The Geology of Part of the South Slope of the St. Joe Mountains, Shoshone County, Idaho

By

Warren R. Wagner
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THE GEOLOGY OF PART OF THE SOUTH SLOPE OF THE ST. JOE MOUNTAINS, SHOSHONE COUNTY, IDAHO

by

WARREN R. WAGNER

INTRODUCTION

Purpose and Scope of the Investigation

The investigation represented by this report was undertaken by the Idaho Bureau of Mines and Geology for the purpose of obtaining detailed geological information on some of the lesser known mining districts of the state. The present report covers the geology and ore deposits of the Slate Creek, Black Prince and southern half of the Placer Center mining districts of Shoshone County, Idaho.

The northern half of the Placer Center mining district, which lies on the north slope of the St. Joe Mountains, contains some of the richest producing mines of the famous Coeur d'Alene lead-zinc-silver mining district, but the southern half, which lies on the south slope of this same east-west-trending mountain range, has only one or two small inactive mining prospects. The Black Prince and Slate Creek districts join the Placer Center district to the south and east respectively, and a number of inactive prospects are located in each of them.

Since 1880, these three districts have been prospected intermittently but with little success. During 1910 a geological reconnaissance was made of the southern portion of the south slope of the St. Joe mountains, but the geology of the south slope has never been extended into the Coeur d'Alene district. This report is an attempt to tie the geology of the two districts together. For convenience the area will be referred to as the Avery district throughout the remainder of the report.

Field Work and Acknowledgements

The field work began June 1, 1946, and continued through August 30 of the same year. During this period every known mining prospect was visited, and a detailed geologic map (Plate I) of the entire area was made, using as a base an enlargement of part of the U. S. Forest Service map of the St. Joe National Forest. The map showed topography with 200-foot contours for about two-thirds of the area; and streams, ridge crests, and trails for the remaining portion. The map was not all that could have been desired for detailed work, but when enlarged to two inches per mile it proved fairly satisfactory.

The geology shown in Secs. 14 to 23 and 26 to 35, T. 47 N., R. 3 E., is of reconnaissance nature only as the field work in this part of the area, which is quite inaccessible, was twice interrupted. First by injury to the writer, and second by a forest fire which required the services of the writer for the last few days of the field season that had been reserved for this portion of the region.

The writer was ably assisted in the field by Mr. John S. Holland, a graduate student in the School of Mines at the University of Idaho.

Courtesies extended by the residents of the area and personnel of the U. S. Forest Service at Avery were greatly appreciated.

The writer wishes especially to acknowledge his gratefulness to each member of the faculty of the Department of Geology at the Johns Hopkins University for criticisms and suggestions while the report was in preparation. Also the helpful suggestions made by Dr. Vernon E. Scheid, while he visited the writer in the field, are greatly appreciated.

Outcrops

The detail and correctness of interpretation of the geology of any area depends largely upon the frequency and nature of bed-rock exposures. Where road cuts, railroad cuts and stream canyons expose the underlying rock in this area, most of the outcrops are good. Road cuts along the St. Joe River, Big Creek, Slate Creek and the North Fork of the St. Joe River; and the Milwaukee Railroad grade along the north bank of the St. Joe River and along the canyon walls of the North Fork of the St. Joe River offer excellent exposures. Everywhere in the region, from river grade up to approximately 5,800 feet in ele-
vation, the area is covered with a rather deep soil mantle supporting a dense snarl of brush which is further entangled by down timber from the fire of 1910. Traversing away from the cleared trails is next to impossible except along the highest ridge tops. One traverse up the canyon of a small stream by the writer required three and one-half hours to cover one and one-half miles; more than one mile of this distance was accomplished by walking along the trunks of down trees. Less than 20 percent of the total area was exposed sufficiently well to permit accurate work.

**Literature**

Prior to the present investigation only one report has been published that deals directly with part of the region studied. J. T. Perdew included in his report, "Geology and Mineralization of Upper St. Joe River Basin, Idaho" (U. S. Geological Survey Bulletin 470, Part I, 1910, pp. 39-61) the work of D. F. McDonald and E. L. Jones, Jr., which included approximately one-half of the area studied by the present writer.

Four additional publications are significant in the interpretation of the present area. These are:


**GEOGRAPHY**

**LOCATION**

The Avery district lies along the St. Joe River in the central part of Shoshone County, Idaho, and is the southern extension of the well-known Coeur d'Alene mining district. The area, of about 180 square miles, is bounded on the east by the North Fork of the St. Joe River, which empties into the main river at Avery; on the south by the St. Joe River; on the west by Big Creek, a tributary that joins the main river at Herrick, Idaho; and on the north by the crest of the St. Joe Mountains. (See Fig. 1).

The largest settlement in the area is the village of Avery with a population of about 150 people, located in the southeast corner of the district. This is the point on the Chicago, Milwaukee, St. Paul and Pacific Railroad where the power changes from steam to electricity on the east-bound units. The town is strictly a railroad community consisting largely of a roundhouse, repair shops and quarters for the crews.

**ACCESSIBILITY**

The town of Avery is most easily reached by the Milwaukee Railroad from St. Maries, Idaho, 83 miles to the west. It may also be reached by roads from St. Maries and Wallace, Idaho. The Avery-St. Maries road is poor and narrow for about half the distance to St. Maries; and the Wallace-Avery road is extremely steep, narrow, and crooked throughout the distance of 32 miles.

A few old logging roads and U. S. Forest Service roads lead off into the back country from these main roads. For the most part, however, the interior must be reached by trail and on foot. At the time of the study, some of the trails of the region were being cleared for the first time in four or five years. The main trails are suitable for packing, but there are no pack animals available in the district. Travel, except on cleared trails and roads, is practically impossible.

**VEGETATION AND CLIMATE**

Prior to 1910 the region was heavily forested, but during that year one of the largest forest fires ever to occur in the United States completely burned over the entire area with heavy loss of property. Lumbermen had only just begun in the district and the Milwaukee Railroad had not recently been completed. At present the vegetation consists of a so-called "chope forest", with scattered second growth fir, cedar, and white pine, the whole forming a dense, matted covering up to approximately 5,500 feet in elevation. Above the 5,500-foot contour the ridge tops are barren and rocky except for scattered patches of bunch grass; these are used during the summer months as sheep ranges.

Several large tracts have been replanted to white pine by the U. S. Forest Service.

The luxuriant growth of vegetation is aided by climatic conditions. Rainfall averages about 30 inches annually and is scattered equally throughout all months except August and September, during which drought conditions exist. The growing season is between May and mid-September. There are no great extremes in temperature. Winter temperatures seldom drop below 0° F. The winter snows, which usually begin about mid-December, c.
Fig. 1. Index map of Idaho showing location of area in relation to the Coeur d'Alene district.
deep and linger late into the summer in the higher elevations. The summers are cool and pleasant except for a few days in August and September when the temperatures may exceed 100°F.

**TOPOGRAPHY AND DRAINAGE**

The Avery district is mountainous. Physiographically it is in the Northern Rocky Mountain province and lies on the south slope of the St. Joe Mountains, a more or less east-west trending group near the southern border of the Coeur d'Alene Range as defined by Calkins (1910, p. 13). The mountains may be described as the maturely-dissected plateau type as the ridges rise to accordant summit levels. The erosional history has been complex as recorded by a series of old erosion surfaces at various elevations. The oldest and highest may be seen from a vantage point as flat, gently north dipping surfaces on the crests of the highest mountain ridges such as Cedar Mountain (elevation 6,199 feet) the highest point west of Slate Creek which divides the district approximately in half, and Mastodon Mountain (elevation 5,925 feet), the highest point west of Slate Creek. From Cedar Mountain and Mastodon Mountain, although interrupted by later dissection, the rolling plateau surface slopes gently northward to the crestline of the St. Joe Mountains with elevations of 6,329 feet at Striped Peak, 5,612 feet at Bad Tom Mountain, 5,711 feet at Moon Peak, and 6,028 feet at Stevens Peak. Striped Peak and Stevens Peak are monadnocks above the old penepaleon surface. From a vista point, an observer may see that this dissected plateau character of the topography may be traced many miles in all directions away from the area.

A second and less extensive erosion surface is carved into the older surface and is recorded by a system of ridges and benches with uniform elevations approximately 1,000 feet below the older surface. This second surface is at an elevation of 4,800 to 5,200 feet.

A third and rather limited erosion surface at elevations of 3,200 to 3,500 feet is represented by gravel-covered benches cut into the flanks of the ridges that are topped by the second erosion surface. Only small remnants of this surface remain in the Avery district, but it is well developed in the drainage basin of Marble Creek immediately south of the district.

This erosion surface is probably the remains of an old age valley that was cut into the second surface after uplift. It is deeply dissected by the present drainage system of the St. Joe River which occupies much of the same position formerly followed by the old valley. The present stream bottoms are about 1,000 feet below the gravel-covered relics.

An interesting feature that is evidently connected with the third erosion surface is a number of gravel-filled flats well back toward the headwaters of several of the tributary streams of the St. Joe River. These streams flow in a north-south direction in deep valleys across the district. The valleys change in character along their course from steep-walled youthful canyons in the lower parts to broader, mature valleys in the upper part. In the youthful parts, the stream gradients are steep, and rapids and waterfalls are common, while in the mature part, the stream gradients are gentle and the streams meander somewhat. The flats are at elevations of between 3,200 and 3,500 feet. One is beautifully developed along Slate Creek in secs. 1 and 12, T. 46 N., R. 4 E., and secs. 25, 27, 36, T. 47 N., R. 4 E. (Fig. 2). The flats also occur along the upper courses of both the North Fork of the St. Joe River and Big Creek (See Plate 1).

The broader, mature increments of these stream valleys were probably inherited from the third erosion surface. The northwest-trending fault system of the region has uplifted and rejuvenated the lower stream courses and the ancient drainage pattern has been protected north of the faults. In one or two cases, more resistant rocks have been downthrown across the valleys and have preserved the old drainage pattern. This is illustrated along Ames Creek, a tributary of East Fork of Big Creek, secs. 27, 28, 29, T. 47 N., R. 3 E., where a normal fault (Pine Creek fault) has dropped resistant sandstone beds of Striped Peak formation into juxtaposition with soft argillites of the Wallace formation.

A glacial cirque, the floor of which is occupied by a small, circular lake perhaps 200 feet in diameter, is located on the northeast slope of Cedar Mountain, sec. 18, T. 46 N., R. 5 E. The broad, rounded, almost U-shaped character of several other valley heads on the same side of the mountain suggests rather extensive glaciation, but later erosion has erased the characteristic features and ruggedness of ice work.

The district is drained by the North Fork of the St. Joe River, Slate Creek and Big Creek, all of which flow southward and join the St. Joe River flowing to the west along the southern margin of the area. The St. Joe River eventually empties into Coeur d'Alene Lake 60 miles to the west. The course of the three main streams is controlled by a system of joints trending north to north 20° E. These are the arc cleavage planes of the northwest-to-southeast-trending folds. They will be discussed more fully under the section on structure. The drainage pattern, particularly in that part of the area drained by the North
FIG. 2. Gravel-filled flat along Slate Creek. This topographic feature is partly due to faulting and partly inherited from an earlier erosion cycle.
Fork of the St. Joe River and Slate Creek, is probably best termed trellis drainage.

The basin of the St. Joe River and its tributary streams east of Herrick, Idaho, offers an excellent site for a hydroelectric power and flood control project. Extreme caution, however, must necessarily be used in the selection of a dam site because of the many great faults in the area drained by the St. Joe River.

GEOLGY

GENERAL FEATURES

The geology of the Avery district is the southern continuation of that found in the Coeur d'Alene district. With the exception of the small, granitic stock (referred to below as the Herrick stock) in the southwest corner of the district, the area is underlain by pre-Cambrian sediments generally known as the Belt series. These rocks are in most cases like their counterparts in the Coeur d'Alene district. Near the Herrick stock, however, they are so metamorphosed that positive correlation is impossible.

