GEOLOGY OF THE SOUTHERN THIRD OF THE MULLAN AND POTTSVILLE QUADRANGLES, SHOSHONE COUNTY, IDAHO

by

S. W. Hobbs, R. E. Wallace and A. B. Griggs

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CONTENTS

ILLUSTRATIONS

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INTRODUCTION

The area comprising the southern third of the Mullan and Pottsville quadrangles was studied during the summers of 1948 and 1949 in the course of a remapping and restudy of the Coeur d'Alene mining district by the U. S. Geological Survey. This is the first of several preliminary maps and reports to be issued as the work progresses.

The authors express their appreciation to the officials, engineers, and geologists of the mining companies holding property in the area for the help given during the course of the work.

GEOLOGIC FORMATIONS

The rocks which underlie the area studied are composed almost exclusively of the St. Regis and Wallace formations of the Belt series of pre-Cambrian age. A few lamprophyre and metadiorite dikes cut both the St. Regis and the Wallace formations. The valley of the South Fork and a few of its major tributaries contain deposits of Quaternary terrace gravels and Recent alluvium, and small deposits of glacial moraine occupy the upper parts of several tributaries to the main valley. Monzonite stocks, which may have a common origin with the ore deposits, crop out a short distance to the north but have not been found within the mapped area.

St. Regis Formation

More than 50 percent of the mapped area is underlain by the St. Regis formation. The largest area of exposure is in the core of a broad, somewhat complex west-trending anticlinal structure and extends from the Montana line westward beyond Rock Creek, where it plunges under the overlying Wallace formation. Two small wedge-shaped areas of the St. Regis rocks are exposed between the Big Creek and Placer Creek faults in the southwest corner of the area mapped. The St. Regis formation in this part of the Coeur d'Alene district has been divided into two members. A lower member comprises the main part of the formation and an upper member forms a zone of transition into the overlying Wallace formation.

Lower member

More than 1,200 feet of St. Regis strata have been measured in the East Fork of Willow Creek, and structure sections indicate a total thickness of over 2,000 feet of St. Regis rocks in the area east of Willow Creek. (See section D-D'.) The measured section is fairly representative of the rocks in the lower member of the formation, which here comprises a series of fine-grained, predominantly argillaceous sedimentary rocks that are thin-bedded and commonly laminated. Of the 1,200 feet that was measured in detail, approximately 60 percent is classed as argillite containing less than 25 percent of interbedded or interlaminated quartzite; 35 percent is classed as interbedded quartzite and argillite containing more than 25 percent but less than 75 percent quartzite; the remaining 5 percent is classed as quartzite containing less than 25 percent argillite. In addition to the argillite and quartzite, a considerable amount of carbonate occurs as a recognizable constituent in over 45 percent of the beds in the St. Regis formation. The carbonate is iron-bearing, most commonly a variety of ankerite, but locally the composition approaches that of siderite. It occurs most commonly as discrete crystals and clusters of crystals, generally many times larger than the grains of the rest of the rock but also as a filling of the interstices between the grains of the sediment. Only rarely does it constitute more than 20 or 30 percent of the rock volume. The carbonate shows a marked preference for the purer quartzitic layers, and, consequently, it is scattered through the formation more or less in proportion to the abundance of quartzitic beds or lenses interbedded with more argillaceous rocks.

Most rocks in the St. Regis formation in the Coeur d'Alene district are various shades of purple, and generally the formations may be distinguished by this feature. Locally alteration has bleached the purple to a gray or light gray-green or yellow-green hue.

The purple color is retained on weathered outcrops of the noncarbonate-bearing portions of the formation. Weathered outcrops of beds containing carbonate, however, have a light- to dark-brown rind, which, in rock with a relatively high percent of carbonate, is soft and punky.

