MR 78-1

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see also 87-10

REPORT OF PROF. JOHN D. IRVING

GENERAL STATEMENT

The future development of copper deposits in Southeastern Alaska, both as regards the value and permanence of these deposits which have been so far discovered, and the promise of future discoveries, is dependent in a large measure upon geological considerations. For this reason, a brief general description is here given of the several types of deposits, the extent and character of the copper-bearing rocks, and of the climatic conditions which have determined their prospective value. The bearing of these facts on the future productiveness of the country is then discussed.

THE COPPER DEPOSITS

Copper occurs in the region explored in six distinct types of deposits. Four of these types are associated with amygdaloidal greenstones and diabases. One belongs in the group of ore deposits known as "contact" deposits, and one is due to the extensive mineralization of a quartz-diorite. These six types may be tabulated as follows:

A. Associated with Amygdaloidal Greenstones.

1. Deposits of secondary sulphides, bornite, bornite and chalcocite.
   - (a) in limestone
   - (b) in greenstone
2. As native copper in greenstone.
3. As placer copper.
4. As lenses of primary chalcopyrite in slates and schistose greenstones.

B. <u>Contact Deposits.</u>

5. Deposits of primary bornite and chalcopyrite at the contacts of intrusive masses with limestone, the copper minerals being intergrown with garnet, pyroxene, and other contact minerals.

C. <u>Impregnations.</u>

6. As extensive impregnations of low grade sulphides in quartz-diorite and also in other intrusive rocks.

COPPER DEPOSITS ASSOCIATED WITH GREENSTONE

<u>Character and Extent of the Greenstone.</u> Two great belts of greenstone occur in the Southern Interior region. The first and most important of these is that lying in the Copper River Basin made by the Chitina and Nazina Rivers. This belt is about 25 miles in width and extends from the mouth of the Kotsina River a little south of east for 110 miles and for an indefinite distance toward the east in the Skolai and St. Elias mountains where its limits have not yet been determined. It passes to the north beneath the Chitistone limestone and ends to the south against the Valdez series in the Chugach mountains. The formation dips rapidly to the northeast at about 25 or 30 degrees. The greatest thickness of greenstone exposed is 4,000 ft. and it is not known how much thicker the series is as it is not cut through at any point yet studied. The greenstone and associated limestone are covered by later sediments in places, but for the most part is well exposed.

These greenstones are successive flows of basalt poured out possibly under a considerable depth of water. They are of greatly varying texture, some of them being intensely amygdaloidal and closely resembling the Lake Superior amygdaloidals. The amygdules are filled with chlorite, serpentine, laumontite, opal, quartz and epidote. Diabases of a dense texture occur through the series, sometimes amygdaloidal, in part due to the expansion of included gases which has been permitted by local relief of pressure. Conglomerates like those of Lake Superior region do not occur nor are any sandstone beds present in the series. These greenstones differ from those of the northern belt in being surface flows piled successively upon one another-- the northern greenstones on the other hand were forced through the rocks or thrust in between them in intruded sheets. The overlying limestones, in some places separated from the greenstones by a thin bed of red shales, were deposited upon them conformably without break in the normal succession. The copper deposits which occur associated with this greenstone may be expected to recur whenever it is present.

The northern belt of greenstones is less well defined than the southern. It is not a solid greenstone belt, but comprises disconnected intrusions of this rock in large areas of sediments. It is made up of smaller masses of rock usually intruded between argillites and generally less amygdaloidal than the southern belt, being characterized by fewer amygdaloids and more diabases. Its greenstones are, however, intensely amygdaloidal at the head of White River and also along the same river near the Alaska-British Columbia boundary. This belt of greenstone rocks extends irregularly from the Nesbesna river in a southeasterly direction to the British Columbia boundary and is reported by Brooks to extend far east of that into British Columbia and to carry deposits of native copper in that country. Wherever these rocks occur, and especially is this true where they are of amygdaloidal character, copper may be expected to occur both as sulphides and in the native form.

THE COPPER DEPOSITS

Copper occurs associated with these greenstones in three general types of deposit.

1. As bodies of secondary chalcocite in the limestone.

2. As impregnations of secondary chalcocite and bornite along vertical sheeted or shear zones in the greenstone series, or as impregnations in that series near the contact of the greenstone.

3. As native copper in the greenstone.

1. Deposits of Secondary Sulphides in Limestone and Greenstone. The secondary sulphides, bornite and chalcocite, occur in the limestone alone or together above its contact with the greenstone and in the greenstone itself. The Bonanza mine is the most important of such deposits. It consists of irregular deposits of chalcocite along fissured zones in the limestone. These deposits occupy (1) the fissures themselves, replacing the limestone between the several planes of fracturing; (2) make out into the limestone along favorable beds in great irregular masses and fill and partly replace the limestone in stockwork masses along subordinate joints and cracks. Disintegration of the limestone by frost has broken down the ore masses at the Bonanza mine so as to form a great area of slide rock which contains workable quantities of copper. At other places, as the Jumbo and Erie, these ores are also found, but in these places bornite and some chalcopyrite are reported to occur. At the Bonanza, most of the ore occurs some distance above the contact, but in other places it is present actually at the contact.

Persistence in Depth. It is believed that these deposits were derived from original deposits of chalcopyrite and that where great depth is attained they will pass into that mineral. It is probable that the chalcocite has been deposited over a much greater area than the original chalcopyrite, replacing the limestone more widely on its downward passage than did the solutions which passed upward and deposited the original ore. There seems little question that the original deposits of chalcopyrite derived their copper from the greenstones which contain it in appreciable amount.

Other Occurrences Similar to the Bonanza. Other occurrences similar to the Bonanza are not unlikely to be found as there seems to be no feature of its occurrence that cannot be easily repeated along the limestone contact.

2. Chalcocite in the Greenstone. The sheeted zones along which the chalcocite occurs in the limestone extend downward into the greenstone below. Chalcocite has been deposited here as disseminated grains in the greenstone replacing it to limited distances along planes of fracture. These deposits are spotty and irregular and cannot be expected to form the basis for any very rich mines although the aggregate amount produced from them inasmuch as they occur in some numbers may be very considerable with improved conditions of transportation and the possibility of less expensive operation than is now possible. Sheeted zones of this kind occur in the greenstone away from the contact with limestone and there seems to be no basis for the belief that the contact is the most favorable place for the ore occurrence. Chalcocite and bornite occur as frequently in the greenstone many hundreds of feet below the contact as near it.

Passage Into Low Grade Ores. In some cases chalcopyrite has been found in the greenstone, notably in the Nikolai mine, and these chalcocite and bornite impregnations may be expected to pass into low grade ore not far below the present surface. At what depth such depreciation in value will occur cannot be determined. That will depend upon the amount of erosion that has taken place. Erosion aided by frost is rapid in Alaska, especially in the higher points where rocks are unprotected by moss and it seems reasonable to expect that the depth of the richer sulphides will not be great.

3. Native Copper in the Greenstone. Native copper occurs in or associated with the greenstones in five different forms.

a. As large slabs in joint planes.

b. As fillings of amygdules associated with limonite.

c. As disseminated particles in the rock.

d. In epidote-quartz-calcite veins.

e. Placer copper.

a. Large Slabs in Joint Planes. The large slabs in joint planes were observed on the British Columbia-Alaska boundary at the Harris property. These are large flat masses often turning at the bottom to follow cross joints and partially replace the rock at the contact, unreplaced feldspar occurring with them. A little chalcocite is found interwoven with the copper on the edges of the native copper. After careful study the copper is believed to be the later mineral and these slabs are believed to be secondary, or due to the oxidation of chalcocite by surface waters.

b. Copper in Amygdules. Copper is reported to occur in amygdules with laumontite and other zeolites at a number of localities described on page 95 and specimens examined seem to show this to be true. Copper so associated is to be considered primary, as the olivine, an easily altered mineral, is fresh and a peculiar reddish mineral termed iddingette, which is a product of hot waters due to metamorphism is abundantly associated with the copper.

c. Disseminated Copper. Disseminated copper occurs in diabase or an altered diabasic greenstone on the upper Kotzina river and Kluvesna creek. The rock on the Kotzina is a dense fine-grained dark green greenstone with the usual texture of a diabase. The constitutent augite of the rock has been altered to hornblende, a change characteristic of deep-seated metamorphism and not produced by surface weathering. The rock is perfectly fresh and has not been acted upon by superficial alteration. The copper occurs as minute flakes and particles sometimes 1/8 inch in diameter associated with specks of quartz and minute grains of epidote. The quartz, epidote and copper have probably been deposited by circulation of hot waters. That these have accompanied the metamorphism of the rocks from an original basalt to a greenstone is shown by the uniformity with which the copper is disseminated in the rock over considerable areas. An assay of this rock 0.65% copper, a figure which would seem too low for profitable exploitation under the isolated conditions of the region.

The copper in this greenstone is probably derived from small quantities contained in the silicates of the original rock and concentrated during metamorphism, wherever the activity of the causes which have produced the metamorphism have been specially active. This seems to be shown by the presence of copper up to 1/2% in much of the greenstone of the region.

Another occurrence of disseminated copper in greenstone and likewise primary in character is that from Kluvesna creek. The particles in this occurrence are more solid than those in the Kotzina rock and seem to indicate a more advanced stage of concentration. Chalcedonic silica, quartz, chlorite, and some epidote make up the rock. Copper in quartz-epidote seams is closely associated with these deposits. Their extent was not determined as only specimens were examined and the district not visited. The copper was present in the rock to the amount of 3.04%.

Native copper from areas of greenstone has been reported from numbers of localities throughout the belt of copper-bearing rocks and the promise which such deposits give of the occurrence of workably deposits is encouraging. Native copper in greenstone is of all forms of copper occurrence the ore which is least liable to undergo depreciation in depth, so that occurrences of this type will depend for their downward continuation on the depth and extent of the enclosing rock.

In the light of the secondary nature of many of the sulphide deposits, it would seem advisable to examine carefully all native copper occurrences as such deposits if of workably size and grade may be expected to support a much more permanent production than the sulphides.

d. In Quartz-epidote-chalcite Veins. Native copper also occurs, often in very large irregular masses in epidote veins carrying quartz and calcite. These veins are sometimes arranged in comb structure and contain large amounts of quartz. The copper is especially associated with the quartz. The order of deposition of the minerals is generally; epidote, quartz, copper. Epidote often occurs as a surface alteration product and undoubtedly is such in some cases in these greenstones, but in the majority of the occurrences their general character is such as to suggest their origin in the same way as those in the Lake region of the United States. It seems not unlikely they may have been formed during the metamorphism of the original diabases to greenstones. These veins have not proved important as copper producers and it is doubtful if they will become so owing to their small size.

e. Placer Copper. Placer copper occurs in all of the gulches and streams within the greenstone belt. Masses of copper sparsely disseminated in epidote veins or in joint planes in the rocks or as masses and nuggets in the greenstone have upon the disintegration of the enclosing rock supplied the material for these placer concentrations. The nuggets are often of great size, as for instance that in Nugget gulch, a small tributary of the Kuskulana, which is buried in the gravel and is 8' x 3' x 5 in size. Gold placer mining on Dan Creek likewise revealed immense quantities of native copper, some of the nuggets weighing several hundred pounds. The forms are irregular, but the masses usually quite solid. It is interesting that this native copper should often contain native silver in the same relations as the two metals exhibit in Lake Superior. Native silver nuggets likewise occur in the placers, i.e. the two metals occur together but are not alloyed with each other as would be the case had they been original ingredients of the greenstones that cooled from fusion.

The occurrence of this copper along the streams does not, of course, in itself signify the occurrence of workable deposits of native copper in the rocks from which the nuggets and masses were derived for great mechanical concentration has occurred and widely separated and scattered masses may readily have been brought together in the same placer, but it is evident at least that the great frequency of such placer copper indicates much copper in the greenstone. This together with the probable persistent character of such deposits will reasonably give color to the hope that workable deposits will be found. Where exceptional conditions are such that gold occurs in placers containing copper, the latter metal may be expected to yield a valuable by-product of gold mining, but in ordinary stream gravels there is reasonable doubt whether placer deposits would pay for operation.

4. Chalcopyrite Lenses in Slates and Greenstones. Copper also occurs along the coast in lenses of primary chalcopyrite in slates and intruded greenstone. These lenses have suffered little enrichment or secondary alteration, although in some cases it has been sufficient to be of economic importance. The lenses are irregular and discontinuous and vary much in size. They occur on LaTouche Island and at many points on Prince William Sound, one of the most notable

being at the Clamar mine. As such deposits vary greatly in size, large lenses may be expected. No increase in value with depth is to be expected, but little diminution in value of mineral is to be expected in depth on the other hand. The number of such occurrences and their easy accessibility, situated as they are on islands and along the coast are such that while no great mines may ever be found, their aggregate production operated on a small scale is likely to be great provided a local smelter were to afford the reduced expense of shipment and ready facilities for smelting.