Igneous activity is represented by rocks of four different ages. The oldest are dioritic sills and dikes of a probable pre-Cambrian age. Next youngest is the St. Joe stock considered late Cretaceous in age, which is closely followed by aplite and lamprophyre dikes. The young- est igneous rocks are small, unconnected remnants of basalt flows found near the west margin of the district. These are considered to be part of the Columbia River basaltic of Miocene age.

In structural features, the Avery district greatly resembles the Coeur d'Alene district; in fact some features of the latter area, such as the Pine Creek fault and Striped Peak fault, may be traced into the Avery district. In general, the structure consists of northwest-southwest-trending, multiple faulted anticlines and synclines. The structural features are shown on the accompanying geologic map (Plate I), in as much detail as outcrops and map scale permit. The scarcity of good exposure combined with the difficulty of access makes it impossible to work out all the minor details.

The two districts are also greatly similar in character of mineralization and type of ore deposits. The minerals of the Avery district are essentially the same as those in the Coeur d'Alene district, and the ore bodies are much alike structurally.

SEDIMENTARY ROCKS

The sedimentary rocks of the district belong to the Belt series of pre-Cambrian age. They are an unalterable group of shales, sandstones, impure limestones and impure quartzites with abundant shallow-water markings such as mud cracks and ripple marks. In several localities where metamorphism has been more intense than usual, some of the rocks have changed to slates, phyllite or schists. In addition to these consolidated sediments, there are a few terrace gravels of Tertiary age and the larger stream valleys contain some recent alluvium.

Of the six formations of the Belt series found in the Coeur d'Alene district, five of them, the Burke, Revett, St. Regis, Wallace and Striped Peak, are exposed within the district. The Wallace underlies approximately 70 percent of the total area. Table I, is a generalized section of the Belt series of the Avery district.

BURKE FORMATION

General features and distribution: The Burke formation, next to the oldest recognized formation in the Belt series, underlies a considerable area south of the St. Joe River, but only a very small part outcrops within the area studied. It is exposed in the road and railroad cuts along both sides of the river in the southwest part of the region, west and south of the section line between sec. 17 and 18, T. 45 N., R. 4 E. Here it is so metamorphosed that positive correlation with the Burke of the Coeur d'Alene district is not certain. However, observations of exposures in the type area at Burke, Idaho, show similar features. The lithologic character of the Burke in the type area ranges from a dark gray siliceous shale in the lower part, to a fairly pure white quartzite toward the top. One of the most noticeable features is the very thin laminated character of some of the beds in the formation. In the exposures of the Avery district this same thin lamination is preserved in outcrops mapped as Burks.

Thickness: The metamorphic nature of the rocks combined with the folded and faulted structure prevented measurement of the formation. Additional work to the south of the area might afford at least an estimation of the thickness, but no figure could be obtained in the district.

Lithology: The rocks are light to dark gray, micaceous schists which grade upward into thin-bedded micaceous, white schistose quartzites. In the schists, bedding can sometimes be discerned by alternating, often paper-thin, lighter and darker laminae. The lighter laminae seem to be more arenaceous while the darker ones are more argillaceous. The bedding planes and schistosity or flow cleavage are at times parallel and these planes are covered with many small scales of white
mica, giving a silvery sheen to the rock. A few small (1-1.5mm) black tourmaline crystals also occur. Where the schistosity and bedding are not parallel, but make a small angle with one another, the bedding plane surfaces show this intersection by parallel lines. The long direction of the black tourmaline crystals is parallel to these intersection lines or lincation (Fig. 3). The schistose white quartzites are thicker-bedded than the schists, and in the majority of cases, have less white mica. The same lincation shows on the bedding plane surfaces of the quartzite as in the schists, but the tourmaline crystals are rare or lacking.

Under the microscope the schists prove to consist mostly of quartz with some altered and mashed biotite, a great many flakes of white mica and numerous tourmaline crystals. The white quartzite is primarily quartz with some grains of white mica. In both rocks, the quartz is fractured, annealed, and stretched into elongated grains showing undulatory extinction.

**REVETT QUARTZITE**

General features and distribution: The Burke formation grades upward into the Revett quartzite, composed almost wholly of massive, white beds. The transition from one formation to the other is gradual, and probably no two observers would draw the contact at the same horizon; however, in this instance, it has been placed at the base of the first thick (2-3 feet) white quartzite beds. Below this the beds are thinner (2-6 inches), darker in color, and show some flow cleavage.

The Revett quartzite underlies two widely separated parts of the area. One on the south side of the St. Joe River opposite the mouth of Harvey Creek, sec. 17, T. 45 N., R. 4 E., forms high cliffs along the road from Avery to St. Maries. To the north of the river it is cut off by the St. Joe fault and southward the strike carries it out of the area. The other exposure occurs in the northwest corner of the district, mainly in sec. 17, T. 47 N., R. 3 E.

**Thickness:** The formation is 800 feet thick in the outcrops opposite Harvey Creek, but the thickness in the other area could not be determined. Calkins (1908, p. 35) gives the thickness of the Revett in the Coeur d’Alenes district as 1,000 to 1,200 feet. This would indicate that the formation thins to the south.

**Lithology:** Lithologically the Revett quartzite is the most homogeneous of the Averys district sediments. It consists almost entirely of hard, pure, thick-bedded quartzite. The purple quartzite is white, occasionally the beds are tinted greenish or pinkish. The texture is very fine to dense, and a fresh surface shows conchoidal fracture with a vitreous luster. Many of the strata are so hard that they cannot be scratched with steel. The bedding is massive; some beds up to 12 and 15 feet in thickness were measured.

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<tr>
<td>Striped Peak formation</td>
<td>2,000'</td>
<td>Thick-bedded pinkish to purple sandstone and purple shale. Sandstone predominates and is somewhat quartzitic. Much sericite mica along bedding and cleavage planes.</td>
</tr>
<tr>
<td>Wallace formation</td>
<td>5 500'</td>
<td>Black thinly-laminated non-calcareous shale.</td>
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<td>4 550'</td>
<td>Gray-green limy, sandy shale, weathers tan to buff.</td>
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<td>3 850'</td>
<td>Black thinly-laminated shale much like No. 5.</td>
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<td>2 600'</td>
<td>Thick-bedded calcareous sandstone, some black shale.</td>
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<td></td>
<td>1 2,000'</td>
<td>Impure qtzite, as, is, and sh; some calcareous beds.</td>
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<tr>
<td>St. Regis formation</td>
<td>600'</td>
<td>Green and purple banded, thin-bedded quartzite and siliceous shale. Some peculiar conglomeratic material. This horizon not readily recognized in the district.</td>
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<tr>
<td>Revett Quartzite</td>
<td>800'</td>
<td>Thick-bedded white quartzite with a few thin beds of sandy shale near the top. Beds badly fractured.</td>
</tr>
<tr>
<td>Burke formation</td>
<td>Unknown</td>
<td>Gray micaceous schists and quartzitic schists with considerable white schistose quartzite in the lower member.</td>
</tr>
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Ripple marks are present in the upper, thinner beds but do not occur on the massive ones.

Flow cleavage is poorly developed in some of the thinner, less pure quartzite beds but is altogether lacking in the more massive ones. In the exposure opposite Hot Creek the strata are highly fractured and shattered, and the fractures contain considerable introduced sericite.

Numerous small (1-2 mm) specks of iron oxides on weathered surfaces form a conspicuous character of the Revett in the northwest part of the region.

Microscopic studies show the massive quartzite beds to be composed almost entirely of subangular quartz grains with a few detrital grains of feldspar and mica. One slide contained considerable turbid material, thought to be interstitial mud. The iron oxide spots, mentioned above, came from the oxidation of minute siderite grains disseminated through the quartzite of the northwest portion of the area. The quartz grains are stretched, fractured and show undulatory extinction. The individual grains commonly fit closely together, showing only faint boundaries or none at all. Occasionally a few grains are cementsed with quartz carrying considerable sericite, but more commonly there is little or no cement. One slide from the area along the river has considerable late quartz and sericite as minute veins filling fractures that cross the entire slide.

ST. REGIS FORMATION

General features and distribution: The Revett quartzite passes rather abruptly from thick-bedded, white quartzite upward into the impure green and purple banded quartzite that is referred to as the St. Regis formation, and the contact between these formations is the most sharply defined of any that separates the members of the Belt series within the Avery district. The rocks of the St. Regis are more quartzitic in character and contain fewer shale beds than are found in that formation in the Coeur d'Alene district.

The exposures mapped as St. Regis are found at two different localities. The largest is along the St. Joe River at the mouth of Slate Creek, in sec. 10, T. 45 N., R. 4 E., while the smaller is in the northwest part of the region occurring mostly in sections 15 and 17, T. 47 N., R. 3 E. These two areas are located in or adjacent to, structurally deformed belts and the rocks have undergone considerable deformation and alteration that has made impossible the exact delineation of outcrop and interpretation of structure.

Thickness: The thickness could not be determined with any degree of assurance as sections suitable for measurement are not exposed in the district. Near the mouth of Slate Creek, however, the formation is estimated to be between 600 and 800 feet thick.

Lithology: The lithology differs somewhat in the two areas exposed. The exposures at the mouth of Slate Creek and those in the northwest part of the district resemble closely the complete section of the St. Regis in the Coeur d'Alene district as described by Calkins (1908, p. 37), except that the beds in the northwest area are thoroughly bleached by late hydrothermal solutions. The strata at the mouth of Slate Creek are unusual in that they have a conglomeratic character. They show angular to sub-angular light green fragments with an occasional rounded and stretched fragment, in a matrix of purplish material, that imparts a mottled appearance to the outcrop. At first glance, or from a distance, the rocks seem normally bedded, with a banded character due to alternating light green and purplish layers. However, upon close inspection, the light green bands are found to be discontinuous or fragmental, with purplish material filling the interruptions (Fig. 4). Less commonly, the purplish material is found as fragments in a light green matrix. Toward the bottom of the formation, near the contact with the underlying Revett, and toward the top, near the contact with the overlying Wallace, this conglomeratic character is absent and the rocks are ordinary light green and purplish banded quartzites.

Calkins (1908, p. 38) offers three explanations for the same type of rock found along Boulder Creek in the Coeur d'Alene district. He suggests that they may be friction breccias, true conglomerates or intraformational conglomerates, and considers that the latter explanation is most probable. The writer's observations lead him to agree, that this seems to be the most probable interpretation for the unusual facies of the formation.

The strata are normally thin (2-4 inches), but an occasional thick (2-3 foot) bed is found. The purple color predominates and the thicker layers are invariably of that color. In the northwest area the formation is bleached to a pale green and the banding is entirely lacking. The strata in both localities are mostly quartzites and siliceous shales, though a few impure sandstones occur.

Microscopic examination shows the rocks to be composed of fine, angular quartz grains with a few feldspar grains. The purple beds are usually coarser in texture than the pale green beds and the coloring matter in the former is iron oxide, while in the latter it is chlorite. The cementing material is quartz and sericite. The thin sections show many
FIG. 3. Sub-parallel alignment of black tourmalite crystals in Brekke quartzite schist near the Harrick stock. X-nets, 44 X.

FIG. 4. Conglomeratic character of part of the St. Regis formation shown by polished surface of a sandstone section. Light colored bands are interbedded with dark fragments embedded in purple quartzite.

FIG. 5. Thin section of rock shown in Fig. 4 above. Note difference in grain size. Coarse-grained material in upper right portion is purple quartzite. X-net, 44 X.

FIG. 6. Plan view of mud cracks in the Wallace formation. Picture near the mouth of Jumbo Creek.

FIG. 7. Plan view of mud cracks in Striped Peak formation. Picture taken on ridge one mile north of Sheep Drive.

FIG. 8. Cross-section view of filled, mud cracks in lower Wallace formation. Beds are right side up. On road one mile west of Wallace summit.
small cross-cutting quartz veinlets and such accessory minerals as tourmaline, rutile, zircon and magnetite.

**WALLACE FORMATION**

General features and distribution: The contact between the Wallace formation and the underlying St. Regis is difficult to determine as one is transitional into the other. The line between the two formations has been placed where the purplish colored beds are missing and the predominant color is pale green or gray. Also the pale green beds of the lower Wallace become less quartitic and weather white to ivory in color. Thin chips have translucent edges and the white layers have a "horny" appearance. In areas thoroughly bleached by hydrothermal solutions, the contact between these two formations cannot be drawn with any degree of accuracy.

