite is found in the laminae, instead of pyrite.

The carbonate minerals in the Belt Series occur both as a primary constituent and as one introduced secondarily by hydrothermal solutions. By far the greatest amount used deposited when the sediments were formed. The primary carbonate minerals occur in all formations, but in the older rocks up through the lower half of the St. Regis, they are present in minor amounts only, or are restricted locally to narrow zones or thin beds. As an important rock-forming mineral they bulk large only in the lower Wallace and in a carbonate rich zone in upper Wallace. In the remainder of the upper Belt rocks they occur in many beds and zones, but percentage wise are not important.

During the "bleaching" alteration, varying amounts of carbonates were introduced, replacing the sericite and quartz. Some carbonate minerals were undoubtedly dissolved by hydrothermal solutions from Belt rocks at one place and deposited at another, but most are probably from some primary source, for in this area the solutions traveled up through the older carbonate-poor formations.

Most of the primary carbonate mineral in the Belt Series is a ferroan dolomite. Although no chemical determinations have been made, such evidence as the rusty brown limonitic rind or stain on the weathered surfaces of the carbonate rock shows the presence of a fair percentage of iron. Furthermore, the index of refraction of the carbonate mineral is higher than dolomite and lower than siderite. The only calcite-bearing rocks are some limestone beds in the upper Wallace and the cores in the "molar tooth" structures. Both of these reacted vigorously to cold dilute hydrochloric acid.

From studying thin sections of lower Wallace rocks, the carbonate mineral content was found to vary widely. Most of these contained from 5 to 50 percent and averaged about 25 percent of ferroan dolomite. The quartzitic rocks generally contain a greater amount than the argillaceous ones. A dark-bluish gray, dense dolomite contained only a few percent of quartz and sericite impurities. Beds of this purity are rare.

The carbonate mineral occurs in irregular grains or crystals of rhombic form. The latter are more common in the quartzitic rock where they are as much as 0.2 mm. in size. The usual range in size is from 0.02 to 0.1 mm. The dense dolomite is made up of irregular grains, most of which are under 0.01 mm.

Rust speckles due to the oxidation of an iron-bearing carbonate are common in the more quartzitic rocks. These speckles range in size from 1 to 5 mm. There appears to be a ratio between the size of the speckles and the purity of the quartzite; the more quartzitic the rock the larger the speckles.

Color

The colors of the Belt sediments are different shades of gray ranging almost to black, and pinks, purples and greens. These colors are due primarily to iron-bearing minerals, carbonaceous material, sericite and chlorite. The pink tints are imparted by hematite, which is found in the rocks in exceedingly small hexagonal scales. The various tints of purple are the result of a combination of colors, the red of hematite and green of sericite or chlorite, and the tints of green are from sericite or chlorite or a combination of the two. The various shades of gray are due to extremely minute opaque particles that can be made out only under high magnification. These are probably mostly carbonaceous material. However, in the Prichard they may be in part iron-bearing material, as the rusty staining on weathered surfaces cannot all be explained by the oxidation of iron sulfides.

Rock types

During the field studies, the series of rocks grading from argillite to quartzite were sub-divided into the following types: argillite, siliceous argillite, impure quartzite, fairly pure quartzite, and quartzite. With this breakdown a more systematic description of the rock has been achieved, and these terms are used in the descriptions that follow in the text. It is based upon mineral composition, color, hardness and grain size, all of which are more or less recognizable in the field. The argillites are extremely fine grained, consisting predominantly of sericite, which makes them relatively softer. They are more colorful, being medium to dark shades of gray, or medium to dark tints of purple, or light tints of green. The siliceous argillites are also very fine grained, consisting predominantly of quartz, making them harder than the argillite. They are somewhat less colorful. The impure quartzites are fine grained, consisting predominantly of quartz, a fair proportion of which is in grains of fine size which are coarser than the very fine matrix of sericite and quartz. They usually are light to medium gray in color, but some may have a light greenish to purplish tint. The fairly pure quartzites are fine grained, and are 75 plus percent quartz, most of which is of a fine to medium sand grain size, in a very fine-grained matrix of sericite and quartz. They are usually light gray in color, although some have a pale purplish or green tint. The quartzites are fine grained, are 95 plus percent quartz, almost all of which is of a medium to fine sand grain size, and are light gray to almost white in color. A few are of a pale pink to purple tint. A small amount of very fine-grained sericite and quartz fill interstices in the quartzites.

Lower Prichard formation

The largest area of lower Prichard rock lies east of the Dobson Pass fault, where it forms a part of the southeastern limb of a broad, northeast-trending anticline. These rocks represent the greatest thickness of lower Prichard exposed in the area. An estimate of 5,000 feet for the thickness of this section is fairly accurate, as the structure is relatively simple. At least 3,000 additional feet of lower Prichard is exposed to the north in the Murray area (Shenon, 1938, p. 4). Two other exposures of lower Prichard rock in the area are small; one occurs in the crest of an anticline in Granite Gulch in the northeastern corner of the area, and the other is in the crest of a complex fold bounded on the north by the southern Gem stock and on the south by the Mexican fault.

The lower Prichard rocks in the Canyon-Nine Mile Creeks area range from argillite to muddy quartzite in composition. These range in color from medium to dark gray, with the slaty varieties showing slight bluish hues. In weathered outcrops the rocks usually have a faded appearance, making it difficult to distinguish one type from another. Excellent sections of parts of the lower Prichard are exposed in long cross cuts at the Interstate, Red Monarch and Carlisle mines. In mapping these it was found that a major amount of the rock is a siliceous argillite, with argillite next most frequent. The bedding is fairly regular; individual beds are usually under 12 inches, with the great majority between 2 and 6 inches in thickness. At many places they show faint to good lamination. Pyrite, or to a less extent pyrrhotite, is found concentrated along many bedding partings, or in thin, sandy laminae which are a millimeter or two in thickness. Irregular grains of these iron sulfides may also be sparsely disseminated through the rock. In some places the iron sulfide rich seams are so frequent that the pyrite or pyrrhotite must make up over five percent of the rock.

A well-defined zone of interbedded quartzite and argillite occurs about 3,000 feet below the upper contact of the lower Prichard. Many of the quartzite beds in this zone are fairly pure and light in color. They range up to five feet in thickness and predominate over the argillaceous rock in the upper and lower parts of the zone. In the Red Monarch adit the upper quartzite rich part is 150 feet thick, the central argillite rich zone is 75 feet thick, and the lower quartzite rich part is 100 feet thick; in the main Carlisle adit the similar series of beds have thicknesses of 250, 140 and 120 feet. Similar persistent quartzite zones in the lower Prichard have been found in the Pine Creek area, in the vicinity of Kellogg, and in the Murray area. Whether they are all parts of the same zone is problematical; the location of the zone in the lower Prichard section at the Murray and Kellogg localities is not known, but the Pine Creek occurrence has an estimated additional 5,000 feet of argillite overlying it.

Lower Prichard rocks are usually easily distinguished in the field. A reddish-brown, rusty iron oxide stain, which is mostly due to the oxidation of the iron sulfides, covers most weathered surfaces. This plus the regular bedding, blocky jointing and characteristic lithology distinguishes lower Prichard rocks from the rest of the Belt Series. However, the monotonous similarity of the rock makes it difficult to unravel structure. Many faults have not been recognized because of this, and the direction and amount of movement on others cannot be estimated. This makes valuable any marker beds such as the middle quartzite zone.

Upper Prichard formation

Upper Prichard rocks crop out in a scattered pattern east of the Dobson Pass fault. The largest area is along the northwestern side of the Gem stocks, where they occur in a discontinuous manner, in part as large inclusions within the southern stock. Sharply folded upper Prichard rocks are also exposed in both limbs of an anticline south of the southern stock. In the vicinity of the town of Burke, the top of an irregular domal structure has Upper Prichard beds exposed in its eroded cap, and nearby a wedge shaped area is exposed east of the O'Neill Gulch fault. Upper

Prichard rocks also rim Granite Gulch in the northeastern corner of the mapped area.

This formation consists of a heterogeneous collection of interbedded argillite and quartzite, forming the transition zone between the argillaceous rock of the lower Prichard and impure quartzite of the Burke. But as they are consistent in their heterogeneity throughout the section and persistent throughout the Coeur d'Alene district, they have been split off from the rest of the Prichard. These rocks are well exposed along the crest of the ridge running northwest from Goose Peak, where the following section was measured.

Section from top of Goose Peak northwest along ridge crest

Rock description	Feet
Light- to medium-gray, impure quartzite interbedded with light-gray, purer quartzite. All spotted with green biotite speckles.	127
Burke - Upper Prichard contact	
Laminated light- and dark-gray argillite interbedded with impure quartzite.	23
Light-gray, fairly pure quartzite interbedded with some medium-gray, impure quartzite; some argillaceous partings.	79
Predominantly laminated argillite with interbeds of impure to pure quartzite; mud cracks and ripple marks are common.	86
Interbedded light gray, fairly pure quartzite and medium-gray, impure quartzite; a few argillaceous partings; 12-foot zone of laminated argillite near center.	166
Laminated argillite interbedded with siliceous argillite and some impure to fairly pure quartzite. Shallow water features are common.	47
Dominantly medium-gray, impure quartzite; interbeds of fairly pure quartzite and some laminated argillite near base.	145
Argillite, dark-gray with slight bluish hue interbedded with laminated argillite; a few interbeds of quartzite.	112
Medium-gray, impure quartzite interbedded with light-gray, fairly pure quartzite; all speckled with green biotite spots, a few beds of laminated argillite.	223
Interbedded laminated argillite and argillite, dark- to medium-gray; coated with rusty staining; shallow water features are common.	49
Interbedded fairly pure to impure quartzite with siliceous argillite to argillite; the latter laminated in part; green biotite speckling is common.	268
Dark bluish-gray argillite interbedded with some laminated argillite and impure quartzite; latter is speckled with green biotite spots. Rusty stain occurs on surface.	192
Predominantly medium-gray, impure quartzite; some argillite and laminated argillite.	172

	Feet
Medium-gray siliceous argillite grading down into interbedded impure quartzite and laminated argillite.	94
Medium- to dark-gray, impure quartzite with a few argillaceous partings.	87
Interbedded impure quartzite, siliceous argillite and argillite.	48
Upper Prichard - lower Prichard contact	1,918
Less lower Burke	127
	1,791

About five miles southeast of this locality near Glidden Pass another section of upper Prichard measured somewhat less than 2,000 feet in thickness, which checks closely with the Goose Peak section. However, as already mentioned, some 25 miles to the southwest in the Pine Creek area, the upper Prichard is only 600 to 800 feet thick. In the Libby quadrangle, Gibson (1948, p. 11) noted that the transitional zone between Burke and Prichard was 300 to 500 feet thick. As here defined, the upper Prichard includes those rocks in the transitional zone between Burke and lower Prichard. The upper limit is determined by the first argillite, usually laminated, and the bottom limit is determined by the disappearance of the quartzite.

In the Goose Peak section almost two-thirds of the rock is quartizitic, of which one-third is fairly pure quartzite and the remainder impure quartzite. About two-thirds of the argillite is thinly laminated. The thinly laminated (1 mm. plus or minus) argillite layers become less frequent toward the base. This is also true of the purer quartzite beds. Generally the more quartzitic the rock, the thicker the beds, and some of the purer quartzites are over three feet in thickness. The impure quartzite beds are usually less than one foot thick, and the argillite beds are a matter of inches in thickness. Shallow water features such as ripple marks, mud cracks and pseudo-conglomerates gradually die out downward. Gradational bedding, for thicknesses of a fraction of an inch to several inches is characteristic of the entire section. The reddish-brown rusty surface staining becomes more noticeable towards the base.

The characteristic features of the upper Prichard are the interbedded dark gray argillite and light- to medium-gray quartzite, the finely laminated nature of much of the argillite and the regularity of bedding. The presence of pyrite in fine grain along bedding in the lower parts, and sparsely disseminated crystals or irregular blobs in the upper part are also characteristic. The lack of carbonate-rich beds with their usual rusty-brown weathered rind differentiates the upper Prichard from similar rocks in the upper Wallace formation. The middle quartzite zone in the lower Prichard, with which the upper Prichard might be most easily confused, contains no shallow water features.

Burke formation

The Burke formation underlies almost a third of this region, which is much more than that of any other member of the Belt Series. The largest area of Burke rocks crops out on either side of Canyon Creek from Gem to the eastern edge of the map. It underlies most of the ridge between Canyon Creek and the east fork of Nine Mile Creek and the lower portions of the ridge to the south. The strata usually are at high angles of dip, having been sharply folded or tipped to these attitudes in faulted blocks. Lower Burke rocks are exposed in the trough of a small syncline on the southwestern slope of Goose Peak. They also outcrop east of the Dobson Pass fault north of Beaver Creek and just south of the east fork of Nine Mile Creek. At the latter place the rocks are broken and shattered, and outcrops are few and poor. One of the large xenoliths within the northern end of the southern stock consists of recrystallized quartzitic rock and is undeniably Burke; the other mapped as upper Prichard may also be lower Burke in part.

The best acquaintance with the Burke as well as the Revett and St. Regis formations can be gained from studying an almost uninterrupted section of these rocks exposed in the glaciated country near the head of Canyon Creek. This region is from 2 to 4 miles east of the edge of the map in the vicinity of Military Gulch and Glidden Lakes. The writer assisted S. Warren Hobbs in making detailed measurements of this section in 1947. The thickness of the Burke calculated from these measurements is 2,670 feet. However, this may be off several hundred feet because of displacement along a fault which cuts the section near the center of the Burke formation. A similar thickness was estimated for Burke rocks lying between the Revett, capping Tiger Peak, and the upper Prichard-Burke contact in the Hercules mine No. 5 crosscut. The Burke formation is almost 1,000 feet thicker to the west in the Pine Creek area, where it was measured by Good and Campbell (1952). At the type locality at Burke the rock is faulted to such an extent that no accurate measurements of thickness can be made.

The preponderant rock in the Burke formation is an impure quartzite. The beds are usually from 2 to 6 inches thick and platy in character.

These rocks are typically light greenish gray in color. The basal part of the formation consists of the typical variety with some interbedded, more massive quartzite and fairly pure quartzite. From the base to the center the number of purer quartzitic beds diminishes progressively. Near the center several zones of quartzite as much as 20 feet or more in thickness occur. Some of these quartzite zones have a faint purplish tint, but most are light gray to almost white in color. In going on up in the section, the rocks are found to be more and more quartzitic. Also the individual beds become thicker, being in general from 1 to 4 feet thick. The boundary between the Burke and Revett is a transitional zone several hundred feet thick, and the contact is placed where the massive quartzite beds become predominant. This contact is difficult to determine and is in marked contrast to the relatively sharp upper Prichard-Burke contact.

Some of the more argillaceous beds, even though light- to medium-gray in color, might more properly be classified as siliceous argillite, and some perhaps even as argillite. A 100-foot thick lenticular zone of interbedded dark gray argillite and gray impure quartzite occurs stratigraphically several hundred feet above the upper Prichard contact on the ridge between the head of the east fork of Nine Mile Creek and Granite Gulch. Carbonate-bearing beds are sparsely scattered through the Burke in this area.

An almost universal characteristic of the Burke is the good development of sericite on bedding planes and partings, which gives them a decided sheen. This criteria, plus the general impurity of the quartzite, the platiness of the bedding, shallow water features and the gray color with slight greenish cast, are diagonostic for the lower part of Burke. With the exception of sericite sheen on partings, these characteristics gradually diminish in the upper part, and the predominance of impure to fairly pure quartzite becomes the guiding criteria. Thin interbeds of more argillaceous rock, which are fairly common, help distinguish the upper part from Revett rocks.

Revett formation

As the Revett formation consists mainly of massive quartzite, it is a most resistant rock and forms numerous bold outcrops bordered at the base with talus. Even more characteristic are the piles of scree, formed of blocks of massive quartzite, which cap ridges or trail down their slopes (see pl. 10B). In these forms it is found at, or near, the crest of the ridge south of Canyon Creek and in the small remnant forming the top of Tiger Peak. It also occurs along Canyon Creek for a short distance at the east edge of the map, and is exposed within several faulted blocks west of the Dobson Pass fault in the vicinity of Blackcloud Gulch. Like other rocks at this latter locality, it is badly shattered.

The section of Revett measured on the east side of Military Gulch was calculated to be 2,400 feet thick. However this section is broken by a long dip slope in which there are no exposures, and by a fault of large displacement, so that the measurement is not reliable. Just east of the southeast corner of the map the entire formation is fairly well exposed at the head of a cirque, where it is approximately 1,200 feet thick. This thickness is in close agreement with the estimates of Calkins (Ransome and Calkins, p. 35, 1908) for the eastern part of the district. Some 15 miles to the southwest near the head of the east fork of Pine Creek a measured section is 3,400 feet thick.

The succession of massive light-colored quartzite through much of the formation makes the Revett the most easily recognized unit of the Belt Series in the Coeur d'Alene district. Except for the transition zone at the base and a similar group of rocks at the top it is also the most uniform. The interbeds of fairly pure to impure quartzite at the base rapidly diminish in number within a few hundred feet. Then follows the great bulk of the formation consisting of beds of fine- to medium-grained quartzite, usually from 1 to 6 feet in thickness. The rocks are white to very light gray in color. These in turn are capped by a zone several hundred feet thick containing appreciable amounts of interbedded impure to fairly pure quartzite. Interspersed at rare intervals through the formation are thin interbeds of much more argillaceous rock, some of which has a rust stained rind, indicating a fair carbonate content. Fine, dark laminae, a millimeter or less in thickness, and containing a concentration of heavy minerals, are common in some beds. They are usually spaced an inch or less apart. The well developed cross lamination so characteristic of many of the beds is commonly made more evident because of similar laminae of heavy minerals. Iron oxide speckling on weathered surfaces like those in all the other purer quartzites in the Belt Series is common.

St. Regis formation

The largest exposed area of St. Regis rocks lies west of the Dobson Pass fault and north of Blackcloud Gulch. Much of it is altered so that the characteristic purplish and green hues of the rock appear in an irregular patchy pattern among those which are rusty tan to white in color. In the vicinity of the Dobson Pass fault these rocks are much faulted and shattered. Just to the south of this area a narrow strip of St. Regis, which is faulted off to the north, crops out on the crest of the ridge. Other areas of St. Regis are found in the fault blocks along the crest of the ridge south of Canyon Creek; the largest exposed area here is within a synclinal trough pitching steeply to the southeast.