CONTACT DEPOSITS

In the Nabosna River region, great bodies of quartz diorite have been intruded into limestone as also have masses of diabase. At the contact of such masses, occur bodies of garnet, tremolite, actinolite, specularite, pyroxene, calcite and quartz intergrown with mingled bornite and chalcopyrite. Such deposits are known as contact deposits, and owe their origin to the intense alteration produced by the intrusions on the limestone and the introduction of material into the limestone as solutions of vapours emanating from the cooling intrusive rock. Bornite and chalcopyrite are often mixed with magnetite; a combination which is impossible under ordinary conditions of ore deposition and which, therefore, serves at once to identify this class of deposit. Economically considered deposits of this kind are extremely irregular, opening out into large masses of pinching out entirely without regularity or warning. They are, however, often very productive as at Clifton-Morenci in Arizona, and the Seven Devils district in Idaho. Gold and silver values in such deposits are characteristically low, generally too low for profitable working. The bornite and chalcopyrite of such deposits are essentially primary and may be expected to continue in depth, without change in character wherever the masses of ore occur, and may be repeated at any depth along the contact.

Such deposits are found at the foot of the Nabesna Glacier. They are small and unworkable, but the alteration is extensive and the irregularity of such occurrences leads to the belief that exploration may well be expected to reveal bodies of workable size.

Another contact deposit of similar character occurs at Field's mine on Jacksina Creek near its junction with the Nabesna River. Gold occurs here in veins and somewhat unusually high grade for this type of deposit. Copper has so far been found at this locality in very small amounts, but the great area and strength of the mineralization makes the occurrence of workable masses not improbable. Similar occurrences are reported at Wilson's camp on Notch Creek.

IMPREGNATIONS

A great area of mineralized quartz diorite occurs at Orange Hill at the foot of the Nabesna Glacier. Copper has been shown to be present by sampling to the extent of 3.18% in one sample, but usually lower. The oxidized zone has not been entirely removed by erosion so that it is possible that sufficient secondary enrichment has been occurred to warrant a little development and careful sampling. The mineralized rock covers a great area--one by one and one-half miles in extent. The rock is cut by fissures in every plane and with every orientation, the pieces of rock between fissures being impregnated with pyrite carrying very small amounts of copper. Secondary sooty chalcocite, a copper sulphate stains and thin films of bornite are present. It is possible that a secondary zone may here occur and if so, it is likely to be near the surface. A little exploration to ascertain this would seem justified.

EFFECT OF ALASKAN CLIMATE ON THE COPPER DEPOSITS

It is well known that many deposits of sulphide containing copper owe their richness to the action of surface decomposition and that as originally deposited, they would be of little or no value. Bodies of low grade chalcopyrite and pyrite carrying unworkable quantities of copper are often enriched by surface waters. Such waters charged with free oxygen dissolve the pyrite and chalcopyrite, forming the soluble sulphate of copper and iron. Passing downward along cracks and fractures in the rock, such solutions meet unaltered primary sulphides below and the copper is precipitated in the form of the secondary sulphides, bornite and chalcocite and also covellite, thus forming a comparatively rich workable zone of variable thickness between an often worthless outcrop, and a body of low grade unworkable ore below.

The possibility of such secondary enrichment is dependent almost entirely upon the ratio of chemical activity to degradation or erosion. Where waters are cold and chemically inert or where ice exists a short distance below the surface, as in much of the Alaskan copper region, solution and oxidation proceed with extreme slowness and erosion, aided by frost breaking the rock and glaciation exposes fresh masses of unaltered sulphides before oxidation can occur or any zone of enrichment can have time to form. This accounts for the presence of so much primary sulphide at the surface throughout the more deeply eroded parts of Alaska. Secondary sulphides are not now forming on any deposits which I have observed, except possibly those of chalcopyrite along the coast where the climatic conditions are less regorous, and there only to a minor degree. Even oxidation is absent on many deposits, as the chalcocite of the Bonanza, which is strikingly free from oxidation.

There is no question that the climate has been colder in the past than at present and the glaciers and ice fields more extensive so that no secondary enrichment nor extensive oxidation can have occurred later than the beginning of the cold climate. Evidence shows, however, that the climate was much warmer and more humid before the beginning of the glacial period and the secondary enrichment which has occurred must have taken place at that time.

All of the mineral deposits of Alaska with the exception of the native copper lodes may be assumed to have been once covered by oxidized gossan outcrops and in many cases to have been secondarily enriched. This was the condition at the beginning of the very rigorous climate of the glacial period, while now much moderated, has continued sufficiently cold to prevent secondary enrichment or extensive oxidation up to the present time.

During the cold climate, however, erosion has been as rapid as chemical activity has been slow. The result has been the removal of all of the gossan or oxidized zone and a large part, or in many cases all of the secondary enrichment zone. Where primary deposits occur at the surface, both zones have been removed. This is the case in much of the White River country. Where secondary sulphides occur as at the Bonanza, only the oxidized zone has been removed and a large part--how much cannot be determined without extensive work--of the secondary zone remains. The chalcocite and bornite lodes in the greenstone and limestone are of this character. Such deposits may be expected to pass downward into unaltered chalcopyrite and low grade ore.

In some few cases where ores are on southern slopes or favorably exposed as in the Nabesna country, a little oxidation seems to have occurred since glacial times, but in most cases it is slight--hardly more than a few inches--an exception instance of it may be seen at the Field's mine, but it is very shallow. At Orange Hill, where the mineralized area is very extensive and flat, the old zone of oxidation may have been very deep so that it is possible that the oxidized matter here is a remnant of the old gossan that subsequent erosion has not removed. If this is the case, a secondary zone might occur beneath Orange Hill and a little developement would seem justified to determine this.

A few general deductions may be drawn from the above discussion which may be serviceable in connection with the building and operation of a railway.

POSSIBILITIES OF THE COUNTRY

The profitable maintenance of a railway in Alaska must depend in part at least upon the ore tonnage afforded by the mines, although the largest item will perhaps be transportation of the supplies for those who are exploiting or prospecting for mines. The unprofitable or at least doubtful character of many of the deposits with which this report is especially concerned would at first seem a rather unfavorable sign of future promise. It need not, however, offer so discouraging an aspect as might be at first apparent.

Indications of mineralization, as may be seen from the widely separated location of many of the deposits, are widespread, and the proportion of worthless prospects to workable deposits even in the present unexplored condition of the country is no greater, if as great, as elsewhere. The exploration and prospecting has been confined almost entirely to river beds, for the difficulty of obtaining supplies has prevented prospecting in the mountains which may be expected to hield much more favorable results than the moss covered valleys. The number of men, especially in the White River country, is extremely small. Summer seasons are so short that prospects are no sooner reached than they must be left in order for men to get out of the country before the frost, and transportation of supplies is so expensive as to be often prohibitive. Under these conditions, it is surprising that as many prospects have been discovered and opened up as is actually the case. With suitable facilities for the transportation of supplies and shipment of ore, the lengthening of the working season by independence of frost and quick arrival and departure, great numbers of prospectors may be expected to enter the country and the discovery of workable ore bodies may be expected with reasonable confidence.

The smaller deposits, of which there are many, may be expected to yield in the aggregate a large tonnage of ore though not of sufficient size to justify extensive mining operations. At present, so little development has been carried on in any deposit that with the best of judgment it would be difficult to form an idea of its value. An excavation twenty-five feet in diameter in a region buried everywhere in moss gives little information as to value or extent of a deposit. Proper facilities for work will enable prospectors to do sufficient development work to enable experts to form intelligent estimates of value.

CONCLUSION

Character of the Deposits of Permanent Value. It is clear from the above presentation that the ore deposits of Alaska may, commercially considered, be divided into two groups.

1. Deposits for which early exhaustion may be anticipated.
2. Deposits of probable permanence.

1. Deposits Likely to be Exhausted. The secondary sulphides, chalcocite and bornite cannot be expected to maintain Alaska's copper production indefinitely. The Bonanza mine, while rich and likely to afford a high tonnage of ore for a limited time, will be so easily mined that its life, however profitable, will be correspondingly brief. Other chalcocite bodies in limestone may reasonably

be expected and if so their discovery will maintain the production of this class of ores for a longer period, but such mining will probably not be deep and in such case a rapid exhaustion may be anticipated. The frequent occurrences of bornite and chalcocite in the greenstone can with good transportation facilities be expected to yield a considerable aggregate tonnage if worked by many individuals on a small scale. Their passage into low grade chalcopyrite may, however, be soon expected; under circumstances many of them will probably have to be abandoned. If large enough masses of chalcopyrite occur, it may be possible for them to be worked and such may be the case at the Nikolai mine, but their future is at least very doubtful.

For this reason, it is obvious that this class of ore cannot maintain a permanent copper production. The continual discovery of new ore bodies will be the only way in which production can extend over any considerable period of time.

2. Deposits of probable Permanence. Deposits of primary sulphides are the first of this class. Such are the gold vein at Beaver Creek and other similar lodes. Indications of extensive mineralization are so promising that the further discovery of such lodes is to be expected, especially in the Nabesna and White River regions.

The second class, and what seems to me to be of greatest promise, is the native copper deposits. The nature of such occurrences is such that they may be expected to continue in depth if found in bodies of workable size. Primary native copper as before stated occurs in considerable amount and is widely distributed. It has not yet been found sufficiently concentrated to form workable deposits unless the Kotzina deposits prove profitable, but there seems to me every reason to hope that such deposits may yet be discovered.

BONANZA MINE KX 87-64

LOCATION. The Bonanza mine is situated on the southward slope of the Wrangell Mountains about ten miles north of the Nizina River and approximately 180 miles from Valdez.

More exactly the location is on the west side of a southwardly projecting spur which dies out southward in the Nizina valley. This spur forms the divide between the deep gorge of McCarthy Creek on the east and the Kennecott Glacier on the west and descends from the summit, which here attains an altitude of 7,000 feet, by a very abrupt and precipitous descent into these two valleys about 5,500 feet below. The mine is about 1,000 feet below the summit of the ridge and approximately 4,000 feet above the level of Kennecott Glacier.
TOPOGRAPHY. The main ridge has been cut into by a very irregular indentation about a mile in width in a north and south direction. Into this from the north, there project toward the south a number of comparatively narrow, very abrupt ridges which are bounded by cliffs and separated by broad open valleys ending in cliffs to the north, and filled with great slopes of talus or slide rock broken by frost from the surrounding cliffs. The ridges pass northward and eastward into the main divide and are often weathered into almost perpendicular pinnacles of rock. On one of these ridges the Bonanza mine is located, the broad slide rock filled amphitheater called Horseshoe Draw on the west and that which I have called the Bonanza Draw on the east.

On the west side, this ridge is extremely abrupt and precipitous, descending by a series of steep cliffs, often two to four hundred feet in height to the talus filled valley below. (A good idea of this abrupt face may be gained from the illustration, taken from Spencer and Schrader's, which is given below.

The second No. 2 will also show the approximate detail of the cliffs. On the eastern side the ridge is less abrupt as the slide rock extends from near the crest into the bottom of the Bonanza Draw. Its slope near the crest is about 33 deg. but it gradually lessens until it merges into the rather evenly sloping bottom of the valley and joins the main talus slope derived from the cliffs at the head of the valley.

GEOLOGY. The accompanying maps, Nos. 2 and 3 respectively, will illustrate the details of the geology in the vicinity of the Bonanza mine. No. 2 is on a scale of 250 feet to the inch and will show the general features of the geology. Accompanying it is a section on the same scale which will show the relation of the several formations to one another. Map No. 3 is the enlargement of that of the Bonanza ridge and is designed together with the section accompanying it to show the occurrence of the ore and the character of the fissuring.

The west slope of the Wrangell mountains is made up of two principal formations, an immensely thick series of bedded greenstones or altered amygdaloids and diabases termed the Nikolai greenstones below, and a conformable limestone series above known as the Chitistone limestone, with a maximum thickness in this region of about 2,000 feet. A thin bed of about 5 feet of red and green shales separate these two formations. The dip is a little to the east of north at a varying angle here about 22 deg., but at other points both steeper and shallower. This carries the greenstone series below the limestones to the north where the whole series is overlaid by later sediments with intrusive prophyries and by the recent volcanics of the Wrangell mountains. Faults repeat these higher formations to the south, but are unimportant in the present discussion.

THE GREENSTONES. The greenstones are a series of extrusive eruptive rocks and were poured out either upon the surface of a land area or at the bottom of a land area or at the bottom of a considerable depth of water. They lie in parallel layers of varying thickness, the layers being remarkable for the regularly bedded character which they exhibit. The separate flows vary in thickness from four or five feet to one hundred or more feet in thickness, being especially thick in the lower members of the series. Such great thicknesses were not observed at the Bonanza mine, but occur along the Chitistone River.

The rocks are of a dark, olive green color, sometimes becoming lighter and in some flows become slightly reddish in cast due to the presence of minute scales of hematite or iddingsite which have usually been formed by deep-seated causes from the olivine. Some of the members are porphyritic showing good sized crystals of feldspar and are then usually very dense and non-amygdaloidal and seem to have been intruded flows forced in between the earlier layers in their efforts to reach the surface. Instances of this kind were observed on the Chitistone River.