The entire formation bears evidence of shallow water deposition; the more shaly facies are mud cracked, while the sandy facies are ripple marked. Mud cracks (Fig. 6), are particularly characteristic of the shales and slates of the lower and middle part of the section.

The Wallace formation underlies the greater part of the Avery district. Five lithologic units may be recognized within the district. The contacts between them, however, are transitional and at time somewhat obscure. The five divisions become more difficult to recognize toward the north. Calkins (1908, p. 40) recognized three divisions in the Coeur d'Alene district but mapped them as a unit. Shenon and McConnell (1939, p. 4) recognized four members and also mapped them as a unit in the Silver Belt of the Coeur d'Alene district.

The best, and least structurally complex exposures within the present area are found along the canyon of the North Fork of the St. Joe River from Avery north to the head of the stream.

**Thickness:** No complete section of the Wallace is found at any one place within the district. The uniformity of character throughout considerable thicknesses, and the transitional character of the contacts of the various members of the formation makes picking of key horizons impossible. Furthermore, several lower members have lithologic characteristics identical to beds higher up, and it is difficult to tell one from the other. Another feature adding to the task of obtaining a true thickness for the formation is the intricate, at times minute, crumpling found in much of the section. Calkins (1908, p. 40) estimates that 20 per cent should be allowed for thickening of the beds by the minute folds, but the writer would increase this figure to 30 per cent or even 35 per cent in some of the shales.

The writer estimates, however, that the total thickness of the Wallace formation in the Avery district is not over 4,500 feet. Shenon and McConnell (1939, p. 4) in their report on the Silver Belt of the Coeur d'Alene area, estimate that the formation in that district is between 4,500 feet and 6,000 feet in thickness. Thus it appears that the Wallace like the Revett and St. Regis formations, is thinning toward the south.

**Lithology:** Lithologically the Wallace formation is the most heterogeneous of the Belt series. Examples of rock types typical of each of the other formations of the series may be found within it. In the present area, the formation is divisible, on lithologic grounds, into five mappable stratigraphic units. Toward the northern part of the region, particularly near the headwaters of Slate Creek, hydrothermal bleaching along large faults has made it difficult to map them as independent units.

The characteristics of the five subdivisions in order of age are as follows:

1. A heterogeneous sequence of thin-bedded (2-10 inches) light gray to dark gray, banded, impure quartzite, shales, sandstones and occasional pure limestone, all more or less calcareous, with the shale facies predominating. These beds become gray-green to green toward the contact with the underlying St. Tesgis. Shenon and McConnell (1939, p. 4) measured 2,900 feet of these beds in the Coeur d'Alene district, but about only 2,000 feet or less are exposed in the Avery district.

2. The contact between the basal member and the next higher one is transitional. The latter is composed of alternating thick-bedded (2-15 feet) calcareous or magnesian sandstones with a few beds of pure limestone and black, mostly non-calcareous, thin-bedded (1/4-4 inches) shale. On fresh surfaces the calcareous sandstone is a dense, fine-grained, light gray material and the shale is dark gray to black. On weathered surfaces, the impure sandstone is buff to tan and a delicate cross-bedding shows as a result of solution of carbonates of lime and magnesite. On some surfaces of the more pure limestone beds, a cellular structure known as "molar-tooth" structure (Gilson and others, 1941, p. 375) is common and is characteristic of this horizon. On weathered road cut exposures this part of the formation has an outstanding black and tan, banded appearance (Fig. 9). This horizon, after allowing for considerable minute crumpling, proves to be about 600 feet thick.

* In a later and more detailed report, as yet unpublished, Shenon maps these four divisions separately.
3. The number 2 horizon grades upward into a non-calcareous black shale that has been metamorphosed at places to a silvery colored phyllite or slate. The rock is thinly laminated, with occasional laminae of fine white mica; these thin sandy laminae increase toward the top. On fresh surfaces it is dark gray to black and weathers to a lighter gray with the more sandy parts becoming a dull, olive drab. Based upon calculations from a stadia traverse the horizon is about 850 feet thick.

4. This member is a light gray-green to dark gray, sandy, calcareous or dolomitic shale. It is thin-bedded (1/2 - 2 inches), and weathers buff to tan with bricked spots. Some of the thin beds are pure shale, while the thicker beds are usually cretaceous limestone or dolomite. The weathered outcrops have a characteristic platy structure. This horizon measures approximately 550 feet in thickness.

5. The impure shale of number 4 grades slowly into a black, non-calcareous shale or argillite with paper-thin laminae. These laminae alternate light and dark (Fig. 10) with the light ones being made up of fine grains of quartz and the dark one of clay and silt. In most outcrops it is strikingly wrinkled and faulted on a very small scale. These beds grade upward into the gray-green, cretaceous strata of the transition zone between the Wallace and the overlying Striped Peak formation. Allowing for the crumbling, the beds are about 500 feet thick.

**STRIPED PEAK FORMATION**

General features and distribution: The youngest formation of the Belt series is known as the Striped Peak, taking its name from the peak of the same name situated just beyond the northern boundary of the district. The peak was originally named because of the striped appearance imparted to it by the varicolored strata of this formation.

The contact with the underlying Wallace formation is gradational. The upper, thinly-laminated, black argillite of the Wallace gradually lightens in color and becomes a light, pinkish-tan, sandy shale which passes into the gray, impure, thin-bedded sandstone of the lower Striped Peak. This transitional character makes the contact somewhat indefinite, but it has been placed where the first two-to-three-inch impure sandstones appear.

In sec. 10, T. 46 N., R. 3 E., along the trail up the east fork of Big Creek, a two-foot bed of impure sandstone at the base of the Striped Peak contains angular fragments of shaly material. This is probably an intraformational conglomerate, but indicates that there may have been some minor breaks in sedimentation between these formations.

The formation underlies three separate, irregularly shaped tracts (Plate 1) along the trough of the faulted Packsaddle syncline. This syncline, one of the major structural features of the area, trends northwest-southeast and plunges to the northwest. The easternmost exposure forms a relatively thin capping on Cedar Mountain, while the other two areas, being at successively lower elevations, show thicker sections toward the northwest along the topographic low formed by the trough. In all, the total area extent of the formation is approximately 50 square miles.

**Thickness:** Exact measurements of the Striped Peak could not be obtained within the boundaries of the district. It is estimated from borehole measurements to be approximately 800 feet on Cedar Mountain, 1,500 feet at Dam Ridge, and 2,000 feet along the middle part of Big Creek at the west boundary of the area. The total thickness of the formation cannot be determined in the Avery district as the upper part is missing.

**Lithology:** The Striped Peak is lithologically the most consistent formation in the district. It consists of alternating beds of sandstone and shale which grade in color from pale greenish-gray for the shale and pinkish-gray for the sand members of the lower beds upward into deep purple for the shale and lavender for the sand members of the higher beds. The lower 500 feet of the section is characterized by the lighter color, while the remaining part is more strongly colored. Furthermore, the shales in the lower part are thicker, show less shale parting, and some of the beds may be classed as mudstone. One of these lower mudstone beds measured 12 feet thick; however, the general thickness is seldom over one foot. The sand beds usually measure from one to three feet in thickness.

The sandstones, as they are usually termed, might be described as impure quartzite. Although at most outcrops they are soft enough to be scratched with steel, they have the vitreous look of quartzite. One or two of the specimens collected gave a carbonate reaction with hot, dilute hydrochloric acid. This would indicate a magnesium carbonate content.

A majority of the quartzite bedding-plane surfaces show ripple marks (Fig. 11) while many of the shale beds show mud cracks. Several of the impure quartzite beds show mud cracks superimposed on ripple marks (Fig. 13).

Under the microscope the shales are so fine grained as to make identification of individual components virtually impossible. All thin sections of the shale examined showed some quartz and sericitic. The impure quartzite is made up of angular quartz grains and a few
FIG. 5. Banding and crumpling in No. 3 Horizon of the Wallace formation. On weathered surfaces these beds have characteristic black and tan colors. Picture taken along Milwaukee Railroad one-half mile north of Avery.

FIG. 10. (A) thinly-laminated upper Wallace shale.

FIG. 10. (B) Thin section of (A). X-scales, 64 X.

FIG. 11. Oscillatory ripple marks on slabs, notice that the sharp crests point down, thus the slabs is overturned and these are casts of the ripple marks.
subangular feldspar grains cemented by dark unresolved material which is probably original mud. Much sericite is also present in the cementing material. A few grains of tourmaline, zircon and magnetite are present. The purple color seems to be due to the presence of finely divided hematite dust, while the green color comes from minute flakes of chlorite. The massive mudstone beds at the base are highly siliceous.

TERTIARY AND QUATERNARY DEPOSITS

A few small areas of bench gravels are found on old stream terraces about 800 feet above the present level of the St. Joe River west of Avery. These are thought to be of Tertiary age and equivalent to the terrace gravels of the Coeur d'Alene district. The gravels consist chiefly of well-rounded pebbles and boulders of old sedimentary and igneous rocks of the district. The prevailing rock types are quartzite and sandstone.

Along the valley of the St. Joe River and the valleys of its larger tributaries, considerable alluvium deposits have collected on the wider portions of the valley floors. These recent alluvium deposits are made up of pebbles and boulders from all the more resistant rocks of the underlying formations. Quartzite and sandstone dominate.

IGNEOUS ROCKS

A variety of igneous rocks, representing three widely separated ages, are found in the district. The oldest are thick pre-Cambrian sills and dikes cutting the Wallace formation. These have been cut by younger intrusives of granitic composition such as the Herrick stock (Cretaceous) and associated dikes. The youngest igneous rocks are one or two scattered remnants of Columbia River basalt.

Pre-Cambrian Sills

General features and distribution: The thick, dark-colored sills that occur at several horizons in the Wallace formation are a striking feature of the region. One, 200 feet thick where the road from Avery to Wallace crosses Rognin Creek on the line between sec. 16 and 21, T. 47 N., R. 5 E., can be traced from the creek in a northwesterly direction into the Coeur d'Alene district. To the southwest it is persistent beyond the map limits. The sill is conformable with the bedding of the strata in the lower Wallace. Another sill of similar rock type but much thinner and about 1,500 feet stratigraphically below the top of the Wallace, outcrops along the North Fork of the St. Joe River two and one-half miles north of Avery. Here the sill is 50 feet thick, strikes east-west and is almost vertical.

A faulted segment of the same type of intrusive crosses Kelley Creek one-half mile south of Avery in sec. 15, T. 45 N., R. 5 E. It is in lower Wallace and is 80 feet thick. A number of small sills and dikes of 0-15 feet thick cut the wall rock at various places but are too small to map.

Age of Sills: The age of the sills cannot be determined within the boundaries of the district. They are folded and faulted and must have been subjected to all periods of deformation that affected the host formation. The Herrick stock (Cretaceous) cuts off a thin sill near Marble Creek, therefore, the sills must be older than Cretaceous. Parde (1910, p. 47) and Anderson (1928, p. 7) have found the sills elsewhere in the St. Joe River Basin. Anderson (1930, p. 23) found the same type of sills in the Prichard formation of the Belt series in the Clark Fork district, Idaho, and called them the Purcell sills. He accepted the age designation as Algonkian by Canadian workers in the Purcell trench farther north of the Clark Fork district. In more recent literature, the Belt series is referred to the pre-Cambrian; thus, as no new data for determining the age of sills was found during this work, they are called pre-Cambrian.

 Petrography: The sills are mostly dark, ranging from gray or dark gray to dull greenish-black; the color depends upon the concentration of dark minerals. The weathered surface is dark, rusty green, whereas a fresh surface is gray or black. Grain size changes from extremely fine at the contact with the sediments to rather coarse at the center, with average grain size about 2 mm and an occasional facies, particularly the darker varieties, having crystals up to 5 or 6 mm.

