CONFIDENTIAL to J.M. CARR

Geology and Economic Geology of Kamloops Area, B.C.

E. Livingston

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GEOLOGY AND ECONOMIC GEOLOGY OF THE [illegible]

By Ed Livingston.

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SUMMARY

This report describes an area centered on the Iron Mask batholith located south of Kamloops. This batholith, probably of Coast Range age, is unique in this area in being a center for Tertiary intrusion, structure, and mineralisation. The batholith invades Cache Creek (Carboniferous) sediments and Nicola (Triassic) volcanics and sediments. The batholith is partly covered by, and is in fault contact with a thick series of Oligocene Miocene volcanics and sediments, possibly with some later basaltic flows and minor intrusions. Around the margins of the batholith are numerous small to medium sized intrusions of olerite (peridotite) and two types of hypabyssal dioritic rocks along with minor light and dark dykes.

A number of types of mineral deposits are known, the most important types being disseminated chalcopyrite and pyrite in fine grained Tertiary intrusives and copper mineralization in large zones of tectonic breccia. Poor exposures and a minor amount of exploration of these indicate that both types are of sub marginal grade. Exploration is difficult because geologically favorable areas are mostly covered by thick glacial overburden. Geophysics has so far been ineffective in indicating these types of mineralisation. A combination of geochemical and magnetometer surveys along with overburden thickness data may prove to be effective, but insufficient data are available at present to substantiate this. McPhar's I.P. technique has been tried here; these data are being evaluated at the present time.

Other areas of economic interest in the district are discussed.

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GEOLOGY & ECONOMIC GEOLOGY OF KAMLOOPS AREA
by E. Livingston

History

The earliest prospecting done in this district was for placer gold. This was carried out in the 1860's and 70's, and a little gold was recovered from Tranquille Creek, Louis Creek, McGillivray Creek and a few other small creeks. The main copper showings south and west of Kamloops, lode gold showings on Jamieson Creek and at Stump Lake, and iron and mercury showings, were also located at about this time. The first production other than placer gold was started in the period 1900 to 1910 when magnetite was shipped from Cherry Creek (for smelter flux), copper-gold ore from the Copper King at Cherry Creek and copper from the Iron Mask mine. Production in the district was sporadic, mostly from the Iron Mask and Copper King, and continued until 1940. The largest producer was the Iron Mask producing from 1901 to 1928 about 189,000 tons of ore grading 1.37% Cu per ton with about ½ oz. Ag per ton. The best grade ore was from the Copper King which produced between 1906 and 1940 about 7,500 tons grading 2.61% Cu, .158 oz. Au and .3 oz. Ag per ton. Other small shipments of copper and gold ore have been made from other prospects. The gold mine at Stump Lake produced about 77,500 tons of ore averaging .19 oz. Au, 3.26 oz. Ag, 1.43% Pb, and .24% Zn per ton.

In 1952 Kennecott Copper Co. (Northwest Exploration) optioned the old Pothook property from Axel Berglund of Prince George and after doing an EM survey drilled 14 diamond drill holes. The results were considered discouraging and the option was terminated.

During the period of high copper prices in the 1950's, interest in the district was revived by the promoters who proceeded to acquire all the old copper prospects and establish companies to explore them. These efforts were all unsuccessful as far as exploration is concerned.

In the late 1920's CM & S Co. of Trail acquired a prospect near Jacko Lake west of Knutsford. This ground was held and more ground acquired in the 1950's. Exploration consisting mostly of diamond drilling was carried out at this time ending in 1956. The ground is still held by CM & S.

The work done by the recent promoters has given much valuable geologic information from random diamond drill holes, bulldozer cuts, adits and shafts.

History (continued)

The most recent regional geologic mapping was done between 1939 and 1944 and is covered by G.S.C. Memoir 249 "Geology and mineral deposits of Nicola Map Area". By W. E. Cockfield 1948.