In the valley of Boulder Creek and between Boulder Creek and Willow Creek the St. Regis formation includes massive lenses of breccia of undetermined origin. Individual lenses are as much as 5,000 feet long and 200 feet thick. The breccia is comprised for the most part of subangular to rounded fragments of argillite and quartzite in a matrix that resembles in composition and texture the sedimentary layers adjacent to the breccia zones. Most of the breccia fragments are less than an inch in maximum diameter, but some are several inches long. Many of the fragments in the breccia are chloritized and some are replaced by barite but the significance of these changes is not fully understood.

Upper member (zone of transition)

A distinctive rock that merits special consideration forms the zone of transition between the St. Regis and the Wallace formations. Although this member ranges in thickness from 150 to 450 feet, its characteristics are so marked that it has been used very successfully as a key unit in the mapping of the geologic structures. The rock is a very fine-grained, thinly laminated siliceous argillite, in part porcellaneous, with a distinctive light apple-green color. In detail alternate laminae are nearly white and apple-green with some slight brown staining in certain layers that contain carbonate. The rock maintains these characteristics even on deeply weathered slopes, and the horizon may be recognized and its area delineated from small chips in soil or slope wash.

Calkins (Ransome and Calkins, 1908, p. 40) 1/ described a very fine-grained, gray-green, massively bedded but laminated rock as the lowest unit of the Wallace formation. However, evidence collected in the course of our present work suggests a more logical relationship of this unit to the St. Regis formation than to the Wallace formation, and it has been so mapped. Not only are the rocks in this unit very thinly bedded and laminated, like those in the St. Regis formation below it, but the lower beds are locally interbedded with typical purple rocks of the St. Regis formation.

Wallace Formation

Rocks assigned to the Wallace formation underlie most of the western third of the map area and extend in a band along the crest of the ridge that follows the southern border of the map eastward to the Montana line. A discontinuous strip of Wallace formation crops out along the north border between the town of Mullan and the eastern limits of the area. These Wallace outcrops represent part of the north limb of the major anticlinal fold of which the St. Regis rocks form the core.

The most complete section of Wallace formation is in the upper part of the East Fork of Willow Creek between the outlet of Lower Stevens Lake and the crest of Stevens Peak. Shenon and McConnel (1939, pp. 4-5) measured a total thickness of 3,270 feet at this locality but estimated the true thickness to be approximately 2,900 feet. The authors measured a partial section of 1,500 feet which checks, as far as it goes, the section measured by Shenon and McConnel. Because of widespread small-scale crumpling of the beds in the Wallace formation, the section has been thickened and the measured thickness must be reduced to reach an estimate of the true thickness of the undeformed beds. Calkins (Ransome and Calkins, 1908, p. 40) thought that 20 percent was sufficient allowance for the thickening of the section.

1/ References are listed at end of report.

Wagner (1949, p. 12), who studied a section of the Wallace formation less than 6 miles south of the Willow Creek section, estimated that the factor for thickening should be increased to 30 or 35 percent. This larger figure may possibly apply to some of the very thin bedded argillaceous units in the part of the section above that ore exposed in the map area, but for the Willow Creek section a factor of 20 percent is more probable. Using this factor, the thickness of 3,270 feet measured by Shenon and McConnel would be reduced to an approximate true thickness of 2,600 feet.

The Wallace formation in the Coeur d'Alene district has been subdivided by Shenon and McConnel into four units on the basis of lithology. Wagner in the adjacent area to the south, recognized five units, the lower two of which appear to be equivalent to Shenon and McConnel's lowest unit. All the sections of the Wallace formation in the map area described in this report belong to the lowest unit as defined by Shenon and McConnel.