Microscopic studies of thin sections from the sills reveal a number of rock varieties. The chief rock type is metadiorite, but gabbro and quartz gabbro are also present.

The sill at Rognin Creek varies in composition from gabbroic to dioritic. The feldspars are zoned with a composition of labradorite Ab4 An2 at the center and sodic andesine Ab9 An4 in the outer shell. The rock has an ophitic texture with pleochroic laths in a groundmass of hornblende and minor pyroxene (augite). The pyroxene occurs as cores in the hornblende crystals. Specimens of this same sill, collected in the Coeur d'Alene district and studied by Calkins (1908, p. 52) have augite as the principal dark mineral. In the finer-grained facies the feldspar laths are in an unresolvable groundmass of dark minerals. Micropegmatitic quartz and orthoclase fill interstices in some sections. Abundant grains of iron ore are present. These are evidently ilmenite, as the grains show the characteristic skeleton crystals of that mineral. Other acces-
sory minerals are titanite, pyrite, pyrrhotite and apatite.

All the sections show the rock to be altered; the feldspars are clouded with sericite and at places partially replaced by epidote and clinozoisite, and much of the hornblende has gone over into chlorite and the feldspars to leucocene.

Along the North Fork of the St. Joe River and near the mouth of Kelley Creek the sillts are lighter in color than the one at Rough Creek and have the composition of a metabdiotite. Microscopically they are rocks with an allotropic morfgranular texture, of fine grain and made up of hornblende, often with augite cores, anodesite (Alm An92), and minor quantities of interstitial plagioclase (Fig. 14). Such accessories as biotite, apatite, garnet, zircon, monazite, pyrrhotite, pyrite and orthoclase occur. Nearly all of the hornblende and biotite is altered to chlorite and the feldspars are clouded with sericite, kaolin and considerable epidote. The augite cores of the hornblende suggest that all of the hornblende has formed from augite. The thin sections show an interesting textural relationship between the quartz and plagioclase (Fig. 15). In these structures the plagioclase is host and the quartz is vermicular. Often the ptyalite twinning of the plagioclase is preserved, and it appears that the quartz is deuteric, or introduced by later hydrothermal processes.

The small sills and dikes range in composition and color between the two types described above.

**Herrick Stock and Associated Dikes**

General features and distribution: The largest intrusive rock mass is the Herrick stock located in the southwest part of the district near the settlement of Herrick, Idaho. It is exposed over an area of approximately 15 square miles. Two roof pendants composed of metamorphosed strata of upper St. Rejas or lower Wallace formation occur and the center of the stock. On the northwest corner, the stock has been capped by lava flows. The contact between the stock and sediments is sharp, cross-cutting, and dips outward along the eastern side and most of the northern side, but is gradational to west and south. The southern contact is along a fault that existed before intrusion of the stock, and post-intrusion movement has complicated this boundary. Contact phenomena are well developed in the intruded rock bordering the stock to the south and west. The intruding magma assimilated some of the sediments and magmatic solutions permeated outward for considerable distance into the country rock with the result that a zone of hybrid rocks was produced.

Numerous small aplite dikes (Fig. 16) cut the stock and the intruded sedimentary rock. A short distance north of the stock, an aplite dike 6-15 feet thick can be traced for two or more miles. Another prominently exposed aplite dike, not so closely associated with the stock, outcrops at the mouth of Treago Gulch, sec. 7, T. 45 N., R. 5 E., five and one-half miles east of the nearest exposure of the main intrusive mass.

In sec. 23, T. 46 N., R. 3 E., near Sheep Drive, a small irregular body of granophyre outcrops, but its relationship to the intruded rock could not be determined because of the heavy covering of fruit and dense growth of brush. The body is probably a dike.

Near Avery, at the mouth of the North Fork of the St. Joe River a small lamprophyre dike (2-5 feet thick) in the canyon wall, cuts the Wallace formation. The dike cannot be traced any great distance and was not mapped.

Age of the stock and related intrusives: The age of the Herrick stock and closely allied dikes cannot be definitely established from evidence within the Avery district. The intrusives cut all the lithified sediments and pre-existing igneous rocks of the district and in turn are covered by basalt flows of Miocene age; therefore, they cannot be younger than Miocene. The stock is similar in rock type to the Idaho batholith (Cretaceous) that lies a few miles to the south (Fig. 17), and it is considered by the writer to be an outlier of the batholith. The associated aplite, granophyre and lamprophyre dikes were formed by intrusion of late stage magmas at or near the close of consolidation of the upper crust of the stock and are considered as acid and basic differentiates that have come up from a deep-sited source within the magma chamber.

Petrography of the stock: The stock is made up, for the most part, of inequigranular, gray to light gray rock in which the texture varies from quite noticeably porphyritic as at Black Prince and Agatha Creeks to nearly equigranular as in the railroad cut west of Marble Station. Where it is porphyritic, the medium-grained groundmass is gray and the phenocrysts are pink and white orthoclase, but where it is more equigranular the rock is usually a darker greenish-gray. The greenish color comes from chlorite that has formed from hornblende and biotite. The phenocrysts ordinarily show a definite sub-parallel arrangement and have an average size of 1.5 cm. by 1 cm., with an occasional crystal up to 3 cm. long. Biotite is the main dark mineral, but rarely does it make up more than 10 per cent of the rock. At one or two localities the dark mineral is chiefly hornblende. Near their borders the dark minerals are quite well aligned.
FIG. 12. Oscillatory ripple marks in place on a bedding plane of the Striped Peak formation. Individual ripples one inch high.

FIG. 13. Mud cracks and ripple marks on the same bedding plane.

FIG. 14. Intertellial myrmekite: intergrowth of quartz and orthoclase. X-scope, 64 X.

FIG. 15. Vermicular quartz in plagioclase feldspar. X-scope, 64 X.

FIG. 16. Subtle silt in the Bunkie formation. Bedding and cleavage are parallel. Photographed near the mouth of Marble Creek on the Marble Creek road.
Fig. 17. Map of Idaho showing the relation of the Herrick Stock to the Idaho Batholith and the Gem Stock.
and at places form elongated and flattened clots. The alignment of minerals is not constant but is of greater intensity toward the outer boundaries. This lineation is discussed more fully under structure.

The prevailing rock type is quartz monzonite, but the composition of the rock as a whole ranges from granodiorite to granite with one small area on Blackstack Creek having the composition of syenite. In the porphyritic facies the rock is quartz monzonite, whereas the more equigranular facies is usually granodiorite. Fig. 18 represents the modes of 15 specimens plotted on a triangular diagram according to Johansen's scheme.

In thin section, the rock is generally hypautomorphic - granular. The non-porphyritic varieties are inequigranular as in the groundmass of the porphyritic parts. Near the south side of the stock, the feldspars and quartz grains are crushed, fractured and reheated by quartz (Figs. 19 and 29), because of movement along the St. Joe fault.

The order of crystallization of the minerals is biotite and hornblende, plagioclase (Ab₃₉, An₃₉), orthoclase and quartz. The porphyritic texture has been superimposed upon the original somewhat inequigranular rock by addition of orthoclase, rarely microcline. The phenocrysts seem to have formed about grains of existing minerals by replacing them. This is shown by rounded and partially resorbed fragments of orthoclase (Fig. 22), quartz, biotite and plagioclase in the phenocrysts. From this microscopic evidence it appears that the stock had the composition of granodiorite when intruded, but later potash and silicic-rich solutions have added sufficient potash feldspar and quartz so that much of the stock now has the composition of quartz and monzonite.

Accessory minerals magnetite, ilmenite, zircon, apatite, allanite and titanite occur in varying amounts. Titanite (Fig. 21) is the most abundant and was probably the last to form. The accessories are thought to be deuteric minerals introduced by late-stage solutions into an already solidified rock. Gibson, Campbell and Jenks (1958, pp. 365-68) found the same phenomena in the Libby Quadrangle, Montana.

The dark minerals are extensively altered to chlorite, and the plagioclase crystals are clouded with kaolin, sericite and a considerable amount of coarse epidote and clinozoisite. The orthoclase is altered to sericite and kaolin but does not show much epidote.

Petrography of the aplite dikes. The numerous aplite dikes cutting the Herrick stock and sediments at its periphery have the characteristic zecchindale texture, but some of these at considerable distance from the stock are extremely fine-grained. The thick aplite dike at the mouth of Trego Gulch (Fig. 25), has a dense "porcelain-like" texture on its outer walls but is coarser grained toward the center. The dikes range in size from microscopic to 15 feet thick and in color from pure white to light gray or cream. The larger ones, because of the white color, stand out prominently from their more drab-colored surroundings.

In thin section the aplites are xenomorphic-granular. The grains are interlocking and quite equigranular. They are made up mostly of quartz and orthoclase, however, an occasional embayed or corroded phenocrystal of quartz (Fig. 23), orthoclase or oligoclase occurs. In general, there are no dark minerals, but occasionally a few crushed biotite crystals are found. The tendency toward a porphyritic texture seems to be confined to the dikes at

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* Modes of the minerals are illustrated graphically in Fig. 18.

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FIG. 18. Triangular diagram (after Johannsen) illustrating the modes of 15 specimens from the Herrick Stock. Numbers correspond to those in Table II, p. 20.
FIG. 19. Broken plagioclase crystal healed by quartz grains. X-nicols, 64 X.

FIG. 20. Shattered quartz grains reconstituted by late quartz. X-nicols, 64 X.

FIG. 21. Titanite crystal (T) with fiamme blocks. X-nicols, 64 X.

FIG. 22. Corroded remnant of orthoclase (O) in later replacement orthoclase phenocryst. X-nicols, 64 X.

FIG. 23. Quartz phenocryst (Q) in aplite dike. X-nicols, 64 X.

FIG. 24. Granophyric groundmass of granophyre dike with crystal of epidote (E). X-nicols, 64 X.
a distance from the stock. The occasional feldspar phenocryst is altered to sericite and all sections studied show the rock to be flooded with secondary, finely coarse, white mica.

Petrography of the granophyre: The term granophyre is used in the same sense as Johansen (1950, Vol. 2, p. 299) uses it; that is, to describe hypabyssal porphyries with a micropoissmatitic groundmass.

The granophytic porphyry near Sheep Drive is light gray to medium gray in color and the feldspar phenocrysts are chalky white on weathered surfaces while white or pink on freshly broken surfaces. The groundmass is fine-grained, rarely dense; and the numerous phenocrysts, that make up approximately one-third of the rock mass, range in size from 5 mm to 1 cm in length.

Under the microscope the groundmass is made up of quartz, orthoclase and biotite with some oligoclase. The quartz and orthoclase crystals are intimately intergrown and show the characteristic granophytic texture (Fig. 24), while the biotite and oligoclase have fair crystal boundaries and are somewhat larger than the average quartz or orthoclase grains. The phenocrysts are predominately oligoclase (Ab$_5$ An$_5$), but a few are orthoclase or quartz. They are embayed and corroded and interpenetrated by the matrix minerals. The porphyritic texture with the corroded phenocrysts points to two rates of cooling.

The accessories are zircon, apatite, titanite and epidote. The epidote (Fig. 24), is interstitial but some grains have sharp, straight boundaries against other minerals. It appears to be a primary, late-stage mineral along with the other accessories.

The feldspars are altered to kaolin and sericite, and biotite has almost completely gone over into chlorite.

The groundmass of the rock has the composition of granite with a high oligoclase content; but, adding in the oligoclase of the phenocrysts, the composition is granodiorite. The rock is best described as a granophytic, granodiorite porphyry.

Petrography of the lamprophyre: The single lamprophyre dike found in the Avery district resembles the metadolomite in outcrop, but close inspection reveals numerous, slender, hornblende crystals from 5 mm to 1 cm long in a dense, fine-grained groundmass. The color of the rock depends upon the proportion of dark minerals to light. In most cases the dark minerals predominate, and the rock is dark gray to greengrey black on fresh surfaces. It weathers readily to rusty-brown.

The chief minerals are plagioclase, hornblende, biotite and minor augite. The dark minerals are usually in good crystal form. As the plagioclase crystals are small, zoned, and almost completely altered to sericite and kaolin, the composition could not be satisfactorily determined, but a few simply twinned crystals indicate a composition near Ab$_5$ An$_5$.

