THE GEOLOGY OF THE AUFEAS MINE
AT SILVER CREEK, B.C.

by
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THE GEOLOGY OF THE AUFEAS MINE
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INTRODUCTION:

One hundred miles east of Vancouver, the Fraser River cuts through the western flank of the Coquihalla River area. The region is one of rugged topography characterized by numerous small streams which rush down clefts in the steep mountain sides into the heavily wooded valleys. On such a creek is the Aufeas Mine. The creek referred to is Wardle Creek, a tributary of Silver Creek and the mine workings are 3000 feet west of the junction of the two. A good road runs to within 1/4 mile of the workings and a good, though steep, pack trail leads to the adit, 1000 feet above the road. The Cariboo Highway which crosses Silver Creek 3/4 of a mile below the start of the pack trail carries dependable bus and good trucking services at all seasons of the year. In addition, both the Canadian Pacific and Canadian National Railways serve the town of Hope, 5 miles north-east of the mine.

Details of the history of the mine are not abundant
but they do relate that it was found in 1909. Charles Camsell made passing reference to it in his report on the area in 1911 but apparently little work had been done. Brewer examined the mine in 1914 for the British Columbia Department of Mines and included in his report a detailed description of the underground workings. At the time of this examination an aerial tram linked the lower adit with the road, but this was later removed and a system of rawhiding was introduced. Cairnes made a rapid examination of the property in 1923, and found it substantially as Brewer had left it nine years earlier. It is evident from these reports that most of the work done since these examinations has been in the form of stoping on the main vein from the lower drifts. The ore is hand-picked underground and shipped to Tacoma for smelting. Because of its high arsenic content, the ore incurs heavy penalties during treatment and it requires well over 3/4 oz./ton to make the mine a commercial success.¹ The average grade is 1.08 oz./ton for gold and about 1 oz./ton for silver.

¹ A. C. McGillis (lessee, Aufeas Mine, 1941) personal communication.
The Coquihalla Map Area consisting of strips of land on both flanks of the Coquihalla River from above its headwaters down to Hope on the Fraser River, comprises a sheet that is over 35 miles long and about 10 miles wide. The area lies entirely within the northward extension of the American Cascade physiographic province. This province, crossing the boundary between the 120th and 122nd degrees of longitude, extends as far north as the Thompson River where it grades into the Interior Plateau. At the 49th parallel the province is broken into three mountain ranges: the Okanagan Range on the east, between the Similkameen and Okanagan Rivers, the Hozameen Range between the Skagit and Similkameen Rivers and the Skagit Range between the Skagit River and the edge of the coastal depression at Sumas.

All parts of the area are characterized by extremely rugged topography with elevations varying from 160 feet for the river valleys up to heights of over 7400 feet on some of the loftier peaks. The mountains less than 6000 feet have been rounded on their peaks by glacial action but those of greater elevations are usually matterhorns, often with small mountain glaciers on their northward slopes.
GENERAL GEOLOGY:

Rocks of pre-Carboniferous age are absent from the area; they may have existed at one time but now have been either completely removed by erosion or covered up by subsequent deposition.

A submersion of the land in the Pennsylvanian, or possibly the early Permian, accompanied by widespread sedimentation and some vulcanism, provided the oldest rocks in the area—the Cache Creek series. These rocks, composed of andesite, greenstone, limestone and chert, are intensely folded and faulted, and usually dip steeply to the southwest. They occupy a north-west trending belt about 5 miles wide cutting through the middle of the map area, and are also exposed to a smaller extent east of the town of Hope.

Following the deposition of the Cache Creek group there was a period of uplift and erosion which was in turn, followed in the mid-Triassic by another period of sedimentation and widespread vulcanism, during which the rocks of the Nicola Series, represented in the area by the Tulameen Group, were laid down. These rocks consist mainly of medium to basic volcanics, together with a number of horizons of grey to black slate. They are very limited in extent and are found only in the extreme north-east portion of the district.

The late Triassic saw a recession of the seas,
accompanied by crustal warping along the Pacific border, which was followed in the middle Jurassic by another submergence of the land. Sedimentation brought about by this inundation of the area, resulted in the formation of the Ladner and Dewdney Creek series of conglomerates, slates and volcanics. The latter formation lies conformably on the Ladner series and the whole is folded into a tight, north-west striking syncline. This synclinal belt is three miles wide and lies along the north-east contact of the main exposure of the Cache Creek Series.