The lowest unit of the Wallace formation is less heterogeneous in its characteristics than the formation as a whole. The lowest unit is composed for the most part of beds that range from 1 inch to 12 inches in thickness, with a predominance of beds less than 6 inches thick. Approximately 15 percent of the section is composed of beds over a foot thick and these beds are scattered more or less at random through the sequence. Lithologically the rocks of this part of the Wallace constitute a series of interbedded, very fine grained quartzites and argillites and rock types that are intermediate in composition between these end members. Ankerite and related carbonates are abundant throughout the section, and for the most part are minor constituents in either argillite or quartzite. In only a few localities does any one layer have sufficient calcium and magnesium carbonate to be called a limestone. More commonly the relatively pure carbonate occupies the cores of ovoid structures, an inch or two in diameter, that form layers along one or more bedding planes. Certain groups of beds as much as 500 feet thick in the upper half of the Wallace formation exposed in the valley of Willow Creek contain more carbonate than the rest of the formation and stand out because of the rusty brown staining on the weathered surfaces of the numerous carbonate-bearing beds.

On fresh surfaces, the striking appearance of the Wallace rocks is due to the alternation of dark gray or black argillitic layers with light gray quartzitic layers. Carbonate-rich layers tend to have a dark slate- or blue-gray color on fresh fractures.

The lithologic variations in the series are shown even more strikingly on weathered outcrop. Argillitic layers remain dark, whereas quartzitic beds weather a very light gray or nearly white. Because of the presence of iron, the carbonate-bearing layers weather a buff to light brown or dark brown color. Where more carbonate-rich layers are interbedded with carbonate-free layers, the rock has a pronounced ribbed appearance on the outcrop because of differential weathering. Some of the beds are finely laminated.

Dikes

At least five metadiorite dikes and one lamprophyre are known to crop out in the map area. Several other metadiorite dikes are known only in mine workings; others of both types are likely present but are concealed by surface debris. The three best-exposed metadiorite dikes are on the slope west of Willow Creek. The rock is dark greenish gray, fine- to medium-grained, and generally equigranular. These features are in contrast to those of the lamprophyre dike in sec. 31, T. 48 N., R. 6 E., which is very fine grained or apahanitic and porphyritic, with the dark minerals both in the groundmass and as phenocrysts. One other "dike" whose continuity cannot be proved is exposed in a small outcrop on Placer Creek. Other dikes likely exist throughout the area but they escape notice because of the great ease with which their outcrops weather down to a soft earth.

STRUCTURE

The rocks of the mapped area have been folded into anticlines and synclines some of which are overturned. Faults, formed contemporaneously with the final stages of the folding or subsequent to it cut the sedimentary rocks along lines that are nearly parallel to the axes of the folds. Shear zones accompany some of the major faults and other shear zones have been formed in areas that show relatively little displacement. Axial-plane cleavage accompanies most of the folds.

Folds

The major structural feature of the map area is a broad complex anticlinal arch that plunges gently to the west. This structure is illustrated on the map by the presence of St. Regis rocks in the core of the fold, surrounded by rocks of the Wallace formation on the south, west, and north. At least seven smaller anticlinal folds, with the corresponding synclines, are superposed on the major structure. Many of the minor folds parallel the main structural trend but some of them, especially in the central part of the area, appear to trend slightly more northwest. The trend of the major fold axis is slightly north of west in the eastern two-thirds of the area, but the axis appears to swing to a more northwesterly direction in the western third. This change is reflected by the trend of the contact between the Wallace and St. Regis formations, as well as by the trend of the minor fold axes near the town of Wallace. Whereas several of the smaller folds may be traced for long distances, others die out along the strike, and, in several places, an anticline is replaced by a syncline on the same strike line. Some of the secondary fold axes plunge gently to the west in the same direction as the main structure, but others plunge to the east. Several folds plunge both ways from the center.

The intensity of folding increases from south to north. Rather broad, open, and nearly symmetrical folds are exposed along the crest of the ridge at the very southern edge of the area, whereas folds that are closely compressed and commonly overturned to the north occur along the valley of the South Fork of the Coeur d'Alene River. This difference in the character of the folding is illustrated on the map and structure sections, especially in sections C-C' and D-D'. The beds in overturned folds are rarely rotated more than 20° beyond the vertical. Many overturned dips as low as 30° or 40° are shown on the map, but these are on steep hill slopes and in soft or altered rocks where the amount of overturning is exaggerated by rock creep. Where exposures allow adequate observation, the distortion of dips by creep is seen to be extraordinary; extreme caution must be used in interpreting structure where creep may be a factor.