Because of poor exposures, alteration, and incomplete sections of the rock, a complete understanding of the characteristics of the St. Regis formation cannot be gained in this area. To refer again to the section at Military Gulch, here the entire formation is well exposed and is found to be 1,390 feet thick. However, like other formations of the Belt Series in the Coeur d'Alene district the St. Regis shows a fairly wide latitude in thickness from place to place. In the vicinity of Stevens Lake the formation is at least 2,000 feet thick (Hobbs, 1950, p. 2). At the western end of the district it is even thicker.

Characteristic purplish and green colors have been used to define the boundaries of the St. Regis. Because of this, massive white quartzite beds identical to those in the underlying Revett are interbedded with the purple hued quartzitic rocks in the lower hundred or so feet of the St. Regis. On up in the section, purple argillaceous rocks begin to occur more and more frequently. The lower several hundred feet of the formation is a transitional zone between the quartzite of the Revett and the heterogeneous assemblage of rocks in the remainder of the formation. The great bulk of these rocks are argillaceous, usually thin-bedded or laminated. This is well illustrated by an analysis made by Hobbs (1950, p. 2) of the upper 1,200 feet of the formation measured in the vicinity of Stevens Lake and which follows:

".....approximately 60 percent is classed as argillite containing less than 25 percent of interbedded or interlaminated quartzite; 35 percent is classed as interbedded quartzite and argillite containing more than 25 percent but less than 75 percent quartzite; the remaining 5 percent is classed as quartzite containing less than 25 percent argillite."

In the present mapping program a persistent zone of thinly bedded to finely laminated, greenish to cream-white siliceous argillite has been included in the St. Regis. Formerly it had been included in the overlying lower Wallace. Lithologically these rocks have a closer similarity to the underlying St. Regis, and locally they are interbedded with purplish rocks. Their lamination stands out because of the alternation of cream-white and light-green colors. Some of the beds weather an ocher color due to the oxidation of the included carbonate. This zone ranges from 50 to 450 feet in thickness. Float of this type of rock was found at the top of the St. Regis north of Blackcloud Gulch, but no attempt was made to map it separately because of lack of outcrops and because of its identity has been partly masked by hydrothermal alteration.

The amount of carbonate-bearing beds within the St. Regis varies from one locality to another. In this region they were sparse, whereas in the partial section measured in the vicinity of Stevens Lake many were coated with the tell-tale rusty rind on weathered surfaces.

Locally, lenses of breccia which are in part chloritic in composition have been found within the St. Regis. None of these is exposed within this area.

Many exposures of St. Regis and Striped Peak rocks are identical and cannot be told apart except by their position in the Belt Series section. Both display the same purple, red, and green colors, both are heterogeneous groups of rock, and both contain similar shallow water features. Several characteristics, though, do make parts of them different. None of the massive quartzite beds found near the base of the St. Regis are known to occur in the Striped Peak, and the upper part of the St. Regis is generally more argillaceous than any part of the Striped Peak section. Furthermore the purer carbonate-bearing beds of the Striped Peak are not duplicated in the St. Regis.

Lower Wallace formation

All of the lower Wallace rocks in this area crop out on the western side of the Dobson Pass fault. The narrow, northwest trending block in Blackcloud Gulch is a faulted graben-like segment. To the north a much larger area is exposed in a broad, gently arched structure. The axis of this anticline strikes northwest. The dip of the northeast limb steepens away from the axis, and in the ridge just south of Beaver Creek the lower Wallace rocks give way to the overlying upper Wallace. To the southwest a sharp synclinal flexure brings St. Regis rocks to the surface. This area underlain by lower Wallace is heavily covered by timber and outcrops are extremely rare. Therefore most all of the structural evidence and ideas on lithology are based on findings gained from the underground workings of six prospects scattered along the headwaters of Nine Mile Creek, and from a few outcrops in the Beaver Creek drainage to the north.

No good estimate of the thickness of the lower Wallace could be gained from this area. Furthermore, no complete section of well exposed lower Wallace, not interrupted by faults, is known in the Coeur d'Alene district. However, the greater part of it is laid bare on the northern glaciated slopes of Stevens Peak, about 10 miles to the southeast. Here Shenon and McConnel (1939, pp. 4-5) measured this section between the top of the St. Regis and the summit of Stevens Peak and found it to be 3,270 feet thick. In 1947 S. W. Hobbs, with the writer, measured the lower 1,500 feet of the same section. Their measurements checked well with the earlier work, as far as their study went. Shenon and McConnel did not believe there was a great gap between this lower member and the upper part which they measured at Striped Peak, 7 miles to the southwest, which they found to be 1,400 feet in thickness. They estimated the total thickness of the formation at from 4,500 to 6,000 feet. This would make their estimate of the thickness of the lower Wallace from 3,000 to 4,500 feet.

The Wallace formation, and particularly the lower part, is characterized by minor folding and crumpling over the entire district. Earlier investigators have considered this crumpling to have thickened the formation by as much as 20 to 35 percent. This may well be true where the deformation was intense. At such places the responsible forces may have caused a shortening laterally that would have compensated for the thickening vertically. But in areas of relatively simple structure it is doubtful that such a thickening has taken place. From what has been observed in the field it seems more logical to believe that local thickening by crumpling at one place has been compensated by thinning at others, or at least in part. In this way the cumulative effect has been nil, or only slight, at many places.

The Stevens Peak area is one of relatively simple structure. The rocks are in the limb of an open fold, having a regional dip of 30° to 50°

to the south. Even though the rocks do show crumpling, it is doubtful whether the section has been appreciably thickened. If this is true, the entire lower Wallace must be at least 3,500 feet thick and may be over 4,500 feet.

The lower Wallace as here defined includes only the lower subdivision of the formation described by Shenon and McConnel (1939, p. 5) and conforms fairly closely to the lower two subdivisions that Wagner (1949, p. 12) set up for the St. Joe country to the south. The break from the green argillaceous St. Regis to the alternating argillaceous and quartzitic rocks at the base is usually sharp as is the break into laminated argillite at the top.

Alternating beds of light gray quartzitic rock and dark gray argillite make up a very large part of the lower Wallace (see pl. 12A). Carbonate minerals, almost always in amounts considerably less than the combined quartz-sericite content, are present in most of them. In the section at Stevens Peak which is probably representative of the formation in the district, the lower part is a monotonous succession of such rocks. Most of the beds are under 6 inches in thickness. Some of the quartzitic beds, however, are thicker, a few being from 1 to 3 feet. The alternation of carbonate-bearing argillaceous and arenaceous rocks continues in the upper part, but is interrupted by many zones in which one type of rock predominates. These include zones of quartzite which are impure to fairly pure, and almost all carbonate bearing; zones of argillite, in part finely laminated, and zones of carbonate-rich rock. A few of the carbonate-rich beds are of sufficient purity to be termed ferruginous dolomite. These are dense, bluish-gray rocks which occur in beds up to several feet in thickness. The carbonate-rich zones, some of them tens of feet in thickness, stand out in the cliffs because of the rusty ocherous color of their weathered surfaces.

A feature peculiar to the lower Wallace is the "molar tooth" structures (Gibson, 1948, p. 16 (see pl. 13B). They are irregularly conical or cylindrical masses rimmed with quartz-rich material and with cores of calcite. They are usually from half an inch to 3 inches in diameter and somewhat longer in the other dimension. Their orientation, although variable in some ways, is consistent in that they lie in groups parallel to the bedding. Some are flattened parallel to the bedding and others may be flattened parallel to the plane of fracture cleavage. It is possible they are an original sedimentary feature, but it seems more plausible that their present shape has resulted in part from deformational effects.

The same characteristics typical of the lower Wallace at Stevens Peak are found in the Canyon-Nine Mile Creeks area. The preponderance of carbonate-bearing rocks, the alternation of argillaceous and quartzitic rock, and the crumpling are the same. In addition "molar tooth" structure and shallow water features are also found there.

Upper Wallace formation

The upper Wallace formation is exposed on either side of Beaver Creek at the northwest corner of the mapped area. Here the beds have a general northwesterly strike and dip moderately to steeply to the northeast. They overlie lower Wallace and in turn are capped by Striped Peak, so that the entire section is exposed. However, its estimated thickness, over 3,000 feet, is about double that of the upper Wallace as measured by Shenon and McConnel (1939, p. 5) at Striped Peak. Repetition of part of the formation may occur here due to faulting. Such faults could easily be masked by the alluvium in the valley of Beaver Creek or might occur on to the north where outcrops are scarce. If there has been no appreciable dislocation, a marked thickening has occurred. Credence is given to this possibility by Gibson's (1948, p. 13) remarks that in the Trout Creek and Libby quadrangles to the east and north of here the entire Wallace formation going from south to north thickens from an estimated 7,000 feet to a possible 16,000 feet.

At this locality the most typical rock in the upper Wallace is a finely laminated argillite, made up to a great extent of alternating muddy and more or less sandy laminae, of a millimeter plus or minus in thickness. Their colors range from dark gray for the argillite to light gray for some of the more sandy laminae. The laminated rock gives way at many places to thin-bedded argillite. Intercalated with both the laminated and thin-bedded argillite are some quartzitic layers. The latter are usually carbonate-bearing rocks, as are some of the argillaceous beds. The amount of carbonate-bearing rocks is distinctly less than in the lower Wallace.

The central zone of dark colored, arenaceous, ankeritic limestone in the Striped Peak section was not found here. Such a zone, several hundred feet thick, was found near the top of the upper Wallace in the next ridge north of the mapped area. It undoubtedly occurs here, but was not recognized due to lack of outcrops.

These rocks could most easily be confused with the upper Prichard.

They differ in several ways, however. The upper Wallace has been crumpled on a minor scale throughout, has a rusty brown to buff colored weathered surface where it is carbonate bearing, and is irregularly bedded. In contrast, the Upper Prichard shows little crumpling, is coated with a rusty red stain due to oxidation of iron sulfides on weathered outcrops, and has regular bedding.

Striped Peak formation

The top of the Belt Series in the Coeur d'Alene district, the Striped Peak formation, is poorly exposed at two localities in this area, both along the western edge of the Dobson Pass fault. At the northernmost locality a remnant of the lowest few hundred feet lies conformably on upper Wallace. At the other an elongate block of Striped Peak rocks is bounded on either side by faults that dip at angles of 30° towards one another, giving it a wedge shape. The block bottoms against the fault planes somewhat over 1,000 feet below its top. At neither of these localities is more than several hundred feet of the Striped Peak section exposed. The top of the type section at Striped Peak has been eroded away, leaving the lower 1,500 feet. To the south Wagner (1949, p. 9) measured 2,000 feet of Striped Peak rocks, but again, as at Striped Peak, part of the top has been eroded away. However, to the north in the Libby quadrangle Gibson (1948, p. 16) estimates the thickness of the entire formation at from 2,000 to 2,500 feet.

The most common rock in the Striped Peak formation in this area is a purplish impure quartzite, which grades in color into gray or dark red. It is usually in beds from 1 inch to 4 inches thick and is somewhat flaggy. Not infrequently dark red to gray argillite is intercalated with them.

The argillite occurs in thin beds or as partings between the quartzitic layers. Mud cracks and mud chip breccias occur in many of the argillaceous rocks and ripple marks occur in the quartzitic beds. Many of the rocks are now light green to almost cream in color, due to the bleaching of hydrothermal solutions.

A close similarity to the St. Regis formation is apparent, and individual outcrops could easily be mistaken for it. But the greater overall percentage of quartzitic rock distinguishes it from the upper part of the St. Regis, which these Striped Peak rocks most closely resemble.

Older gravels

The older gravels are so designated because of their location on ridge crests or on higher terraces. These are in contrast to similar deposits on lower terraces bordering the South Fork of the Coeur d'Alene River, which are definitely much younger in age. The older gravels have been found at four widely scattered localities in this area. The highest is at an elevation of about 5,800 feet on the divide just east of Gorge Gulch, where Calkins (Ransome and Calkins, 1908, p. 56) found a number of stray quartzite boulders. In the northeastern corner of the mapped area on the ridge crest north of Beaver Creek, pebbles and cobbles of quartzite were found scattered over the surface for several hundred feet, near an elevation of 3,675 feet. Two small patches of gravel remain on the top of the ridge between the East Fork of Nine Mile Creek and the main stream. The largest deposit caps the ridge between Canyon and Nine Mile Creeks, between elevations of 4,125 and 3,500 feet, for a distance of over a mile, and to widths of 1,500 feet. A number of bulldozer cuts made in the southern end of this deposit expose unconsolidated material ranging from clay and sand to boulders, and show that it is well over 100 feet thick. Although some of the material has been broken down by weathering, most of the purer quartzitic gravel has not been affected. Some rude stratification was noticed.

All of these deposits are from 500 to 1,000 feet above the present neighboring streams. In contrast, those lower and bordering the South Fork of the Coeur d'Alene River are from a few to 200 feet above stream level.

Higher terraces along the St. Joe River, the next main stream to the south, are nearly equivalent in age to the older ones here, as they are around 700 feet above the river. Some of these are capped by remnants of basalt flows, Miocene in age (Wagner, 1949, p. 17) which indicates that the older gravels were deposited during Tertiary time.

Glacial deposits

Several small occurrences of glacial material, most probably Wisconsin in age, are found within the area. The largest is a thin veneer of unconsolidated bouldery debris which extends from below the lip of the cirque on the east side of Tiger Peak down to Gorge Gulch. As observed in several road cuts, it consists mostly of angular fragments of quartzite, generally coarser than cobble size. A small remnant of boulder till lies at a break in gradient in the upper part of Granite Gulch. Fluvioglacial material occurs at two places along Canyon Creek, one at the east edge of the map and the other just below Gem. The one below Gem rims the east side of the valley from the ridge point where the stream turns to the south for almost 3,000 feet downstream. The lower adits of the Formosa, just south of the map, and Verda May prospects both cut this deposit. The first goes through 140 feet of this glacial material before intersecting bedrock, and the second 200 feet. In these workings the material consists of fine angular quartzitic material in a sandy matrix with a few scattered thin lens of sandy silt. It contains none of the argillite that crops out in the adjacent slope above, and is found up to 75 feet above stream level.

All of these deposits are the result of local glaciation. The lack of any evidence in this area of encroachment by continental ice sheets confirms the idea that they terminated farther north (Gibson, 1948, p. 50).

Alluvium

Recent silt, sand and gravel cover the valley floors of Canyon, Nine Mile and Beaver Creeks. Although the thickness of this cover is not known, it is considered to be relatively shallow because of the good gradients of these streams. A veneer of jig tailings was deposited along parts of Canyon and Nine Mile Creeks, but now the thicker and richer portions have been mined.

IGNEOUS ROCKS

In the Coeur d'Alene district all of the igneous rocks are intrusive. They include a number of small monzonitic stocks, and diabase, lamprophyre, monzonite, aplite and diorite dikes.

The two largest monzonitic stocks in the Coeur d'Alene district and several adjacent apophyses crop out within the Canyon-Nine Mile Creeks area, and have been named the Gem stocks. They are the southernmost of a group of such igneous bodies which is aligned along a northeasterly trending zone for a distance of slightly over 9 miles. They extend from Canyon Creek near Gem north to beyond Prichard Creek. About 3 miles west of the southern end of this group is a cluster of similar intrusive bodies. Somewhat similar monzonitic stocks outcrop 18 miles to the southwest along the St. Joe River (Wagner, 1949, p. 17) and 20 miles to the northeast on Vermillion Creek, which is a tributary of the Clark Fork River (Calkins, 1909, p. 47). Whether all have had a common origin or not is questionable, but their good alignment and lithologic similarity would so indicate. They may have been intruded along a zone of weakness not now apparent.

Dark greenish-gray fine- to medium-grained diabase dikes are found scattered throughout the Coeur d'Alene district. However, only three were observed within the area studied. If the evidence found in underground workings is indicative, the dike-like apophyses (monzonitic to dioritic in composition) are numerous around the stocks. Other dikes of similar composition, having no apparent connection with the stocks (e.g., the one exposed in the Interstate workings and the one in the Fourth of July crosscut of the Hercules mine), are undoubtedly contemporaneous with the stocks. Lamprophyre dikes are numerous within the area, but because of the ease with which they weather, they are seen underground or in man-made surface cuts only. A few aplitic dikes cut the monzonite or the sediments near the intrusives.

Monzonitic rocks

The Gem stocks, though the largest igneous bodies in the district, are relatively small in areal outcrop. The southern one, underlying a part of the ridge between Canyon and Nine Mile Creeks and a part of the valley of the East Fork of Nine Mile Creek, is only 2.8 square miles in extent. The northern one, underlying a part of the southern and eastern slopes of Sunset Peak and the upper valley of the East Fork of Nine Mile Creek, is considerably smaller, having an areal extent of only 1.0 square mile. Elongate in a northeasterly direction, they vary in width from slightly over a mile near the south end of the southern stock to a few hundred feet at the north end of the northern stock. Mine workings, which at many places have intersected the contact of the stocks with the Belt sediments, show that they increase in size with depth at a gradual to moderate rate. A comparison of the surface map (pl. 2) and the underground map (pl. 5) will give an idea of this increase.

The contacts of the stocks are irregular, both in gross pattern and in detail. The embayments, projections, apophyses and larger inclusions (the latter undoubtedly in part roof pendants) all point up this fact. Underground one sees an even more intricate pattern in the border zone, where a maze of dikes and apophyses extend out from the igneous rock, and numerous xenoliths occur near the contact. On a still grosser pattern it is evident that all of these stocks are cupolas of the same batholith. Their outcrop pattern, their close similarity lithologically and the findings of an aeromagnetic survey are almost incontrovertible evidence of such a fact.

The complex fold pattern of the Belt sediments at their margin attests the intrusive nature of the stocks. These have intruded the southeast limb of a large anticlinal fold; their trend parallels its axis. The beds of upper and lower Prichard rock which are exposed to the northwest of the Gem stocks in this limb have a general dip of 30° southeast. However, at the margin of the stocks they are intricately folded and nearly vertical in attitude, or even overturned. Near the head of Granite Gulch just the cap of an apophysis of the northern stock is exposed. At and around it, the Burke quartzite has been broken into blocks, some 10 feet or more on a side. Apparently these blocks were jostled about by the intruding magma, since they now are at random orientation to one another. The space between the blocks is filled with monzonite and hybrid rock formed through varying degrees of replacement. The large number of dikes, which are similar in composition to the stocks, plus the type of contact metamorphism in the aureole around the stocks, also indicate the intrusive nature of these rocks.