The zoned plagioclases show no distinct borders between the zones but shade into one another.

The groundmass contains a little late-stage orthoclase and quartz in graphic intergrowths.

The hornblendes predominate and forms long, slender, brown phenocrysts that are quite fresh, but the brownish biotite tablets are mostly altered to chlorite. An interesting feature of the hornblendes is that the centers, particularly, near the western border of many of the crystals are occupied by feldspar (?). The composition of these cores could not be determined for certain but they appear to be close to that of the matrix groundmass and are probably made up of calcic plagioclase that began to crystallize earlier than the hornblendes.

Augite is rare. A few stout brown crystals are recognizable only in thin section. Apatite and epidote are present as accessory minerals. Secondary minerals are chlorite, calcite, sericite and kaolin. The calcite seems to be pseudomorphous after olivine as a number of calcite areas have the outline of olivine crystals, and in one of these a few irregular remnants of olivine remain.

The composition of the lamprophyre is that of a diorite and could be called a spessartite, but as this name is easily confused with the garnet spessartite, the dike is best called a dioritic lamprophyre.

Columbia River Basalt

General features and distribution: Three areas near the western border of the district, are capped by basalt flows. These basalt caps occur at about the 3,500-foot contour level on the remnants of an old erosion surface, and mark the easternmost points on which basalt is found in the St. Joe River Basin. The old erosion surface is completely barren of basalt east of Harvey Creek although it can be traced to a point just beyond the eastern border of the Avery district. Any basalt that advanced further up the valley than Harvey Creek has been removed. The four remaining remnants are now about 700 feet vertically above the floor of the St. Joe River.

The largest area is in sec 32 and 33, T. 46 N., R. 3 E., and consists of about 50 feet of basalt made up of a number of flows each from 3 to 10 feet in thickness. The other three
areas are merely scattered piles of basalt fragments two or three feet deep representing the remnants of flows.

Age of Basalt: A series of basalt caps, increasing in size and thickness, can be traced westward from the Avery district until they join the main body of the Columbia River basalt near St. Maries, Idaho. The age of the basalt has been determined by its relation to the Latah beds which occur between the flows at a number of horizons. Brown (1940, pp. 163-206) has assigned these beds to middle or upper Miocene.

Petrography: In the weathered outcrop the rock is rusty brown to greenish-black, but on a freshly broken surface it is dark gray to black. The flows are often columnar and may be vesicular near their top. A hand specimen shows a dense, aphanitic rock with an occasional feldspar phenocrystal up to 1 mm long. One or two freshly broken fragments showed irregular, yellow-green olivine grains.

The chief minerals seen under the microscope are labradorite (Ab, An), augite, magnetite and olivine with quartz as an occasional accessory. Some brownish colored interstitial glass occurs in the very fine-grained varieties.

Metamorphism

Metamorphism in the Avery district is not pronounced except near the Herrick stock. That so great a thickness of ancient sedimentary rock could pass through the numerous periods of regional deformation that have occurred since their deposition and remain as unchanged as most of the Belt series have, is, indeed, remarkable.

A certain amount of metamorphism is evident everywhere in the Belt rocks, and it is difficult to determine how much is caused by exhumations from intruding igneous magmas and how much by regional deformation that preceded intrusion. Sericite is abundant in most beds, particularly the arenaceous ones, and quartz grains are recrystallized in many of the arenaceous beds. The sericite occurs in two grain sizes near the stock. It is also more abundant along the large faults. This would indicate two stages for the development of the sericite, first during regional metamorphism and second during intrusion. The coarser grains of white mica are due to intrusion and disappear at short distance from the stock. The finer-grained sericite formed during earlier regional metamorphism and is widely distributed. The greater abundance of the mineral along the faults would evidently mean that the faults acted as channels for late hydrother-
FIG. 25. Aplitic dike near the mouth of Tepa Gulch. Picture taken looking northwest.

FIG. 26. The south limb of the broad State Creek syncline. Picture looking northwest from a point on State Creek road opposite the mouth of the West Fork of State Creek.
STRUCTURE

General Statement

The complex deformation of the pre-Cambrian Belt rocks of the Avery district is the result of folding, faulting and igneous intrusion. The monotonous of the strata throughout great thicknesses, together with the lack of exposures over large areas, make it impossible to work out all details of the intricate structure.

The geologic and structural map (Plate I) shows the trend of the major folds and faults. During the course of field work over 5,600 attitudes were taken on bedding, cleavage, flow structures, faults, joints and folds. Plate II shows the structure for three miles along the Milwaukee Railroad, from Avery to Stetson. This map, at a scale of 500 feet to the inch, has the structure projected to the plane of the railroad bed. As these outcrops are the best exposures in the district, many of the structural interpretations elsewhere in the area are based on it, and the section A-A' (Plate III) is a generalization of this detailed work. Plate IV illustrates the structure in and around the Herrick stock.

The deformation of the region is the result of at least three periods of orogenic movement and perhaps more. In the following pages each of the elements such as folds, faults, etc., will be discussed and illustrated, and finally, a general analysis of the structure of the district will be presented.

Folds

The strata of the Avery district have been thrown into a number of folds by forces acting in at least three separate directions at different periods of time. The first deformation folded the rocks into small, gentle, open, north-south-trending anticlines and synclines to the inch, but largely obliterated by later folding and faulting. The second period of deformation was caused by forces acting almost normal to those of the first and produced a large, open, asymmetrical synclinorium which, although it is now considerably interrupted by faults, is still the predominant structure of the district (Plate III). The folds of the third system are the result of the Herrick stock intrusion and are confined to the area surrounding the stock.

Packsaddle syncline: The Packsaddle syncline is a synclinorium as it is of considerable size, and both limbs are folded into numerous smaller folds whose axes parallel the main axis. The south limb dips more steeply than the north limb and is complicated by a greater number of small folds. These die out along their axes to the west, so that the south limb is rather simple and north-dipping west of Slate Creek.

The geologic map (Plate I) shows this structure. For simplicity, the early, north-south folding has been omitted along with the majority of the small flexures. Only a sufficient number of strike and dip symbols are used to clearly delineate the N. 76° W. trend of the main Packsaddle syncline and its component folds and faults. The syncline was named by Pardee (1910, p. 40) who mapped the structure in the upper St. Joe River Basin to the east of the Avery district, and called it the Packsaddle syncline after a mountain of the same name near its eastern limits.

The trend of the axis is emphasized on the map by the patches of Striped Peak formation that increase in size and thickness to the northwest along a trend of 10° plunge of the fold axis in that direction.

Slate Creek syncline: The Slate Creek syncline takes its name from that creek as it is beautifully exposed in the creek canyon (Fig. 26), two miles north of where Slate Creek empties into the St. Joe River. The syncline parallels the Packsaddle syncline and is the largest of the minor flexures on the south limb of that fold.

Forty-nine anticline: The Forty-nine anticline is asymmetrical with gentle south-dipping and steeply-dipping, vertical or overturning north limb (Fig. 27). It trends N. 50°-60° W. and is bounded to the north by the Mastodon Mountain fault. At Mastodon Mountain the fold becomes lost in the complicated fault zone formed at the junction of the Pine Creek fault and the Mastodon Mountain fault, but it is easily traced north of the Pine Creek fault.

Folds near the Herrick Stock: The strata about the periphery of the Herrick stock reflect the intrusion of the stock in varying degrees of intensity and form on different sides. To the north, the beds dip northward away from the intrusive body. Near the stock, on the east side, the beds show a few gentle, parallel, north-south-trending folds that plunge at a low angle to the north. The south and northwest sides are highly deformed, and the intensity of this deformation lessens away from the stock. Here the beds are folded into tight, at times isoclinal, folds overturned to the south (Figs. 28, 29, 30) and plunge in most cases about 20° southeast (Fig. 30). A few plunge to the northwest.

Faults

The many faults of the district disrupt the trend of the major folds and are reflected in the topography. The vertical displacement
FIG. 22. General view with detail of cleavage developed on the steep north limb of the asymmetrical forty-five degree antiform. Note crumpled bedding in the upper center of general picture dipping steeply to the right. At the center of the picture is a large rock hammer. Note that geology is to the left, thus the upper surface of the bedding is to the right. In detail, light-colored, crumpled bands are bedding.
along the faults ranges from a few feet to more than 2,000 feet. The fault planes vary from simple, clean-cut fractures with little gouge to broad crushed zones. The faulting is recognised by finding a formation in contact with another not adjacent to it in normal sequence, by discordant attitudes on either side of the plane of contact, and by actual observation of the fault plane or zone in underground workings or in well-exposed surface areas.

The existence of a fault is suggested by certain topographic features such as abrupt changes in the character of a stream valley (see Plate I, sec. 13, T. 46 N., R. 4 E.) The relatively rapid rate at which erosion takes place in fault zones tends to localize stream valleys along them and to form saddles where the faults cross ridges. An alignment of saddles is usually a sure criterion for a fault in the Avery district, but other evidence should be used to prove the existence of the fault.

St. Joe Fault: The course of the St. Joe River along the southern boundary of the area follows the St. Joe fault. Fardelle (1910, p. 48) mapped a series of faults in the upper St. Joe River basin and named one of them after the river. The writer has extended this name to cover the fault zone which has controlled the course of the river entirely across the Avery district. The fault is not a simple, single plane but is made up of an interpenetrating system of fractures and faults. It is a normal fault trending almost due east-west, with greatest displacement at the southwest extremity of the district where the Burke formation is in contact with the lower Wallace formation. The downthrow is to the north and the vertical displacement is approximately 2,200 feet. At the mouth of Kelley Creek sec. 15, T. 45 N., R. 5 E. the fault shows as a breccia zone 400 feet wide. Drag on this fault (Fig. 31) shows along the railroad cuts near the town of Avery.

Mostodon Mountain Fault: The most interesting fault in the region is the Mostodon Mountain fault, a reverse fault with a vertical displacement in the neighborhood of 1,500 feet on the east side of Mostodon Mountain from which the fault takes its name. Here the number three horizon of the Wallace formation is in contact with the Striped Peak formation. Southeast from Mostodon Mountain, along the strike of the fault the displacement lessens in amount until it is less than 500 feet where the fault leaves the area. The fault trends in a sinuous manner No. 45° to 65° W. with vertical or steeply south dipping fault plane. A short distance beyond the north boundary of the district it joins, is cut off by, or ends, against the Striped Peak fault. Beyond the eastern boundary of the district, the southeast end of the fault merges into the complicated fracture zone of the St. Joe fault.

The fault plane is not well exposed anywhere; however, where it crosses the North Fork of the St. Joe River, the upthrow side has complex crumpling and cleavage (Fig. 32) for a considerable distance away from the fault plane. On the downthrow side, the beds are much less deformed and are almost horizontal at places.

Striped Peak fault: The Striped Peak fault is expressed in the topography of the district along the south slope of Striped Peak where Elbow Gulch, a part of the headwaters of Slate Creek, has been cut along the fault zone (Plate I, sec. 17 and 18, T. 47 N., R. 4 E.). The fault is normal. It drops the lower part of the Striped Peak formation into juxtaposition with the upper or number 5 horizon of the Wallace formation. The fault trends N. 75° W. and is vertical or nearly so. It leaves the district both to the northwest and southeast.

Pine Creek fault: Collings (1923, Plate II) mapped the Pine Creek fault in the Coeur d'Alene district and his map shows it passing through the low Kellogg Saddle into the Avery district where it trends N. 45° W. with large downthrow to the southwest. It is a normal fault with the fault plane vertical or dipping steeply to the southwest. Where exposed in an unnamed prospect tunnel along the Middle Fork of Big Creek in sec. 28, T. 47 N., R. 3 E. the fault is a single fracture with sharply defined walls containing three to four feet of gouge and crushed material. The slickenside striations are vertical. The exact vertical displacement is not known, but near the prospect tunnel, must be close to 1,000 feet as upper Wallace beds are in contact with middle Wallace strata. At its southeastern end the fault enters a complexly deformed zone and becomes lost in an undiscernable fracture zone near the Mostodon Mountain fault.