As the Jurassic drew to a close, the seas retreated from all but the deeper valleys and the existing strata were deformed along a north-west, south-east axis. Accompanying this deformation was the intrusion of a number of acid rock types. This period of intrusion was, however, only the vanguard of injection on a much grander scale extending into the middle Tertiary. Following the initiation of this igneous cycle, early Cretaceous sediments were laid down in the valleys that still remained under water. These rocks consisted mainly of poorly stratified conglomerate and sandstone, some of the pebbles of which were derived from the Jurassic intrusives. The sediments outcrop in the lower and upper parts of the sheet and in all cases are folded to a considerable extent. The upper Cretaceous saw the continuation of the intrusion begun in the Jurassic with the
formation of a large batholith of granite and allied rocks in the extreme northern part of the district. The orogenic disturbances of the Laramide Revolution which closed the Mesozoic, uplifted the surface and further deformed the existing strata; such deformation providing a basis upon which a separation of pre and post-Laramide intrusion can be made.

The Tertiary, commonly noted for its volcanics, is in this area equally important for its intrusives. The sole representative of the extrusives is the Coquihalla Series of rhyolite and basalt flows which outcrop in the north-eastern portion of the sheet. They have been but slightly deformed and generally dip at angles less than 25 degrees. They are Miocene in age. The intrusives of this age are mainly quartz-diorite and outcrop in the southern part of the district only. As implied earlier, the placing of these rocks in the Tertiary rests almost entirely on the fact that they present a relatively unsheared appearance which is in marked contrast to the sheared intrusives of pre-Tertiary age.

The Pleistocene brought glaciation. The ice sheet swept across the area in a south-westerly direction and rounded the summits of most of the mountains. It did, however, leave a number of arêtes as exhibited by the higher peaks in the Skagit Range.
PETROGRAPHY:

Six specimens from the wall rock adjacent to the main vein were taken from the upper adit and examined in thin-section. In both the hanging wall and the footwall the procedure was identical; one specimen was taken at the vein, another 1$\frac{1}{2}$ feet from the vein, and a third 6 feet from the vein.

The wall rock of the mine is a medium to fine-grained quartz diorite. In the hand specimen it is light in color, containing 60 per cent feldspar, 15 per cent hornblende, 15 per cent biotite, and 10 per cent quartz. It is remarkably sheared and in some places exhibits an almost gneissic banding of the darker constituents.

Microscopically, the predominating mineral is an albite-twinned feldspar with a maximum extinction angle of 19 degrees and an index of refraction of 1.55. These characteristics determine the composition of the feldspar at about $A_{336} A_{n4}$, thus placing it well within the andesine range. The grain size of the andesine is extremely variable but the majority of the crystals are over .5 m.m. in size. The feldspar is nearly always fresh, but in places where the rock is fractured it is altered to sericite, calcite and some chlorite. In some instances it was noted that the feldspar was closely intergrown with the biotite and hornblende and frequently appeared in the latter mineral producing a
poikilitic texture. The amphibole is common hornblende and is present as rather large, irregular flakes and masses showing light brown to dark green pleochroism and altered in some parts to chlorite. A few of the flakes show a twinned extinction and at the same time are vermicularly intergrown with quartz. It is possible that these grains are the result of deuteric alteration of a pyroxene since enstatite has been reported as a constituent of a quartz diorite occurring about one-half mile north of the mine. Brown biotite, occurring as large sheets and small remnants, accounts for 10 per cent of the slides. In the specimens taken farthest from the vein, the mica is not altered to any great extent, but where alteration has proceeded, Chlorite is developed. Quartz, forming about 8 per cent of the slides, appears as small to medium-sized grains replacing the feldspar and as fine-grained particles intergrown with biotite and hornblende. The accessory minerals, magnetite, ilmenite, apatite, pyrite and zircon, make up about 2 per cent of the rock. Of these, magnetite is the most abundant and together with the other metallics is found in small irregular patches associated with the biotite and hornblende. Apatite occurs as small rounded grains and lath-shaped crystals second only in number to those of magnetite. Pyrite and zircon are very minor accessories, one or two grains of each being found in the slides. In some places patches of ilmenite are surrounded by an opaque mineral
which is white in reflected light; it may be leucoxene.

Nearer the vein the wall rock alteration becomes more intense. The products of this alteration now amount to almost 40 per cent of the slide with sericite accounting for almost 1/2 this figure. The feldspar is present in about the same proportion as in the fresh rock, but it has become heavily stippled with calcite, sericite and chlorite. Hornblende is entirely absent, while biotite, now reduced to about 5 per cent of the rock, appears only as bleached fragments surrounded by a mass of sericite, calcite, magnetite and chlorite.