The manner of intrusion is probably the result of several factors. The folding of the Prichard rocks along the northeast side of the stocks indicates that the magma made room for itself, at least in part, by forcing the sediments aside. The feldspathization of the sediments immediately adjacent to the contact, and the partial digestion of inclusions of sediments (see pl. 16B) show that, in part, it invaded by replacement and fusion. That "overhead stoping" as suggested by Calkins (Ransome and Calkins, 1908, p. 72) is also partly responsible, seems plausible.

The Gem stocks vary both in composition and texture. The great bulk of the rock is a monzonite; from this it grades into syenite and diorite facies. It is usually a somewhat coarse-grained porphyritic rock. However, it ranges from a not uncommon equigranular medium-grained variety to a strikingly porphyritic type, which is a syenitic facies. Because of the lack of outcrops over most of the area underlain by the stocks, and because of the unusually complex nature of the gradations, both in composition and texture, from one kind of rock into another, the varieties have been shown on the map as a single unit.

The usual rock is a massive, light-gray, medium- to coarse-grained monzonite, in which prismatic potash feldspar phenocrysts give it a porphyritic character. Its predominant constituents are feldspar with which are scattered greenish-black hornblende needles. Other minerals that may be present in minor amounts, and which can be discerned without the aid of a microscope, are quartz, sphene, epidote, pyroxene, and a rare flake of biotite. In the fresh rock, usually found underground only, the light gray to flesh-colored unstriated potash feldspar can be distinguished from the milky white plagioclase, but in the weathered surface exposures both have the same dull white appearance. In some places, particularly along the northeast margin of the southern stock, the weathered rock has a dull brownish appearance; this is due to numerous minute specks of rust-brown iron oxide along the margin and along the cleavages of the mineral grains.

The diorite facies, which makes up but a minor amount of the rock, is restricted to the margins of the stocks. Some of the more mafic inclusions are also dioritic. Part of the offshoots and dikes at the margin are made up of diorite. These generally contain a higher mafic mineral content and are therefore darker. Some should more properly be classified as granodiorite, because of their higher quartz content. This latter phenomena is probably the result of partial assimilation of silica-rich wall rock.

Almost a third of the southern stock is syenite. Most of it is at the south end where it underlies almost a square mile between Canyon and Nine Mile Creeks. It also rims the northern part of the same stock, particularly along the northeastern side. Croppings and float of similar rock have also been observed at the northern end of the north stock. The syenite is usually a light-gray, coarse-grained porphyritic rock. Mafic minerals are a minor constituent in this preponderantly potash feldspar rock. However, in some places it grades into a rock in which either hornblende, or hornblende and augite is equal to or dominates over the feldspar.

An interesting type of the porphyritic syenite is that in which the potash feldspar occurs in flat tabular crystals, which measure up to a quarter of an inch in thickness and to as much as two inches in the other dimension. In this type the potash feldspar usually makes up 75 percent or more of the rock. It is well exposed in the old railroad cut just above the point at which the Dobson Pass road starts up grade out of the valley of Nine Mile Creek. Here the feldspar phenocrysts have a markedly preferred orientation.

They strike from west to northwest and dip from near vertical to 35° to the north and northeast. A similar orientation of the feldspar phenocrysts in many other outcrops of syenite at the southern end of the south stock was noted.

The inclusions of hornblende- or augite-rich rock in the syenite vary in size from small clots to bodies which are several hundred feet in length. They are probably partly assimilated xenoliths of Belt sediments, for several thin sections made from them contain granular aggregates of garnet and small remnants of undigested quartzite, which occur both in the groundmass and in the feldspar phenocrysts. These mafic inclusions are rich in the accessory minerals such as titanite, magnetite and apatite. In some, magnetite and titanite may make up as much as five percent of the rock.

Although these monzonite rocks differ in composition and texture, the kinds of minerals in them are the same. It is the varied ratio and size of the grains which causes the different types. The essential minerals are the potash feldspars, orthoclase and microcline, plus plagioclase, hornblende, augite, and small amounts of quartz. Accessory minerals include titanite, magnetite, apatite, zircon, and allanite. Epidote, chlorite, sericite, clinozoisite and actinolite as well as several of the minerals already mentioned are probably deuteric in origin. Other minerals found in some specimens are biotite, muscovite, pyrite, albite and calcite.

Two potash feldspars, orthoclase and microcline, usually make up over 50 percent of the rock. Orthoclase commonly predominates over the microcline. Both occur in the groundmass as well as in the form of phenocrysts, and both vary in shape from irregular grains to well formed crystals. The phenocrysts are typically microperthitic, and contain as much as 30 percent exsolved albite, which is included in an irregular pattern. Inclusions of earlier formed augite, hornblende, plagioclase and orthoclase, which commonly occur as oriented remnants, make it evident that part of the potash feldspar phenocrysts are very late in the crystallization cycle.

The plagioclase (An_{20} to An_{35}), on the oligoclase-andesine border, makes up 20 percent or more of the rock; in the dioritic facies it predominates. The usual subhedral grains vary in size from a fraction of a millimeter to as much as a centimeter. Many of the larger grains are zoned and the more calcic centers are intensely clouded by alteration. A large proportion of unzoned grains are also clouded, although to a much less degree. Almost all show good albite twinning. Some of the grains are irregularly indented by potash feldspar; all that remains of others are remnants within the potash feldspar.

Hornblende is the most consistently numerous mafic mineral, usually making up at least five percent of the rock and in a few of the darker inclusions it predominates. Its characteristic occurrence is in elongate prisms a few millimeters in length, which have a well developed six-sided cross section. They have corroded edges and in many instances are only skeletal, having been partly replaced by potash feldspar, magnetite, chlorite and epidote. A faint green augite is present in minor amounts as remnants or irregular grains in much of the rock. In some of the porphyritic syenite it is the only mafic mineral present. Some of the augite has been partly replaced by hornblende, in which it can be observed as remnants; to a lesser degree it has been replaced by a bladed actinolite, chlorite or epidote. The grains are usually a millimeter or more in size. Flakes of biotite, usually at least partly replaced by chlorite, are of rare occurrence.

Of the accessory minerals, titanite is the most common, in some instances it makes up from 2 to 3 percent or even more of the rock. Characteristically, the titanite occurs in well developed lance-shaped crystals, ranging in size from a fraction of a millimeter to 2 or 3 mm. Next most common is magnetite, which occurs in small irregular grains or octahedral crystals. A few small hexagonal prisms of apatite were observed in all the slides, and in some they were quite numerous. Zircon in doubly terminated prisms less than a millimeter in length was occasionally observed under the microscope, and an irregular grain of allanite was seen here and there in some of the thin sections.

Secondary minerals of a probable deuteric origin are universally present. Sericite, in minute flakes, clouds much of the plagioclase, particularly the more calcic centers of the zoned variety; it is also scattered through some of the potash feldspar. Present also are clinozoisite, in granular aggregates replacing feldspar; epidote, in the same form replacing both the feldspar and mafic minerals; and chlorite replacing augite, biotite and to a minor degree hornblende.

Quartz is usually a minor constituent making up only a few percent of the rock; specimens taken from the marginal parts of the stock are the only ones having a higher percentage. The latter are granodioritic and may well be hybrid types. The quartz occurs, interstitially among the other minerals, as small irregular grains, or in a myrmekite of which the host is small orthoclase grains on the margins of the potash feldspar phenocrysts.

Some of the syenite and, to a lesser extent, the monzonite contain minor amounts of small irregular albite grains, which rim or indent the margins of the potash feldspar phenocrysts. Pyrite is common in the vicinity of ore deposits, where it replaces hornblende and magnetite. Granular aggregates of a pink garnet were observed in some thin sections, but these are probably within hybrid rocks. Calcite, occurring in small amounts in veinlets which cut all minerals and replace some, is undoubtedly very late.

Replacement and alteration phenomena are clearly in evidence throughout the rock of the Gem stocks, and are most probably due to deuteric effects occuring very late in the magmatic stage. The most striking of these is replacement by the potash feldspar phenocrysts of earlier hornblende, plagioclase, orthoclase, and quartz, remnants of which can be seen poikilitically included within the large grains of orthoclase and microcline or embayed by them. The albite both in the perthitic arrangement in the phenocrysts and as small grains along and embaying the large grains of potash feldspar, and the myrmekitic quartz and orthoclase in a similar arrangement, are all probably related to the same late processes. All of the accessory minerals are found enclosed within the potash feldspar phenocrysts, but with the exception of the titanite and magnetite, which probably formed relatively late in the magmatic sequence. The titanite and magnetite are different in that some are enclosed within pyroxene and hornblende, and, at least in part, are considered early in the sequence.

The most clearly deuteric minerals, probably hydrothermal in origin, and most likely formed after consolidation of the magma, are epidote, chlorite, clinozoisite and sericite. The epidote is seen replacing the feldspar or ferromagnesian minerals as small invading veinlets or granular aggregates. Chlorite encroaching on the ferromagnesian minerals and to a minor degree on the feldspar has clearly resulted from alteration; the sericite and clinozoisite have similarly replaced the feldspar. Pyrite in the stock rocks is restricted to the vicinity of the ore deposits and is logically considered to have been formed at the same time as the ore bodies.

Whether the minerals discussed above under deuteric effects are the result of endomorphic changes of a post-magmatic stage as suggested by Anderson (1949, p. 179) is questioned, as the field evidence favors more strongly the above suppositions. If potash-rich emanations had invaded the stocks after they had become solidified, and had brought about such profound changes right out to their borders, it is hard to believe that the adjacent country rock would not exhibit similar effects. No evidence of any such changes could be found in them. Furthermore, the preferred orientation of the potash feldspar in the porphyritic syenite is most plausibly explained by flowage of the magma before it had entirely crystallized; further evidence is that they do not show any strain effects.

Whether the gem stocks are outliers of the Idaho batholith or not is a matter of conjecture. Most authors have so considered them, but

Anderson (1951, p. 597) believes them to be of a different petrogenic province. Analyses of rocks from the Idaho batholith and the Gem stocks, which are given on the following page, differ in some respects. These differences are not so great, however, that they might not be explained by differentiation of a common source magma, or by a change caused by the partial digestion of the rock invaded.

Analyses of rocks from Gem stocks and Idaho batholith

	1	2	3	4
SiO_2	61.41	58.53	69.15+	69.56
Al_2O_3	17.99	16.85	14.49	15.29
Fe_2O_3	2.93	3.49	.93	.86
FeO	1.39	2.37	2.62	2.06
MgO	1.20	1.46	.42	.69
CaO	4.75	3.93	2.14	2.81
Na_2O	4.01	4.05	3.84	3.97
K_2O	4.59	7.12	3.98	3.36
H_2O-	.11	.12	.20	(.86
H_2O+	.68	.49	1.47	(
TiO_2	.53	.71	.30	.55
P_2O_5	.19	.24	.10	.16
SO_3	.05	.04	—	—
MnO	.16	.19	—	—
BaO	.11	.10	—	—
SrO	.14	.14	—	—
	100.24	99.83	99.64	100.17

1. Ransome and Calkins, 1908, p. 47, Quartz monzonite from near Gem, Coeur d'Alene district, Idaho. G. Steiger, analyst.

2. Ransome and Calkins, 1908, p. 49. Porphyritic syenite from near Bradyville, Coeur d'Alene district. G. Steiger, analyst.

3. Ross, C. P., 1934, p. 37. Idaho batholith, quartz monzonite from Mayfield Creek, Casto Quadrangle, Idaho. J. C. Fairchild, analyst.

4. Lindgren, Waldemar, 1900, p. 81. Idaho batholith, granitic rock, Shafer Butte, Boise County, Idaho. G. Steiger, analyst.

Diabase dikes

Only three diabasic dikes were observed in this area. Others are undoubtedly present, but as they weather relatively easily, they have escaped attention. One is along the Ruth fault at Blackcloud Gulch, another is along the San Jose fault near the West Star workings, and the other is exposed in the Verda May prospect. The largest, along the Ruth fault, is up to 50 feet wide and has been traced for 2,400 feet. Where exposed in the No. 2 adit of the West Star, the one along the San Jose fault is 20 feet wide. The diabase dike in the Verda May prospect averages less than five feet in thickness. All have been intruded into fissures along which there has been subsequent movement, and, in the case of the Ruth and San Jose faults, the later movement may have amounted to hundreds of feet. The dikes along the San Jose fault and in the Verda May prospect strike east-west, and the one along the Ruth fault strikes N. 70° W. All dip to the south or southwest from 70° to 75°. This similarity is striking, but these three are far too few examples for generalizations on attitude.

The rock in these dikes is a fine- to medium-grained green diabase. All of it shows some chloritic alteration, with that in the dike in the Verda May prospect intensely chloritized. Calkins (Shenon, 1938, p. 9) describes similar diabase rock consisting predominantly of zoned plagioclase lathes (An_{55}-An_{20}), which are now mostly saussuritized. It also contains augite, now mostly replaced by a pale amphibole, rather abundant slightly greenish-brown biotite enveloping ilmenite, and some needles of apatite.

Monzonite and diorite dikes

A number of dikes, dioritic to monzonitic in composition are found in this area. Their geographic location and composition show them to be offshoots of the monzonitic stocks. The porphyritic monzonite dike exposed in the Interstate-Callahan mine is an almost exact replica of the predominant variety of the stocks. It varies from 10 to 40 feet in width, has an average strike of east-west, and dips from 65° to 70° N. In the lower part of the mine it divides the Interstate vein into two parts, cutting across it at an acute angle. The dike is pre-ore since veinlets of sphalerite penetrate it, but later faulting along the dike has offset the vein over 100 feet (McKinstry, 1942, p. 229). The more dioritic varieties are exemplified by the dike exposed in the Fourth of July crosscut on the No. 5 adit level of the Hercules. It is also porphyritic, but the plagioclase makes up more of the rock than the potash feldspar, and hornblende is more abundant. Similar dikes much closer to the stocks occur in the Tamarack, Rex, Nipsic and Ambergris workings.

A rather unusual monzonite dike occurs in the ridge just south of Beaver Creek near the west edge of the map. It is a gray porphyritic rock with a fine groundmass. Although it is not apparent in the hand specimen, microscopic inspection shows that it has been largely altered to a mixture of albite, clinozoisite, epidote and chlorite. The phenocrysts are up to 2 millimeters in size and make up almost half of the rock. They were originally mostly orthoclase, but are now albite clouded with sericite and clinozoisite. Hornblende in small prismatic needles, which made up about 20 percent of the rock, is now almost entirely replaced by a mixture of epidote, sericite, and chlorite. The groundmass is a felted mass of the alteration minerals. Small crystals and grains of magnetite are a common accessory. Less common are titanite, apatite, and allanite.

Aplite dikes

Aplitic dikes cut all the intrusive rock types and extend out into the sediments. They are characteristically a fine-grained, whitish, sugary rock. Mineralogically they differ from the monzonite in that they have a higher quartz content, contain minor amounts of muscovite, and have almost no mafic and accessory minerals in them. They are equigranular rocks in which the mineral grains are usually under one millimeter in size. All the aplite dikes seen were small in size, being less than 12 inches in width. They could be traced for only a few tens of feet. A typical aplite dike cuts monzonite above and to the west of the Success mine. In it orthoclase, in irregular microperthitic grains, makes up half of the rock. Plagioclase (An_{25}) in clouded grains, microperthitic microcline, and quartz are present in nearly equal amounts. A few percent of muscovite in irregular shred-like flakes makes up the remainder. Calkins (Ransome and Calkins, 1908, p. 46) reported that the stocks are cut by some pegmatite dikes. The only one observed was a small dike-like body, associated with quartz veins, which occurred in metamorphosed sediments near the edge of the southern stock.

Lamprophyre dikes

A large number of dark-colored, fine-grained dikes, which are characterized by either biotite or hornblende phenocrysts, have been observed underground and in surface cuts. The relative ease with which they weather has precluded the probability of seeing them in many natural outcrops. Although the one in the Black Bear and Black Bear Fraction workings was over 20 feet in thickness, they usually are less than five feet thick. Individual dikes are apparently seldom over a few hundred yards in strike length. Like ore-shoots, they tend to branch, split, and occur in groups in an echelon pattern. Shannon (1921, p. 478) noted that they were most numerous in the Prichard and that they became progressively scarcer in the overlying rocks. In the Canyon-Nine Mile Creeks region the same generalization can be made, but this may be more apparent than real as most of the mine workings are within older rocks. They apparently are more numerous where the structure is complex, which here coincides with an area underlain by older rocks.

In mapping underground it has been found that a large majority of the lamprophyre dikes strike near N. 20° W. and dip steeply to the southwest. This makes the angle between the dikes and a great number of the veins about 50°. This fact indicates that a different set of stresses was in effect during the forming of each group. The lamprophyre dikes are clearly younger than the ore deposits as they have been observed crosscutting veins in the Rex and Black Bear Fraction workings. Ransome (1908, p. 35) and Shannon (1921, pp. 480-492) also noted that they cut the ore at a number of deposits, among them the Hecla, Frisco, Standard-Mammoth and Marsh. The most discussed of these dikes cuts the Hecla ore body; it was intruded along the shoot, and replaced part of the ore. Sometimes it was found on one side, sometimes on the other, or in the middle, and persisted ~~through~~ through the entire ore body.

During field investigations the lamprophyre dikes were divided into two groups. In one biotite phenocrysts were the dominant mineral; in the other it was hornblende. Usually these are the only two minerals that can be determined megascopically, but coarser grained varieties in which the feldspar is evident have been observed. Microscopic inspection shows that they fall into three types depending upon the ferromagnesian phenocrysts and the dominant feldspar. The groundmass of the biotite-bearing rock is characteristically potash feldspar-rich, whereas the groundmass of the hornblende-rich rock may have either plagioclase or orthoclase predominating. From specimens studied it appears that those in which orthoclase predominates far outnumber the plagioclase varieties. To indicate more clearly their relationship it is better to call them biotite and hornblende syenite lamprophyre, and hornblende diorite lamprophyre rather than minette, vogesite, and spessartite.