Jumbo Creek fault: The Jumbo Creek fault can best be seen where it crosses Big Creek near the mouth of Jumbo Creek, sec. 20, T. 46 N., R. 3 E. The fault trends N. 80° E. and like the Pine Creek fault becomes lost in the complicated zone on the south slope of Mostodon Mountain. This normal fault has the downthrow to the north, but the attitude of the fault plane is unknown. The vertical component of displacement is approximately 1,500 feet where the number 1 horizon of the Wallace is in contact with the number 5 horizon of the Wallace. There are no persistent, recognizable key beds to measure from.

Joints
One of the most noticeable features of the sedimentary rocks in the Avery district is the
FIG. 28. Looking along the strike of the axis of a tight fold in the Burke formation. Field is located on Marble Creek road, one-half mile south of the southern boundary of the Avery district.

FIG. 29. Cross joints (a-e joints) in the same fold as above.

FIG. 30. Lamination parallel to axial plane of fold. The angle this lamination makes with the horizontal is the plunge of the fold, 30° S. E. in this case. The lamination is due to the intersection of building planes with strata.

FIG. 31. Down throw of the southern side of the St. Joe fault. Picture is taken from the railroad crossing east of Avery.
pronounced N. to N. 20° E-trending vertical or nearly vertical joints. These joints are usually normal to the axial planes of the main northwest folds; they are the ac joints as referred to the system of fold-coordinates shown in Fig. 34. The stream drainage pattern is to a great extent controlled by this prominent joint system.

Within the granitic mass of the Herrick stock and in the sedimentary rocks at its periphery, joints are profuse. Detailed mapping of these, often closely spaced joints revealed three major systems. The stock is best exposed where the Milwaukee Railroad grade cuts through it on the southern border, and Plate IV shows the distribution of the joints particularly along the south side.

The most numerous are the "cross-joints" (Cloos, 1937, p. 47). These joints strike N. 20° E. to N. 20° W. and are vertical or dip steeply in either direction. They are termed cross joints as they are approximately normal to the trend of the fold planes. Any change in direction of the flow planes is accompanied by a shift in trend of the cross joints and the right angle relationship is thus maintained. The cross joints may be closely spaced, forming shear zones, or they may be relatively far apart. A few of the joints dip at random, but the detailed mapping (Plate IV) brought out the fact that the cross joints in the western part of the stock dip east and those in the eastern part dip west; this, a vertical east west section through the stock would show the joints converging downward to form a fan.

The next most abundant joints are the "strike joints" (Cloos, 1937, p. 49) that trend N. 70° W. and dip gently (10° - 20°) into the intrusive mass. These joints parallel the flow planes in strike but dip much more gently. Both the cross joints and the strike joints may extend outward into the intruded sediments and the latter commonly have aplite dikes along them.

A less prominent system of joints is found along the western border of the stock. These trend N. 70° E. to N. 75° W. and dip from 30° to 70° either north or south.

Cleavage

Cleavage is prominently developed in the rocks of the district. When dealing with great thicknesses of monotonous rocks such as the Belt series, cleavage is especially helpful to the observer in determining tops and bottoms of beds and in finding one's position in relation to fold axes. It is quite useful in underground work where many times cleavage is the only feature by which tops and bottoms of bedding may be determined. Fig. 35 demonstrates the use of cleavage in deciding the attitude of the bedding. Shimer and McComnel (1940, p. 440) have shown the usefulness of cleavage and sedimentary features in interpreting the structure of the Silver Belt of the Coeur d'Alene district, and the writer made use of all the factors discussed in their paper to decipher the structure of the Avery district.

True cleavage or flow cleavage is well developed in the rocks near the south border of the Herrick stock (Figs. 35, 36, 40). The relation of flow cleavage and bedding near the stock is shown by Fig. 35. In this figure, a joint lineation is visible which is caused by the intersection of bedding planes with cleavage. Away from the intrusive mass the flow cleavage or schistosity dies out.

Elsewhere in the district, the cleavage corresponds more closely to false cleavage or fracture cleavage as discussed by Cloos (1937, p. 64), and Hill (1941, p. 97). Figs. 35, 36, 37, illustrate this type of cleavage.

Primary Flow Structures in the Herrick Stock

Primary planar flow structures (Cloos, 1937, pp. 36-49) can be seen in the granitic rock of the Herrick stock where railroad and road cuts expose fresh rock. Natural exposures are so weathered that the rather faint structures of the flowage phase are not visible. The flow planes produced by the alignment of minerals, clusters of minerals, or oriented fragments, have been mapped in detail and are represented in a generalized manner on the map of the Herrick stock, Plate IV. On this map, most of the geology has been omitted in order to emphasize the structure of the flowage phase.

The flow elements found in the stock are aligned biotite flakes or clusters of biotite flakes (autochths), flattened and oriented wall rock fragments (xenoliths), and clusters of feldspar phenocrysts oriented as a cluster as well as within the cluster itself.

The most characteristic planar structure is caused by the alignment of individual biotite flakes and flattened and aligned clusters of biotite flakes. Less noticeable but important is the sub-parallel arrangement of the fragments of feldspar phenocrysts. These clusters range in size from a few inches to several feet in longest dimension. The clusters are flattened, three-dimensional bodies oriented with the longest axis in the direction of flow, the shortest axis normal to the direction of flow, and the intermediate axis parallel or sub-parallel to the strike of the flow lines. Within the clusters the feldspar phenocrysts have a similar orientation.

The cumulative pattern of the planar flow
Fig. 34. ELEMENTS OF A FOLD
FIG. 26. Cleavage in sandstone of Striped Peak formation. Bedding and cleavage dip in opposite directions with the bedding dipping more steeply, thus beds are right-side up to the right. Antilithumlithum fault to the left. Picture taken on ridge crest one mile north of Sheep Drove.

FIG. 34. Effect of cleavage on competent sandstone (thicker beds) and incompetent shale beds of the Striped Peak formation. Picture taken at same location as Fig. 26.

FIG. 37. Differential effect of cleavage on sandstone and shale of the Striped Peak formation. Picture taken near the crest of Cedar Mountain.

FIG. 39. Crest of fold showing lineation caused by the intersection of bedding planes and flow cleavage. Note cross (x-z) joints.

FIG. 40. Detail of lineation along crest of fold shown in Figs. 38, 39.
elements trends N. 70° W. and dips 65° to 85° N. E. throughout much of the stock. This trend is sub-parallel to the south border of the stock. Near the eastern boundary, the flow plane complex is deformed enough to parallel that border, but heavy soil and timber prevented complete mapping here.

From the direction of the flow plane, it is inferred that the magma that ultimately consolidated to form the stock moved upward at an angle of 65° to 85° along the fractured and weakened zone formed by the St. Joe fault. This inference is further borne out by the fact that south of the intrusive mass the sedimentary strata are thrown into tight folds overturned to the south. North of the stock the beds dip outward away from the stock (See section B-B', Plate III).

Structural Analysis

The tectonics of the Avery district are so interrelated with those of the Coeur d'Alene district that an attempt at an analysis of the structural features of the former alone is insufficient. The deformation pattern of the two districts originated during and following the Laramide Revolution at the close of Mesozoic time. Before the entire picture and history of this complex deformation can be completed, extensive detailed mapping must necessarily be done in all directions away from these districts. Particular attention should be given to fault intersections, direction of fault movement, the structures of all intrusive masses, and the position of the remaining remnants of the old erosion surfaces that occur at different elevations in the area.

On the tectonic map (Plate V), are shown the major structural trends of both the Avery and Coeur d'Alene districts. Faulting is the chief feature, while folding, now much interrupted by the faulting, plays a minor role.

The great Osburn fault which divides the Coeur d'Alene district approximately in half is the dominant structure. According to Ump-ley and Jones (1923, pp. 11-14) this fault cuts all other structures in the district and has a horizontal displacement of 10 to 15 miles and a vertical displacement from less than 1,000 feet to more than 10,000 feet. The fault zone dips steeply south and the downthrow is toward that side. South of the Osburn fault and parallel to it at intervals of 3, 6, and 12 miles respectively are the Place Creek fault, Striped Peak fault and the St. Joe fault. These are normal faults that trend N. 70° to 80° W. Between the Osburn fault and the Place Creek fault is the Big Creek fault, a reverse fault that trends N. 60° W. and dips steeply south. Between the Striped Peak fault and the St. Joe fault, is the Mastodon Mountain fault, a reverse fault, that trends N. 50° to 60° W. and dips steeply south.

Normal or gravity faulting indicates formation under tension. Reverse faulting indicates formation under compression. The formation of both normal and reverse faults at the same time seems incompatible and can best be explained by two periods of faulting under different sets of forces. The normal faults followed the folding of the region as they displace the folds. When the forces that caused the horizontal movement along the Osburn fault originated, an entirely new set of faults, the reverse faults, developed in response to compressive stresses set up by irregularities along the strike of the great Osburn fracture.

The chief normal faults such as the Osburn and St. Joe existed before the intrusion of the Herrick stock (Cretaceous) as this timeous mass was intruded along part of the St. Joe fault zone. That movement along the fault continued after the intrusion is demonstrated by the crushing and fracturing in that part of the stock nearest the fault zone.

Age of the Faults

Dating the faults of the district is difficult. Poor exposures combined with the intricate nature of the fault intersections prevent determining with any degree of assurance the exact relation of one to the other.

The St. Joe fault is probably the oldest fault in the district. The Herrick stock (Cretaceous) is intruded, in part, along this fault. The Cenozoic age of Idaho batholith has been proven by Reed (1937, p. 8) from determination of the lead-uranium plus thorium ratio of pitch-blende from the Warren district, Idaho. The writer considers the Herrick stock to be an offshoot of the batholith; therefore, the St. Joe fault is pre-Cretaceous. The Striped Peak fault is probably the same age. As stated above, Mastodon Mountain fault may end against or join each of these. Its age is problematical, but as it interrupts the old erosion surfaces described earlier under topography, a probable age can be assigned it. The youngest erosion surface that the fault cuts is the third or old valley surface. Anderson (1938, pp. 758-761) assigns an age to this surface as between the end of the Eocene and middle Miocene. The upper limit is based on the erosion surface having been formed, uplifted, and partially dissected before the Columbia River basin invaded and filled valleys during middle Miocene time. A few small areas of Miocene basalt are along the western edge of the district but are not near the Mastodon Mountain fault. The fault does not appear to interrupt the basalt and is, therefore, post Eocene but pre-middle Miocene.

The Pine Creek fault may be younger than the Mastodon Mountain fault.
SUMMARY OF GEOLOGIC HISTORY

Sedimentary Record

The geologic record begins with deposition of a thick series of sediments in a vast, shallow sea throughout the latter part of late pre-Cambrian time. The sediments are characterized by fineness of grain size, by conformable sequence, by abundant ripple marks and mud cracks and by gradual transition of one formation into another. These facts indicate that the land mass from which the sediments were derived was of low relief and that erosion was slow. The abundant mud cracks show that deposition took place in shallow water on extensive mud flats frequently exposed to the drying rays of the sun. The extremely thin and evenly-spaced lamination of many of the beds points to deposition in extremely quiet water.

The sedimentary history is a blank from the end of the deposition of the Belt series until early Tertiary time when sand and gravel were deposited along old-age stream channels.

The latest events in the sedimentary record occurred in Quaternary time when a few small glaciers (Pleistocene) carved cirques in the higher peaks and upon their retreat left scarm valley trains (too small to map) in at least one valley. More recently the present streams have deposited alluvium along their channels.

Igneous Record

The earliest igneous activity is recorded by thick sills in the Wallace formation. There is no way of determining the exact time of intrusion, but it must have been at the close of pre-Cambrian time or in early Paleozoic time as the doleritic sills have suffered all of the orogenetic movements that have affected the Belt rocks.