A number of the slides showed an opaque mineral which was white in reflected light. The author hesitates to determine all these aggregates as leucoxene since concentrations of titanium on such a scale would undoubtedly be determined by chemical means. Microchemical tests, however, made on several specimens showed no titanium present. With these results in mind, it is probable that a great deal of the material resembling leucoxene is actually kaolin resulting from the weathering of the feldspar.

The wall rock has been subjected to two periods or types of alteration; first chloritization followed by sericitization and carbonatization. The ascending solutions, slightly alkaline and containing some carbon dioxide reacted first with the ferromagnesium minerals, converting the amphibole to chlorite, which was in turn altered to sericite. The
biotite, under the action of the solutions, was reduced to a fine-grained mass of sericite while the feldspar, being attacked along fractures and grain boundaries, was converted to sericite and calcite. The quartz, in general, remained unaltered although in places it too showed development of sericite along fractures in the grains. Kaolin which is present in the altered wall rock, is regarded as being supergene (as is possibly leucoxene) and forming through the action of downward moving meteoric solutions leaching the already sericitized rock. During these processes of alteration, there was some change in the concentrations of the mineral groups within the rock. Silica and magnesia, for example, were reduced, but alumina remained fairly constant. Potash was increased to some extent due to the widespread formation of sericite. Water, carbon dioxide and some lime were also added.

STRUCTURE:

The structure of the deposit is simple. The location of the ore has been controlled exclusively by a major shear zone trending N85°E and dipping south at 50 degrees. All the ore mined has been taken from this one zone. A second, less important shear striking N20°E and dipping south-east at 65 degrees is cut by the main adit 120 feet from the portal and is exposed in the caved drift 190 feet from the entrance of the mine. As may be seen from the accompanying map, this
minor shear is striking so that it will intersect the main shear in the west drift. Such an intersection could be responsible for the large amount of gouge present in this drift. It will also be noted that large quantities of ore have been removed from the stope above the west drift. As far as the author has been able to determine, this extensive mining is not due to an increase in the grade of the ore in this part of the mine but rather to the fact that the large quantities of compact gouge make the removal of rock in stoping a relatively easy operation.

ORE DEPOSITS:

The property consists of the Jumbo group of five claims straddling Wardie Creek. The development work has, however, been confined to two veins outcropping on No. 2 claim above the south bank of the creek about 3000 feet west of its junction with Silver Creek.

Of the two, the upper or main vein has received the majority of the work, having been followed on the surface for over 150 feet and underground for more than 350 feet. It strikes parallel with the main shear zone at N85°E and dips south at about 50 degrees. At the surface, the vein consists of an irregular band of massive arsenopyrite with smaller amounts of chalcopyrite and quartz, accompanied on the footwall by about 6 inches of red gouge. The sulphide band is extremely irregular and varies in width up to 6 inches; in
some places it disappears completely, only to reappear further along the strike, again in lenticular form.

A second less important vein, striking parallel with the first but dipping south at only 20 degrees, outcrops 50 feet below the main vein. It is made up largely of quartz with some arsenopyrite and very little chalcopyrite. It reaches a maximum width of only a little over 3 inches and exists as a vein for less than 100 feet along the strike. After this distance it becomes a thin shear filled with grey gouge. Because of the low angle of dip and the absence of a similar vein in the lower adit it is probable that this second vein joins the main vein at some point between the upper and lower crosscuts.

The main vein has been exposed on two levels by underground work. The upper, and shorter of the two adits, has been driven 40 feet below the outcrop of the upper vein and intersects the vein 47 feet from the portal. The lower tunnel cuts into the hillside about 200 feet below the upper crosscut and intersects the main vein 387 feet from the entrance. Drifts approximately 190 feet in length have been run to the north-east and south-west along the strike of the vein and three stopes have been opened up above these drifts.

The main ore body as exposed on the lower level consists of an irregular vein of massive sulphides occupying a shear zone, within the quartz--diorite, striking slightly
north of east and dipping to the south at 50 degrees. For the greater part of the exposed distance the zone maintains a constant width of two and one-half feet. Occasionally, however, it pinches or swells. Shearing has been extensive along the zone and as a result of the movement a great deal of gouge has been formed; this is especially noticeable in the west drift and west stope.

The vein, composed of arsenopyrite and quartz together with some smaller amounts of chalcopyrite and pyrite, is located near the footwall of the shear. It averages four inches wide but contains several lenses exceeding one foot in width. It is not uncommon for the vein to finger out into two or three smaller stringers which may or may not unite to reform the vein. Frequently, however, all but one of the branches die out, the remaining one increasing to the size of the original vein.