The biotite and hornblende phenocrysts stand out from the fine-grained groundmass and usually range in size from somewhat less than 1 up to 2 millimeters. The orthoclase in the syenitic varieties is usually in irregular grains. It sometimes contains inclusions of other minerals, is less than a millimeter in size, and not uncommonly has a rolling extinction. The plagioclase occurs in small irregular lathes, usually poorly twinned; it may be zoned, varying in composition from labradorite out to oligoclase. Other minerals common to many of the dikes are: augite, which is usually in part altered to chlorite; diopside, which occurs less frequently than augite but which is similarly altered; olivine, which is almost without exception replaced by other minerals, such as antigorite, talc, magnetite, and in one specimen by an iron-stained aggregate of calcite and quartz (see pl. 23); quartz, which occurs in rounded grains which are probably foreign particles of the country rock; and accessory crystals of magnetite and apatite. In some, the groundmass is partly glassy. Shannon (1921, pp. 483-485) noted a selvage sample as being glassier and finer grained than the central portion of a dike in the Marsh mine.

STRUCTURE

The complexity of the pattern of folding, faulting, and cleavage over much of this area is well illustrated by the mapping. The Belt Series has undergone a great amount of deformation, from which the intrusives have not escaped; they have been shattered, sheared and displaced along numerous faults. The amount of disturbance in a large part of this area is greater than that which is found in much of the surrounding country. This center of disturbance roughly coincides with the occurrence of alteration and larger mineral deposits.

A part of the deformation, particularly the faulting, was observed underground only. Some of these structures would have escaped detection. Because of the lack of outcrops over large areas, the sameness of lithology throughout great thicknesses, and the obliteration of diagnostic characteristics of the sediments by widespread alteration, the position and attitude of many of the faults and folds could have only been inferred. The regions containing few mine workings and those in which outcrops are rare, such as that underlain by Wallace along the northwestern edge of the mapped area may have a somewhat more complex structure than depicted. Even so, this region would not compare in complexity of structure with the altered and mineralized areas. Mapping and reconnaissance in the surrounding country, parts of which are well exposed, has borne out the belief that simplicity of structure generally means lack of mineral deposits and alteration.

Only those faults which appeared to be persistent laterally for several thousand feet or more, and along which the movement was considerable, were plotted on the maps. Likewise, numerous local folds have not been shown.

Folding

Folding has played an important but not the dominant role in the deformation of the Belt sediments in the Canyon-Nine Mile Creeks area. Many small irregular folds occur in the region, none of which however can be traced for much more than a mile. An exception to this is a large open anticline, a part of whose southeast limb lies along the eastern edge of the Dobson Pass fault. The majority of the folds have a north to northwesterly trend, but the strike of others lies in the northeast quadrant. The heterogeneity of their trends is indicative of the many different stresses brought to bear on the rocks of the region.

The oldest traceable deformation of Belt sediments in northern Idaho was the forming of north to northeastern trending large open folds. A part of the southeast limb of an anticline, which is mentioned above, is the best representative of this period of deformation in the Canyon-Nine Mile Creek area. It continues north more than 10 miles beyond the edge of the map, trending N. 35° E. Later disruption by the intrusion of the stocks and subsequent folding and faulting has masked it in part. Even so, it is evident that this fold continued to the southern edge of the map. The anticline exposed in Granite Gulch at the northeast corner of the map is probably a subsidiary fold formed by the same compressive forces. It pitches to the south and dies out near the head of Gorge Gulch. The same holds true for the ill-defined syncline between these anticlines. Before later disturbances altered the structural picture, this large anticline and its satellites probably occupied the entire area, as the rocks became progressively younger towards the southeast.

With the intrusion of the stocks, bordering Belt rocks were contorted and folded. This deformation is well illustrated underground in a number of workings including the Success, Rex, Nipsic, Laclede, Gem, and Frisco, where the border zones are exposed. At the Rex, where lower Prichard rock is exposed at many places for almost 1,500 feet along the contact with the stock, the beds trend from east to northeast, in general more or less paralleling the edge of the stock. The folds are tight as the beds usually dip at angles greater than 65° and are overturned in some places.

The asymmetrical syncline along the northern edge of the northern stock is the largest fold that might be ascribed to intrusive forces. For most of its length the syncline strikes about 65° E., roughly paralleling the edge of the stock. The limb next to the stock is decidedly steeper than the one to the northwest. This fold may be older than the Puritan fault as it extends south for a short distance beyond the fold. The shallow syncline whose axis coincides with the top of Tiger Peak also may have been formed at the time of intrusion.

A domal structure along Canyon Creek at Burke dips away in all directions in an irregular manner, being decidedly steeper to the east. As the attitude of the bedding is similar on opposite sides of the faults that cut it, the dome must be older than the faulting. The northeastern corner is warped into a small sharp anticline, which underground mapping has shown up much better than surface work (see pl. 5).

Some folds are restricted to individual fault blocks and are believed to be contemporaneous with the faulting. The best example is the well developed syncline bounded by the Frisco, Banner, and Standard faults. No continuance of it to the north and west beyond the Frisco and Banner faults is evident, and the abrupt change in attitude of bedding across these breaks is striking. To the east the attitude of the bedding on either side of the Standard fault is somewhat similar, so that the evidence is not so clear cut. The syncline dies out to the south as the Frisco and Standard faults diverge. This evidence is believed to indicate that the fold was formed during the period of movement along the faults.

The anticline south of the southern Gem stock ends abruptly against the Mexican fault. Again it is more logical to believe that the fault and fold came into being more or less at the same time, rather than the fold being formed earlier.

Other folds have no definite relationship to other structural elements and thus may have occurred at most any time during the period of structural disturbances.

Cleavage

Cleavage, which is so widespread in the Belt rocks of the Coeur d'Alene district, has resulted from two different sets of circumstances.

One was the compression of the rocks into folds, and the other was widespread shearing. Under both circumstances a true cleavage was formed in some of the argillaceous rocks. The rock, which has a true cleavage, will split along numerous parallel planes, because of the good orientation of the sericite flakes. In most of the rocks, however, the cleavage is not so well developed; in them it is a false cleavage, and the rocks split along certain planes only. The associated quartzitic rocks are jointed, or sheared.

The cleavage formed during folding is described as fracture, or false cleavage and flow, or axial plane cleavage (Billings, 1946, and Hills, 1940). The fracture cleavage which has developed along the limb of the folds and is most common. Its strike is parallel to the axial plane of the folds, but its dip differs from that of the axial plane; their intersection is at an acute angle. The dip of the fracture cleavage is most commonly steeper than that of the beds, where the beds are right side up; where the beds are overturned, the reverse is true. The axial plane cleavage develops parallel to the axial plane, near the crests of the folds.

In the Canyon-Nine Mile Creeks area the cleavage, which has resulted from folding, is not so widespread or as well developed as in adjacent areas, particularly in those to the south (Hobbs et al, 1950, p. 8). Here most of the compressed folds are restricted to areas in which quartzitic rocks outcrop, which probably accounts for the poor development of, or even lack of, fracture cleavage.

Shear foliation or cleavage occurs in two settings. One is local, being restricted to definite zones of shearing or accompanying faults. The other is regional in distribution, and may show no relation to earlier folds or faults, which it may cross without any deviation from the general attitude. The latter type is the most interesting in this area. It has one dominant trend, varying from about N. 30° W. to N. 60° W., and generally dips between 60° SW. and vertical. It is most highly developed in the southeastern corner of the mapped area along the crest of the main ridge between Canyon Creek and the South Fork of the Coeur d'Alene River. Here the more argillaceous varieties of the St. Regis have been changed into a purplish phyllite, which at places exhibits a true cleavage. The quartzites of the lower St. Regis and upper Revett are also foliated. In them, however, a shear has developed in a succeedingly grosser pattern with an increase in quartz content in the rock. This knot of intense deformation is elongate in an indefinite pattern parallel to the strike of the foliation, and it decreases in intensity to the northwest and southeast. To the southwest it apparently dies out in a series of small tight folds. But to the northeast it ends abruptly against the O'Neill Gulch fault; little or no similar effects can be seen in the Burke rocks on the east side of it. Shear foliation with similar attitudes occurs on to the northwest beyond the stocks.

As the folding took place during several periods of deformation, the accompanying cleavage likewise was formed at different times. The shear foliation must be relatively late as it cuts across many other structures.

The fracture cleavage is unusually helpful (Shenon and McConnel, 1940, p. 440) in determining tops and bottoms of beds. However, care should be taken in using cleavage to make such determinations; a false interpretation could result from using shear foliation.

Faulting

Faulting has been the major result of the deformation in this area. There are numerous persistent faults along which the movement has been in hundreds or thousands of feet. However, these larger ones are relatively few in comparison to those along which the movement may be measured in inches to tens of feet. The mapping of thousands of feet of underground workings has made this fact apparent. One also realizes how pervasive the stresses must have been.

The faults in this area are unusual in several respects, and their mode of origin is perplexing. Both normal and reverse faults are abundant. They are also interspersed, one among another. Furthermore, those of reverse movement are steeply inclined; most of them dip at angles of 60° or more. In addition, the largest, the Dobson Pass fault, is normal in movement with a low angle of dip of around 30°.

The high-angle reverse faults and the low-angle normal fault have come into being through stress systems different from the usual ones set up within the earth's crust. Hubbert (1951) has demonstrated and supported by good evidence that the average dip of reverse faults is near 25° and that the average of normal faults is near 60°. Billings (1946, p. 188) has pointed out that the forming of a reverse fault formed by thrust movement, with an angle of dip of more than 35°, is impossible, as the force necessary to move the thrust block would be beyond the crushing strength of rock. If horizontal pressure had played an important part, the disruption along the reverse faults would be markedly greater than on the associated normal faults formed due to tension. From numerous observations no appreciable difference was apparent in the amount of gouge and shear along these two kinds of faults. The possibility that the high-angle faults are essentially a strike slip variety, as one might conclude from Anderson (1942, pp. 12-20), does not seem likely for most of them. The irregularity of their strike and their relative shortness horizontally, together with a noticeable lack of buckling of the strata, rules out this hypothesis. A possible exception is the Mexican fault, where a fold on the north may be due to a strike movement along the fault. The stresses responsible for the pattern of steep reverse and normal faults must have been due to forces, the large component of which was vertical. The movement along these faults was intermittent and it continued over a considerable period of time. Because of the variety of stresses that affected them, the movements were undoubtedly in many directions. The cumulative movement, however, must have been mostly along the dip, with varying degrees of obliqueness. If this hypothesis is correct, the reverse and normal faults need not have come into being through a sequence of the reverse faults first, during a period of compression, followed by the normal faults later, during a period of relief and tension. Generally the field evidence supports a contemporaneity between the two types, although those with a west to northwest trend, which are mostly normal, probably came into being somewhat later than the north-trending faults.

Much of the adjustment along these faults is probably related to the large horizontal displacement along the nearby Osburn fault. A movement of as much as 12 miles, with the south side moving west in relation to the north side, has been suggested (Umpleby, 1924). Calkins (Ransome and Calkins, 1908, p. 73) has noted that the Dobson Pass fault, where the dip is low and the movement much extended, cannot be explained by the force of gravity alone. The differential movement along the Osburn fault at least offers a partial answer to how the Dobson Pass fault may have formed. The mechanics were right for setting up the great tension necessary for the formation of the Dobson Pass fault.

No strict division of faults by age can be made. They do, however, fall into two groups based on strike directions. One has a near north trend and the other a west to northwest trend.

North striking faults

A group of near north-trending faults are the most persistent and largest in the area. These are the Dobson Pass, Puritan, Frisco, Standard and O'Neill Gulch faults. Along two of these, the movement has been normal, and along the other three, it has been reverse. Although no positive proof can be found, most field evidence suggests that they are the earlier faults in the area. This is based primarily on their persistence, as well as on the fact that no evidence could be found of their off-setting the many faults that end against them. Of the others having the same general trend, some are probably contemporaneous, but still others are considered to be either older or younger.

Dobson Pass fault

The most notable structure within the area is the Dobson Pass fault, along which the movement has been normal and which has a dip of about 30°.

It has been easily traced across the mapped area, continues for a mile beyond the edge of the map to the south to its termination against the Osburn fault, and was mapped an additional four miles to the north by Calkins (Ransome and Calkins, 1908, p. 64). This makes it at least 10 miles long.

The Dobson Pass road, going over the divide from Nine Mile Creek to Beaver Creek, crosses the fault nine times in five miles; the fault shows up in the road cuts at all of these crossings. It has also been intersected in the workings of the Panhandle mine, and in the east crosscut of the Nine Mile Mining Company. It was also cut by a vertical diamond drill hole from the 800 level of the Dayrock mine. From this evidence, as well as other good surface indications, its position and attitude are well established. The surface trace is highly irregular, but this is due to the fault's low-angle of dip and the uneven relief along its course. Upon projection to a horizontal plane (see pl. 5) the strike is found to be nearly north to Beaver Creek, where it turns sharply to a N. 40° W. trend.

At one place the youngest and oldest formations of the Belt Series are in contact across the fault. This mutual relationship between lower Prichard and Striped Peak, however, is in part due to another low-angle normal fault to the west, along which the now remaining wedge of Striped Peak rocks were dropped down to the east. This fault is older than the Dobson Pass fault for it ends abruptly at their intersection. Discounting this older fault, upper Wallace would be in contact with lower Prichard here, so the vertical displacement amounts to at least 14,000 feet. The amount of movement decreases towards the south.

The rock in the hanging wall of the fault is shattered and broken, and to some extent it is sheared for many hundreds of feet away from the fault. This is particularly true of the quartzitic rock of the Revett and St. Regis formations to the north and south of Blackcloud Gulch. At some places this shattering is intense; a bulldozer cut below the Panhandle workings exposed Revett quartzite so shattered that it can be pulverized in the hand. Across Nine Mile Creek in the workings of the Dayrock mine the brecciation gradually dies out to the west. In the footwall, the lower Prichard in the vicinity of the fault is contorted and folded, and the monzonite is shattered and sheared. The shattered condition of the rock in the hanging wall, as well as the contortion of the lower Prichard and shearing of the monzonite in the footwall, substantiates the belief that the fault is due to much more than the force of gravity alone. It is wondered if the cohesiveness of the rock in the hanging wall was great enough to keep it from rupturing as it moved down off the footwall block. For this reason the suggestion is made that the footwall block was the active one, and that the motion was rotational on a fault plane that steepened with depth. However, no evidence was found to show any increase in dip.

Puritan fault

The Puritan fault, so named in the workings of the Tamarack mine, is about four miles long. It has been traced with a fair amount of confidence from its convergence with the Standard fault north beyond the mapped area. At the southern end it strikes about N. 20° W. and dips 55°-60° NE. From this it changes to a north strike and vertical attitude at the northern edge of the map. In the Tamarack workings it is normal in character, with Burke dropped down on the east. To the north, however, because of the position of the monzonite in the hanging wall, it would be more logical to conclude that the movement was reverse. The contact of the stock must have dipped inward here, for farther north, displacement of the contact between upper and lower Prichard also is normal. This is the same fault that McKinstry (1942, p. 228) described as the Wallace fault in the Interstate-Callahan mine.

Mine workings make it possible to follow the fault as its surface trace is questionable for long distances. At the southern end, the Puritan fault has been cut on most levels of the Tamarack mine and, in addition, is exposed on the 200 and 1,200 foot levels some distance from the veins. The lack of metamorphism of the sediments along the contact of the stock farther north is indicative of the fault. However, there is no question of its presence, as the Interstate 1,500 foot level adit follows along it for 900 feet, and cuts it again 2,000 feet farther north. Some 4,000 feet north of the Interstate workings it is cut again on the 1,000 foot level of the Idora, about 200 feet in from the portal. Occasional marked changes in the attitude of bedding and shattered rock in a road cut are the only evidence to mark its surface trace in the intervening distance. Beyond the map's edge on the north side of Beaver Creek recent bulldozing has exposed a probable extension of the Puritan fault.

The Puritan is one of the few large faults along which any mineralization occurs. At the Tamarack mine, ore minerals occur along the fault over a vertical distance of more than 1,000 feet. Locally, they were in sufficient concentrations to be mined. In the lower part of the mine the ore deposits are in the footwall, but in the upper part they are in a different group of veins in the hanging wall. Any post-ore movement is considered to have been small.

Frisco fault

The Frisco fault is named after the Frisco mine where the veins end against it on the east. On to the north it is exposed in the No. 4 adit of the Black Bear mine and near the portal of the main adit of the Black Bear Fraction. In all of these workings it shows up as a strong structure. It contains 6 to 18 inches of gouge and a number of small subsidiary faults and shears which occur for several feet in one wall or the other. On to the north across Canyon Creek, what is most likely its continuation is evident from the great contrast in the attitude of the bedding on either side of the fault. There is also a marked change from hydrothermally altered rock on the east to unaltered rock on the west. A pit on the crest of the ridge between Canyon Creek and the East Fork of Nine Mile Creek has been dug into the sheared zone along it. The fault is again picked up underground where it is crossed by the No. 5 adit and 200 level of the Tamarack mine. The manner in which the block of upper Prichard wedges out indicates that the Frisco ends against the Puritan fault on the north, near the knob just south of the portal of the Interstate-Callahan 1500 level. South of the Frisco mine no evidence could be found to show that it continued beyond the Star fault, thus its length is about $2\frac{1}{2}$ miles.

The average strike of the Frisco fault is N. 5° E., but due to irregularities it varies from N. 20° E. to N. 10° W. In the Frisco workings the fault has an average dip of about 85° W., but in the Black Bear Fraction the dip is 80° E., and at the Tamarack it is 70° and 65° E. At the southern end the movement is apparently not much over 100 feet, but on to the north it must be many times that to account for the large duplication of Burke rocks. Like many other cross faults along which veins end, the Frisco fault is pre-ore in age. The south (Frisco) vein strikes near N. 65° W. and ends abruptly against the fault, but the North vein curves from a position almost parallel to the South vein to one almost parallel with the Frisco fault, showing that the North fissure was formed contemporaneously with the fault. Furthermore, the associated Gem fault had ore deposited along it.

Standard fault

Because of the obvious discordance in the attitude of the bedding of the upper Prichard rock on the east and Burke rocks on the west, the Standard fault is most evident at the surface where it crosses Canyon Creek. This relationship continues on the same trend for 1,000 feet to the south, and because of marked changes in dips of Burke rocks the fault can be followed farther. It must die out shortly beyond, however, as no evidence could be found to indicate that the break continued into the cirque at the head of the gully which was eroded along it. Few surface indications could be found to the north of Canyon Creek, but its position is well established by the many exposures in the Standard-Mammoth mine, and again on the 1200 and No. 5 tunnel levels of the Tamarack. From plotting the position of the fault in the underground workings, it is seen to strike into the Frisco fault at the north. As no trace of the

Standard has been found beyond the Frisco fault, it must end at their junction. Thus the Standard fault is estimated to be about 12,000 feet long.