The next and greatest igneous activity occurred during the Laramid Revolution when the rocks were folded and faulted. The accompanying igneous intrusions are the Herrick stock and its related dikes. The intrusion of the stock folded and faulted the sediments about its border. Faulting continued after solidification of the stock, and as differentiation took place in the magma chamber below, numerous pegmatic solutions were injected into the upper already solid part of the stock and into the intruded sediments where they solidified as aplite dikes and sills. More basic differentiates were given off a little later and formed lamprophyric dikes in the sediments enclosing the stock. These were closely followed by mineral-bearing solutions which deposited mineral veins in fractures in the stock and in the sediments. Solutions given off by the cooling granitic magma bleached and metamorphosed the sediments near the contact.

The final chapter in the igneous record occurred in Miocene time when the flows of Columbia River basalt invaded the St. Joe River valley from the west and formed the sheets of basalt that now exist as caps on the low hills in the southwest part of the district.

Physiographic Record

The present topographic features are the result of a long complicated erosional history. By the close of Cretaceous time, the region had evidently been reduced to an area of low relief that is now represented by concordant summit flats on the crests of the highest mountains. Following the reduction of the area to low relief the region was again slowly uplifted, probably during early Tertiary time, and intensive erosion was again inaugurated. A second, much less extensive, peneplain was then carved about 1,000 feet below the older one. This peneplain was probably complete by Eocene time. Uplift again renewed erosion and by Miocene time the land surface was carved much into its present form and the streams had reached an old-age stage and had widened their valleys producing a third peneplain which is now represented by a few gravel-covered benches about 800-1,000 feet above the present stream bottoms. The land then was again re-elevated and incised. During middle Miocene time, the Columbia River basalt flowed in from the west and blocked the main stream channels. Subsequent erosion has been mainly by streams, but glaciers have carved small cirques in some of the higher mountains.

ORE DEPOSITS

HISTORY AND PRODUCTION

The history of the Avery district goes back to the settling of the lower St. Joe River valley in 1842 by the Jesuits and to the opening of the Coeur d'Alene mining district in 1878 when the first mining claim was located. The Avery district adjoining this famous district to the south, has been prospected intermittently since that time, but with little success as there is no recorded production from any of the properties within the boundaries of the area defined above as the Avery district. It is reported, however, that several small shipments of low-grade copper ore have been made from the Franklin property.

GENERAL CHARACTER OF THE DEPOSITS

Surface evidences of mineralization are scant in the Avery district. The known depo-
its are small and insufficiently developed; the underground workings, in most cases, are inaccessible. Although the deposits vary somewhat from place to place, they may all be classified as replacement deposits along fissures and fractures. Where the country rock is of sedimentary origin (usually calcareous quartzite of the number 2 horizon of the Wallace formation), the mineralizing solutions have extensively replaced the wall rock; however, where the country rock is granitic or pure quartzite the veins show only minor replacement of the wall rock. The former have siderite as the chief gangue mineral, whereas in the latter quartz predominates or is equal in amount to siderite.

**Mineralogy of the Veins**

Mineralogically the veins are rather simple. They consist of pyrrhotite, pyrite, gersdorffite, arsenopyrite, tetrachloride, chalcopyrite and sphalerite in a gangue of siderite or siderite and quartz. All of the veins are reported to carry gold, but it is not found in visible quantities. Galena has been reported from the district, but none was found by the writer. Secondary minerals are sparse, but where present they are usually malachite and scorodite. For convenience of description, the minerals are grouped into primary metallic minerals, gangue minerals, and secondary minerals.

**Primary Metallic Minerals**

Pyrrhotite (Fe₉₋₁₅S₈) to (Fe₄S₄)₈ The magnetic sulfide pyrrhotite, is the chief metallic mineral of the veins in all but one property; it occurs in all deposits as the first ore mineral to form. The mineral is easily recognized by its bronze to reddish-copper color and slightly magnetic character. In polished section, it forms the main masses of metallic minerals and is cut by all other minerals except pyrite with which it forms mutual boundaries. The pyrrhotite irregularly replaces, forms cross-cutting veins, or forms veins along cleavage planes in the siderite.

Pyrite: (FeS₂) Pyrite, the iron sulfide, is found in varying amounts in all veins. It is more abundant in the deposits where quartz is equal to or greater in amount than siderite as gangue. At the Cougar group of claims pyrite forms the greater part of the metallic minerals.

Gersdorffite (Ni₂As₄S₈) This sulfarsenide of nickel occurs in microscopic quantities in most of the deposits. Shannon (1924, pp. 275-276) reported the occurrence of an iron-cobalt-nickel mineral which he called gersdorffite, from the Beals-Flomelake property one mile north of the mouth of Slate Creek. The writer was unable to obtain specimens from this property as the ore is no longer in sight, but ore from the Franklin property contains microscopic veinlets and bieles of gersdorffite which shows evidence of replacement by later minerals (Fig. 41).

In polished section the mineral is isotropic and has a silvery white color with a pinkish tinge. Microchemical tests for nickel, iron and arsenic were obtained, and qualitative chemical tests on fragments known to contain the mineral gave strong nickel tests and doubtful cobalt tests.

Willard (1941, pp. 541-543) reported gersdorffite below the 900 foot level of the Polaris mine in the Silver Belt of the Coeur d'Alene district.

Arsenopyrite: (Fe₃As₄S₂) The subharsenide of iron, arsenopyrite, was found in the ore of the Copper Prince property. It occurs in small bieles in pyrrhotite and as crystals in quartz. At the other properties, it is rare.

Tetrachloride: (3Cu₂S·5Sb₂S₃) Tetrachloride or gray copper occurs as microscopic veinlets (Fig. 43) and blates in the ore of all properties studied in polished section. It replaces pyrrhotite and the veinlets cut the gersdorffite.

Chalcopyrite: (CuFeS₂) Chalcopyrite or copper pyrite is present in the ore of all properties examined. In polished section it is seen as small grains cutting all of the above minerals. At times, it is found replacing siderite and often is the only sulfide present in considerable masses of siderite. It may form thin films along cleavage planes and fractures in the siderite.

Sphalerite: (ZnS) The sulfide of zinc, sphalerite, is the latest mineral to be deposited. It occurs in small veinlets cutting all other minerals (Fig. 44), or in a few instances it is replacing earlier minerals such as gersdorffite (Fig. 41).

**Gangue Minerals**

Siderite: (Fe₂CO₃) Siderite is the principal gangue mineral of the district and occurs in all deposits, although, at the Cougar group of claims it is rare and is subordinate to quartz at the Copper Prince property. It is invariably coarse-grained, massive and has a light tan or buff color. Surface exposures are black or reddish-brown because of the oxidation of iron and manganese. It is commonly cut by irregular, ramifying veins of quartz which in places follow the cleavage planes of the siderite. At places, the quartz veins intersect and enclose isolated rhombo of siderite.

Quartz: Quartz is present at all properties and is the predominant gangue mineral at the
FIG. 41. Veinlet of sphalerite (S) cutting pyrrhotite (P) and tetrahedrite (T). The sphalerite is also beginning to replace gersdorffite (G) around its borders. Polarised light, 150 X.

FIG. 42. Illustrating successive reopening of fractures. Pyrrhotite (P) has been fractured and the fractures filled with tetrahedrite (T), then the fractures have been reopened and partially filled with sphalerite (S). Polarised light, 150 X.

FIG. 43. Veinlets of tetrahedrite (T) filling fractures in haematized pyrrhotite (P). Polarised light, 150 X.

FIG. 44. Chalcopyrite (C) replacing siderite (dark) and both are cut by a veinlet of sphalerite (S). Note some straight boundaries of chalcopyrite against siderite. Polarised light, 150 X.

FIG. 45. Pyrrhotite (P) and tetrahedrite (T) replacing siderite (dark). Note irregular inclusions of siderite in the pyrrhotite. Polarised light, 150 X.

FIG. 46. Triangular grain of chalcopyrite (C) cutting pyrrhotite (P) and tetrahedrite veinlets (T) and in turn being cut by veinlets of sphalerite (S). Polarised light, 150 X.
Copper claims and the Copper Prince property. It forms a reticulated pattern in siderite where that mineral is the chief gangue. Its contacts with the siderite are often angular because they follow the siderite cleavage.

The quartz often contains numerous residual grains of siderite and both of these minerals are veined and replaced by sulfides.

**Secondary Minerals**

Malachite: (CuCO₃, Cu(OH)₂) The green copper carbonate, malachite, is present in small quantities as thin films on surfaces and filling small cracks at the outcrop of most veins.

Schorodite: (Fe₂(AsO₄)₂·2(H₂O)) This hydrous ferric arsenite occurs as a pale yellowish-green stain on the vein outcrop at the Copper Prince property.

**PARAGENESIS**

The minerals of the district show evidence of having been deposited in a definite but interrupted sequence (Fig. 42). The earliest deposited mineral was the siderite, and its deposition was followed by shattering. Next, quartz was deposited and the veins again fractured. Following the fracturing of the quartz and siderite, pyrrhotite and pyrite were deposited. The veins again underwent a period of fracturing, and gersdorffite, arsenopyrite and tetrahedrite were introduced in the order listed. In part, chalcopyrite probably formed at about the same time as tetrahedrite as it shows mutual boundaries with that mineral in some cases, but in other cases it clearly cuts the tetrahedrite (Fig. 46). Following the chalcopyrite fracturing again took place, and then sphalerite was introduced. The sphalerite cuts all other minerals (Fig. 44).

Table III below shows the mineral sequence in diagram.

**TABLE III**

<table>
<thead>
<tr>
<th>Stages:</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
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<td>Pyrrhotite</td>
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<td>Gersdorffite</td>
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<td>Tetrahedrite</td>
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<td>Chalcopyrite</td>
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<td>Sphalerite</td>
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**GEOLGIC DISTRIBUTION OF THE DEPOSITS**

The mineral deposits occur in both sedimentary and igneous rocks. In the sediments, all members of the Belt series within the district contain some evidences of mineralization. The Franklin property, the largest in the district, and the Menstodon property are in the number 2 horizon of the Wallace formation. The Copper group of claims and the Copper Prince property are both near the contact of the granitic rock of the Herrick stock fault the quantities of the lower Wallace formation. At these two properties the veins are in fractures cutting both the igneous rocks and the sediments.

The metasedite sill in the lower Wallace formation also contains a few stringers of quartz and siderite with some pyrrhotie and pyrhotite, but none of these have been explored within the district.

**STRUCTURAL RELATIONS OF THE DEPOSITS**

The deposits are closely associated with areas of marked structural disturbance. They occur in fractures developed during the period of deformation that produced the regional faults. These fractures are parallel to or at a small angle to the main faults. They strike from east-west to N. 70° W. and dip from 45° to 80° S. Only one of the prospect tunnels cuts a major fault. This adit, on an abandoned property, the name of which could not be learned, cuts across the Pine Creek fault in sec. 28, T. 47 N., R 3 E. The main break is unmineralized, but small fractures in both the hanging and footwall contain stringers of quartz and siderite with some pyrrhotie and chalcopyrite.

**NATURE OF THE ORE BODIES**

As none of the properties within the district have proved to be of commercial value, the development work on the veins is not extensive, and little could be observed as to the nature of the ore bodies. At the Franklin property, however, the southernmost tunnel exposes an ore shoot approximately 12 feet wide by 80 feet long from which ore is reported to have been shipped. This ore shoot formed where the mineralizing solutions moving upward along a steeply south-dipping fracture came in contact with gently south-dipping calcareous, quartzite beds of the number 2 horizon of the Wallace formation and irregularly replaced them. The main mass of the shoot is siderite which has been fractured and the fractures subsequently filled with quartz and sulfides (Fig. 45).
ALTERATION OF THE WALL ROCK

The replacement of the wall rock by sulfdes and gaseous minerals varies in intensity from a few inches outward from the vein when the walls are granitic or pure quartzite to considerable distances where the walls are of more easily soluble nature. This replacement of the wall rock has been accompanied by hydrothermal alteration. The sedimentary rocks are bleached near the veins. Sericite is abundantly developed in the bleached zone and minor amounts of silica, carbonate and pyrite are also present. Where the wall rock is igneous, it takes on a greenish hue and often a greasy feel from chlorite developed by hydrothermal solutions. Pyrite and sericite are also conspicuous.