In the summer of 1956 Dr. J. M. Carr of the B. C. Dept. of Mines did some mapping in the vicinity of the Iron Mask batholith south of Kamloops which was the area of most activity at that time. This work is described in the Report to the Minister of Mines for 1956. It is concerned largely with the economic geology of the area and includes descriptions of now inaccessible underground workings which had been opened up in the exploration at that time.

Regional Geology

The latest geologic map of the district is G.S.C. Map No. 886A which accompanies Memoir 249.

This report deals mostly with the area around the Iron Mask Batholith which is just south of Kamloops. As far as economic geology is concerned the Kamloops area could probably be extended beyond the boundaries of Map 886A in all directions particularly to the north and northwest to the limit of the Cache Creek Rocks. Except for the presence of the Iron Mask Batholith which seems to be unique similar geologic conditions prevail over a large area.

Cache Creek Group

This is a thick series of sediments and volcanics of Permian and probably Carboniferous age. These rocks extend from Kootenay and Okanagan Lake to the Prince George district, being covered in part of this area by Tertiary volcanics. This group includes thick sections predominantly of sediments and thick sections predominantly of volcanics and in some parts interbedded volcanics and sediments. In the Kamloops area the Cache Creek Group is composed mainly of sediments. To the west in the Clinton-Pavilion area the Cache Creek includes the Marble Canyon limestone, a thick section of massive limestone.

A characteristic feature of the Cache Creek rocks is the presence of chert both in the sedimentary and volcanic parts of the group. There are sections of ribbon chert varying in color from white to black and including red and green. In addition, much of the limestone and tuff is cherty. Fossils are scarce.

Under conditions of dynamic metamorphism these rocks become quite schistose.

Nicola Group

These rocks are predominantly green volcanics with minor amounts of sediments. The volcanics are mostly flows and agglomerates with lesser amounts of tuff. Grey, green, and red waterlain well bedded tuff are found occasionally in the volcanic sections. Sediments include limestone and argillite often tuffaceous. Nicola sediments occur on the southwest side of the Iron Mask Batholith. Although the volcanics often give the appearance of being metamorphosed the sediments are often very well preserved and show excellent graded bedding, slumps, and other original structures and textures.

Generally speaking, few attempts have been made to do any detailed mapping of the Nicola rocks, but work at Copper Mountain and more recently southwest of Merritt show that enough stratigraphic features are present so that structure and stratigraphy can probably be worked out.

Coast Intrusions

The plutonic rocks of the district have generally been correlated with the Coast Range Batholith, but in most cases definite evidence of age is lacking. These rocks to the west were emplaced from Lower Jurassic to Lower Cretaceous time and the plutonic rocks of this area are probably of the same age. As the Iron Mask Batholith shows certain features which are probably unique it may well be of slightly different age than other plutonic rocks. In this study plutonic rocks other than the Iron Mask Batholith have not been studied in any detail. In general they are fairly uniform medium grained rocks with a little quartz ranging in composition from diorite to granodiorite. Mafic minerals include biotite, pyroxene and amphibole. The Guichon Creek Batholith from work at Bethlehem Copper is known to be made up of more than one intrusion. The Wildhorse Mt. Batholith is described as being a composite mass also. The Iron Mask Batholith is made up of at least 2 distinct phases. Detailed study may disclose a similar situation in other batholiths of this area.

Contact metamorphism along the contacts of the plutonic rocks is not often seen. Although these contacts are often faulted and are often hidden, if widespread contact metamorphism were present it would probably be seen occasionally. Skarn zones are known west of Little Fort which is about 60 miles north of Kamloops, at Westwold which is south east of Kamloops, and around Merritt, where the Craigmont ore body is probably a type of contact metamorphic deposit. Random drill holes in limey Nicola sediments along the south side of the Iron Mask batholith show no contact metamorphism.