The strike of the Standard fault averages about N. 30° W. along an irregular trend. Through the Standard-Mammoth workings it consistently dips 75° NE., and the dips are similar in the Tamarack mine. The movement has been reverse with the maximum vertical displacement at least 500 feet at Canyon Creek and probably somewhat more to the north. Where exposed in the No. 5 tunnel of the Tamarack, the fault contains 12 inches of gouge and the rock is sheared for 8 feet. Ransome (1908, pp. 119-121), who named the fault, wrote that in the Standard-Mammoth mine it contained 5 inches of dark clay gouge, with 10 to 12 feet of sheared quartzite in the hanging wall. He also stated that the evidence strongly suggested that the fault was older than the ore deposit, and thus acted as a dam at the eastern end of the Standard-Mammoth lode.

The mutual relationship of the Standard, Frisco and Puritan faults is peculiar. The manner in which they join--the Standard against the Frisco, the Frisco against the Puritan, and the Puritan against the Standard--suggests that they are more or less contemporaneous. However, it would seem more logical if the wedge of upper Prichard between them had been brought into its present position by reverse movement along the Standard and Frisco, and later isolated by subsidence of the block to the east of the Puritan.

O'Neill Gulch fault

The O'Neill Gulch fault, so named by Calkins (Ransome and Calkins, 1908, p. 64), is another of the strong north-trending structures in the area, extending beyond the boundaries of the map in both directions. To the south in a short distance it apparently swings into a northwestern trending structure. To the north, however, its probable extension forms a fault contact between monzonite and Prichard rocks about two miles down Granite Gulch from the edge of the map. Altogether it may be considered to be at least 8 miles long.

The strike of the O'Neill Gulch fault changes abruptly from N. 30° W. to almost north at the junction with the cross fault from the Standard fault, and continues from there with a northern trend to the north. It is a steep reverse fault, which was observed to dip 75° E. in the Tiger-Poorman mine (Ransome and Calkins, 1908, p. 173); to the south the dip is similar in part of the Hecla workings, but at the above mentioned junction with the cross fault the dip steepens to vertical. In the Ajax workings to the north the dip is not known as the fault is tightly lagged.

Because of the irregularities in strike, the displacement along the fault must have been mostly up dip. This amounted to over 3,000 feet vertically at the southern end of the map where altered Burke is in contact with unaltered but sheared St. Regis. At Canyon Creek, where the bedding is almost as steep as the fault, a large section of Burke is duplicated and some upper Prichard exposed. The movement here must have been almost as great. At the head of Granite Gulch, however, the displacement is only a few hundred feet at most.

No other fault in the area is so well expressed by the topography. The streams in Granite, Gorge and O'Neill Gulches follow closely along the fault's surface trace, and saddles mark where it crosses divides. In Granite Gulch the O'Neill Gulch fault coincides with the axis of the anticline exposed there.

Ransome (1908, p. 173) noted that the Tiger-Poorman vein ended against the O'Neill Gulch fault, and that there had been some post-ore movement along it. Other similar relations indicate that the fault is pre-ore and acted as a dam to the ore solutions.

Other north striking faults

Among the lesser faults of this group are the Russell and Gertie faults east of and parallel to the O'Neill Gulch fault. They dip 85° W. or counter to the O'Neill. They also are reverse in nature, as they cut out about 500 feet of Burke. This reverse movement is also substantiated by steepening of bedding at the faults. The Gertie is the much more persistent one, and therefore the one along which the movement was probably greater. It continues south beyond the edge of the map, and the Cougar and Elite faults apparently end against it. If the next fault to the east, which parallels these two, has a similar dip, it is normal in character. It ends against a northwestern-trending fault, and therefore may be later in the sequence.

The Fraction and Gem faults, just west of the southern end of the Frisco fault, are apparently supplementary to that fault. They have similar attitudes and the direction of movement has been the same on all three. The attitude at which they have been found at a number of places in the Gem and Frisco workings, indicates the probability of their joining south of these mines. Furthermore, only one fault was found along their trend in the adjacent Betty Lou workings. Farther south this fault must die out, as no trace of it could be found south of the Star fault. The Frisco and Gem faults apparently die out a short distance north of Canyon Creek. The Gem fault has had ore deposited along it for a short distance, showing that along with others of this group, it is pre-ore in age. The Fraction fault acted as a dam on the east for the Fraction ore body.

The Carlisle fault at the northern edge of the map also may belong to this group. It strikes N. 20° W. and dips 75° SW. The movement along it is reverse and has amounted to approximately 200 feet. On the main haulage level of the Carlisle mine the fault has been drifted along for almost 1,400 feet, where 6 to 36 inches of clay gouge and sheared rock are found along it. Sulfide minerals associated mainly with quartz, but also with some siderite, occur in short lenticular shaped bodies which are found either in the hanging wall or in the footwall of the fault. Although there has been some post-mineralization movement, the relatively unshattered condition of the quartz and sulfides indicates it has been minor.

A group of north trending, normal faults, including the Zanetti, Upper and Lower Murray, Haff, and an unnamed one to the east, lie just west of the Dobson Pass fault at Blackcloud Gulch. They have been intersected in the Dayrock and California mines and associated workings, where their dips have been found to range from near vertical to 50° W. They are believed to be contemporaneous with one another and their accumulated movement has amounted to well over 1,000 feet. As two of them, the Upper and

Lower Murray, displace the Ruth fault, they are considered to have been formed at a relatively late stage of the deformation. A logical conclusion is that they have resulted from the movement along the Dobson Pass fault. Some of them cut either the California or Dayrock ore bodies. There has been some post-ore movement, but this is apparently small.

The fault, bounding the western side of the Striped Peak rocks exposed along the Dobson Pass road in the northwest corner of the map, has already been mentioned. It strikes about N. 20° W. and dips 30° NE. Undeniably older than the Dobson Pass fault, it may well be the oldest fault in the area.

West-northwest striking faults

The west-northwest striking faults are the more numerous group, but they are generally less persistent than the others, and the displacement along most of them is less than along the larger north trending faults. As a group they are considered to be younger than the north trending ones. The large majority of these faults dip 60° or more to the south or southwest, and the movement along most of them has been normal. A few which are exceptions either dip in the opposite direction or the movement along them has been reverse. Superficially the Banner fault, the cross fault between the Standard and O'Neill Gulch faults, and the Cougar fault, appear to be displaced segments of an older fault. However, this is impossible; the cross fault dips in the opposite direction, and the Cougar and the Banner are probably normal faults, whereas the cross fault is reverse in nature.

The Elite and Cougar faults in the southeastern corner of the area, which strike west and N. 70° W., undoubtedly join before ending against the Gertie fault on the east. The large offset of the rocks makes the Cougar fault apparent at the surface, but the only evidence of the Elite is sheared rock on the dumps of two prospects along it. They both, however, are strong structures where they have been cut in the Gertie workings. The movement along the Cougar fault is normal and the vertical displacement must be near 1,000 feet. The movement along the Elite is probably in the same direction, but considerably less in amount.

The San Jose, Mexican, Commander, Star, and Omaha faults form a contemporaneous group near the southern edge of the area. They are all normal and the rocks are successively dropped down to the southwest along them. They vary in strike from N. 45° W. to west and in dip from 60° to 85° SW. or south. The 60° bend in the strike of the Star fault might be questioned if the true relations were not so evident in the Black Bear Fraction workings. At the sharpest bend in the curve some adjustment has taken place by bedding plane slips on to the northwest, but the main break swings to the southwest. Southeast beyond the edge of the map the Star fault and Star-Morning vein are coincident for some distance. Here some post-ore movement has occurred, but again the major displacement was probably pre-ore. Where lower Prichard is in contact with Burke along the Mexican fault, the vertical displacement is at least 2,000 feet; the movement on any one of the others was not more than a few hundred feet.

The Oreano and Mart faults together with a number of other northwest to west-trending faults lie north of Canyon Creek between the Standard and O'Neill Gulch faults. Along three of these, which are exposed in the Hercules crosscut, the movement has been reverse; along all the others it has been normal. With the exception of just one, all of these dip to the southwest or south at angles greater than 60°. The displacement along any one of them has probably not amounted to more than a few hundred feet. The Mart fault cuts off the ore shoots at the Sherman mine on the west. What may be a continuation of the joined veins to the west contains mostly quartz, pyrite and hematite. The fault apparently acted as a dam to the later lead and zinc carrying solutions.

The Silver Star and Blackcloud faults in the southwest corner of the area west of the Dobson Pass fault are both reverse faults. The Silver Star strikes west and dips vertically to 85° south; the Blackcloud strikes N. 65° W. and dips steeply southwest. The Blackcloud is by far the larger structure. It continues for more than three miles beyond the map, and the displacement along it is at least 2,000 feet, whereas the Silver Star is not much more than two miles long, the displacement along it being only a few hundred feet. The Ruth fault just north of these two is normal in movement. It strikes N. 70° W. and dips 70° SW. The maximum vertical displacement along it must be at least 1,000 feet. All three of these faults apparently end against the Dobson Pass fault.

In the Coeur d'Alene district a number of sliver-like blocks of rock lie between more or less parallel faults along which the movement has been in opposite directions. However, in so far as the writer is aware, the block of upper Wallace rock between the Blackcloud and Ruth faults is the only one that is graben-like in form. All the others are horsts.

Structural interpretation

In order to interpret the structure found within this area it is necessary to go afield and examine the pattern that may be observed there. The dominant structural element of the entire adjacent region is the Osburn fault, which lies from 1 to 3 miles south of the Canyon-Nine Mile Creeks area. It trends about N. 75° W. and dips almost vertically to the south. Down-dropped to the south with an apparent maximum vertical displacement of over 8,500 feet, it is a sheared zone several hundred feet wide with multiple planes of movement rather than a single break. The Osburn fault has been traced for 35 miles to the west-northwest (Anderson, 1940), and for a further distance to the east-southeast, making it one of the major breaks in the earth's crust. A large number of faults subparallel to the Osburn occur within the next 15 miles to the south, and most have a similar attitude (Hobbs, 1950, p. 6, and Wagner, 1949, p. 37). The majority of these, including the largest and most persistent, the Placer Creek and St. Joe faults, are normal faults, but interspersed among them are others reverse in nature. The major folds within this same region have nearly the same trend as the faults.

Immediately north of the Osburn fault the great majority of the structures are still nearly parallel to it, but within a mile or so these either end or change to a more northern trend. This change takes place in the southern part of the Canyon-Nine Mile Creeks area. From here, for a number of miles to the north, the major structures, both folds and faults, have a northern trend, varying from north-northwest t• north-northeast.

The Osburn fault has been considered to be a large tear slip with the horizontal component amounting to about 12 miles. This large displacement is based on the matching of somewhat similar structure and lithology on either side, and is substantiated by the relationship to it of the adjacent faults to the south. Many of these join at small angles, as if formed by tension caused by the movement along the Osburn fault. The northeast block has moved to the southeast in relation to the southwest block.

Some of the structural elements north of the Osburn fault appear to be the older ones. This is particularly true of the large open folds, especially if credence is given to their matching on opposite sides of the Osburn fault. Similar structural relationships exist along the Hope fault, 50 miles to the north. Whether north-trending faults were next in the sequence is not nearly so clear, but it is logical to believe some were intitiated by the same compressive forces that formed the folds.

The sequence for the remaining structural events is much more uncertain. If the horizontal movement along the Osburn fault is as large as suggested---and the evidence seems to be convincing---the deformation in the adjacent country, including the Canyon-Nine Mile Creeks area, probably resulted from the same stresses that caused it. The movement must have been intermittent and continued over a considerable length of time. Although these stresses must have been similar for the greatest part of this time, at intervals they had to be different to cause the complex structure that has resulted.

Whether the stocks were intruded after much of the structural disturbances of the region had taken place is not clear. Their parallelism with the earlier northeastern trending folds would seem to be more than a happenstance, and indicative of the fact that they were at least intruded after this early folding. The evidence is good that some of the folding is related to their intrusion, and undoubtedly some of the faulting was also caused by it. The fact that they are cut by the Dobson Pass and Puritan faults shows that they had been emplaced and solidified long before the deformation was completed.

The persistent north trending faults probably were formed first, with the west-northwest trending group subsequently coming into being. However, intermittent movement along the faults continued throughout the period of deformation. The diabase dikes, intruded into early breaks, have had later faulting along them. That there was post-ore movement along the north trending faults is a well established fact. In addition some movement has occurred along many veins since the deposits were formed. Even some of the lamprophyre dikes, the latest igneous rocks to be intruded, are sheared and faulted.

The bleaching alteration might be interpreted as being pre-faulting in age because of its abrupt ending at some faults. A good example of this occurs at the Frisco fault. For almost half a mile the fault forms a sharp boundary between altered and unaltered rock. The trend of the alteration here is at a large angle to the fault. For this reason it is highly doubtful that the movement was great enough to bring unaltered rock into the relationship shown. Furthermore, the mineralization is believed to have occurred as a somewhat continuing phase of the alteration, and no large post-ore movement along faults is evident.

There is no good evidence that any faulting has occurred since the present physiography was formed. Furthermore, most of the movement along the faults probably had ceased before the period of erosion during which the country was worn down to the level of the accordant summits of the present ridge crests. With the beginning of the present cycle of erosion the country must have been raised a considerable distance, as the bottom of the valleys are usually 3,000 or more feet below the present summit levels.

The sequence of events suggested by the evidence is as follows:

1. Formation of north trending folds and probable starting of some north trending faults.
2. Beginning of movement along the Osburn fault and some of the other faults.
3. Intrusion of monzonite stocks with related disturbances.
4. Continued faulting, folding, and shearing, much of it after the solidification of the intrusives; intrusion of diabase dikes.
5. Hydrothermal alteration; disturbances still continuing; setting up of system of west-northwest tension shears and fissures, in which mineral deposits were formed.
6. Continued faulting; setting up of a system of N. to N. 20° W. fractures dipping steeply to southwest into which lamprophyre dikes were intruded.
7. Faulting and other disturbances continue; erosion of country down to accordant level of present ridge crests.

8. Regional uplift; faulting apparently minor.

9. Rejuvenated erosion which was temporarily disturbed by flooding of valleys by basalt flows in mid-Miocene time.

Recent age determinations made of uraninite from the Sunshine mine in the Silver Belt of the Coeur d'Alene district (Kerr and Kulp, 1952, p. 87) indicate that it is 750 million years old (late pre-Cambrian). This uraninite comes from veins that are younger than the major deformation in the Coeur d'Alene district, as they cut the large overturned Big Creek anticline which lies just south of the Osburn fault, south and west of the town of Osburn. This would make the deformation, the intrusion of igneous rocks, and the mineralization pre-Cambrian in age. This differs sharply from the usually held idea that they occurred in late Mesozoic to early Tertiary time.

In spite of this new data the writer believes that the age of the deformation, the related igneous intrusion and formation of the ore deposits is logically Laramide (late Mesozoic to early Tertiary). Eardley (1951, pp. 308-314) has shown rather conclusively that the Coeur d'Alene area lies well within the region affected by both the Nevadan and Laramide orogenies. It is difficult to understand how this area could have remained relatively undisturbed through these two great periods of deformation. If the uraninite is the same age as the veins that contain it, this must be the case, as there has been little disturbance since the veins were formed. If the age determinations are correct, it is more likely that the uraninite in the veins has resulted from the reworking of pre-Cambrian deposits by later solutions.

REGIONAL METAMORPHISM

Regional metamorphism, though relatively slight, has affected all the rocks to some extent. The quartz has been recrystallized to angular grains in which the original rounded form is rarely observable under the microscope. Much new sericite must also have been formed. Chlorite, which is mostly a product of this metamorphism, is a minor constituent of many rocks. The accumulation of ankeritic dolomite, or some closely allied carbonate, into irregular patches which dot most of the purer quartzites probably took place during the same time. Their presence is startlingly apparent on weathered surfaces, where the oxidation of the carbonate results in a rusty speckling. Magnetite and ilmenite were also newly formed or enlarged, as the octahedra and irregular particles are up to 0.5 mm. in diameter, which is much larger than the associated quartz grains. Tourmaline in elongate prisms and rosettes larger than the associated grains is of the same history. The pyrrhotite in the lower Prichard may have been formed at the expense of pyrite during the regional metamorphism.

Heat and pressure must have played the dominant role in transforming the deeply buried sediments, but the effects of dynamic forces are also evident. In many thin sections of argillaceous rocks, reorientation of the sericite flakes is apparent. They now are parallel to directions of ease and are at angles to the bedding. The deformation was great enough to cause a slaty cleavage to develop in some of the more deeply buried Prichard rocks. South of Burke, in the vicinity of East Grouse Peak, shearing of sufficient force has changed argillaceous St. Regis rock into purplish phyllite. In the same general area deformed and tightly folded quartzite is cut by an anastomosing net of quartz veinlets, the formation of which must be related to the same dynamic forces (see pl. 11B).

CONTACT METAMORPHISM

Contact metamorphism around the stocks and of the inclusions of country rock engulfed within them is mainly due to the effects of heat. Immediately adjacent to the intrusives, however, the sediments have been feldspathized for a distance which can be measured in inches, or at most, a few feet. The rocks grade imperceptibly from the metamorphosed sediment into the igneous rock with a gradual change in mineral assemblage.

Within this feldspathized rock plagioclase usually dominates over the potash feldspar. Recrystallized quartz is plentiful. The reddish-brown biotite and colorless muscovite of the metamorphosed sediment has been replaced by hornblende and augite. Aggregates of a light reddish garnet in irregular grains are found in some thin sections. Sphene, magnetite, and zircon occur in this selvage; the sphene is abundant enough in some places to make up several percent of the rock. A colorless diopside is present at places and was particularly noticeable in the selvage zone around carbonate-rich rock in the large western inclusion at the north end of the southern stock. Such minerals as epidote, clinozoisite, chlorite and sericite are also present, all having the same secondary relationships as observed in the igneous rocks.

The effect of the magma on the Prichard and Burke sediments, around the Gem stocks, grades from marked changes near the contact to a mere coarsening of the mica within a few hundred feet. Even in the most argillaceous rock, little or no change can be detected at distances of

1,000 feet or so from the contact, and in the purer quartzites the effects grade out much more rapidly. In spite of the general lack of good outcrops a marked irregularity in the contact aureole is evident. This probably is mostly a reflection of the irregularity of the outline of the intrusives, although the type of rock invaded and its attitude are contributing factors. The only effect of the metamorphism on the purer quartzites is to recrystallize them, which coarsens the grain, giving the rock a sugary appearance.