In texture they show a remarkable variation. Dense fine-grained diabases without amygdules, amygdaloids with small or large amygdules and rocks which actually grade into gabbros are of frequent occurrence. The commonest type of texture is the diabasic texture and even where the rock is intensely amygdaloidal the texture persists. The minerals which form them are labradorite feldspar, olivine and augite with much subordinate magnetite.

Alteration has changed much of the augite to hornblende and chlorite, but even in the intensely metamorphosed types olivine is frequently fresh.

The amygdules contain a variety of minerals sometimes several occurring together. The following are the most important:

Chlorite
Serpentine
Chalcedony and Opal
Calcite
Laumontite
Quartz
Epidote

The amygdules are not confined to the upper portions of the separate flows, but are scattered through them with little or no regularity, occurring as frequently in the lower portions of a flow as in the upper. They are likewise often present in some areas of a given flow and absent in others. This is a significant fact as compared with the Lake Superior greenstone where the amygdules occur in the upper portions of the separate flows and are, therefore, conclusive proof that the rocks have been poured out on the surface. Amygdules are not of uncommon occurrence in diabases, are not necessarily the result of surface cooling, but may occur wherever the pressure has been relieved to a sufficient extent to allow the expansion of the included gases. From the texture of these diabases, even where amygdaloidal cavities occur in considerable numbers, it seems probable that considerable pressure from some overlying material was present to prevent the formation of the great number of such cavities that characterize ordinary basaltic surface flows. For these reasons, it is probable that this series of greenstone flows represent a succession of eruptions poured out on the sea floor beneath a considerable depth of water.

The greenstone series is cut by great numbers of epidote veins which may be observed with a great variety of strikes and are especially strongly developed on the north side of the Horseshoe amphitheater across from the Bonanza mine. They are also abundant in the neighborhood of the Independence vein. These epidote veins sometimes show a well marked comb structure in which successive layers of epidote, quartz and calcite have been formed. They do not pass upward from the greenstone into the limestone, and are often intersected by the later fissures which carry the ore. In these epidote veins, which have a maximum width of one foot or more are often found isolated masses and sheets of native copper, usually found closely associated with quartz and furnishing a close parallel to the vein occurrences in the Lake Superior region.

Epidote also occurs in the sheeted zones which carry chalcocite and bornite, but is generally in small amount. It is always replaced by the bornite and is distinctly earlier. In one instance, however, the reverse relation was observed. It is difficult to tell whether these epidote veins are of surface origin or not, but the presence of quartz and calcite, their vein structure and their similarity to certain of those at Lake Superior seems to show them to be of metamorphic origin.

THE RED AND GREEN SHALE. The greenstones are separated from the limestones by a fine intervening layer of shales which have a total thickness of not over five feet. In the lower portion, these shales are colored dark red by iron oxide and in the upper portion have a light greenish color. As they lie right upon the solid greenstone, they usually make a shelf along the cliff, as shown in the columnar section sometimes as much as 50 feet in width. They are usually obscured by the detritus which has fallen from the limestone cliffs above so that they cannot be observed unless one examines the contact between the two formations very carefully. Their presence has, for this reason, been previously overlooked. They are not in the least altered by contact metamorphism.

THE LIMESTONE. The limestone is light grey through most of its thickness with a slightly bluish cast. In the lower portion for fifty or sixty feet above the contact, it is extremely thin-bedded but becomes heavier above this point until in its upper portions it is extremely heavy bedded. It is interrupted at a number of points by thinner beds. This lower, thin bedded portion is characterized by a peculiar structure produced by the presence of a large amount of clay and represented in the accompanying figure. The proportion of clayey impurities in these beds is much greater than in those higher up and it does not seem to have been so susceptible to mineralization as the upper and purer beds. This is seen if the outermost of the two fissures is observed in the face of a cliff which may be seen from the point where the contact crosses the ridge. The chalcocite is here observed to pass downward until it meets this limestone. It then terminates and extends laterally into a flat body. The presence of this shaly and argillaceous limestone may diminish the thickness of favorable ore bearing rock below the contact and in this respect is of considerable practical importance, as the total estimated thickness of limestone at the winze between the main tunnel level and the contact is only 150 feet and the possible barrenness of this bed would, therefore, reduce it by one-fifth. At a number of points generally at a considerable distance above the contact occur beds of marbleized or crystalline limestone of a purplish color. These are probably due to the metamorphism to which the series has been subjected. In general, the limestone does not show the effect of any appreciable alteration. No contact metamorphic minerals are present and crystalline character is not developed except in certain individual beds.

Throughout the whole of Bonanza ridge, the limestone is much shattered by fissuring and calcite filled fissures, masses and bunches are frequently present. In some places, it is even extensively brecciated and the fragments cemented together again by calcite. The calcite within these fissures has undoubtedly been derived from surface waters which have dissolved the limestone and redeposited the calcite in their downward passage from the surface.

STRUCTURE. The geological structure is simple.

The contact with overlying limestone and underlying greenstone dips N 30 deg. E. and crosses the ridge about 600 ft. from the mountain from which it projects.

The main mass of the mountain is made up of limestone with a maximum thickness of about 1,000 ft. to the greenstone below. The contact appears a little below the Bonanza mine and dips to the north -N 30 deg. E. exactly at an average angle of 22 deg. A V-shaped cap of limestone thus projects southward out into the Bonanza ridge with the apex of the V pointing south. The two arms of the V made a rapid descent northward. The eastern arm of the contact disappears beneath the slide rock about 50 feet from the apex; the western arm runs downward in a zig-zag line along the face of the cliff for 700 ft. where it disappears beneath the slide rock, to reappear on the opposite side of the Horseshoe amphitheater. This contact may be admirably seen from across the Horseshow draw--as is shown in the well known photograph on page 24 which was taken from about the point ? on Map No. 2. The lighter colored rock is the limestone; the dark is the greenstone.

Along this contact the greenstone projects out a little beyond the overlying limestone along the face of the bluff owing to the presence of the shale beds and makes a narrow ledge sometimes 50 ft. in width, but usually much narrower. This ledge is covered with a thin capping of red shale now almost completely obscured by limestone debris from above. It is shown on both maps by the purple color. The formations are slightly undulating owing to a little open folding, so that the dip and strike vary from point to point now rising to 28 degrees or 30 degrees now falling to below 20 degrees. The strike is N 60 deg. W. Instrumental determination of this dip said to have been made have been stated as 19 deg. This is too low as the measurements were made along the contact at a considerable angle to the strike. The true average angle is about 22 deg. This is important as it gives a greater depth of limestone, the important ore bearing rock, between the surface and the contact than the lower determination.

The contact crosses the Bonanza amphitheater beneath the slide rock and reappears again on the east side, where it crosses the ridge and runs northward into McCarthy Creek.

FISSURING. The limestone and the underlying greenstone on Bonanza ridge are much more fractured and broken than the balance of the formations. This fracturing is in the nature of sheeted zones which consist of a series of fracture planes nearly parallel and closely spaced, the rock intervening between them being often no more than one-half to one inch in width. There is one especially prominent zone of vertical sheeting which dominates the others and has chiefly determined the occurrence of the ore. This zone of sheeting extends with the ridge in a direction of N 30 deg. E., is about 60 to 70 ft. in width and is vertical in position. It passes through location monument No. 5 in the greenstone, as shown on the map, and extends northeast for 700 ft. It passes downward without interruption into the greenstone. A careful examination of the contact shows that the rocks are slightly faulted along certain planes in this sheeted zone. In one instance a displacement of as much as two feet was observed. This is at the southernmost extremity of the limestone. No extensive faulting, however, has occurred. The main vertical sheeting has been especially intense along two lines about 30 to 35 ft. apart, and of these the westernmost is the stronger. These intensely fractured portions of the sheeted zone have caused the localization of the largest bodies of ore, giving rise to the two main so-called veins of the mine.

Subordinate series of vertical or nearly vertical fracture planes run in the following directions: N 55 deg. E, N 81 deg. E, and N 35 deg. E. The most northeasterly of the ore occurrences on the ridge follow two of these subordinate directions, viz., N 35 deg. E and N 81 deg. E.

Besides the vertical systems of sheeting, there are others dipping at low angles which have markedly influenced the deposition of the ore. One series dips toward the west at an angle of about 50 to 60 deg. In places, it becomes steeper in its inclination. The strike of this system of fracturing is parallel to that of the main zone. Another system of sheeting also parallel to the main zone dips 36 deg. toward the southeast. Still another system of more nearly horizontal sheeting is especially well developed at the southwest entrance to the north tunnel where it has almost the appearance of bedding planes.

These several systems of fissuring have divided the limestone upon the ridge into a series of polygonal blocks in some cases small enough to form a breccia and have afforded an extremely intricate network of openings for the reception of ore. The fracturing has also permitted the operation of frost erosion to proceed along the ridge with more than usual rapidity and is the chief reason for the weathering of the limestone into such abrupt cliffs and pinnacles. That the degradation has not proceeded even more rapidly than it has is due to the presence of chalcocite and calcite which have cemented and bound together the blocks of limestone.

An additional effect of such intense complicated shattering together with the action of replacement has been the production of an ore deposit of extremely irregular form.

Concerning the persistence of the fissuring in depth, there is no doubt that the main sheeted zones extend down through to the contact into the greenstone, for they may be obserged beyond the end of the limestone outcrop. The other systems of fractures will probably be found also to continue down through the contact.

The localization of the ore of the Bonanza mine upon this ridge has undoubtedly been due to intersection of this complicated series of fractures and while it is by no means improbable that a like combination of fractures may recur at other points along the same contact, a careful search will probably be necessary to locate such favorable areas.

THE ORE BODIES

Copper occurs at the Bonanza mine in four different forms:

1. As irregular replacement bodies in the limestone.
2. As a stockwork in limestone.
3. As disseminated particles in the greenstone along the main sheeted zone.
4. As an extensive area of talus or slide rock extending downward from the southeastern side of the ridge into the open Bonanza amphitheater.

1. Ore in Limestone. The main masses of ore in the Bonanza mine occur as replacements of the limestone by chalcocite. This replacement has formed vertical ore bodies along the most intensely fissured portions of the main sheeted zone by the replacement of the rock intervening between the separate fractures, flat shoots which make out into lateral sheeted zones, great irregular masses such as that in the winze, isolated bunches of smaller size that cannot be assigned to any one system of fractures, and disseminated particles scattered through the low grade rock.

The feature which characterizes all of these masses is their excessively irregular form which it is practically impossible to describe. Even where the ore occurs in the vertical masses, it occurs in shoots within the sheeted zone which are of extremely irregular form.

The principal body of chalcocite which is to be seen on the surface occupies the more westerly portion of the main zone of sheeting and runs along the edge of the cliff in a direction about N 30 deg. E, itself forming the face of the cliff in part of the course. This body is 250 feet in length and is termed the main fissure. It is from two to four feet wide at the southern end and is a solid mass spreading out and diverging downwards. Towards the north, the ore is not continuous but separates into stringers and bunches distributed at intervals along the fissure. At the far northern end, it becomes represented by a few isolated patches and then disappears entirely.

At two points this ore mass diverges downward having been deposited not only in the main fissure, but in a plane of sheeting which connects with it and dips about 50 to 60 deg. to the west and forms the face of the bluff for some distance. The ore has thus the form of an inverted V with the eastern arm inclined to the west and forming the face of the cliff. All of the overlying rock has been stripped from this arm of the fissure and has left the great body of chalcocite plastering the surface of the cliff. A sketch of this was made from across Horseshoe draw and is given below. It will illustrate the irregularity of the replacement bodies or shoots which occur within the sheeted zones.

This V-like mass of ore has been cut into at a point where the section passes through the ridge and a remnant of it may be seen near the south end of the north tunnel. It was probably formerly connected with the vertical mass of ore.

Parallel with the main vein--if that term can be used for so irregular a body of ore--is a second much less pronounced vein near the eastern side of the main sheeted zone. It is about 35 ft. to the east and is strongest at the south end of the ridge, where it contains quite a fair body of ore, and again as a slightly mineralized fissure near the north end of the main vein. It is represented in the north tunnel by an extremely attenuated thin crack carrying chalcocite. This may or may not be connected with the surface. This second fissure is important because the bodies are so irregular that the merest threads of ore may at any time open out into a large body of ore.

North of the main fissure are two subordinate sheeted zones containing bunches of chalcocite, one striking N 81 deg. E and the other N 55 deg. E. The bunches are not along the same fracture, but angle across the zone, each succeeding one occurring along a separate fracture. These may open out into large ore bodies below. In the winze and the level from it, 32 ft. below, a large irregular body of chalcocite is cut which sends out stringers and apophyses in the limestone in all directions.

In the winze level, the main fissure is cut at the north end of the workings and is here a solid body of chalcocite 3-1/2 ft. wide. Between the point where it is cut and the winze, a great flat mass of excessively irregular form is cut in the level, sending out innumerable apophyses and stringers in the limestone from its under side. The drift does not extend to its upper surface, so that its size cannot be estimated. An alteration of the south side of the drift in which this mass occurs is shown in the sketch below. This will give some idea of the extreme irregularity of the ore.