A poorly defined dyke also occupies the shear. It is confined, for the most part, to the footwall of the vein but is, in places, cut by the ore so that it appears in the hanging wall of the vein. The intensive shearing in the zone has, however, reduced the dyke to a soft, grey gouge, thus making it very difficult to obtain a fresh specimen.

One or two narrow veinlets of calcite, with some arsenopyrite and quartz are commonly found paralleling the vein and close to the hanging wall of the shear. These stringers rarely exceed one inch in width and generally strike
and dip with the sulphide vein. They appear to have been formed at about the same time as the main mineralization.

Mineralization has proceeded into the wall rock for a short distance. Arsenopyrite and chalcopyrite are found in fractures in the altered quartz-diorite on the footwall and also to some extent on the hanging wall. All traces of metallics, however, usually disappear within four inches of the shear. It does not appear that replacement played a very large part in the mineralization of the wall rock for the sides of the veinlets in the quartz-diorite nearly always match perfectly.

MINERALOGY:

The mineralogy of the deposit is not complex. Arsenopyrite is the most abundant metallic mineral. It is present both as large irregular masses and as well formed crystals, although the latter are generally restricted to the smaller veins and stringers. Chalcopyrite is next in abundance and occurs as anhedral masses in the arsenopyrite and also closely associated with pyrite. The latter mineral is present in amounts almost equal to the chalcopyrite and is characterized by good crystal form. Sphalerite, a light variety probably low in iron, is present in very minor quantities as dendrites and small irregular masses in the chalcopyrite.

The non-metallic gangue minerals, quartz and calcite,
PLATE II.

Chalcopyrite replacing Sphalerite.
Specimen from West Stope.  Mag. 600X.
PLATE III.

Chalcopyrite replacing Shalerite. Specimen from East Stope. Mag. 650X.
Chalcopyrite replacing Sphalerite.
Specimen from East Stope. Mag. 650X.
are not particularly abundant. Quartz is present in the main vein as a minor constituent but in the smaller subsidiary vein it is one of the predominating minerals. Calcite, though present in the main vein, is of small account. It is, however, abundant in the calcite stringers mentioned earlier.

PARAGENESIS:

Examination in polished section shows the following general relationships: Quartz was the first mineral to form and was probably long-continued in its crystallization, overlapping some of the sulphides. Pyrite was the next mineral to form, followed successively by arsenopyrite, calcite, sphalerite and chalcopryite.

The fact that quartz is the first mineral to crystallize is shown in one or two of the specimens where arsenopyrite definitely veins the quartz. The long-continued deposition is suggested by the apparent veining of masses of arsenopyrite by quartz. It is, however, probable that the greatest period of quartz deposition was post-arsenopyrite because examples of this mineral invaded by quartz are much more common than examples of the reverse.

The arsenopyrite-pyrite relations are difficult to determine since their ages of formation are close; in part, they are contemporaneous. In general the pyrite is earlier than the arsenopyrite as shown by the fact that some of the fractures passing through the pyrite terminate abruptly on
reaching the arsenopyrite. The suggestion of contemporaneity is derived from the presence of several "mutual boundaries" in which the pyrite-arsenopyrite contact is ill-defined.

The calcite is assigned the next place in the paragenetic scheme, mainly on the basis of its cutting relations with respect to the later minerals. It is found around the edges of the arsenopyrite and pyrite and is definitely replaced by chalcopyrite. This replacement is frequently so extensive that the mineral takes on the appearance of a groundmass of calcite dotted with chalcopyrite.

The sphalerite-chalcopyrite associations are particularly interesting. The sphalerite appears in the chalcopyrite groundmass as minute dendrites or star-shaped particles (-Plate II, III, IV.) without any apparent orientation controlled by the crystal structure of the groundmass. They can hardly be related to unmixing because of the abundant evidence for replacement shown by nearly all the examples; their boundaries are seldom smooth and where two or more grains join there is enlargement, which is in distinct contrast to the features observed in most unmixing structures. It appears, rather, that the chalcopyrite has replaced the sphalerite in very much the same manner as described by Fairbanks, who mentions "residual veinlets" of sphalerite in chalcopyrite.

These specimens, taken from Harcuvar Mountain in Arizona, are apparently similar to those from the Aufeas Mine except that

in the ore from Arizona the sphalerite was commonly bordered by fringes of chalcocite, a feature which is absent in the local material.

The only gold recognized in the sections was seen under the high power of 480 magnifications, as small particles, about one-eighth the size of rice grains, in massive arsenopyrite. Unfortunately they were etched before being photographed and could not be located subsequent to repolishing. An intensive search of the other sections failed to reveal further examples of the metal. Gold does not, in these sections, appear to be a late mineral. From its form it is evidently intimately associated with the arsenopyrite and may occur in part at least in a colloidal state with the sulphide.