The first change, found farthest from the stocks, is the recrystallization of the sericite into muscovite, which gives the rock a micaceous sheen, particularly on partings. Next is the development of biotite which has light-brown to reddish-brown pleochroic colors. It forms in aggregates of irregular plates, replacing the muscovite and, apparently to some extent, the quartz. These speckle the rocks or form as layers. The argillaceous rock near the contact, which has undergone the most intense metamorphism, contains garnet, andalusite, sillimanite, zoisite, and hornblende, in addition to the micas and recrystallized quartz. These new minerals usually occur in aggregates of irregular grains in a patchy or banded appearance, apparently replacing both the micas and quartz. Garnet is relatively rare, but where observed it is in aggregates of irregular grains which are brownish-red to almost colorless in transmitted light. Andalusite is found in irregular grains, some having a faint red pleochroism. Much of this mineral contains inclusions of quartz. It is a common mineral in this zone, and where abundant imparts a pinkish color to the rock. Sillimanite occurs in short needles which are in plumose arrangements, in wavy bands through the rock, or in felted masses in the quartz grains. Zoisite is in colorless fine-grained aggregates. Hornblende, which is relatively rare, occurs in patches of irregular grains. It exhibits a light-green to almost colorless pleochroism and has the characteristic amphibole cleavage. Minerals that occur in minor amounts in the sediments such as zircon, tourmaline, and magnetite or ilmenite are also found in the metamorphosed aureole. The zircon apparently is unaffected, as it is found in the usual minor amounts throughout, commonly as inclusions in the other minerals. In the more highly metamorphosed rocks, tourmaline and the black opaque oxides of iron and titanium are rare.

The effect of the intrusives on carbonate-bearing rocks extends much farther from the contacts. This has been observed in the northwest corner of the mapped area, near the head of the small tributary which flows north into Beaver Creek along the extreme western edge of the map. Here lower Wallace rocks have been changed to a fine-grained banded green hornfels. The nearest exposed monzonitic stock is fully a half mile to the west beyond the edge of the map. The rocks consist predominantly of muscovite and quartz, recrystallized from the same original minerals, and newly formed diopside, hornblende and green biotite. The varying abundance of the latter three minerals gives the rock its banded green appearance.

Most of the contact metamorphic rocks are best described as hornfels, although some have schistose characteristics. They range from fine to medium grain with many having a granular texture. Many of the rocks have a pseudo-schistosity due to concentration of different minerals in bands paralleling the lamination. Others, however, have a well-developed foliation due to orientation of the mica flakes parallel to bedding. At a few places a decided sheen parallel to cleavage indicates a foliation in that direction. From this evidence it would seem that stresses were not too important factors during the period of contact metamorphism.

ALTERATION

Several types of hydrothermal alteration have left their effects on the Belt sediments in the Coeur d'Alene district. The most widespread has been given the name "bleaching", as its most apparent effect on the rocks is to change their darker hues to pale green tints, even where the alteration is obviously slight. A marked chloritic alteration (Hobbs, 1950, p. 9) is found in the rocks at the Atlas mine near Mullan. It also occurs in several narrow east-west zones for a mile or so to the east and west of the Atlas mine. So far as is now known, it is restricted to that locality. In the underground workings of a number of mines surrounding the Gem stocks, still another kind has been found, which is typified by the presence of green biotite, chlorite, and garnet.

The bleaching that has been investigated and reported upon (Shenon, 1939, Sorenson, 1947 and 1948; Hobbs, 1950) lies within an east-west zone a mile or more wide and 10 miles long. It lies just south of the Osburn fault, and extends from Big Creek east to the Montana border. This is within the Silver Belt and its eastward extension. Here the intensity of the alteration varies from a slight phase, in which there has been a mere loss of color, to one in which all the sedimentary features are obliterated. The resulting rock is a green phyllite appearing rock consisting almost entirely of sericite. The changes in the rock have been attributed to sericitization and the introduction of iron-carbonate minerals, predominantly siderite, and, to a lesser degree, of pyrite and quartz. The alteration closely parallels the structure, having worked out from faults, shear zones, and in some places along bedding and cleavage. Thus the alteration occurs in an anastamosing pattern enclosing blocks of unaltered rock, large and small. Mapping, both underground and on the surface, shows that this alteration tends to fan out upward. A lessening of pressure has probably allowed a more widespread permeation of the hydrothermal solutions near the surface. Recently in his work on the alteration problem, Mitcham (1952) doubts that there is any appreciable enrichment in sericite in the altered rocks.

An alteration, similar in most respects to the bleaching, has been mapped in the Canyon-Nine Mile Creeks area. Its areal extent is shown on an overlay sheet to the surface map (pl. 4). By necessity the outcrop pattern on this overlay sheet is diagrammatic. It is a gross pattern, because of the lack of detail in mapping and the paucity of outcrops. The difficulty of differentiating between alteration and regional metamorphism has made it impossible to draw definite boundaries. The largest area of altered rocks lies in the southeast quarter of the map. On the west they are bounded in part by the Frisco fault. This zone has a general northwest trend except where it extends north along faults, particularly the O'Neill Gulch fault. The next largest area lies west of the Dobson Pass fault in the vicinity of Blackcloud Gulch, where it has spottily affected rocks ranging in age from Burke through Wallace. On to the north the faulted wedge of Striped Peak rock west of the Dobson Pass fault is bleached in several places. The only area of contact metamorphic rocks affected lies within the small zone along the northwestern edge of the northern stock.

Most of the bleached rocks in this area are quartzitic sediments of the Burke formation. These, plus some Revett quartzite and upper Prichard rocks, exhibit varying degrees of the alteration. At the surface the most noticeable effect is the brown staining by iron oxide of the weathered rocks. Blocks as much as a foot thick are permeated with a rusty stain; talus areas and scree slopes of such rock show a marked contrast to the gray and white quartzite of unaltered areas. Such weathered rock has a punky appearance, and gives a hollow sound when struck by a hammer. In some areas the quartzite has a tan to dead white appearance, and here brown staining occurs along joints, fractures and bedding planes (see pl. 14A). A common weathering feature of these rocks is a brown limonitic staining an inch or so thick bordered on the interior by narrow red hematitic selvage (see pl. 14B). In some of the more argillaceous rocks the same tell-tale greenish color of the usual bleaching is apparent. Underground where the rocks are not weathered, this light greenish color is the most apparent effect, but a thin rusty rind on much of the rock is also typical. The more argillaceous the rocks, the more apparent is the alteration.

In studying thin sections, no evidence could be seen to indicate an appreciable addition of sericite. However, a small amount may have been added through the alteration of the feldspars, no trace of which could be seen in the altered rocks. A noticeable change in the rocks was the alteration of the black opaque minerals. A cream-colored opaque, which is probably leucoxene, has replaced most of them. The porousness of the weathered rock must be due to the leaching of iron carbonates that were present, but are now gone; the iron staining remains as evidence.

It is believed that the greatest change effected by the alteration was the introduction of iron carbonates and leaching out of iron. Here, as elsewhere in the district, the bleaching occurs in areas of complex structure, and is usually more noticeable adjacent to faults and their related disturbances. A relationship between the alteration and ore deposits exists to the extent that they occur in the same general area. However, many ore deposits are outside bleached zones, or at least in part so. Apparently the bleaching preceded the ore deposits by an interval sufficient to allow the opening of some additional new fractures. These together with older ones became the channelways for part of the ore solutions.

Over and beyond the contact metamorphism in the Belt rocks surrounding the stocks are changes undoubtedly due to hydrothermal solutions. On the outer fringes, as much as a mile from the nearest contact, a black speckling is evident at many places in the more quartzitic rocks. These dark speckles are a millimeter or two in size. Nearer the contact the rock is darkened by splotches or layers parallel to the bedding. In the most intense phase the entire rock is dark in color; along fractures or bedding plane partings, a reddish garnet has formed in layers usually less than a centimeter wide. In addition a narrow bleached seam on either side of the break, or parting, through the center of the garnet layer, is common at many places. The dark color is imparted by a biotite, green in transmitted light which replaces both sericite and quartz. It apparently preferably starts forming around magnetite or ilmenite. In places the biotite in turn is partially replaced by chlorite.

The areal distribution of this type of alteration indicates a relation to the stocks, as it has been found in their general vicinity only. However, it does not occur in a uniform halo around them, being entirely absent at some places, and at others extending far beyond the usual effects of contact metamorphism. The more intense phases have been seen underground only, in the vicinity of the ore deposits, and mapping indicates a spatial relationship between the two. There is also a suggestion that this type of alteration is found in greater intensity around the lower portions of some ore bodies than in the upper portions. However, more mapping needs to be done to confirm this relationship. Biotite, garnet and chlorite are found in replacement selvages along a number of the sulfide-bearing veins, which indicates close relationship to the ore deposits. It is probable that the solutions responsible for the silicates were forerunners of the metal-bearing ones. It is also a possibility that these solutions were one and the same, and that as physico-chemical conditions changed, sulfide minerals were deposited. But the much more widespread occurrence of the silicate mineral replacement indicates that the solutions responsible for them were of a more permeating character than those responsible for the sulfides.

As will be elaborated upon in the section on contact metamorphic deposits, evidence indicates that this alteration occurred after the stocks, as presently exposed, had solidified. An explanation that seems plausible is that the stocks, hydrothermal solutions and ore deposits had a common source, and that the disturbances caused by the emplacement of the stocks and, still later, by the deformation around them formed the channels which the later silicate-forming fluids and ore solutions followed.

NOTES ON THE ORE DEPOSITS

The Coeur d'Alene mining district has had a rich and interesting history, dating back to 1882 when gold was discovered along Prichard Creek near Murray.. The first lead-silver mine opened was the old Tiger at Burke in 1884. In the years that followed, the camp developed quickly and by 1890 the value of the metal produced annually was over $4,000,000; by 1900 it was over $10,000,000; and in 1949 it was $50,700,000. Production from the rich but small gold placers and lodes in the Murray area soon dropped to minor importance. Within a few years lead and silver became the important products, to be joined by zinc in 1905. During the period of 1903-1915, when the Snowstorm mine was active, copper was an important commodity; as a result of the discovery of more silver-copper ore in the Silver Belt, it is now resuming its importance.

As has been the case in the rest of the Coeur d'Alene country, great mines have come and gone in the Canyon-Nine Mile Creeks area. The Tiger-Poorman, Standard-Mammoth, Hecla, Interstate, Success, Marsh, and Sherman are inactive or worked on a small scale only. Periodically the surface dumps or gob within some of the mines are reworked. The Hercules and the Frisco have again become active mines, after being dormant for years. These two, plus the Tamarack, Gem (a part of the original Helena-Frisco), Dayrock, Amazon, Success, and various properties on the Sunset vein system now furnish the bulk of the ore produced in the area.

The following table summarizes much of the information on the properties in the Canyon-Nine Mile Creeks area that have produced at one time or another. In addition to the total production of the mines, the table presents data on the size, shape, attitude, and position of the lodes in the mines. Many interesting comparisons can be made, based on the data. The preponderance of lead to zinc in most of the mines is apparent. Before 1905, however, no attempt was made to save zinc, and since then the emphasis in some mines has been to mine out the more valuable lead-silver ore. What the table does not show is the general increase in the amount of zinc recovered, in comparison to lead as the depth of mining increased. In every case the vein or shoot is longer vertically than horizontally. The general similarity in the strike of the veins is noticeable. Although the veins may dip in either direction, almost all are steep. One of the most interesting and puzzling features of the deposits is their relation to one another spatially in the vertical plan. The Hecla has worked almost down to sea level, whereas the nearby Sherman bottomed almost 5,000 feet above that.

Description of ore deposits

Ore deposits in the Coeur d'Alene district are characteristically replacement veins in fractured and sheared zones along which the movement has been relatively small. Some ore bodies are attributed to fissure filling or at least in part to fissure filling; others replace beds, usually in a disseminated pattern; and another has been described as a contact metamorphic deposit (see discussion that follows); still others have been considered transitional between the contact deposit and replacement veins. Some deposits occur in and along major faults, but these are in the minority. The known ore deposits in the Canyon-Nine Mile Creeks area are replacement veins, of which some may be in small part due to fissure filling.

District wide, the variations in mineral assemblages, both in ore minerals and gangue, are notable. The deposits include ones in which gold, gold-tungsten, lead-silver, lead-zinc-silver, copper, silver-copper, silver-lead-copper, and antimony are or were of prime importance. The amounts, ratios, and kind of gangue minerals present also vary from deposit to deposit. Siderite, or ankerite, which has usually been considered the characteristic gangue mineral in Coeur d'Alene deposits, is not always dominant; in many, quartz, which is universally present, bulks much larger and siderite may be absent or present in only minor amounts. Pyrite is always present in varying amounts. Sericite is a common associate. Pyrrhotite, barite, garnet, green biotite, and chlorite are present in some deposits. As has been pointed out (Umpleby, 1923, p. 19) the variations in mineral content are probably in part explained by continuing disturbances during the period of deposition, causing the damming of some channels. Others remained open, consequently varying concentrations resulted. Another factor, dependent in part on the above, is the amount of replacement of one mineral by another or others that took place during the period of mineralization. Zoning has also played an important part in the variations. More than one period of mineralization is indicated at the Success by one shoot in which the sphalerite was much lower in iron than the marmatitic variety found in the other associated ore bodies. Almost all of the gradations in the ratios of lead, zinc, silver, and copper are represented in different deposits or different parts of deposits within the district, and the same is true for the gangue minerals, all of which strongly indicates a common source. The gold and gold-tungsten deposits of the Murray region and the scattered antimony veins may have no relation to the others, but may be the result of differentiation at the source. All of the Canyon-Nine Mile Creeks deposits are of the lead-zinc-silver variety; in some, lead is the chief commodity, whereas in others it is zinc.

The ore occurs in tabular bodies which are best described as lodes. They are irregular both in plan and section and are generally steeply dipping (70° plus). However, they may flatten at minor rolls or in a few instances have a gentle inclination over the entire ore body. In most instances they are longer in the vertical plane than in the horizontal, and although irregular, the rake varies only slightly from 90° in the plane of the structure. In most of the lodes the ore is not restricted to any one fracture or shear, but forms numerous seams within a zone of nearly parallel, irregular breaks and shears, most of which do not have much continuity. Individual ore seams pinch and swell in an irregular fashion both horizontally and vertically, and although they may attain widths of several feet, they are usually only a few inches wide. Some seams have enlarged into bonanza proportions, as at the Hercules, where a large amount of rich lead-silver ore was taken out; others were selectively mined in some of the deposits in the early days. The amount of country rock included within the vein may bulk large. Horses large enough to cause splits in the vein have been found. Other irregularities, such as branches and parallel or en echelon lodes are not unusual. The individual ore shoots within a lode show the same irregularities. They vary in horizontal length from 100 feet or less to over 2,000 feet, and in vertical length from a few hundred feet to over 6,000 feet. The width of shoots varies from 2 feet plus or minus up to over 50 feet, with the great bulk averaging between 5 and 10 feet. The boundaries are usually vague, depending in many instances upon the frequency and size of the ore filled seams. In others, however, one wall or another will be a sharp boundary limited by gangue or a slickensided surface. Although irregular, the great persistence of many deposits in length, both horizontally and vertically, and in width, has made the Coeur d'Alene district a large producer.

The primary ore minerals, which are important production-value wise, include galena, sphalerite, tetrahedrite, and to a much lesser degree, chalcopyrite. A large number of other minerals, both primary and secondary, have been listed by Ransome (1908, pp. 90-103), and still others are described by Shannon (1926) and Willard (1941).

Ore controls

Structure has been a prime factor in location of ore deposits in the Coeur d'Alene region. District wide, it has been found that areas of complex structure are more favorable loci than those of gently dipping rocks which contain few faults. As has already been stated, however, the great majority of the deposits do not lie along the major faults, but in the associated minor fractures and shears along which the movement has been relatively small.

A great number of veins strike from west to northwest, more or less parallel to a part of the major structural pattern. Others occupy the position of gash fractures in a modified S shape between two parallel faults, lying at an acute angle to each.

Apparently lithology has had little control on localizing the ore deposits in the sense that certain beds were more susceptible to replacement. The marked exception to this is the Snowstorm type of copper deposit where the mineralization is restricted to certain massive quartzite beds. This general lack of localization, however, would be expected, where the rocks containing the deposits are a monotonous repetition of argillaceous and quartzitic sediments many thousands of feet thick. The interbedded carbonate-bearing rocks which are common in the upper part of the section have had no apparent localizing effect in this regard. Shattering has made the rocks more susceptible to replacement, and for this reason the quartzitic rocks may be more favorable to it.

In the early days of the district a general belief was held that the Prichard, Wallace and Striped Peak formations were poor hosts for economic ore shoots. The basis for this hypothesis was the apparent bottoming of some deposits which extended into the Prichard, and the general lack of good deposits within these formations. However, in the case of the Prichard, this has been disproved many times over; some ore has been extracted from deposits in the Wallace, but an economic deposit is yet to be found in Striped Peak rocks. In the case of the upper two formations, the lack of deposits is undoubtedly mostly due to their position at the top of the section. This is particularly true for the Striped Peak, in which the rocks are almost exact replicas of those in the St. Regis formation, which has been the most prolific ore producer.

In the Canyon-Nine Mile Creeks area, an alignment of deposits within somewhat indefinite zones is apparent. They show up best on the underground map (pl. 5) where five may be seen. The deposits grouped along them from south to north are:

1. Black Bear Fraction, Black Bear, Frisco, Gem, Success, American, Treasure Vault, and to the southeast off of the map, the Morning-Star vein system.
2. East Hecla, Hecla, Anchor, Standard-Mammoth, Rex, Red-Monarch, and Blue Sky.
3. Marsh, Tiger-Poorman, Union, Sherman, Humming Bird, and Tamarack-Custer.
4. Hercules, Ambergris, Interstate-Callahan, Blue Grouse, Amazon, and Carlisle.
5. C. & R, St. James, Sunset, Silver Tip, Sitting Bull, Tuscumbia, Parrot, and Idora (last six on Sunset vein system).

The American, Treasure Vault, Anchor, Red Monarch, Blue Sky, Humming Bird, C & R, and St. James are all prospects. Some of these contain considerable sphalerite and galena, but little ore has been taken out of any of them; the others have had no production.