Besides these large bodies of chalcocite, isolated bunches occur in great numbers and often contain some covellite.

A stockwork of filled fractures occurs between the main bodies of ore throughout the greater part of the ridge, the ore filling the cracks and replacing the rock only to a minor degree. The aggregate amount of workable ore is thereby greatly increased. In the large section, another flat mass of ore is seen to make out from the main body along a series of sheeting planes which are so strong as to resemble bedding, but dip toward the east. It is about four ft. thick. In all cases, the form of the ore is such that it can have originated only through the action of replacement, for cavities of solution are the only openings which could have had so irregular a form and such are not known to exist in this region.

2. Chalcocite in the Greenstone. A careful examination of the main zone of sheeting between the end of the limestone outcrop and location monument No. 5 shows that the greenstone here is impregnated with chalcocite and to some extent with bornite. The masses of sulphide are usually extremely small and are shown by the microscope to replace the feldspars and chloritic material of the greenstones and to a less degree the bi-silicates. In some places the grains of sulphide are fairly large, having a diameter of one-half inch or more, but usually they are rather sparsely scattered through the rock and are about the size of a No. 2 shot. Where very fine, they cannot be seen without the microscope. Such disseminated particles of ore in the greenstone extend to only short distances from a single sheeting plane and are frequently absent entirely throughout the whole width of the sheeted zones. The chalcocite does not occur in large quantity and when the sheeting is compared with that at the Independence mine in the open cut, it is seen to be in much less abundance than in the latter locality. It may be reasonably expected to occur in greater amount beneath the main ore bodies. Epidote occurs in lenticular masses in the main zone of sheeting, but most of the epidote fissures are at angles to this zone and are intersected by it being an earlier formation, as the sulphides occur in the epidote as replacements.

Possibilities of Working the Greenstone Ore. Comparing the ore in the greenstone with that in the Independence mine with which it is closely parallel, it may seem: (1) that the ore frequently terminates at some cross fissure abruptly, and (2) that it extends only a short distance from any single fracture plane; (3) that along the strike of the vein chalcocite occurs at irregular intervals and is by no means a constant occurrence in the entire extent of the fissure.

While the greenstone ore is often of workable grade, it is, therefore, which the mineralized outcrops occur, down to a point about 2500 ft. from the center of the ridge. The width of this mass of mineralized slide is approximately 700 ft. as a maximum width, with 2700 ft. as a maximum length.

In regard to its depth, it may be well to note that an even slope of the bedrock below the slide can hardly be expected as its depth must vary at different points on account of the irregularities of the underlying surface. Both limestone and greenstone are characterized by projecting cliffs and irregularities which may often reduce the thickness to by only a half, or again may increase it to a much higher figure than expected.

Between the cabin, as shown on the large map, and a small cliff of limestone at the southeastern extremity of the ridge, is an area of unmineralized slide, which has broken down and covered the mineralized material below. From the position of this unmineralized talus, it is probable that it is underlaid by mineralized material.

4. Native Copper Associated with Epidote in the Epidote Fissures. The epidote fissures which cut the greenstone in many places are distinct in character and origin from the chalcocite ores above. They are closely parallel to the occurrences of epidote fissures in the Lake Superior region, although they do not carry so large a variety of minerals and are characterized only at wide intervals by the presence of masses of copper. They vary in width from a few inches up to more than one foot and show frequently marked banded structure. The copper usually occurs with quartz and is distinctly later than that mineral. It also has been observed in fissures in the epidote, although none with those relations were seen in the vicinity of the Bonanza mine. This copper is in such small amount that it cannot be regarded as a possible future basis for mining.

OXIDATION

The production of the oxidized copper minerals, malachite and azurite extremely irregular and difficult to follow and would be an uncertain factor in mining operations. As compared with the limestone ore, it is of much lower grade. In my opinion the profitable working of the chalcocite in the greenstone below the Bonanza is to be regarded as a somewhat doubtful possibility. The irregularity of the ore will make exploration difficult and its lower grade may not suffice to compensate for the additional labor in locating the shoots and masses of mineralized rock.

It is also to be noted, as will be shown in a later paragraph, that the chalcocite in the greenstone is probably secondary in character and may be expected to pass within a comparatively short vertical distance into low-grade chalcopyrite which will not pay for exploitation. It is possible that the greenstone ore may be mined profitably during the extraction of the large and rich bodies of chalcocite in the limestone above at least for a short distance below the contact. The continuous operation of the mine would at that time reduce the working expenses to a minimum and would render the extraction of the low grade material much cheaper than if left until the richer bodies had been completely exhausted. In any case, the probable passage of the chalcocite into low grade chalcopyrite would effectually prevent profitable mining in any great distance below the contact.

3. Slide Rock Ore. Besides the ore which occurs in the bed rock, a certain portion of the slide or talus composed of frost broken blocks derived from the disintegration of the solid ores contains sufficient chalcocite to furnish a large amount of easily treated and highly profitable ore. While the absence of detailed results on a sampling of this mineralized talus renders it impracticable to outline the area with strict accuracy, still an approximate boundary is shown upon the two accompanying maps. This slide extends in the direction of slope slightly east of south from the crest of the ridge along

by the action of surface waters has proceeded to a remarkably slight degree upon all of the sulphide ores of the Bonanza mine. The chalcocite often stands up at the crest of the ridge in greater prominence than the limestone. In many cases, fresh fractures of chalcocite are exposed for very great lengths of time. Films of malachite and small quantities of azurite occur and generally coat the exposed surface of the chalcocite, but are rarely more than 1/64 of an inch in thickness. In the slide rock they are more abundant.

Oxidation has extended downward into the ore in the winze level as slight films of malachite in the boundaries of the ore, but are so little noticeable that they can be observed only after careful examination. The ore is in some places slightly fractured and the narrow openings filled with carbonates. This is true only of the upper and more exposed portions of the ore.

The cause of the absence of oxidation may be sought in the climatic conditions. Both slide rock and bed rock are frozen solid at a depth of no more than two feet below the surface. Brecciated limestone in the winze is cemented by ice which shows every evidence of having been present for a very great length of time. It is improbable that under the climatic condition prevailing since the beginning of glacial times, surface waters have been able to penetrate to any depth below the surface without having been rapidly frozen. Surface waters even in the summer season have been very cold, probably not rising to a higher temperature than 40 deg. Water at that temperature exerts but little chemical activity on even the most easily decomposed minerals. The summer seasons are likewise extremely short at this altitude (5500 ft.) so that the opportunity even for the slight chemical activity of cold water has been extremely brief. It is, therefore, certain that no secondary enrichment can have occurred to produce these ores since the beginning of glacial times.

As will be later shown, this fact is to be noticed throughout all the ore deposits discussed in this report and has an important bearing upon the prospective value of many of the occurrences of ore within southeastern Alaska. In all cases, the mechanical attrition of both rocks and ores has been much more marked than the chemical alteration. For those reasons, the mechanical degradation-aided by frost breaking off the fragments of ore has proceeded very much more rapidly than oxidation and has served to keep the fresh, unaltered ore always at the surface.

Character of the Ore. The Bonanza ores are almost exclusively chalcocite. A little bornite occurs in the greenstone along the main line of sheeting below the contact, but none can be observed in any of the ore above the contact. A little covellite has also been found in association with the Bonanza chalcocite. The ore is in all cases fine, even grained, silky looking chalcocite, unusually solid and containing no other minerals than the chalcocite itself. Examination of a polished section of this chalcocite under the microscope shows no other identifiable mineral and other than this no ore minerals are found in the mine.

Origin of the Ores. The form of the ore bodies, their irregularity and position make it certain that they have been formed by the action of replacement, the filling of open cavities having operated only in slight degree in the formation of low grade stockworks. Calcite occurs in great abundance both in the limestone and closely associated with the ore. It is in fissures or irregular masses and often cements limestone fragments. The chalcocite frequently replaces the calcite cutting it along cleavage planes and in fractures which pass irregularly through that mineral. Careful search fails to show a single instance in which chalcocite was intersected by calcite.

No quartz or silicate mineral of any kind accompanies the ore in the mine. Calcite derived from the solution of the limestone and the sulphide itself are the only minerals to be observed in the mine, an important point when the question of their origin is discussed.

The Ores Secondary. It is impossible to avoid the conclusion after a careful study of the Bonanza mine, that the ores are secondary in their origin. This, it seems to me, is supported by the following evidence:

1. Chalcocite is later than calcite. The calcite is a mineral produced by surface waters dissolving the limestone and re-precipitating it in crevices and fractures carrying it downward sometimes as far as the greenstone. As the chalcocite is later than calcite, which is a common produce of superficial solution and redeposition, it must have also been produced after superficial agencies had produced the calcite.
2. The ore bodies often show a rough divergence downwards dividing in the form of an inverted V along the main fissure.
3. Chalcocite is notably a secondary mineral usually produced by the action of sulphates upon unoxidized sulphides (chalcopyrite or copper-bearing pyrite.)
4. The chalcocite is extremely free from fracturing and brecciation. Such brecciation has on the other hand broken the limestone and allowed the crevices to be filled with calcite and also with ice, but the ore itself for so brittle a mineral is remarkably free from any evidence of shattering or brecciation.
5. A shaft of comparatively shallow depth on the Nikolai claim on the opposite side of McCarthy Creek shows much bornite on the surface, but considerable chalcopyrite in the bottom of the shaft. There is little question that the bornite in this case is secondary. In occurrences similar to the Bonanza on the contact on the Erie claim, chalcopyrite and bornite have been found and it is my opinion that these ores are clearly of secondary origin. There

seems no good reason why the Bonanza ores, which are similar in every respect insofar as their general occurrence is concerned with those of the Erie, except that only chalcocite and covellite are present, should be regarded as due to a form of deposition of a primary character when other similar occurrences are clearly secondary.

6. The chalcocite in the greenstone and its associate, bornite, in the Nikolai mine and in the Independence mine are associated with chalcopyrite and are clearly secondary. It is, therefore, probable that the chalcocite in the greenstone at the Bonanza mine is also secondary. It would seem hardly reasonable to ascribe chalcocite below the contact along the same zone of fissuring to secondary deposition and that which lies above it in the limestone to primary deposition by uprising waters.

For these reasons, it is my opinion that the chalcocite ores of the Bonanza are all of a secondary nature, produced by the action of downward moving waters upon chalcopyrite bodies which have been reduced by unaltered chalcopyrite below and possibly by the action of organiz matter in the limestone. Such solutions were undoubtedly sulphates and were reduced in their downward passage to chalcocite.

The fact that oxidation has proceeded so slowly at the Bonanza mine and that secondary enrichment of these ore deposits could not occur under present conditions offers no disproof, but simply throws the secondary action farther back in time to a period when a warmer climate prevailed. Such a warm climate must have been pre-glacial as the climate of this region has undoubtedly been much colder in the immediate past. Evidence shows that glaciers have been much more extensive and glacial activity had been vastly greater than it is at the present time. The secondary enrichment of these ore deposits must, therefore, have occurred in pre-glacial times during the close of the tertiary period. So little is known of former climatic conditions in pre-glacial times that it cannot be stated when this secondary enrichment occurred, but it seems probable that a much warmer and more humid climate prevailed in tertiary times. In such a case an upper oxidized zone undoubtedly existed above the present outcrop of the Bonanza mine and has since been removed, together with much of the secondary ore by the rapid frost erosion that has ensued. Later oxidation of the sulphides has been prevented by the coolness of the climate.

The process by which these ores have originated may then be outlined as follows: During the early portion of the tertiary period when the greenstone and limestone now exposed were deeply buried beneath overlying rock, hot ascending water, passing through the greenstone, have become charged with copper derived from the greenstone, have carried it upward in solution and deposited it as chalcopyrite in the greenstone and limestone. Erosion then occurred to some extent and oxidation and secondary enrichment took place. The waters carrying sulphate in solution not only deposited it in the fissures filled with chalcopyrite, but deposited it by replacement near the contact in bodies of much greater volume than those occupied by the original chalcopyrite. It is probable that the chalcopyrite deposits formed in the limestone were comparatively small in size, but of greater vertical extent. The downward moving sulphate solutions, however, penetrated outward into the limestone along the shattered rock and caused the secondary chalcocite bodies to occupy much greater areas than were originally occupied by chalcopyrite.

There seems little question that the ores have been originally derived from the greenstones. Assays of greenstone wherever taken from unmineralized areas have uniformly showed 0.11 to 0.70 copper and it is probable that no specimen of greenstone could be collected which would not show the presence of an appreciable percentage of copper. Time was not available for a determination of the condition in which the copper exists, but its presence is undoubted.

PRACTICAL CONSIDERATION

The important questions that will undoubtedly be asked are:

1. Will the ore extend downward to the contact in workable amount and value?
2. Will the ore extend downward beyond the contact in workable amount and value?
3. Will the ore extend northward into the hill where great depth of limestone lies above the contact?
4. What are the probabilities of similar ore occurrences elsewhere along this contact?