Faults

Faulting was perhaps equal in importance to folding in the structural development of the area. With few exceptions the strikes of the recognizable faults trend in the same direction as the fold axes; and the dips of most of the fault planes approximate the dip of the axial planes of the folds, which are vertical or steeply dipping to the south. In the southern and western part of the area, the more northwest-trending minor fold axes are consistently truncated at slight angles by the major faults.

Major west-trending faults occur near the northern and southern limits of the area; and numerous other faults, most of which are less prominent, occur within the area. The Osburn fault, the major structural feature in the Coeur d'Alene district, skirts the northern edge of the map area and profoundly influences the structure of the rocks adjacent to it. The Placer Creek fault, another very prominent through-going fault, is shown cutting across the lower left corner of the map. At this place the Placer Creek fault apparently is joined for a distance of nearly a mile by the Big Creek fault as shown on the map. The relationships between the two faults are not clear in this area because the movement on the Placer Creek fault is normal and that on the Big Creek is reverse. The Osburn, Placer Creek, and Big Creek faults were not studied in detail in connection with the present report. A discussion of them will be deferred until more geologic data are available.

The D-6 fault has the best surface expression of any fault within the area and is the most continuously mapped. It is a normal fault that brings the Wallace formation in contact with the St. Regis formation for 3 miles in the central part of the area. The stratigraphic throw of the fault near the eastern end of its mapped extent, as determined from the offset of the lower member of the St. Regis formation, is approximately 600 feet. To the west the displacement is probably larger, but no direct measurement is possible. The estimates of displacement make no allowance for an indeterminable horizontal component of movement. The D-6 fault appears to die out to the east in the head of the valley of Boulder Creek. A fault that crosses the heads of East Fork and West Fork of Willow Creek farther east is nearly on strike with D-6 and may be related to it. However, the displacement on the fault to the east is small and opposite in direction to that on the D-6 fault, and a continuity of the two necessitates a pivot or hinge somewhere in the vicinity of the head of Boulder Creek. For lack of more positive evidence of a connection, the two faults are considered to be separate. To the west the D-6 fault is lost beneath the heavy overburden and brush cover in the western part of the area. However, the direction of dip and displacement of the fault, its strength, and its strike suggest that it is coextensive with the Polaris fault. The Polaris fault, described by Shenon and McConnel (1939, p. 7 and pl. 1), is in the Silver Belt area to the west; it has been traced by them to a point within about 3 miles of the westernmost exposure of the D-6 fault.

An area of complex structures nearly a mile wide, containing numerous faults and shear zones, is centered in the valley of Rock Creek north of the D-6 fault. The area has been so severely sheared and altered that the recognition of faults is difficult if not impossible. Innumerable shear planes and gouge-filled seams suggest movement, but there is no way of identifying those which have carried significantly more movement than others. The northern edge of this zone is an intensely sheared zone merging more or less imperceptibly into the broad, sheared area to the south but bounded by a fairly definite footwall on the north. This boundary is called the Blue Jay fault zone footwall.

The amount of movement within the broad area between the D-6 fault and the footwall of the Blue Jay fault zone is difficult to determine as distinctive marker beds are lacking. The contact between the St. Regis and Wallace formations is located definitely in but two places, where the distinctive green horizon of the uppermost part of the St. Regis was recognized. The mapped location of the rest of the contact is based on interpretation and projection from the fold structures within the area. It is possible that the distribution of rock types within this area could be equally well explained by a series of faults, or by distributed shear throughout the zone.

The amount of movement along the Blue Jay fault zone is likewise unknown. The apparent offset of the upper member of the St. Regis formation for a mile or more as shown on the map may be misleading. The fault parallels the strike of the rocks along the north limb of a syncline and a relatively slight vertical movement may have cut out the key bed for a long distance. Furthermore, intense alteration of the rocks along the fault may have made the upper member of the St. Regis formation unrecognizable.