The Tiger-Poorman, Union, and Sherman, and also the Sunset vein system deposits are along two more or less continuous shears, or set of related shears, which show little interruption by cross faults. Many of the others, however, are separated by pre-mineral, major faults, or in the case of a number of them, lie on opposite sides of the monzonitic stocks. Most of the deposits have steep to vertical dips, but within individual zones some may dip one way, whereas their neighbors dip in the opposite direction. In spite of these inconsistencies, one may infer that some relationship exists; the pattern is too good to be more than happenstance. The most plausible explanation is that the stress system, which was in force during the period of mineralization, caused the opening of more or less continuous zones of shear of considerable length. These cut across many pre-existing structures, and the different dips represent complements formed by the same stresses. It may also be true that such patterns are consistent within only certain blocks of ground bounded by very large faults, as this one may be by the Osburn fault on the south and the Dobson Pass fault on the west.

The large faults must have yielded some influence in the location of the ore deposits, at least more than is apparent at the surface, for complexity of structure and ore deposits go hand in hand. Few have been major channels of ore mineralization, at least not to the level to which they have been explored. Several exceptions to this are found within the Canyon-Nine Mile Creeks area. These are the lodes along the Carlisle, Puritan, Gem and Banner faults. In the case of the Gem, the fault apparently was used for a relatively short distance, as the shoot along it is not continuous. In a number of instances in this area, faults have acted as dams to ore solutions. Examples of this are the Standard fault at the east end of the Standard-Mammoth lode, O'Neill Gulch fault at the east end of the

Tiger-Poorman lode, the Mart fault at the west end of the Sherman, and the Frisco fault at the east end of the Frisco veins.

Irregularities along shears both in strike and dip have undoubtedly had some control in the localization of shoots. But to have other shoots persistent over distances of 1,000 feet or more along the strike, and from 2 to 3 times as far down dip, as a number of the larger deposits have been found to be, there must be other causes. They must have been under relative tension over a large area at the same time.

Structural control of other types has also been noted within the region. One of the most interesting was that which localized the rich zinc bonanza of the Interstate mine. The structural setting has been explained by McKinstry (1940). It consists of a local flexure on which stresses were imposed, with subsequent fracturing and shearing on an irregular pattern of the flat-lying beds, and with folding and bedding plane slippage of the more steeply dipping strata. This set up a favorable location for the deposition of ore minerals in the sheared and fractured zone of the disturbance. The deposit lies within lower Prichard rocks and its discovery helped dispel the idea of this formation's being barren of good deposits.

Where interbedded competent and incompetent rock have been under differential stresses, some have become fractured and sheared rather than folded. This has set up loci for ore deposits. Examples of this occur within the middle quartzite zone of the lower Prichard at the Amazon, Blue Grouse and Blue Sky mines. Several other deposits in the Pine Creek district, which lie within the middle quartzite zone of the Prichard, are also similarly located. An excellent example of this type has been determined by the detailed mapping of T. Gillingham 1/ at the Constitution mine. Here the massive middle quartzites of the Prichard were the competent rocks which formed a buttress. With deformation, a fractured and sheared zone favorable to ore deposition was formed. Undoubtedly many other places exist within the Belt Series where rocks of different competency have caused similar effects.

Contact metamorphic deposits

The Success (Granite) mine lies within a deep embayment of upper Prichard rocks within the southern Gem stock. It was first described as an example of a contact metamorphic deposit by Ransome (1908, p. 184) because the evidence at that time indicated that it lay wholly within the sediments, and that the ore minerals were contemporaneous with all of the contact metamorphic silicate minerals. Umpleby (1923, pp. 32-44) who wrote in more detail on the Success, agreed on the type of deposit but found a more complicated history than Ransome. His findings were: (1) intrusion of the stock and contact metamorphism of the enclosed sediments by recrystallization of the quartz and the formation of foliated muscovite and biotite; (2) crystallization of at least the marginal part of the stock; (3) disturbances which caused shearing which extended into the stock; and (4) further alteration of the sediments by the forming of sericite, epidote, pyroxene and garnet, and contemporaneous deposition of the ore minerals along the sheared zone both within the metamorphosed sediments and cutting across apophyses of the stock.

1/ Personal communication.

The evidence found now is partly in agreement with that of Umpleby. It indicates that two distinct phases of alteration took place. The first was the contact metamorphic phase which included the forming of the hornfels and micaceous rocks, plus the feldspathization of the sediment at the selvage of the stocks. The second occurred after the solidification of the stocks and their deformation by faulting. It was then that hydrothermal solutions altered part of the rocks by forming biotite, garnet, and chlorite. The solutions worked up along fractures and faults which were also used by the ore solutions. The length of the time gap between intrusion and the formation of the ore deposits is best indicated by the history of the Puritan fault. This fault cuts the north stock, and from the relationships seen must have done so after the stocks had solidified, at least as much of them as are now exposed; furthermore, the movement along it was large. Then the Tamarack-Custer ore bodies were formed in part along this fault in a position that precludes the possibility of any large post-ore movement along the Puritan. The Tamarack-Custer deposits, along with the rest in the Canyon-Nine Mile Creeks area, are undoubtedly contemporaneous to the Success deposit, because of the close similarity in mineral assemblage. From this evidence it must be concluded that the Success deposit had no immediate source in the adjacent stock, was deposited much later than the intrusion and therefore much later than the contact metamorphism.

The deposits, which were described as transitional, included the Frisco, Rex and Sunset. To these can now be added the Hercules, Tamarack, Interstate, Amazon, others in the Sunset vein system, and several other smaller ones around the periphyry of the stocks. The reason for this grouping was the association of silicate minerals with the ore. This association is best seen where the veins pinch or near their ends, where a definite order of formation is evident. At the outer edge of the vein is green biotite, and in order toward the center are pink garnet, quartz, pyrrhotite, pyrite, sphalerite and galena. Other minerals fairly early in the sequence, which are found in some of the deposits include magnetite, barite and siderite.

Because they lie within shears, the Success deposits should probably be classed as replacement veins, in spite of their location and usual greater irregularity. They, along with the other deposits with which silicate minerals are associated, were undoubtedly formed under different physical and chemical conditions than those, or parts of those, which do not contain such minerals. It is clear that the silicates were the first minerals to form, and it is also evident that the silicate minerals are restricted to those deposits adjacent to the stocks.

Zoning of ore deposits

A fairly orderly zoning of the ore deposits, upward and outward, occurs around the stocks in the Canyon-Nine Mile Creeks area. Those deposits near the intrusives are characterized by the presence of garnet, biotite, and chlorite, and usually pyrrhotite and/or magnetite; in them sphalerite is usually more abundant than galena, at least in the lower parts of the deposits. They include the Success, Rex, Interstate, Amazon, Sunset vein system, Ambergris, Hercules, Tamarack-Custer, Gem, Frisco and several prospects. Those farther away lack the associated silicates. They may have magnetite or pyrrhotite present, the latter usually more abundant at depth, and in them galena is more abundant than sphalerite. They include the Black Bear Fraction, Standard-Mammoth, Sherman, Tiger-Poorman, Hecla, and Marsh. Peculiarities and discrepancies do exist. The most notable of these is that the deposits on the northwest side of the stocks are generally zinc rich, whereas those on the southeast side are lead rich. Exceptions to this are the California and Dayrock deposits in which the ore is of a lead-silver variety with very little zinc; these deposits, though, lie to the west of the Dobson Pass fault in what appears to be an altogether different province. An increase in zinc content with depth is almost universal for the deposits on the southeast side of the stocks, and the amount of pyrrhotite increased on the lower levels of some of the ore bodies.

In going farther away from the stocks the zonal pattern breaks down and a group of different mineralogic types of deposits distributed in a geographic pattern are found. In the southwestern part of the Coeur d'Alene mining region are the Pine Creek deposits in which zinc predominates; lead and silver are less valuable, with pyrrhotite and quartz as the associated gangue minerals. North of these in the Wardner area are a group of lead-silver deposits, in which zinc is less abundant and the principal gangue mineral is siderite. The Silver Belt running east from Big Creek to Wallace and lying south of the South Fork of the Coeur d'Alene River contains a group of deposits in which silver, lead and copper are the important metals, zinc is practically absent, and the major gangue is siderite or ankerite. Those deposits in the area continuing southeast over the Canyon Creek-South Fork of the Coeur d'Alene River divide to the vicinity of

Mullan could well fit into the zonal arrangement around the stocks. But somewhat over a mile north of the last-named deposits are a group of copper ore bodies. To the north in the Murray area are some zinc-lead deposits which might well fit into the zonal pattern, but the gold and gold-tungsten deposits do not. The scattered antimony deposits are also peculiar to a zonal pattern. To try to fit all of these deposits into any one zonal arrangement is impossible, and some other hypothesis is needed to explain their distribution.

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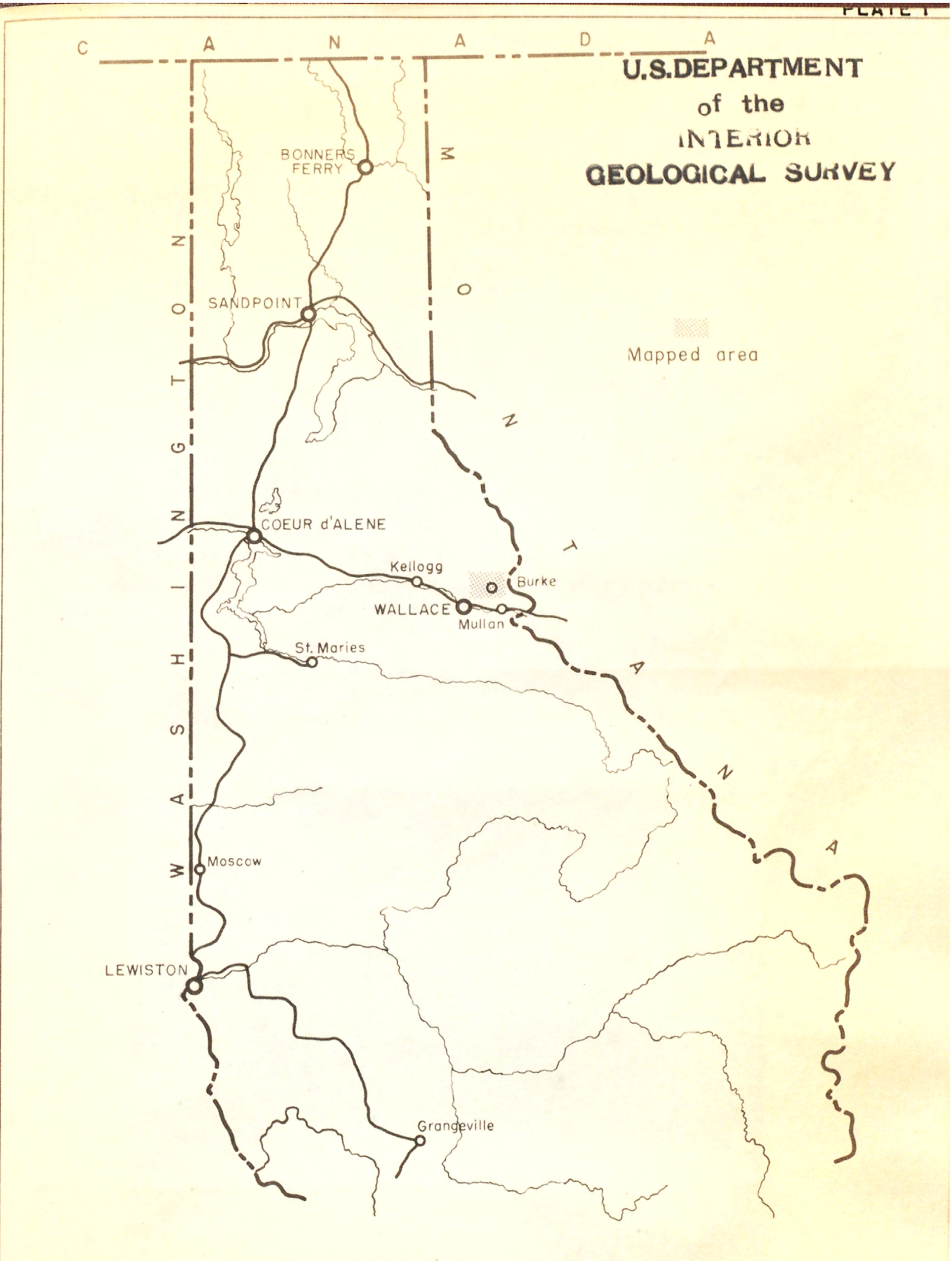
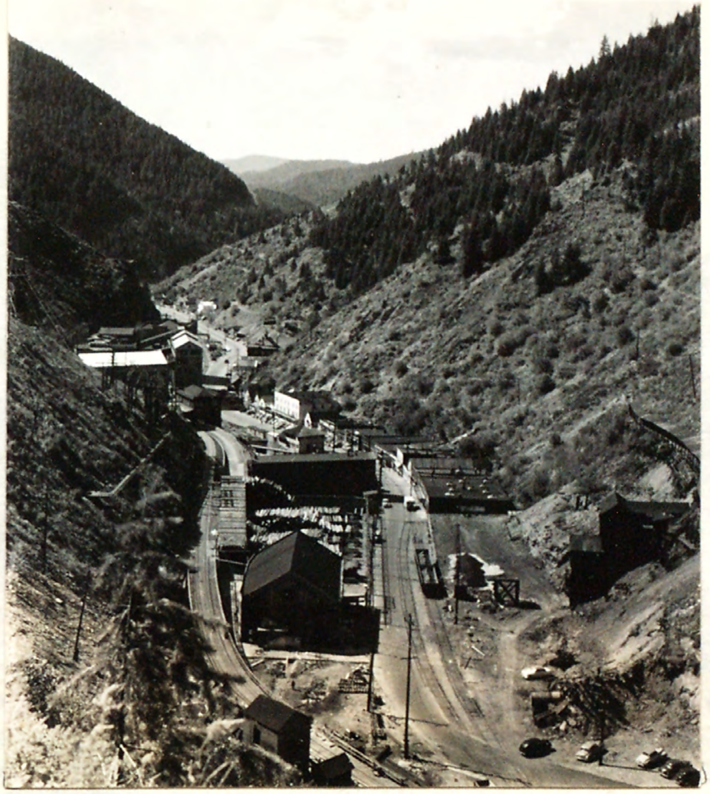


INDEX MAP OF NORTHERN IDAHO
Showing location of north half of Mullan Quadrangle

This map is preliminary and has not been edited or reviewed for conformity with U. S. Geological Survey standards

A- Looking northwest across Canyon Creek, showing accordant summits of ridges. Custer Peak at right.

B- Looking north up Gorge Gulch along the trace of O'Neill Gulch fault.



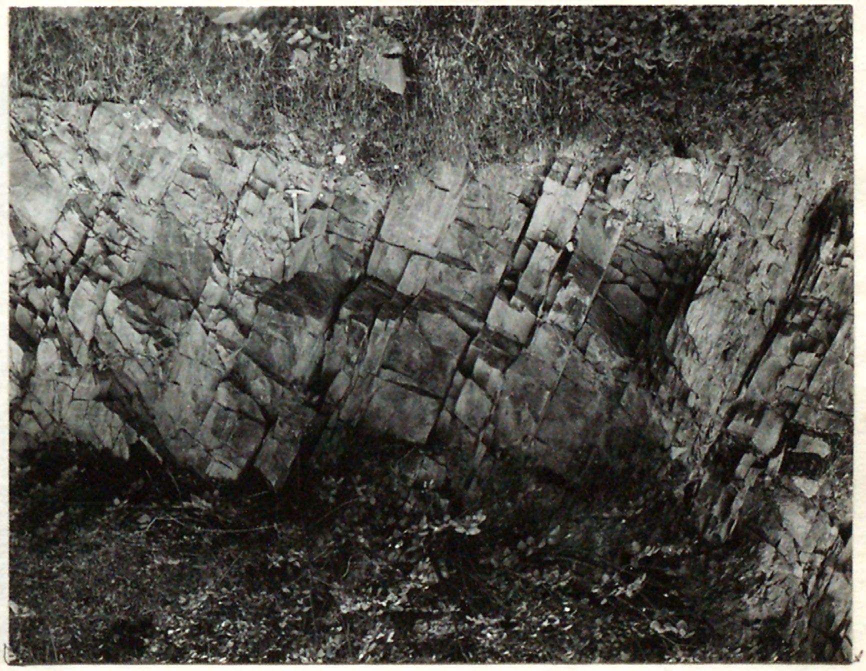
A- Looking west down Canyon Creek; Burke in the foreground; headframe of Hecla shaft at far left.

B- Looking south down Nine Mile Creek; Dayrock mine in middle distance.

A- Goose Peak, Burke-upper Prichard contact just to right of summit; small glacial cirque partly obsured by rocky knobs in foreground. Photo by H. C. Rainey.

B- Lower Prichard middle quartzite interbedded with argillite.

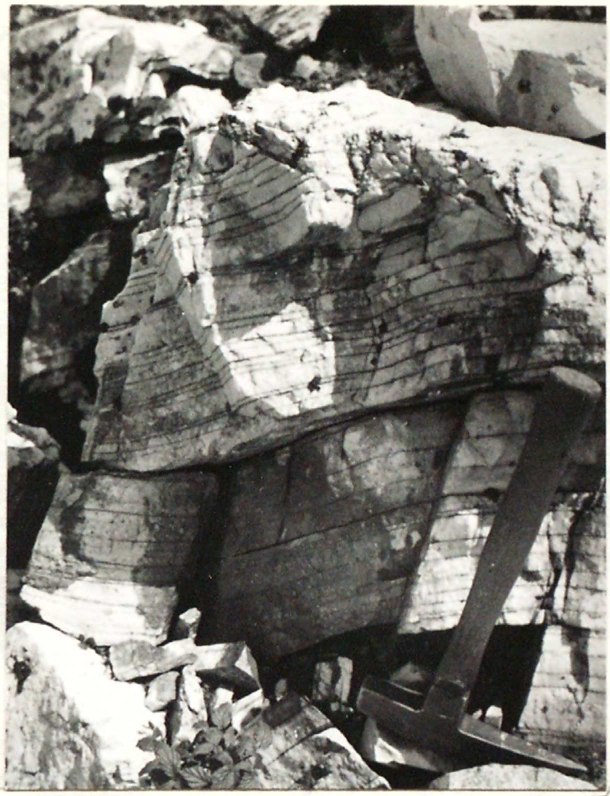
A- Dobson Pass fault exposed in road cut; dark colored rock - lower Prichard, light colored rock - Striped Peak.