PERSISTENCE OF THE ORE IN DEPTH

The extension of the ore from the surface to the contact is dependent on the thickness of the limestone available for mineralization and the continuance of favorable beds to the contact itself.

1. Extension to the Contact. The dip of the limestone is about 22 deg. This as shown on the sections will give a depth of limestone beneath the north tunnel of 250 ft. Passing north into the hill this is rapidly increased by the rising surface and dipping contact. Surface indications, however, terminate about 650 ft. north of the south end of the limestone capping so that depth gained is affected by the doubt of the continuation of the ore in this direction. At this point 650 ft. from the end of the outcrop a total depth of limestone from surface to contact of 450 ft. is present. There is every reason to hope that masses of ore will occur in the limestone for the greater part of its thickness

for the fracturing is strong and passes down into the greenstone and should afford ore wherever favorable rock for replacement is present.

It is to be noted, however, that the lower 50 ft. of limestone above the contact is shaly and contains much clay and is, therefore, less favorable for mineralization than the purer, heavier layers above. Ore does occur, as reported by Mr. Birch, at the contact in some places, however, and this may not prevent its formation, but it is certain that the occurrence of ore in this lower 50-ft. may be less hopefully predicted than in the purer rock above.

In that case, the effect would be to reduce the total available thickness of favorable rock by 50 ft.

2. Extension Beyond the Contact. The Independence mine gives a good idea of the nature of the veins in the greenstone. The ore is irregular, contains more bornite than the limestone, and the shoots are not easily followed: chalcopyrite begins to appear in some quantity and their profitable mining is a matter of at least doubt. The main sheeted zone beyond the limits of the limestone is seen to contain some sulphides, but cannot be said to show promise. A heavier shoot may occur beneath the ore on the ridge and in that event the ore below the limestone might be profitable for some distance. The passage moreover of the chalcocite into bornite and later chalcopyrite is to be expected at no very great depth below the contact. As the hill is penetrated and depth thus gained, the chalcopyrite zone will rise and may even pass upward into the limestone if the ore extends far enough to the north.

On the whole the occurrence of large bodies of ore below the contact is decidedly not hopeful. The chief production of the Bonanza must, in my opinion, come from above the contact.

Northward extention into the Hill. This will depend upon the extent of the fracturing and existence of shoots within it. The fracturing continues up the ridge, but does not seem to me to be so strong or to be characterized by so many places of shattering. That ore occurs in this direction is possible as Mr. Birch reports the presence of a small isolated mass of sulphides in line with the main fissure in this direction. This would seem a hopeful indication as the extreme irregularity of these replacement bodies in the limestone is such that the most minute crack may be expected to open out into a large mass at any time. For the extension of ore in this direction, there is little that will help in coming to a decision. The only way it can be determined is by actual exploration.

Probability of Similar Occurrences in the Limestone. The ores of the Bonanza mine while extremely rich and in large amount will from the conditions of their geological occurrence be rapidly exhausted. Mining is easy on account of the exposed position of the ore. The contact below will be soon reached. The tonnage, therefore, afforded to a railroad by the Bonanza ores, while great for a limited time, will probably be of short duration. For this reason, it seems to me that efforts should be directed toward finding occurrences of ore similar to the Bonanza at other points in the contact of the limestone and greenstone. This contact is exposed over wide areas of country and there is every reason to believe that ores of a similar character will occur elsewhere in the limestone formation. The reasons for discovery of the Bonanza mine are chiefly its exposed position. A little less erosion in the rocks which once overlay the Bonanza ore bodies would have effectually prevented or at least indefinitely delayed discovery. It is, therefore, advisable to explore with unusual care all fissures and crevices containing chalcocite which are to be found in the limestone near to the contact. It is characteristic of such limestone occurrences as these, which are extremely irregular, that a small fissure or opening may lead to large bodies of ore.

VERDI AND ASSOCIATED CLAIMS - HEAD OF WHITE RIVER

NEAR SKOLAI GLACIER

KX 81-92

Location. A number of claims have been located by Mr. E. R. Wiley on the southern slope of a hill at the head of the White River about one and one-half miles from the eastern end of the Skolai Glacier. On one of these claims, the Verdi, a small vein of copper ore, occurs.

Geology. The country rocks here are a series of comparatively fresh amygdaloidal basalts and diabases which dip to the north into the hill at an angle of 30 deg. Their strike is N 75 deg. W. The separate flows of basalt vary greatly both in thickness and texture, now being dense and porphyritic, now so intensely amygdaloidal that the rock is nearly all made up of irregular cavities filled with calcite and laumontite, and now with large and iregular amygdules widely spaced. Flows in some cases have a thickness of 40 or 50 ft., and when showing such thickness are of an even, dense, dark greenish diabase.

The vein is in the amygdaloidal diabase. Higher up the hill the rocks have more the appearance of the Nikolai greenstones, on the Chitina, and are of even greater thickness than at the point where the vein occurs.

Amygdules of chalcedony are abundant but most of them are filled with laumontite. The laumontite amygdules have occasional patches of native copper in them. Laumontite also occurs in the seams between the separate flows, and in one case was observed to carry a mass of native copper about three inches in length.

The lode. The lode on the Verdi claim dips to the north 60 deg., intersecting the lava beds at a slight angle to their direction of strike. It consists of a sheeted zone two feet in width and now replaced by bornite. Only a small outcrop is seen where the slide rock has been cleared away. The bornite is not perfectly solid between the two layers, but is interrupted by barren spaces.

The ledge cannot be traced for any distance in either direction although seams and fractures in the greenstones occur at widely separated intervels containing a little chalcocite and bornite. The largest of these was four inches in width, but did not extend any distance. Hematite in considerable quantity occurs with the chalcocite. The exposure of the lode is in an amygdaloidal layer and as to minor fissures, it was noticed that most of them occurred in amygdaloidal layers, the denser layers--of which one is immediately below the outcrop--being unfavorable for their formation. On the Toby claim, adjoining the Verdi on the west, another small seam of chalcocite and hematite about four inches in width was observed. These chalcocite seams are discontinuous and the mineral in them which is closely associated with hematite is probably secondary in character and cannot be expected to extend to any great depth without passing into chalcopyrite.

Upper Lode. Further up the hill along the edge of a small gulch which runs southward into White River, a sheeted zone occurs 6 ft. in width and vertical in position, intersecting the greenstones in a direction of S 40 deg. W. An epidote vein containing quartz occurs on one side of the sheeted zone and has a width of from 6 to 8 inches. The rock has been impregnated slightly with chalcocite and bornite and considerable hematite and some calcite are also present. This zone closely resembles the Independence vein near the Bonanza, but is less mineralized. It will probably pass in depth into chalcopyrite though at what depth cannot be predicted. It affords less prospect of productiveness than the Independence vein, but in the event of better facilities for transportation, might be worthy of further sampling. Other veins of similar character are reported to occur on the opposite side of White River in the same series of greenstones.

Although these deposits themselves do not appear to be of commercial importance, it is obvious that this part of the country is quite heavily mineralized and it is possible that ore bodies of workable size may be found in the neighborhood.

HARRIS PROPERTY

LOCATION

The so-called Harris property is located along the course of the Upper White River at or near the Alaska-British Columbia boundary. The White River at this point flows north and has cut a deep valley, known as the canyon, whose sides here slope upward at an angle of 30 deg. until an elevation of some 400 ft. has been attained, when the slope passes into a broad, rather flat, deeply moss covered upland. A group of twenty claims are here located as shown on the accompanying map.

<u>Geology</u>. Except where it is penetrated by artificial excavations, the entire region is here so deeply covered by moss that no rock exposures can be seen. Occasionally a small mass of rock projects through the moss, but such instances are rare.

The country rocks exposed in the cuts are amygdaloidal diabases which have been somewhat altered by deep-seated metamorphism and may be termed greenstones. It is probable that they are intruded into sediments of undetermined age. No sediments are present near the open cuts, but shales may be seen near the cabins at the Canyon several miles down stream dipping upstream at an angle of about 30 deg. A limestone is reported to occur in this vicinity also, but wqs not observed. A. H. Brooks, who has been to Kletsan Creek and hastily examined the general region, reports the greenstones to be intruded into sediments, as irregular masses, and records the presence of a limestone near the copper bearing greenstones in Kletsan Creek. In the vicinity of the deposits examined, no rocks can be seen either in the river valley below or anywhere in the vicinity, with the exception of a few outcrops near the open cuts, and in the open cuts themselves. The copper deposits examined lie on the Discovery claim of the Solomon Copper Company. This claim has its west end line at about the center of White River and extends almost due eastward for fifteen huundred ft.

Development. From the river below, the ground slopes up to the east at an angle of about 30 degrees. On this slope and midway between the two sidelines of the claim, about 600 ft. horizontal distance from the river and 350 ft. above it, is a small outcrop of greenstone. This outcrop is 10 or 15 ft. in height and projects above the moss.

Below this a small opencut has been made in the slope of the hill. This cut is termed Cut No. 3, on the accompanying map. It is about 25 ft. in length, runs into the hill for 12 ft. and is 7 ft. deep, representing the removal of approximately 1,000 cubic ft. of loosely compacted rock or perhaps a total of 94 tons, exclusive of the copper. On the same claim in a direction S 45 deg. W from Cut No. 3 at a distance of 300 ft. is another, and smaller cut which runs 10 ft. into the hill, and is 6 ft. in width. Forty two feet from here in a direction S 45 W is still a third cut, but of barely sufficient size to show the bed rock. These cuts constitute the only development noted on the property and are likewise almost the only points at which any clue can be obtained to the geology. Between cuts Nos. 2 and 3 are two masses of greenstone which project a foot or two through the moss, but it is doubtful if they are in place. They show no evidence of mineralization. No attempt has been made to strip off the moss in the areas between the cuts nor at any other point observed on the property.

The Country Rock. The country rock in all cuts and outcrops is the same, varying slightly in texture.

It is an olivine diabase, usually fine grained and of a dark greenish color. In Cut No. 3, it takes a reddish cast due to the presence of minute flakes of iddingsite, a dark red material derived by metamorphism from olivine, and composed in part of microscopic scales of hematite. A few recognizable porphyritic crystals of labradorite feldspar, now stained with chlorite, but on the whole comparatively fresh, are scattered through the rock. The augite and olivine of the diabase are often quite fresh, although the few scattered amygdules are filled with chlorite and serpentine. These amygdaloidal diabases or greenstones are very similar in appearance to those of Lake Superior, although they are not perhaps so profoundly metamorphosed.

The Copper. In the larger of the three openings, or Cut No. 3, above mentioned, occur flat slabs of native copper. The face of this cut is shown in the accompanying photograph, the copper being colored red to distinguish it from the enclosing rock.

It will be noticed that there are three such slabs actually in place in the rock, while the dotted red line indicates the position occupied by a very large slab which has been removed and now stands against a tree near the mouth of the excavation.

The central slab is about four feet six inches long by two feet four inches wide, and two inches thick. The others are about one and one-half inches thick, and two of the slabs are vertical while that removed, and that in the center of the photograph are inclined toward the north about 45 deg. They lie in the joint planes of the rock, and can be in no sense termed fissures or veins. No true veins or fissures are to be observed. The larger slab, that which has already been removed, is eight feet long, five feet wide at the wider end, and three and one-half feet wide at the narrower end. It averages three inches in thickness, with 1/8 inch as a minimum and eight inches as a maximum, and has a total estimated weight of about 4,500 lbs. Quite a number of smaller masses are on the dump.

The total amount of copper in the cut including that on the dump is estimated as about five tons or ten thousand pounds. Assuming a specific gravity of 3.00 for the rock, roughly a little over one hundred and ten pounds of copper per ton of material taken from the cut is represented. This is a very conservative estimate, but is perhaps a higher figure than could be expected to hold over any extensive area in deposits as irregular and uncertain as mass copper must inevitably be.

In Cut No. 2 only one small joint plane carrying native copper was observed. This was exposed in the face for about one foot vertical distance and was about 3/4 inches in width. About 180 cubic feet of rock have been excavated from this cut and possibly 25 pounds of copper. The specific gravity of the amygdaloid being about 3.00, this would mean about four and one-half pounds of copper per ton of rock removed.

The above figures are based merely upon a rough estimate and so are not to be regarded as giving an accurate idea of the yield, but they are of some interest as showing the approximate proportion of copper to country rock in the cuts now opened. In mining, many barren areas would probably occur, if indeed the copper proved to extend over any considerable area. Near the surface, the copper could be worked with but little expense, as the rock is much joined and could be removed together with the overburden of moss, with a trifling expenditure of labor and powder. As the surface decomposition is slight, however, and the rock undoubtedly less broken within a short distance below the surface, it would soon become a matter of greater difficulty to obtain the copper masses, and the removal of much barren ground in the search for other copper masses would involve an expenditure for which large bonanzas along would compensate. It is to be noted that no fissures to guide exploration are observable, the copper occurring merely in the joint planes of the rock--although such fissures may be present in the unexposed portions of the country. It is noteworthy that mass copper mining has never been developed in the Lake Superior region, on so extensive a scale as that on the uniform, but low grade deposits and has frequently proved unprofitable and always uncertain. It has been pursued at intervals owing to the enticing character of large masses of copper.