Iron Mask Batholith

This batholith and also the Guichon Creek Batholith, as far as we know, are unique in this area. Numerous other batholiths and stocks, probably about the same age (Jurassic-Cretaceous), are all rather uniform in character and as far as we know have not been centers for Tertiary igneous activity, Tertiary structure, and mineralization. The Iron Mask Batholith is quite heterogeneous and varies in composition from pyroxenite to granite.

The main mass of the rock is a diorite as seen west of Knutsford and between Cherry Creek and Kamloops Lake. This rock is medium grained, grey, or greenish grey, with a homogeneous appearance. In thin section it has a plutonic texture and is composed of about 60% intermediate plagioclase (Ab6 to Ab5), up to 25% orthoclase often as oikocrysts enclosing plagioclase and pyroxene, 10-15% clinopyroxene of the diopside-hedenbergite series, probably augite, with up to about 2% small quartz grains which can not been seen in hand specimen. Occasionally as much as 10% brown poikilitic biotite may be present often with more than average pyroxene. Accessory minerals are magnetite as disseminated grains (up to 4%), and apatite.

Alteration is very widespread; in fact, it is difficult to find unaltered specimens. In hand specimen the alteration may show as a scaly appearance of the pyroxene. In thin section alteration of feldspars is found to be very widespread; in many cases the orthoclase is very cloudy and is difficult to identify. Plagioclase is often severely altered and only the outline of the lath-like grains may be seen. Usually relict albite twinning is present in some grains, but often this twinning is so poorly defined that it is difficult or impossible to ascertain the composition of the plagioclase. In a relatively unaltered specimen from near the Afton Group sericite (?) alteration is very patchy on a microscopic scale. The center or a side of a plagioclase grain may be a mass of fine grained sericite while the remainder of the grain is perfectly clear with excellent albite twinning (Ab5). Possibly these are later over growths on altered plagioclase. This specimen showed very little orthoclase, so plagioclase overgrowths, if that is the origin of the clear albite, may be at the expense of orthoclase. Near the center of the batholith in the vicinity of a 'roof pendant' or inclusion of volcanic rocks, probably Nicola volcanics, is a body of fine grained quartz bearing rock, probably best described as micro-granite. It is composed of about 50% intermediate plagioclase (Ab6) with lesser amounts of very cloudy altered orthoclase.(?) About 20% of the rock is quarts which is in medium to small grains and also as patches of mosaic

Micrograph

Iron Mask Batholith (continued)

grains. Some specimens show only one type of quartz, others show both. This quartz, which is mostly clear, except for some hair-like rutile (?), is often difficult to see in hand specimen. The mafic mineral, a clinopyroxene probably augite, makes up about 10% of the rock. Magnetite up to about 4% is present as corroded grains. This rock is found in a Makaoo drill hole to be in sharp sheared contact with the more common diorite of the batholith and is therefore thought to be a separate intrusive mass. The included volcanics are cut by numerous small irregular dykes of diorite but the micro-granite is not seen cutting the volcanics.

This rock seems to be particularly prone to a buff colored carbonate alteration seen in almost all the outcrop of this type. This alteration consists of carbonate usually buff colored in reflected light (siderite-ankerite?), which occurs as stringers and replaces part or most of the pyroxene. Two thin sections of rock with this alteration showed numerous stringers of micro-breccia filled with carbonate, magnetite, quartz, and leucoxene. This brecciation seems to occur only on a microscopic scale, as it is not seen in hand specimen; hand specimens often have a crackled appearance.

The area extent of this rock type is not known. It has been seen by the writer only in the Galaxy area and probably is not more than 1½ miles in its greatest dimension.