The Defiance and Tornado faults, two well-defined structures north of the Blue Jay fault zone footwall, are located both on the surface and underground in the Rock Creek tunnel. Little is known about the extent of these faults or the amount of movement on them. Possibly the two faults that are exposed in the Western Silver Lead Company mine about a mile northwest of the Rock Creek tunnel are continuations of them.

Other faults shown on the map either have been recognized on the surface from exposures of the fault zones or have been projected to the surface from exposures in mine workings. Most of the faults in the Atlas mine area are projected from underground, as are those above the workings of the Western Silver Lead mine.

The direction of movement on the faults can rarely be determined with certainty. The best available evidence is an offset of a recognizable unit such as the upper member of the St. Regis formation, but such evidence is rarely found in the thick relatively homogeneous formations of the Belt series. Drag of the beds along fault planes is locally very prominent, and has helped in the mapping of faults and in giving a clue to the direction of movement. In this area slickensides and grooved fault planes are of little value as evidence of direction of major movement, for they represent only the final direction of slippage in a complex history of displacement.

Cleavage

Cleavage is present to a greater or lesser degree in all the rocks of the area. It is best formed in highly argillaceous rocks that split into thin sheets along parallel or subparallel planes--a true cleavage. It is most poorly formed in pure quartzites that have relatively widely spaced "cleavage" planes that more nearly resemble jointing. The difference in the number of cleavage planes in argillite and quartzite is shown not only in the major rock units but also in very thin, interlayered beds of argillite and quartzite.

Most of the cleavage described above is genetically related to the folding of the formations and has been designated as axial-plane cleavage since it bears a definite relationship to the axial planes of the folds. The strike of the cleavage is nearly parallel to the strike of the axial planes of practically all folds. It has a much more consistent direction through the area than the strike of the bedding, which swings around the noses of plunging folds and is involved in drag folding and complicated contortions. The dip of the cleavage in argillaceous beds is nearly parallel to the axial planes, whereas in more quartzitic layers the dip is at an angle to the axial planes. In places the axial-plane cleavage tends to be at a slight angle to the axial plane, and converges toward the axial plane from both limbs of a fold. As the cleavage is generally parallel or subparallel to the axial planes of the folds, its angular relationship to bedding in any location can be used as a key to the superposition of the beds and relative positions of folds (Shenon and McConnel, 1940, pp. 440-444).

In the vicinity of faults, or in such major shear zones as the one centered in the Rock Creek area, the axial-plane cleavage is combined with shear cleavage produced during faulting; the shear cleavage is in almost all places parallel to a fault or major shear zone. Most of the major faults are nearly parallel to the axial planes of the folds in the map area, and so the axial plane and shear cleavages are in many places indistinguishable. Shear cleavage cannot be relied upon for the correct interpretation of folded structure.

ALTERATION

At least 50 percent of the sedimentary rocks of the area have been changed in appearance and composition by a process variously called alteration, bleaching, or seritization. These names apply to the outward changes in the appearance of the rocks as well as to mineralogical changes. The most obvious change is a general bleaching of the darker colors to a pale green cast in slightly affected rocks and a striking apple-green or yellow-green color in intensely altered rocks. The process diminishes the contrast between beds of different composition, and finally causes the obliteration of all sedimentary structures and textures with the production of a greasy-appearing, light-green, essentially homogeneous rock. The most noticeable mineralogic changes in the altered rock are the increase in sericite content and the introduction of carbonate, which may be important parts of the process of alteration.

The process of alteration has been attributed to hydrothermal solutions which permeated the rocks from some source at depth. Complex structures, such as shear zones, fault zones, and highly fractured and tightly folded areas, were the more favored for hydrothermal alteration. The exact nature of the process of alteration is not known, nor is its relationships to the igneous rocks and ore deposits fully understood. Some question also exists as to how much new material was introduced by the solutions that produced the alteration. Many of the more argillaceous rocks contained all of the material necessary for the sericite that was developed in them. Some quartzites are so pure that much of the potash and alumina must have been introduced to make the sericite they contain. How much of such transported material came from depth with the solutions and how much from contiguous rocks has not been determined.