Character of the Copper Slabs. The copper slabs when closely examined are found not to be composed of perfectly solid copper, but contain a coarse central portion and a fine grained, brick-red outer rim about 1/2 inch wide. Through the central portions are scattered quartz, calcite, and irregular areas of chalcocite generally small with reference to the total amount of copper but invariably present. The outer brick-red portion about one-half inch in width and very fine grained has not a metallic appearance. It was for this reason at first supposed to be hematite, but when studied in polished section was seen to be composed chiefly of copper, intimately mingled with fine grained chalcocite and rock material. The rock material is feldspar, sometimes in fairly large crystals and other unreplaced rock constituents such as chlorite, serpentine, etc. Some cuprite also seems to be present, although the amount was so small that this could not be definitely determined. In the central portion, the copper is seen to be later than the quartz, often penetrating it along fracture planes. The relative ages of the chalcocite and copper could not be determined microscopically, but there seems little doubt that the sulphide is the earlier mineral. The fine grained outer portion represents that portion of the copper which has replaced the country rock, the feldspars and other selicates in it representing residual portions of unreplaced rock.

PERSISTENCE OF THE ORE IN DEPTH

The persistence of the ore in depth depends chiefly upon the origin of the copper.

From the facts of the study given above, it is extremely difficult to determine to a certainty whether the copper is secondary; that is, the result of oxidation of the chalcocite, and extremely common process; or primary, resembling the copper in the Lake Superior amygdaloids.

The resemblance of the amygdaloids to those of the Lake Superior region and the frequent occurrence there of mass copper in joint planes as well as the occurrence of primary copper in the Kotsina greenstones would point to a primary origin for this native copper. The sulphides, chalcocite and bornite, often occur in small amounts in the Lake Superior rocks and so would not seem out of place here with primary copper.

On the other hand the intergrowth of native copper with chalcocite is here so intimate that it is almost impossible to ascribe other than a secondary origin to the copper. Native copper is more commonly produced in this way from chalcocite than almost any other sulphide by the simple equation below:

Cu_2S (Chalcocite) plus 2 O equals 2 Cu plus SO_2.

The SO_2 is changed at once to sulphurous acid by combination with water. Such a precipitation would be materially aided by the large amount of ferrous iron in the amygdaloid. Everything considered, it seems to me that the similarity with the Lake Superior is close enough to lead to possible serious error if pushed too far. It would be difficult if not impossible to imagine any process by which the chalcocite had been precipitated by native copper and the intergrowth is so intimate that there must be some chemical relation between the two.

For these reasons the indications are much in favor of the formation of this copper by oxidizing waters acting upon chalcocite in narrow seams--a process which probably took place at some period when the climate was warmer and more favorable to oxidation than at present. It is but fair to state, however, that by some process not well understood they may have had a primary origin. Secondary native copper undoubtedly exists in Alaska, though it cannot be regarded as common and has been noted by Spencer in the Kotsina country. The chalcocite deposits of the region are singularly free from it, although that may be due to the removal of much of the oxidized zone in which it occurred. It is to be regretted that more outcrops are not available as they might throw further light on this somewhat obscure question.

Sampling of the Rock Between Copper Masses. In order to determine whether copper was impregnated in the greenstone in workable amount and obtain further evidence as to the origin of the copper, the fresh amygdaloid between the copper masses was sampled. A sample was first taken across the entire face of the cut, all fissures and rock immediately adjacent to the copper slabs being carefully excluded. The position of this sample, No. W 143, is indicated by the black dotted line of the photograph on page 54 and the sketch taken from it. Below is the result:

No. W 143	0.43% Cu.

Nine samples were then collected of fresh rocks as far as possible from the copper slabs, with the following results:

	% Cu
No. W 138	0.51
W 139	0.51
W 140	0.40
W 132	0.51
W 144	0.55
W 137	0.58
Average	0.51

Two samples of rock were then taken a short distance from the slabs giving the results as follows:

No.	% cu
W 133	0.35
W 135	0.51
W 143	0.58
W 134	0.51
W 147	0.56
Average	0.506

It is at once obvious that the rock becomes no richer in the vicinity of the copper slabs and that there has therefore probably been no introduction of copper into the rock at the time of their formation. Assays made of greenstone elsewhere also show percentages in copper equal to those here given and it seems that the greenstones throughout the region may contain on the average of about 1/2% copper. This being true the copper values in the rock are probably an original constituent and not native copper. This copper may be chemically combined with the silicates. No native copper can be detected in the section.

If I am correct in assuming the secondary origin of this copper, it cannot be expected to continue to an indefinite depth, but it does not, therefore, follow that if present over a considerable area of country, it might not be profitably mined. It may continue for several hundred feet below the surface or even deeper, depending upon the amount of material that has been removed by erosion. Any exact estimate of depth is not justified by the evidence.

EXTENT OF AREA OCCUPIED BY THE DEPOSITS

There is no way in which the extent of area occupied by these deposits can be ascertained except the careful removal of the overburden of moss and loose material that conceals the rock surface. This should be a comparatively inexpensive matter and could be rapidly done by a few men.

Reports of other occurrences of a similar character in the neighborhood were brought to me some time after this examination was completed and A. H. Brooks of the Geological Survey has recorded similar occurrences from the same general region. (Geological Survey 21st A.R. Pt. II, pp. 379-381). There can be no doubt that the greenstone covers a large portion of the area covered by the claims as shown on the map and similar copper occurrences may reasonably be expected whenever that rock is present. A limited amount of money expended in ascertaining the surficial extent of the copper seems advisable as any prospective value the deposits may have will depend largely upon the results of such exploration.

CONCLUSIONS

The following then is a summary of the commercially important conclusions reached:

1. The development is insufficient to furnish any clue as to the extent of area covered by the copper.
2. The probability of its extending over a considerable territory in sufficient abundance to be profitably operated is sufficiently strong to warrant the removal of some of the overburden of moss.
3. The probable secondary character of the copper makes persistence in depth doubtful.
4. The irregularity of the occurrence of the albas will make working uncertain, and a uniform return cannot be expected.
5. The greater solidity of the rock at a distance below the surface will increase the expense of exploration for the mass copper.
6. The body of the rock between the copper masses does not contain sufficient copper to be workable.

RECOMMENDATIONS

In view of these conclusions, I would offer the following recommendations:

1. That the purchase of the property without further development work is not justified.

2. That a limited amount of money be expended in the removal of moss along the bank of White River in directions north and south from the open cut and parallel to this, both above and below the cut to ascertain the extent of area occupied by the copper.

3. That a careful search for outcrops over the area occupied by the claims be made and the absence or occurrence of native copper be noted.

RABBIT CREEK CLAIMS RX 87-101

Location. From its junction with White River, Rabbit Creek heads north by west for about eight miles. It then bends sharply toward the west and heads up into a series of low hills. It is a rather narrow stream and has cut quite deeply into the rock, to form a valley about 200 ft. in depth. About two miles from the bend, this valley becomes a steep, narrow gorge containing a waterfall.

The "Copper Chief Claim" (owned by S. Abert and others) is located with its south end line in the creek bed, about a mile above the right angle bend, which is shown on the accompanying map, Map No. 5. The claim extends in a northerly direction for fifteen hundred ft. Adjoining it on the south is a claim belonging to J. R. Slaggard.

Geology. The geology and the position of the mineralized lodes may be seen from the accompanying map and section No. 5.

The rocks are continuously exposed along the stream from near the bend toward the east as far as explored. They comprise a series of highly inclined argillites or clay-slates of a light yellow or greenish color derived from metamorphism of clay shales, with an extensive series of intrusive diabases, and gabbros usually conformable to the bedding planes, but in some cases intruded irregularly into them.

Above the falls argillites preponderate and the intrusive shoots of greenstone are comparatively widely spaced and thin. At and below the falls, on the other hand, there is but little argillite, the bands being small and infrequent and the country rock throughout is dense, compact diabase. Above the falls the dip is upstream about 80 deg. The strike of the formation is about N 30 deg. W.

On the hills to the north, a great flow of light colored andesiteporphyry, of recent age covers the eroded edges of the upturned slates and greenstones.

Mineralized Zones. The lodes examined consist of irregular zones of mineralization in the country rock, containing disseminated pyrite, pyrrhotite, chalcopyrite and quartz. These minerals are in the form of irregular particles either in the rock itself, or in veinlets scattered through the rock. This impregnation is strong in the diabase, but is not pronounced in the comparatively insoluble and unfavorable clay slate. The lodes are, therefore, zones of impregnation, whether in diabase or slates. They dip more steeply than the enclosing rock, so that they pass from one formation into another. Above the falls, the two zones observed are within the argillite area and are obviously of no value, as mineral matter is extremely scarce in them, the clay of the clay slates being much less susceptible to mineralization than the diabase. Little or no sulphide is present in these upper zones, which are exposed on the "Silver Fox" and the "Black Fox" claims respectively. They do not warrant further attention. The third zone, or that below the falls, on the "Copper Chief" claim is in the diabase, and shows a total width of from 60 to 70 ft. A small sketch elevation of this zone may be seen on the accompanying map. The surface of the lode in the outcrop is heavily stained with iron oxide, so that it may be noticed from a considerable distance, but the iron is merely a thin wash over the surface and no deep oxidation has occurred. The primary sulphides, pyrite and pyrrhotite with some chalcopyrite are the only minerals to be observed in the body of the rock. No secondary minerals of any kind are present.

Value. A sample was taken of this lode across the whole width giving the following results:

Au Oz. per ton	Ag Oz. per ton	% Cu.
None	None	0.06

A selected sample from a small bunch of chalcopyrite was taken from one of the upper lodes to determine whether or not the sulphides themselves carried appreciable values in gold or silver. A high copper value was of course to be expected in this specimen. The following results were obtained:

Au Oz. per ton	Ag. Oz. per ton	% Cu
None	0.50	16.16

From the results of the first assay, it is apparent that the main lode contains no ore of value. The high percentage of copper present in the selected chalcopyrite specimen also shows that no gold and only a little silver is present, too small an amount to be worthy of consideration.

Secondary Enrichment. As these lodes are entirely unoxidized at the surface, and contain only minerals that are distinctly primary, it is clear that no increase in value may be expected with depth. If anything, a decrease should be expected. There can be little doubt, therefore, that these lodes are of no prospective value.

COLORADO AND ADJOINING CLAIMS, BEAVER CREEK

KX 87-102

LOCATION

The property is located on Beaver Creek about half a mile west of Beaver Cabin, and two miles upstream from the junction with Ptarmigan Creek. The Idaho, Colorado, Nevada, Utah and California claims, each 600 by 1500 ft. are located in line end for end, running slightly east of south. The only lode observed was that examined and outcrops on the south bank of the creek just above the stream. More exactly, it is located at the south end of the Colorado claim about 100 ft. south of the north end line and 90 ft. east of the west side line.

GEOLOGY

General. The country rocks of this general region are a series of metamorphic rocks consisting of argillites or clay-slates, stretched conglomerates, graphite schists, and quartz schists. They have been cut by intrusive masses of olivine-gabbro and diorite, the latter rock showing in Ptarmigan Creek to the southeast and not shown on the map. The slates and related rocks are more schistose in the neighborhood of the gabbros, but less altered at a distance therefrom. They are tilted to a high angle and show a strike of N 55 Deg. W, which varies somewhat on the two sides of the river, and dip to the north end at an angle not far from the vertical, but generally in northerly direction. They make up the main portion of the country for many miles around.

Geology Near the Mine. In the vicinity of the mine, Beaver Creek valley is a wide, flat valley about 800 ft. wide and deeply filled with recent gravels. The banks rise abruptly on the north and south, making high hills to the north but a flat table land on the south sloping gently upward and now covered by bench gravels.

The stream has cut into its south bank here at the north end of the Colorado claim and revealed a narrow strip of bed rock about 60 ft. wide between the river gravels below and the bench gravels above. For a distance of about 200 ft. on both sides of the lode, this bed rock is olivine-gabbro. It is then covered to the north and south respectively by the bench gravels which have fallen from above. Four hundred and fifty feet east of the tunnel is a similar strip of bed rock which appears, but is here graphitic schists nearly vertical in position and striking N 65 W. The contact of the schist and gabbro may be assumed to follow about the dotted line shown on the map.

THE LODE.

About 25 ft. above the bed of the stream, a vertical vein of sulphide ore is exposed. The strike of this vein is due directly into the bank. About 20 ft. of vein is exposed between the bench gravels above and slide matter below. A tunnel has been run into the bank for about 15 ft. along the edge of the vein and below it, but shows no rock other than the gabbro. The width of the vein is about four ft.

The ore is an almost solid sulphide consisting of a mixture of pyrrhotite, chalcopyrite and subordinate arsenopyrite, the latter mineral being present only in small quantity. Quartz appears here and there throughout the ore, especially near the center of the vein but is in small amount. The contact with the gabbro walls seems to be clean, but is too obscured by alteration to be carefully examined. A few inches of oxidized matter, chiefly limonite with some flakes of secondary native copper covers the deposit. This was, however, easily removed and the sulphides were seen to be but little altered and without more than the thinnest films of secondary minerals.