The rocks along the large regional faults are often bleached and altered. Shenton and McConnell (1939, p. 6) describe and map this feature in the Silver Belt of the Coeur d'Alene district and connect it with the ore deposits of that region. This bleaching is most noticeable along the northern boundary of the Avery district.

TENOR OF THE ORE

Assay records are not available on any of the properties, but it is reported that all of the deposits carry minor amounts of gold and silver. The Cougar group of claims is said to run from $7 to $15 in gold per ton. Although nickel and cobalt show in tests on ore from some of the properties, microscopic studies show that the minerals containing these elements do not occur in sufficient quantities to be of commercial value. Picked samples from any of the properties could be found to assay from 10 to 15 per cent copper, but the average grade of the known ore bodies would probably be less than 1 per cent copper.

GENESIS OF THE DEPOSITS

The deposits of the district are of hydrothermal origin, but the source of the mineralizing solutions is as yet not certainly known. The hydrothermal origin is indicated by the occurrence of replacement deposits in the wall rock independent of fractures, by the replacement of earlier minerals by those that formed later, and by formation of abundant sericite, silica and pyrite in the wall rock. The mineralogy and texture of the ores indicate that the veins were formed under mesothermal conditions.

The localization of ore was controlled by the existence of satisfactory channelways for the circulation of metal-bearing solutions, and by the concurrent stresses which formed successively new fractures and thus reopened the channels for continued circulation of solutions and deposition of ore.

The relation of mineralization to igneous activity is seen at the Copper Prince property where the vein fills a fracture which cuts not only the sediments and the granitic rock of the Herrick stock but also the pegmatite veins in the stock. They are thus younger than any of the enclosing wall rock.

The deposits are intimately associated with the deposits of the Coeur d'Alene district and they resemble closely the deposits in the Moyie Tank district (Anderson and Wagner, 1945, pp. 7-9) and the Clark Fork district (Anderson, 1930, pp. 54-93). In the Clark Fork district, Anderson points out the close association of the same type of mineralization with Lanamite structural features and early Tertiary magmas that formed dikes in that area. The relation between ore deposits and igneous intrusion are clearly demonstrated by Sampson (1929, pp. 23-24) in the Pend Oreille district. In this district, the mineralization barely preceded the intrusion of lamprophyre dikes. Lamprophyre dikes are regarded as a common sequel to the intrusion of granitic magmas. As the ore deposits of the Pend Oreille region are cut by some of these dikes, it is clear that they were formed during the period between the solidification of the upper part of the granite rock, and the period of intrusion of the lamprophyre dikes.

From the above facts and from the writer's experience in other mining district of Idaho, the solutions that deposited the ores are thought to have originated from deep-seated magma undergoing differentiation during early Tertiary time.

FUTURE OUTLOOK OF THE DISTRICT

The future outlook for the Avery district is none too promising. Surface evidences of mineralization are poor and scattered. The deep mantle of soil and dense growth of brush make prospecting extremely difficult. Of still greater importance, is the fact that a considerable portion of the surface area of the region is underlain by rocks of the Wallace formation. This formation is notably lacking in ore deposits of commercial grade in the neighboring Coeur d'Alene district (Shamosne and Colkins, 1908, pp. 104-107); although, in the upper St. Joe River basin, Pardee (1910, pp. 54-57) describes several deposits that have produced some valuable ore from the Wallace formation. These mines appear to be located in the number 1 and 2 horizons of the Wallace, and it is this part of the formation that contains the Franklin prospect which is the most promising of the Avery district.
PORTAL ADIT No. 3

Scattered sulfides.

Adit driven on lens shaped body of siderite (FeCO₃) which has replaced calcareous country rock.

PORTAL ADIT No. 2

Country rock impure quartzite

5'-12' low grade ore considerable Cu stain

Bunchy quartz, FeS₄, CuFeS₄ in fractured body of FeCO₃

PORTAL ADIT No. 1

EXPLANATION

Fault

Fracture

Mineralization

Strike & dip

Cleavage

SCALE

Franklin Mine

Underground geology

SKETCH MAP

Showing location of the property and adit sites.

To Heyt & St. Joe River 4 1/2 miles
Shenon and McConnel (1939, pp. 8-9) have described and mapped extensive bleached and altered zones in the Silver Belt of the Coeur d'Alene district, and they suggest that this alteration and bleaching is related to the commercial deposits of the district. This bleaching is not a prominent feature in the Avery district. The altered zones show along the northern boundary of the district but become less intense to the south.

If additional deposits are to be located in the Avery district, prospecting should be confined to the belts of greatest deformation.

**PROPERTIES**

Of the numerous prospect pits and mining claims in the district, only three are discussed below in detail. The majority of the exploration tunnels and shafts are caved and few data could be obtained concerning the structure of the deposits at many of the properties. Undoubtedly a number of claims, prior to the 1910 fire, were staked for their valuable timber. Most of the older claims are now open as the assessment work has not been kept up.

**THE FRANKLIN PROPERTY**

The Franklin property is located in sec. 27, T. 46 N., R. 4 E., on Slate Creek 4 1/2 miles north of its mouth. The property may be reached over a poorly-graded, narrow road that is kept open five months of the year by the U. S. Forest Service.

The deposit occurs in impure quartzite of the number 2 horizon of the Wallace formation and is explored by three short tunnels with a total length of 350 feet. The surface plant consists of a cabin for living quarters and the wrecked remains of a compressor house and tool shed. No work has been done on the property for a number of years other than the opening of the tunnel portals in 1942-43 for the purpose of sampling.

According to A. W. Stanley of Wallace, Idaho, the property belongs to the Nickelby heirs of Wallace. The number of claims comprising the holdings could not be learned, and the corner posts are down.

Plate VI shows the location of the adits and the underground geology of each in some detail. Adits numbers 1 and 2 are driven in opposite directions on a fracture zone that trends N. 70° W. and dips 30° to 50° S. The fracture pinches out toward the west in the number 2 tunnel. It increases in width and intensity to the east and attains its greatest breadth in the number 1 adit on the east side of Slate Creek. The fracture zone is made up of a number of sub-parallel breaks of which contains thin gouge seams. The whole zone has been mineralized, but the greatest mineralization is evident in the eastern workings. Siderite and quartz are the chief gangue minerals, and these have been fractured and the sulfides are scattered along the later breaks. The ore body exposed in the number 1 drift has the only ore of any value and that is of rather low grade. The ore body is 60 feet long by 12 feet wide at the widest exposed point. The actual width could not be determined as it has not been completely cross cut. The greatest breadth and most ore occurs where the vein makes a roll, and the dip flattens from 50° to 30°. A vertical 15 ft. winze sunk on the ore at this point was inaccessible but appeared to pass out near the ore a few feet below the floor of the drift.

Adit number 3 is about 1,000 feet north and 75 feet vertically above number 1 and 2. It is driven on an irregular, lense-shaped body of siderite that it not visibly connected with fractures. Surface covering prevented accurate measurement of the body, but it seems to strike N. 70° W. and dip about 30° S. The siderite has entirely replaced the wall rock in part of the body, but at some points, isolated fragments of wall rock are completely surrounded by siderite. This siderite body has been fractured and slightly mineralized with quartz and minor sulfides, mostly chalcopyrite.

The Franklin prospect is the most promising in the district, but the low grade of its ore combined with the tightness of the structure are not conducive to further exploration.

**THE COUGAR GROUP**

The Cougar Group, also known as the Theronult property, is located at the junction of Harvey Creek and the St. Joe River in sec. 18, T. 45 N., R. 4 E. It can be reached from the Avery-St. Maries road by fording the river a few hundred feet east of Harvey Creek.

Th property, consisting of 5 patented claims, belongs to Mr. I. E. Theronult of Avery, Idaho.

Development on the claims includes one tunnel 280 feet long, driven near water level of the St. Joe River, and a number of open cuts that are now mostly filled. Plate VII shows the underground geology of the tunnel. The adit goes in on a shear zone in steeply northeast-dipping, bluish-green quartitic slate of the lower Wallace formation or possibly of the upper St. Regis formation. The vein exposed underground is in a complex, tight fracture zone 3 to 4 feet wide that trends N. 70° W. and is vertical or dips 75° to 85° N. E. Mineralization along the vein consists of quartz, siderite and minor sulfides such as pyrite, pyrrhellite and
Mineralized structure
Fault
Strike & dip bedding

PLATE VII
COUGAR GROUP
SCALE

40 20 0 40 80 feet

Granite
Quartzite
pegmatite vein
Quartzite, somewhat schistose
Sulfides

Harvey Cr
ST. JOE RIVER
chalcopryite mostly in a central fracture from 1 to 2 inches wide. The drift goes in on the structure about 80 feet, then apparently goes off to the east and does not cut the principal vein again even though an attempt was made to pick up the structure farther in by cross cutting.

The property is near the granite-sedimentary contact, but none of the workings expose the contact. In an open cut, above the Milwaukee Railroad, a metadiorite sill or dike about 2 feet wide, striking N. 70° W. and dipping 75° S., has been sheared and mineralized. Whether the fractures that cut the sediments and the dike enter the granite could not be learned, but it is thought that they do. The structure of the Cougar Group is apparently the same as at the Copper Prince a few miles to the west. The veins are thought to be in fractures associated with post-intrusion movement along the St. Joe fault zone which passes through the property but is not exposed by the exploratory work.

No assay records were available on the ore of the property, but according to Mr. Theriault, the owner, the ore assayed between $7 and $15 per ton in gold. Microscopic examination of the ore did not reveal the mode of occurrence of the gold. No shipments of ore have been made from this property.

COPPER PRINCE PROPERTY

The Copper Prince property is located on the St. Joe River at the mouth of Black Prince Creek in sec. 10, T. 45 N., R. 3 E., a few hundred feet south of sec. 3. It is owned by Mr. Mahaffy who lives on the ranch of which the claim is now a part.

The exploration workings on the deposit, both surface and underground, are caved and little could be learned from them; however, railroad and road cuts expose part of the structure to good advantage.

The Copper Prince structure trends N. 70° W. and is vertical or dips steeply either north or south. The vein is made up of a number of parallel, mineralized slits and may be properly classified as a lode. The country rock is metamorphosed quartitic slate of the lower Wallace formation and the granitic rock of the Herrick stock. The deposit has previously been classed as contact metamorphic (Farabee, 1910, pp. 57-58), but the writer thinks that it is a fissure-filling deposit and that the mineralization was not caused by the intrusion of the stock. The metamorphosed sedimentary rock is a small roof pendant on the stock and the shear zone containing the lode cuts the sediments, the granitic rock, and several small aplite dikes associated with the latter. The fracture zone is related to post-intrusion move-ment along the St. Joe fault zone which passes a few hundred feet to the south of the property.

Mineralization along the exposed part of the structure consists of seams and stringers of quartz containing scattered bunches of pyrite and chalcopryite. In a caved portion of one of the tunnels, a component fissure of the lode is 18 inches wide and is filled with quartz and siderite with minor amounts of pyrite, pyrrhotite, chalcopyrite, and a few fine grains of arsenopyrite. The lode is reported to assay $4 per ton in gold, but the copper content is not known.

Many of the fractures in the granite and sediments near the deposit show some signs of mineralization, and a large, rusty, minutely-fractured zone in the granite is exposed in a railroad cut 1,000 feet west of the main workings.

Development work on the property has not uncovered valuable ore bodies and no ore has been shipped.

OTHER PROPERTIES VISITED

Other properties examined include the Silver Svanny in sec. 11, T. 46 N., R. 4 E., the Sailor Boy in sec. 13, T. 46 N., R. 4 E., the Mastodon in sec. 8, T. 46 N., R. 4 E., the Stanley or Beals-Piuteke in sec. 3, T. 45 N., R. 4 E., and a group of properties, the names of which could not be learned. As the working on these claims were either caved or insufficient in extent to expose the vein, no additional information concerning the mineralization of the area could be gained.

REFERENCES CITED


Collins, F. C. (1908) See Ramsome (1908) below.


(1923) See Upleby and Jones below. Plate II of their report by Collins.