B- Impure quartzite of lower Burke exposed in road cut along Canyon Creek. Photo by H. C. Rainey.

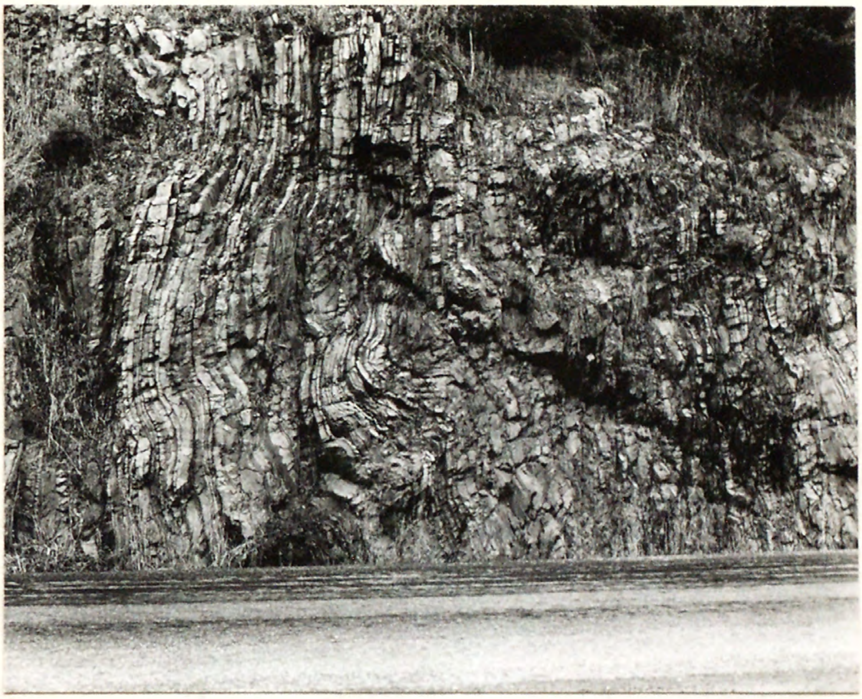
A- Fracture cleavage in lower Prichard argillite, along Beaver Creek.

B- Scree slope of quartzite from transition zone between Burke and Revett formations. Tree at far left is eight inches at butt for scale.



A- Cross laminated Revett quartzite near head of O'Neill Gulch. Bedding surface at top dips at slight angle to right.

B- Highly contorted Revett quartzite near crest of ridge south of Burke. Numerous quartz veinlets not visible.



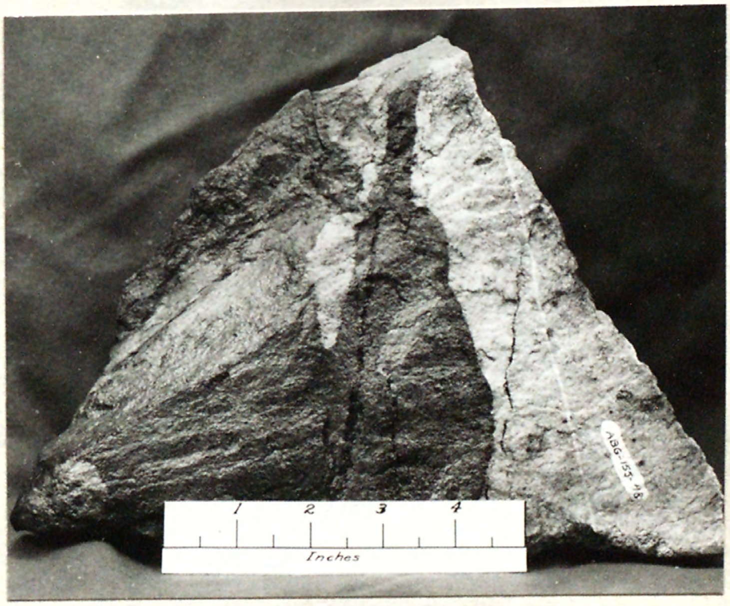
A- Contorted, interbedded quartzite and argillite, lower Wallace formation, in road along Canyon Creek. Photo by R. E. Wallace.

B- Mud cracks in argillite right side up. Photo by R. E. Wallace.

A- Ripple marks in upper Prichard Quartzite near Goose Peak.

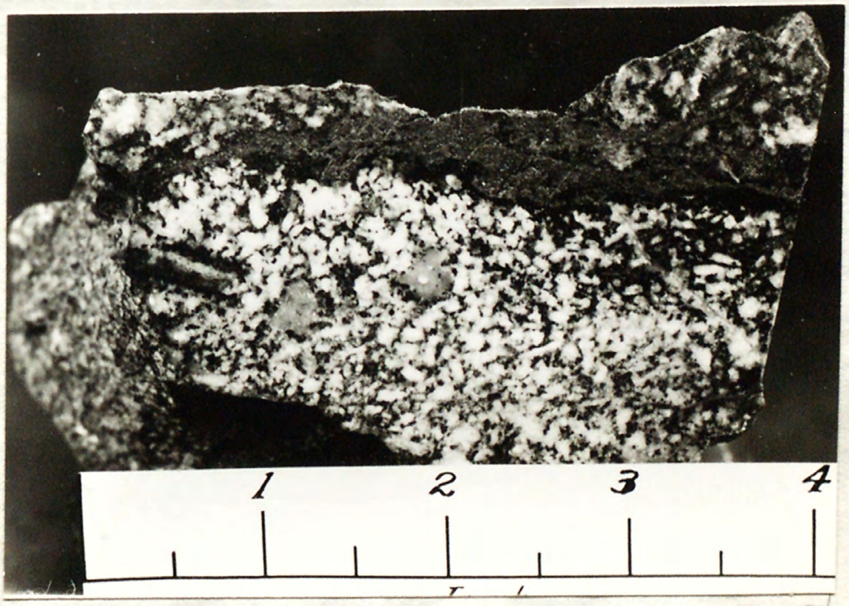
B- "Molar tooth" structure in carbonate rich argillite interbedded with quartzite of lower Wallace from head of Boulder creek south of Mullan.

A- Hydrothermally altered impure quartzite of Burke formation below Sherman mine. Streak of brown limonitic staining runs up to right from hammer head; beds dip steeply in opposite direction.



B- Hydrothermally altered Burke quartzite from near portal of No. 2 tunnel of Standard-Mammoth mine. Dark streak throughout center is oxidized siderite veinlet. Dark color due to limonitic staining bordered on right by red hematitic selvage. Photo by H. C. Rainey.

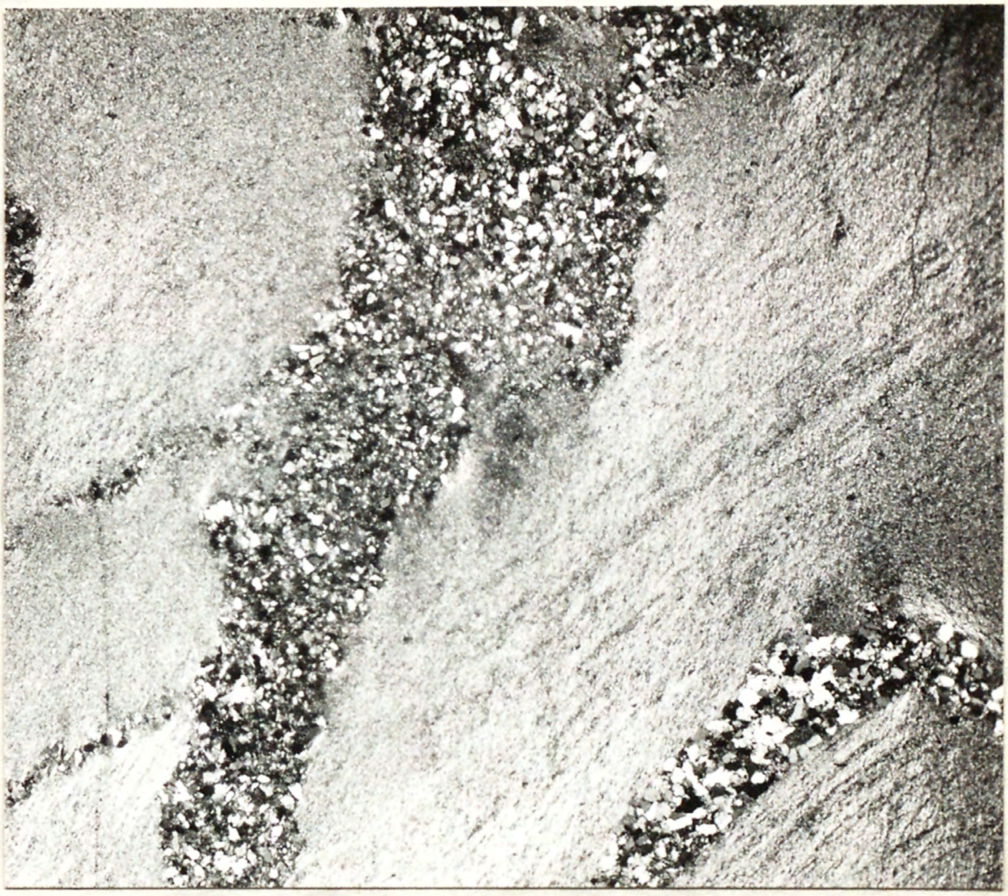
A- Two partly digested fragments of quartzite in monzonite rock from above Success mine. Bedding almost at right angles indicates jostling at time of intrusion. Photo by H. C. Rainey.



B- Sphalerite veinlet cutting porphyritic monzonite from Success mine. Photo by H. C. Rainey.

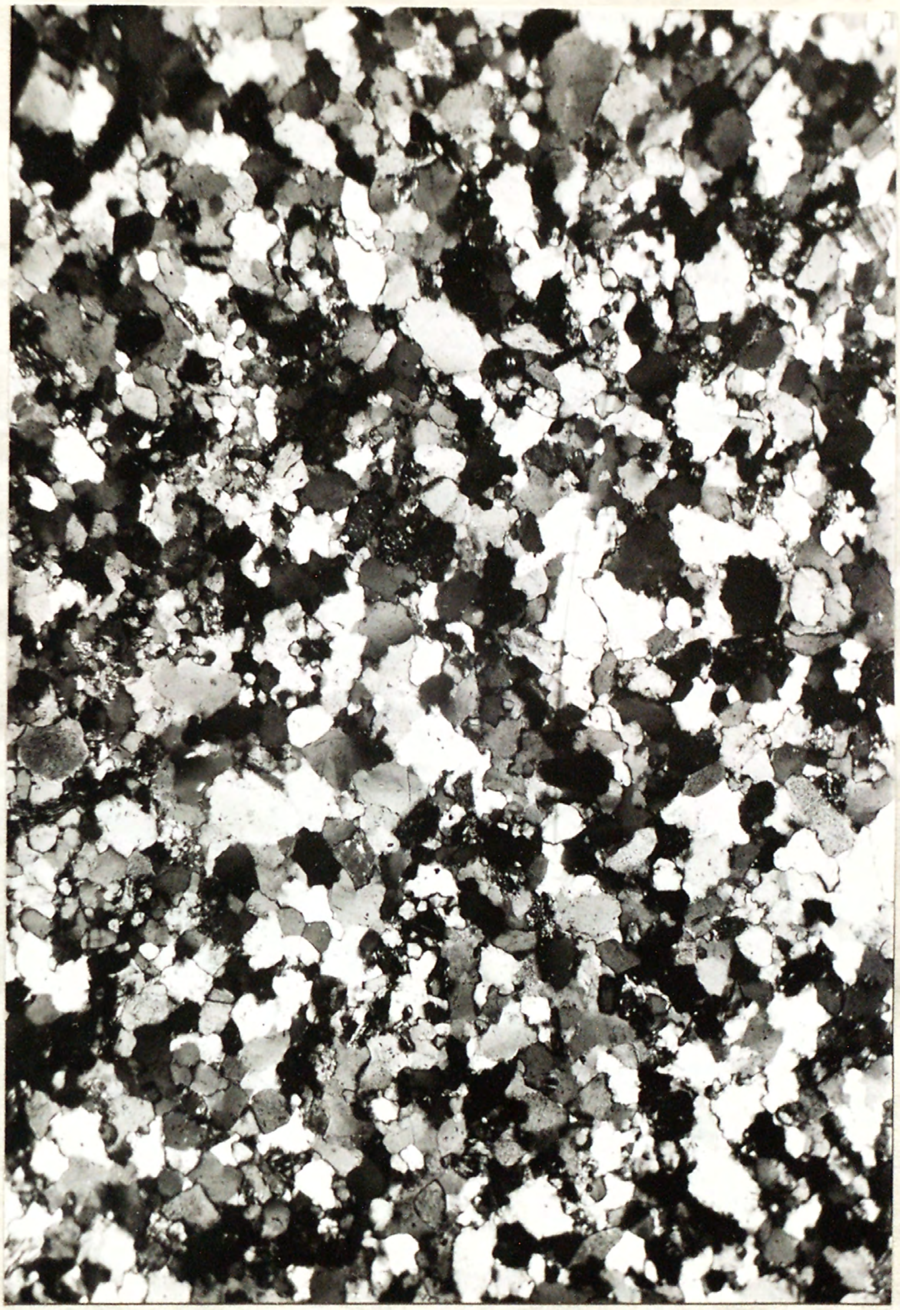
A- Contact between monzonite and Burke rocks in No. 4 tunnel at Tamarack mine; brecciation is post-intrusion as dark hydrothermally altered layers are broken. Photo by S. W. Hobbs.

B- Partly digested zenolith of sediments in porphyritic monzonite in No. 4 tunnel of Tamarack mine. Photo by S. W. Hobbs.

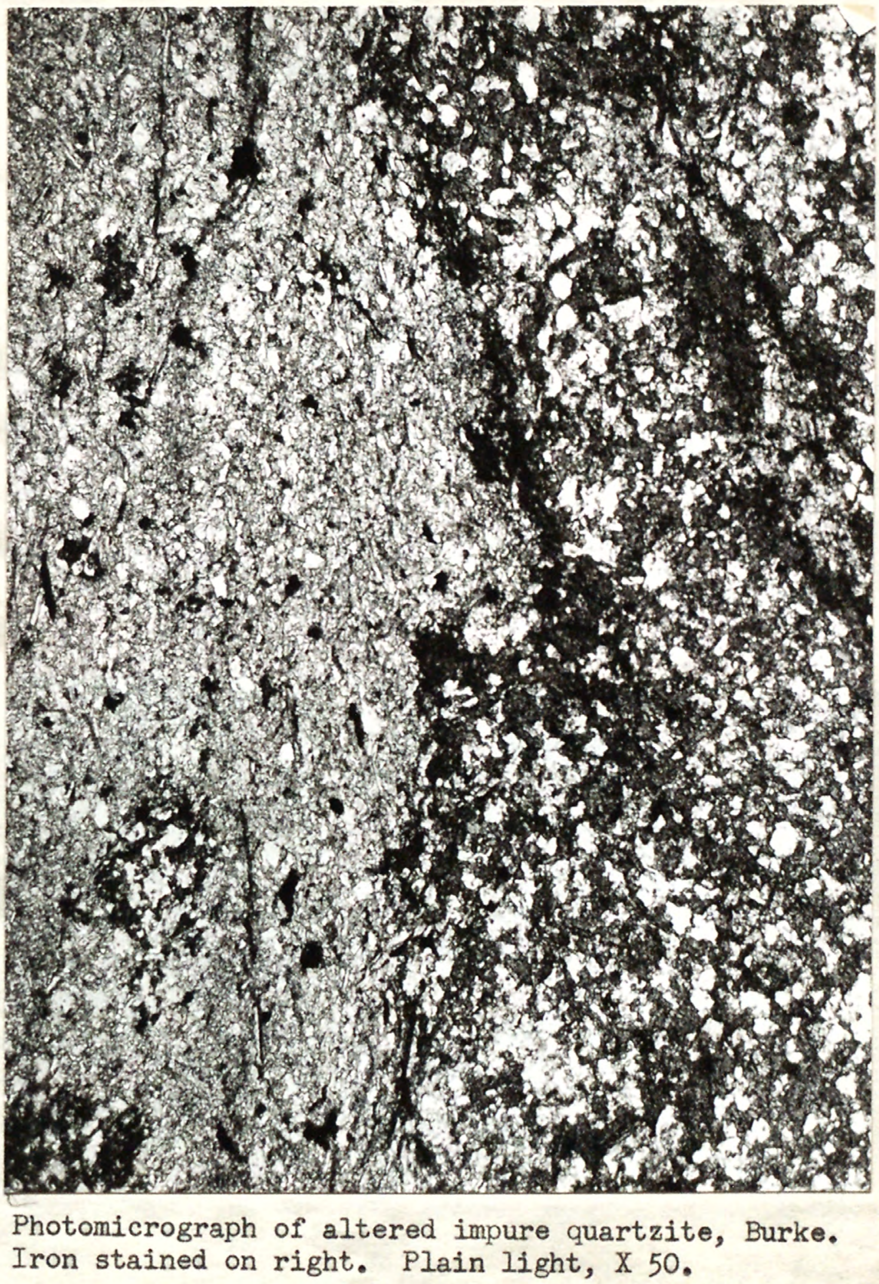


Photomicrograph of argillite with sand filled mud crack, lower Wallace. Banding due to orientation of sericite parallel to cleavage. Crossed nicols, X 20.

Photomicrograph of carbonate rich quartzite, lower Wallace. Mottled grain - ferroan dolomite, black and white - quartz. Crossed nicols, X 50.



Photomicrograph of quartzite, Revett. Note microcline grain in upper right-hand corner. Crossed nicols, X 50.



Photomicrograph of altered impure quartzite, Burke.
Iron stained on right. Plain light, X 50.

Photomicrograph of porphyritic monzonite. Orthoclase phenocryst, microperthitic and rimmed by exsolved albite. Crossed nicols, X 50.

Photomicrograph of monzonite, p-plagioclase, o-orthoclase, h-hornblende, q-quartz. Crossed nicols, X 50.

Photomicrograph of biotite syenite lamprophyre. Note outline of olivine phenocryst now replaced by quartz-white, and calcite-mottled. Crossed nicols, X 50.