Three samples were taken as shown in the above sketch, one across the face at the level of the tunnel sets, one 5-ft. above and a third 8 ft. above this. The result of the assays on these samples was as follows:

	Au Oz per ton	Ag Oz per ton	Cu %	Ni %
No. 1	3.85	3.80	4.68	None
2	3.50	2.50	3.21	"
3	3.45	3.00	3.32	"
Average	3.80	3.43	3.74	None

These values will probably change but little with depth as care was taken to exclude oxidized minerals--the copper may fall off slightly, but the gold in all probability hold in depth. In the crosscut sample from the tunnel and the sample taken from beyond the surface, great care was exercised to exclude all secondary native metals and there seems little reason to expect any diminution of values with depth.

Persistence of the Ore in Depth. The persistence of the ore in depth depends upon the continuation of the vein in reasonable width and the downward continuation of values.

THE VEIN

A very limited outcrop such as this renders it difficult to predict with certainty. The gabbro is a massive rock, however, and so long as the vein remains in it, it may be expected to continue without other than the ordinary pinches and swells so long as it remains in the gabbro. On passing into the argillite series, it will probably either divide into numbers of low grade stringers or possibly disappear entirely. From the granitoid texture of the gabbro, it is undoubtedly a deep seated intrusive mass and probably of considerable size. A porphyritic texture might have been expected with a small mass. As the outcrop is near the northern edge of the gabbro mass, the conditions seem favorable for its continuation to the south for a considerable distance.

VALUES IN THE VEIN

It is well known that values do not usually occur uniformly along a vein, but occur in shoots. There is no means by which the size of this shoot may be determined other than actual exploration. The vein is strong and well defined although narrow, and is likely to have other shoots in it. The ore is clearly a primary ore and not in any sense produced by secondary enrichment. It is, therefore, almost certain that no appreciable diminution with depth need be expected.

CONCLUSION

While the ore is of good grade and may be expected to hold its values, the vein is small and too little work has been done upon it to prove its extent, so that its purchase would hardly be warranted. If, however, the owners could be induced to do some work to prove its length andmake an extensive sampling possible, it is well worthy of a more thorough investigation.

SKOOKUM GROUP - BENSON'S CAMP

LOCATION KX 78-20

A number of claims which have been located between Eureka and Anaconda Creeks, as shown on the accompanying map, were examined.

GEOLOGY

The rocks of this region are a series of metamorphic schists, slates and sandstones with included lentils of gray limestone, tilted to a high angle with a strike of about N 80 W and a dip of about 51 deg. toward the north. Many dikes of greenstone of varying thickness, now rendered highly schistose by metamorphism, are included in these schists and slates.

THE LODES

Intersecting these schists with a variety of strikes are two types of veins: (1) quartz veins; (2) sheeted zones containing small amounts of galena. Quartz Veins. The quartz veins are all of them the same and are made up of milky white quartz with a few scattered specks of pyrite and chalcopyrite in them, but very barren looking as a whole and unless gold bearing likely to prove of little value. The largest of the quartz veins is that exposed on the Beaver, El Dorado and Horn claims. This vein can be followed for a distance of 4,500 ft. It has an average width of about 6 ft. ranging from 3 ft. minimum to 10 ft. maximum. It is composed, as are the other quartz lodes examined, of white quartz much shattered and vertical in position. This white quartz contains very small quantities of pyrite and chalcopyrite. Near the outcrops, this has in some cases been oxidized so that the veins are rusty and occasionally stained by patches of malachite and azurite in a very small amount. A face sample of the El Dorado lode taken where the vein has a width of 10 ft. showed the following values:

	Au Oz per ton	Ag Oz per ton	Cu %
Face sample of the Eldorado lode	--	--	0.53
Selected sample of sulphide bearing portion of Skookum lode	--	0.40	4.77

From these assays, it will appear that these quartz veins even when ore is carefully selected for the purposes of obtaining a high assay yield no result in gold. Silver appears only in the sulphides as shown by the second assay, and then in such small amounts as to be negligible. It is evident that the copper values are derived from the chalcopyrite in first sample and are actually present as that mineral in the second sample. The trace of silver found also appears only in the sulphide. As sulphides occur in these veins in only excessively small amounts, it is evident that they do not hold any promise of value. A number of samples obtained by prospectors from here have purported to carry high copper values, but they have with little question been taken from the few malachite stained patches or the little bunches of sulphide and give no idea of the actual poverty of the lodes.

The Sheeted Zone Containing Galena. A small sheeted zone containing galena is seen on Eureka Creek intersecting the schists. It is too small to deserve consideration.

COOPER PASS PROSPECT. GULCH WEST OF COOPER PASS. KK 78-51

Location. The property here described is located near Cooper Pass in the east branch of Cooper Creek about a mile below the summit of the pass on the Navesna River side. The topographic map is incorrect here, as Cooper Pass and the small lake should be in the east branch and not the west branch of Cooper Creek. A small lake lies in the pass about a mile below the prospect. The property lies in a very steep side gulch heading west from the main gulch and with very abrupt walls, about half way between the main gulch and the summit of the divide.

Geology. The country rock is an extremely folded limestone with beds about 3 to 6 inches in thickness separated from one another by small partings of shaly material. These limestones strike in a northwesterly direction parallel to the gorge of the main pass and extend down in a westerly direction to the bottom of the gorge above mentioned. Here their place is taken on the northeast side of the main gorge by a series of clay slates or argillites, intruded masses of greenstone and diabase. A section from the gorge up the side valley to the point where no ore occurs is given in the sketch below.

The Lode. The folded limestones are cut by a great intrusion of diabase which has itself not exerted any appreciable effect upon the limestone, but is clearly intrusive in origin. The contact with the limestone dips east and the lode extends west for over 100 ft. The diabase has been extensively mineralized with sulphide, chiefly pyrite, with a little chalcopyrite. A little oxidation has occurred so that the outcrop on both sides of the gorge is very much stained with iron oxide and films of sulphur derived from the pyrite are to be seen deposited on the rocks at the bottom of the small stream which occupies the gulch. This lode is reported to extend in a direction northwest and southeast for a thousand feet or more, but it was not followed out.

This pyrite is scattered through the dense diabase quite thickly, but the particles of sulphide are usually small.

<u>Samples.</u> Two samples of this mineralized zone or lode were taken. One of the unoxidized sulphide was taken for a portion of the distance across the outcrop. The oxidized material near the surface was taken from points likely to give the highest values. Gold is reported to have been found in the limonite which fills the cracks and covers the surface of the sulphides along this lode and the sample of oxidized matter was taken with a view to verify these statements. The following are the results of the sampling:

	Au Oz per ton	Ag Oz per ton	Cu %
Oxidized sample	--	--	0.55
Unoxidized sample	--	--	0.52

As both oxidized and unoxidized ores carry the same amount of copper and neither of them any of the precious metals, it is obvious that the oxidation has not increased the value of the ore. The copper is undoubtedly contained in the pyrite as minute particles of chalcopyrite. As these samples were taken from the most favorable looking portions of the lode, the deposits do not hold out any hope of profitable exploitation. This is only another of the many instances which are to be observed in this region, of the existence of primary sulphides at the surface of the ground, the cold climate having been ineffectual in producing extensive and deep oxidation or secondery enrichment. Chemical activity in this cold climate has been so slight that these processes have gone on with great slowness and the erosion aided by the action of frost breaking the rock has preceeded with much greater rapidity than the chemical activity, thus keeping exposed to view at all times the unaltered primary sulphides which constitute the least valuable portion of the ore deposits.

ORANGE HILL AND GALEN'S GROUP

LOCATION

KX 78-14 78-61

Two deposits were examined on the east bank of the Nabesna River at the foot of the Nabesna Glacier. They are marked on the general map by the large red square. A rough geological map has been made of the locality.

One of the deposits is 1200 ft. above the river on the west face of the mountain east of the river. The other on the bench at the foot of the slope.

GEOLOGY

The Nabesna Glacier has carved a very broad, flat valley whose bed has an elevation of 3800 ft. above sea level. The retreat of the glacier has left this wide valley filled with loose morainal material covering up all other formations. On both sides of the valley extending out from the sides of the mountain is a bench some 500 ft. higher than the bottom of the valley.

On the western side of the valley, this bench has been cut into by California Gulch and a rounded oval hill formed between it and the valley, known as Orange Hill. This will appear clearly from the accompanying map. To the east of California Gulch, the mountain rises more and more steeply until it becomes precipitous at an elevation of 1000 to 1200 ft. The geology is simple. Orange Hill and the balance of the bench to the north are composed of quartz diorite which is without doubt the basement rock over quite an area of country. It is undoubtedly the same rock which cuts the limestone at the property known as Field's on Jacksin Creek.

This quartz diorite is a deep seated intrusive rock. Above the quartz diorite for a distance of several hundred feet, the rocks are so covered with moss that their relations cannot be determined. Above this, however, are about

500 ft. of highly altered shales now baked into a compact hornstone and above that again a limestone about 200 ft. in thickness. Still above the limestone are more beds of altered shale and quartzite and at a distance of perhaps 700 ft. higher is a great intrusive mass of diabase and gabbro making the summit of the mountain. The sediments dip toward the northeast into the mountain and down along its face to the north at an angle of about 10 to 15 degrees.

The limestone is a thick bedded series with individual beds of perhaps one to two feet in thickness separated in some places by partings of thinner material. It is fairly pure and contains only a small proportion of clayey material. Along the brow of the hill it makes a row of cliffs.

The diabase which forms the capping at the top of the mountain and forms a much larger mass to the eastward is an intrusive rock. All of the other limestone, underlying shales and limestone, are cut by dikes and irregular masses of this diabase. The shales and quartzite are baked and altered by it, and the limestone intensely altered to granular masses of garnet with subordinate pyroxene, tremolite, specularite, actinolite, magnetite, quartz, and calcite. Some bunches of sulphides, bornite and chalcopyrite, are intergrown with those contact minerals.

FIELD'S PROPERTY

LOCATION

This property is located eight miles west of the Nabesna River on a steep hill just to the north of Jacksina Creek. The hill rises to an elevation of 7,000 ft. above the flat bottom of the valley and is extremely steep and precipitous on its southeastward face. The workings of the mine are in a small gulch on this southeast face of the hill. The hill may be seen in the photograph accompanying. The workings of the mine are at an elevation of about 1,000 ft. above the bottom of the valley.

GEOLOGY

This hill is made up of a series of comparatively pure, rather thin-bedded limestones, now intensely white owing to their advanced degree of alteration. These limestones extend down to the talus or slide 500 or 600 ft. below and dip into the hillside in a northerly direction at an angle of about 20 to 25 degrees. Above the limestone and about midway up from the base of the hill, a comparatively thin series of quartzites and shales are to be seen conformable with the limestone.

Through the limestone a great vertical dike of quartz diorite about 700 ft. in width has forced its way upward sending out many small branches and sheets into the beds of limestone and spreading out above the quartzites in an immensely thick sheet, which now forms the top of the hill.

In the accompanying photograph these rocks may be observed, the central part of the dark portions being quartz diorite, the outer portions being the garnet and the lighter portions being limestone.

The limestone for a distance of several thousand feet from the contact of the dike and also below the contact of the overlying sheet have been profoundly altered by the intrusive rock. They are now completely to a brown garnet, probably glossularite which generally preserves the bedding of the original limestone, but in many cases is so massive that no structure can be observed. Occasionally the garnet is open textured and crystalline easily crumbling into separate garnet crystals. Intermingled with this garnet material and sometimes forming areas several hundred feet in diameter are masses of lime pyroxene of the variety diopside. Such material occupies the first 60 ft. of the tunnel later mentioned. Intergrown with these contact minerals are also specular hematite, magnetite, quartz, calcite, and epidote, also pyrite and very occasionally a little bornite and chalcopyrite.

The garnet masses beside their great extent laterally have in some cases a vertical thickness of over 500 ft. In the accompanying photograph, page 85, the outer edges of the dark areas and in some cases the entire mass of dark material is solid garnet. On the accompanying map this garnet and contact material is colored green. The garnet has been unquestionably produced by the vapors given off by quartz diorite in its eruption.

Such contact deposits as this usually contain bornite and chalcopyrite in large irregular bodies and of workable value. The minerals are in such cases intergrown with contact minerals and mixed with magnetite. This mixture of magnetite and sulphide is an unmistakeable means of identification as such a combination has never been observed in any other type of deposit.

Copper minerals though found here only in extremely small quantities may later be discovered in workable amount.

ORE BODIES

Cutting this diorite and the contact minerals indiscriminately two veins of gold bearing ore have been found.