GENESIS:

The ore body at the mine represents a mesothermal type of deposit and is genetically related to the intrusions of late Jurassic or early Cretaceous age. At the time of the formation of the ore, the present land surface was probably deeply buried and locally overlain by Cretaceous conglomerates. The mineralizing solution ascended through the plutonics and spread out along shears and joints in the overlying sediments which were later uplifted and removed by erosion. A second period of uplift in the Miocene followed by glaciation and continued erosion reduced the land to its
present level. From this hypotheses it may be concluded that the present vein is only the lower part of a once more-extensive lode, reaching into the overlying sediments and represents merely part of the channelway along which the metalliferous solutions ascended.

AGE OF THE QUARTZ DIORITE:

The problem of the age of the quartz diorite from the Aufeas mine is complicated by the fact that contacts between the intrusive and both the older and younger rocks are poorly exposed. It is, however, definitely established that the intrusion cuts the palaeozoic Cache Creek series. West of Hope the intrusive is in contact with sediments of Cretaceous age which appear to be younger than the quartz diorite. Pebbles of the latter, or at least of a rock of similar composition, are found in the conglomerates which overlie the intrusive with some slight unconformity. The evidence for such a break is noted by Cairnes who studied the contact in thin-section and found that "... the gneissic banding in the quartz diorite ran at an angle to, and was truncated by the line of contact."² (between the two formations.) On the basis of these criteria the quartz diorite may be assigned the age of upper Jurassic or even lower Cretaceous.

In differentiating between the older and younger intrusives, it has been found convenient to use the amount of shearing as a yardstick. The earlier intrusives having taken part in the orogeny of the Laramide are usually sheared to a considerable degree, whereas those of Miocene or later age having escaped the early Tertiary movements present a relatively unsheared appearance. It should be remembered, however, that this comparison can be made only between rocks outcropping in the same locality, since the degree of shearing may well have varied considerably from one part of the area to another.

ORIGIN OF SOLUTIONS:

It is notable that all the intrusives in the area were injected within the relatively short period between the upper Jurassic and the mid-Tertiary. It is not then hard to visualize for these rocks a common source which, once being established, obviates the necessity of relating the ore solutions to any particular phase of the intrusion. It may be suggested, then, that the mineralizing fluids had their ultimate origin in the abyssal depths from whence sprung the igneous rocks of the region, and that their ascent and deposition depended entirely on the fortunate existence of suitable channels and horizons.
OTHER DEPOSITS:

In referring to the sketch map of the Coquihalla and Skagit Areas (Plate V), it will be noted that there is a succession of ore deposits towards the east away from the Fraser River and the main intrusion of the Coast Range batholith. The deposits fall into three main groups passing from west to east -

(i) Those in which the dominant values are gold.

(ii) Those in which the values are silver with small amounts of gold.

(iii) Those in which the dominant values are zinc.

In examining these properties there are, however, revealed some striking similarities. For example, fully 80 per cent of the occurrences contain arsenopyrite in close association with gold values ranging from 1.8 to .05 ounces per ton, while over 70 per cent of the deposits have pyrrhotite as an important accessory mineral. Most of the deposits contain small amounts of silver and, with the exception of the Eureka-Victoria mine which is related to a Tertiary intrusive, the silver values rise toward the east reaching a maximum of over 30 ounces per ton in the eastern part of the Skagit Area. The zinc content of the ores also increases as the distance from the Fraser River, attaining a peak of 23 per cent in some deposits on the lower Skagit River.

In the author's opinion, these characteristics
indicate some sort of zonal distribution of the ore deposits with respect to the eastern edge of the Coast Range, but the degree to which such an arrangement can be applied to the discovery of new deposits is not apparent. Further study in the areas, with special attention to the age relations between the various intrusives would, perhaps, bring about a better understanding of the relation of these deposits to the Jurassic intrusion.

ACKNOWLEDGMENT:

The writer wishes to thank Dr. H.C. Gunning of the Department of Geology, under whose direction this work was carried on, for his suggestions and very helpful criticism of the partially prepared manuscript. The author is also indebted to Mr. W.H. Matthews and Mr. Fraser Shepherd for their assistance during the two brief trips made to the mine.

The University of British Columbia,
Vancouver, B.C.

April, 1942.
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<th>Author</th>
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PLAN OF MAIN LEVEL.
AUFEAS MINE.
SILVER CREEK, B.C.
SCALE: 1 IN. = 30 FT.
J. A. WALLACE. OCT. 16, 1941.