One interpretation of the distribution of the alteration at depth is shown on the cross sections that accompany the geologic map. However, exposures in deeply incised valleys and mine workings suggest that the alteration tended to spread laterally at higher elevations or along certain stratigraphic units. This alternative interpretation may be more apparent than real, but it is worthy of further consideration.

Although the intensity of alteration varies between wide limits, only moderately or intensely altered rocks were differentiated in field mapping. The altered rocks differentiated during the mapping were divided into two groups--those that show moderate alteration and those that show advanced or intense alteration. In moderately altered rocks the color change was complete but the original textures, structures, and lithologic units are clearly recognizable; in intensely altered rocks the original textures and structures are indistinct or completely obliterated.

The two groups of altered rocks are difficult to map, not only because of poor exposures and the wide variation in the intensity of alteration, but also because the different rocks are affected in different degrees. Wherever feasible, the approximate limits and interfingering of the altered and unaltered rock are illustrated schematically by a ragged termination of the dot pattern on the map. In places where the position of a contact cannot be approximated and the extent of an area of alteration is problematical, a large dotted query mark is used. Although somewhat crude, the pattern on the map does outline in a broad way the centers of the most intense alteration.

Whereas the production of sericite is the principal and most widespread type of alteration in the area, certain zones are notable for the content of chlorite. Chloritic alteration is abundant in the Atlas mine and in a series of zones that parallel the highway and railroad in the northeast corner of the area. Evidence from the Atlas mine vein system suggests that the chloritic alteration is earlier and the chlorite was replaced subsequently by the sericite. No attempt was made to differentiate the relatively minor chlorite-rich zones on the map.

VEINS

Numerous veins crop out or have been exposed in exploration pits and mine workings in the area. Most of these are carbonate veins. Although many of them are barren, some contain small amounts of sulfides. Some ore has been produced from the vein at the Atlas mine, from the Reindeer Queen vein, and possibly from other veins in the area.

The veins are oxidized at or near the surface and most sulfides that were present have been destroyed. The vein outcrops now are dark brown or black, clinkerlike, porous gossan. In some places where mine workings or prospect cuts have opened the vein below the surface, residual sulfides are recognizable. An attempt was made to classify the veins into four groups, A, B, C, and D, on the basis of the gangue and recognizable ore minerals. A fifth group, E, is reserved for veins whose mineral content or degree of oxidation makes their classification in the other groups impossible. Group A is veins that have visible traces of such sulfides as galena, sphalerite, chalcopyrite, or tetrahedrite in a carbonate gangue. Group B veins contain a notable amount of barite as well as carbonate in the gangue. Group C veins carry a considerable amount of specular hematite and magnetite. Group D veins are predominantly quartz.

One vein may belong to several types and may be classified differently at different places. By far the most numerous veins are those of groups A and E, and many of the group E veins are doubtless akin to group A. The barite veins are strikingly localized along a zone that extends from the middle of sec. 3, T. 47 N., R. 5 E., eastward to the Montana line. The magnetite-rich veins are best displayed in the middle of sec. 32, T. 48 N., R. 5 E.

Most of the veins are nearly parallel to the faults and strike generally west or northwest and dip vertically or steeply south. The close relation between the faults and veins is shown near the head of Willow Creek, where a fault on the surface is followed by a mineralized vein both at depth and along the strike to the east. Very few of the major faults in the mapped area are mineralized, but faulting was a major factor in the structural development of the area and is known to have an indirect control on the location and development of mineralized fractures elsewhere in the Coeur d'Alene district. Several large east- to northeast-trending carbonate veins occupy a diagonal position between major faults and may fill gash fractures. Several veins in the Blue Jay fault zone and near the head of Watson Gulch may be of this type.

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