One of these is in the garnet and other contact materials directly next to the contact. It runs in an almost due east and west direction and passes from the contact materials into the quartz diorite. It has been marked on the accompanying map by a red line. After passing into the diorite, it becomes obscured by debris and has not been farther traced in a westerly direction. To the east, it likewise passes into the diroite but extends only a short distance in that rock where it pinches out and disappears. The total length of the exposed portion of the vein is about 100 ft. and the outcrop is located on an east slope of about 60 degrees. The vein dips in a northerly direction 78 degrees into the hill. At the west end of the outcrop, it is about four feet wide. At the center, it widens out to 9 feet and at the eastern end it is again about 4 feet. A second vein with a strike of N 64 deg. E is cut in the tunnel at a distance of 64 ft. from the mouth. The dip of this vein has the opposite direction, that is, 74 degrees toward the south. It is 4 feet wide.

The ore in these two veins is a porous glassy quartz, extremely rusty and containing only a little sulphide in the outcrops. The open spaces have often the form of pyrite crystals and undoubtedly originally contained pyrite. In the bottom of the cut at a depth of about 12 ft. from the surface sulphides have begun to appear, some fragments of the ore showing little or no indication of oxidation. The sulphide is in all cases pyrite which is usually crystalline.

<u>Origin of the Ore.</u> The quartz pyrite veins represent the last of the solutions derived from the cooling masses of quartz diorite. This rock upon its intrusion into the limestone altered the limestone extensively, forming the masses of garnet and other associated minerals. This alteration of the limestone was partly caused by the heat of the intrusive rock acting by vapors given off by

the igneous rock itself carrying silica, alumina, and iron in solution. After the upper portions of the diorite had cooled, they were slightly fractured and the fractures filled by quartz pyrite ore, deposited by a hot solution escaping from the still uncooled portions of the diorite below. The bearing of this origin upon the persistence of the ore in depth will appear later.

Development. The upper vein has been opened by an open cut which is 95 ft. in length and has the same width as the vein itself; i.e. 4 ft. at either end and a maximum width of 9 ft. in the center. At the eastern end, it is 15 ft. in depth. Two hundred feet lower in elevation in a S 30 deg. W direction at a distance of 270 ft., a tunnel has been driven 104 ft. in length. For the first 45 ft., this tunnel runs N 13 deg. E. It then bends slightly westward and runs 50 ft. to the breast in a direction N 2 deg. E. Fifty-four feet from the mouth, it passes from the contact mineral into the diorite. Nineteen feet from this contact, a second vein is encountered. The balance of the tunnel is in the quartz diorite. This vein is four feet wide and closely resembles the upper vein in its general character.

A rough tramway conveys the ore down the hill from the west end of the open cut to a point near the mouth of the tunnel. It is sent from there to some 206 ft. below in a roughly constructed ore chute. The mill in which the ore is treated is fitted with 3 stamps and one short amalgamating plate. After crushing in the battery, the pulp runs over this plate and the tailings are caught in a small sluice box fitted with cross fiffles.

Value of the Ore. A large sample of the average ore taken to the mill was obtained. This ore shows some sulphides, but is chiefly oxides. A sample also of the sulphide ore from the open cut was obtained for comparison with the average run of the ore. In order to ascertain the extraction, a sample of the tailings was taken from the top of the sluice box and another from the fine slimes at the end of the sluice. These samples gave the following results:

No.	Sample	Au Oz per ton	Ag Oz per ton	Value in Au per ton
W 207A	Average ore	0.40	0.60	$8.0
W 216	Sulphide ore	0.10	—	2.0
W 207B	Coarse tailings much pyrite	0.65	0.50	13.0
W 207C	Slime tailings	0.40	0.60	8.0

Although a more extensive sampling might have been productive of slightly higher values, it is safe to assume that the grade of the ore has been overstated by the owners. From the results a number of inferences may be drawn. The average grade of the ore is low, too low to be of promise in so small a surface showing. As the values are possibly irregularly distributed, it is possible that those portions of the ore first mined may have been of higher grade. As the tailings which contain much sulphide, where the sulphides were concentrated in the riffles of the sluice box gave the highest result, it seems that the pyrite and not the quartz carries the gold values. The very low value of the sulphide ore would then indicate that without concentration, the values are too low to make the mine pay. The extraction as may be seen from both of the tailings assays are unsatisfactorily low, probably on account of the sulphides beginning to appear in the ore.

FUTURE OF THE PROPERTY

The prospective value of this property will depend (1) upon the extent and number of the veins, (2) on the persistence of the veins and values in depth.

1. Extent and Number of the Veins. It is probable from the character of these veins as observed upon, the surface and from their origin, that they will not extend for great distances in the direction of their strike. It is doubtful even if the upper vein will extend sufficiently far toward the west

to be intersected in the tunnel. Veins associated with contact deposits of this type are characteristically irregular and discontinuous. This is especially true when the veins are themselves of small size as is the case here. On the other hand, it is probable that many more veins of the same type will be discovered as the conditions which cause the production of these great contact zones are the same over a wide area of country. The deposits might, therefore, become productive under favorable conditions of transportation and treatment.

2. Persistence of the Veins and Values in Depth. As the sulphide ores are in this case clearly of primary origin, they may be expected to continue without change either in value or character to such a depth as the veins themselves may extend. The values, however, which will thus persist in depth are those of the sulphide ores which according to samples assayed seemed to be very low. Concerning the downward extension in depth of these fissures, little can be said except that they are small and irregular and I should, therefore, expect them to pinch out much more rapidly than lodes of greater width and length.

On the whole, the future of this property is not promising, and certainly from the available workings and exposures it could not support an enterprise of any magnitude, especially in view of its isolated position and the cost of transportation and operation.

OCCURRENCES OF COPPER FROM WHICH SPECIMENS

WERE EXAMINED BUT WHICH WERE NOT VISITED.

Introductory.

Incidental to the work which formed the chief purpose of this expedition, a large number of samples of rock brought out by prospecting parties were collected and subsequently examined.

Such studies, of course, cannot pretend to afford even an approximate idea of the value of the properties from which the rock is taken as extent, value, and occurrence cannot be in any way ascertained. They are of value, however, as indicating possibilities; for the nature of the occurrences of the copper minerals in the rock is a thing which no tampering with specimens can obscure or invalidate.

A number of such occurrences were of especially interest and seemed to me to warrant further investigation. Most of the occurrences were of native copper ores which for reasons earlier stated seem to me to deserve special attention. These occurrences will be described below. The numbers corresponding with approximate locations and numbers in circles as given on the route map No. 1.

Native Copper Occurrences.

Rock containing native copper occurs at a number of localities. Specimens from six such localities were examined and from the descriptions given by those from whom the specimens were obtained and the nature of the rocks in four instances, they seem to me to merit an examination. The evidence afforded by these specimens shows that the copper in all of these four instances is probably of primary character; that is, it is the result of comparatively deep seated processes and not of surface origin, and may be expected to continue in depth as far as the enclosing rock may continue without any change. The reports of extent of mineralized area are probably exaggerated, but that is an inevitable feature of this class of report.

These occurrences are as follows:

1. Kotzina - property belonging to Captain Hartman and others. KX 87-35
2. Kluvesna - property belonging to Jake Nafsted. KX 87-32
3. Middle Fork of White River - property located by John Sinclair and others. KX 87-45
4. Camp Creek - property located by D. C. Sargent. KX 78-28
5. Chisana River - property located by D. C. Sargent - exact locality KX 78-28
   not known.
6. Russell Glacier - near Skolai Glacier - reported by Mr. Warner. KX 87-12.4

KX 87-35 <u>1. Kotsina.</u> A group of claims located by Captain Hartman and associates. The rock brought from this locality is a dense fine grained meta-diabase; that is, a diabase in which the pyroxene one of the constituent minerals, has been altered to hornblende. This type of alteration is produced by metamorphism, the effect of pressure, heat, circulation hot waters, etc. while the rock was deeply buried and is in no sense the effect of weathering.

The rock is extremely fresh, and shows no evidence of surface alteration. Through this rock are scattered minute and thin flakes of native copper, rarely more than 1/16 inch in diameter and often much smaller, but many of them readily detected without a glass. The copper flakes are usually in patches or associated with patches, of glassy quartz, which in some cases fills what appear to have originally been amygdaloidal cavities in the rock. In all cases, the microscope shows the copper to be associated with quartz even when that is not to be observed in the hand speciment, and with epidote. Sometimes the copper occurs in the hornblende, and occasionally wrapped about the grains of magnetite which abound in the rock. No fissures or openings through which it can have gained access to the rock are observable and its relations to the minerals of which the rock is composed point to its deposition during the alteration of the rock from a diabase to a greenstone. It is to be regarded as primary copper--i.e. not produced by the effect of weathering or secondary enrichment. For this reason, it may be expected to continue to as great a depth as the rock in which it occurs.

The enclosing rock is reported to cover a large area, a statement which was not verified but which there seems no sufficient reason to doubt. A large sample of this rock weighing some 5 pounds was sent for analysis, the surface material having been trimmed off, in order to get the perfectly fresh rock. The assay showed 0.65% copper. The owners reported 0.35% copper as the average of a large series of assays so that this figure is probably from a selected piece.

At the Atlantic mine during the last three years as stated by Rickard, (The Copper Mines of Lake Superior, by T. A. Rickard, p. 72, 1902-3-4), the average yield per ton has been 11.4, 11.095, and 12.76 pounds of copper or 0.57, 0.555, and 0.638% respectively. The value of 0.65% in this specimen if uniform over a large area would only be possible in Michigan under the very favorable conditions at the Atlantic mine. Under the isolated and difficult conditions prevalent in Alaska, it could hardly be said to afford much hope of profitable exploitation, certainly not at the present time. A value of 0.35% as stated by the owners is too low to be considered. The occurrence is important, however, as it proves the presence of primary copper in the greenstones over what purports to be a large area, and in connection with other occurrences stated below, lends encouragement to the hope that other and richer occurrences of workable grade may be discovered. A visit to this locality would seem useless at present, unless further work reveals the presence of ore of better grade.

2. Kluvesna. Rock was brought by Mr. Jacob Nafsted, of Tonsina from Kluvesna Creek, which contained native copper in greater quantity. The rock is a dark green, dense, and fresh looking greenstone, probably once a diabase, but now

altered to a mixture of chlorite and quartz. Epidote is present in small amounts, and the alterations which the rock has undergone are to be attributed to metamorphism, and the copper from its relation to the associated minerals, particularly the quartz is probably primary; i.e. not the result of surface agencies. The particles of copper are not over 1/8 inch in maximum diameter, and mostly of smaller size, but scattered quite thickly through the rock. They are solid particles and not flakes.

An assay of this rock yielded: copper 3.04%, a low value in view of the appearance of so much copper in the specimen. Other specimens from the same locality showed much chalcedony, such as frequently fills the amygdules in the greenstone with masses of chlorite, making up the balance of the rock. Copper is scattered through it in large ragged flakes and patches, often of 1/4 inch or more in diameter, usually of later formation than the chalcedony.

The general appearance of these rocks is such that the locality seems to me to warrant examination as the deposit if of any size may prove to be of some importance.

3. Camp Creek. On the summit of the hill near Camp Creek at the point shown on the general map by the black square marked Mr. D. C. Sargent reports the occurrence of native copper in the greenstone there exposed. Samples of nuggets of copper about 1/2 inch or more in size were brought in which are described as being shot through the greenstone. Where they have weathered out through the action of frost, they were picked up on the surface of the ground. A sample of the rock was brought showing no copper, but filled with a dark red mineral with good cleavage and composing about 20% of the rock. An examination of this rock in thin section showed that it was an extremely fresh olivine diabase, though its weathered appearance had led to the belief that it would prove highly decomposed. The olivine, which is a mineral that breaks down most readily under weathering,

was for the most part fresh. The red minerals proved to be iddingsite, a mineral of not very well understood chemical composition, but a product of the metamorphism of olivine-bearing diabases. This mineral is derived from the olivine and the crystals of olivine may be seen partly changed into iddingsite. The mineral is in part composed of minute scales of hematite. This rock shows an assay of 0.11% copper. This result is disappointing - but the locality - if the description of the mode of occurrence is correct, seems promising and might merit examination.

4. Chisana River. A similar occurrence to that on Camp Creek was reported by Mr. Sargent on the Chisana River. The exact locality was not learned, but the appearance of the rock was exactly similar to that from Camp Creek above mentioned.

5. Rock brought by John Sinclair from the Middle Fork of the White River. This rock shows native copper associated with laumontite - an occurrence typical of much of the Lake Superior amygdaloid. The copper is reported to be scattered through the rock and from the appearance of the specimen a deposit may occur there which is of some value. It may be doubted, however, if the locality is worthy of a visit without more reliable information, as the specimens were too small to furnish any idea of the nature of the occurrence and all of the information obtained so far from this source has proved uniformly exaggerated and disappointing.

6. Chalcocite and Native Copper. Another occurrence of native copper in amygdaloid associated with chalcocite is reported by Mr. Warner from the east side of Russell Glacier, near Skolai Glacier. The copper is here associated with chalcocite, and may be secondary, but the material looks promising. The amygdaloid contains calcite, and considerable chalcedonic silica - the last two minerals filling the amygdules. Little can be learned from these specimens, but

an examination of the locality can be made without great expense, and seems warranted by the character of the rock.

J. D. Irving

New Haven, Conn.

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