Along the north east and north sides of the batholith from Knutsford at least as far as the Iron Mask Mine and also near Jacko Lake is a zone, probably continuous, of very heterogeneous dioritic rock. This zone, if it is a zone, is characterized by rapid local changes in grain size from fine grained to very coarse grained (pegmatitic?). There is much more than average magnetite in the rock and this has an erratic distribution which is well shown by a magnetometer survey near the Makaoo property. At the Makaoo where this zone is best exposed, it is not located at the outside boundary of the batholith. A zone of more normal diorite in the order of 3-500? wide lies along the fault contact with pierite. Although this rock would seem to be a product of alteration of normal diorite, the change from normal diorite to this type at the Makaoo seems to be quite sharp and may be seen in a bulldozer cut. There are however a great many faults at the Makaoo so that there this may be a fault contact. Outcrops of this rock are widespread but the best examples of this rock type are seen in Makaoo drill core.

In the only thin section examined the rock was found to consist of 2 distinct phases with a sharp boundary. One phase

Iron Mask Batholith (continued)

consisted of clear calcic plagioclase (Ab_4) with about 15% corroded looking clino-pyroxene grains often with overgrowths (not enclosing) of hornblende. The plagioclase is poikilitic containing smooth rounded grains of magnetite and a little apatite. Several clear grains of plagioclase completely enclose masses of fine grained chlorite (?). These may be overgrowths of fresh plagioclase on altered feldspar. No orthoclase was seen. The other phase consists of extremely cloudy plagioclase which is more sodic (Ab_7). Pyroxene is as before but no hornblende is seen. Instead chlorite, possibly pseudomorphous after amphibole, is found near the pyroxene. No orthoclase is seen but the very cloudy feldspar can not be identified. This relationship is interpreted as albite alteration in which the plagioclase becomes more albitic with alteration of amphibole to chlorite. Possibly the more calcic phase, described first, is a metamorphic rock; this is indicated by the poikilitic plagioclase and cloudy centers of some grains. Overgrowths of hornblende also may indicate such an origin.

One of the problems associated with this rock is why it should occur in a zone near the contact but not against it. The magnetite which causes very intense and local magnetic fluctuations may have been brought in or may be due to a combination of redistribution of original magnetite along with additional magnetite produced by alteration of mafic minerals.

Near the CM & S property at Jacko Lake more intense albitization is seen. Here large patches of the rock are white - probably altered entirely to albite. Less intense albitization is seen in that area as a zone like that described above.

In the batholith at several places there are zones of unknown extent of buff colored carbonate rocks which have a prominent breccia structure on weathered surface. Dr. Gunning suggested that these are altered ultramafic rock (picrite). The rock is in most cases entirely carbonate of high specific gravity, probably magnesite, siderite, ankerite, etc; a little quartz occurs in some places. This is a low temperature CO_2 alteration; the brecciation would result from change in volume if silica is removed.

Potash alteration with addition of orthoclase to the plutonic rock and also to some of the later intrusive rocks is widespread, especially in the DM-Afton area and also near the Kimberley. This alteration is usually accompanied by intense sericite alteration so that thin sections are very cloudy. In some cases the orthoclase occurs as a fine intergranular mosaic. At the Makaoo and to a lesser extent at the Afton bright salmon pink stringers of orthoclase are present often with the mineralization.

Cretaceous? and/or Tertiary (?) rocks near Copper Creek

Rocks occurring along Carabine Creek north of Kamloops Lake are of unknown age. These consist of conglomerate, sandstone, and shale. Where seen by the writer near Copper Creek they have vertical dips and are probably in fault contact with Nicola rocks to the west. Rocks of this type are not found south of Kamloops Lake. These rocks have been correlated by some investigators with the Coldwater conglomerate which contains coal at Merritt. The lack of coal is cited as a reason for rejecting a Coldwater correlation but the fact that the Coldwater coal measures are restricted to local basins to the south does not rule out the idea that conditions favoring coal may not have existed in the local area of deposition of conglomerate north of Kamloops Lake. The local extent and thickness of section are typical of conditions in the Oligocene basins to the south. Post depositional folding is also described in other Tertiary sedimentary basins.

Cretaceous or Tertiary volcanic rocks

A section of red and green tuffs, often poorly lithified, occurring near Copper Creek, of unknown age, are reported by Cockfield to overlie the clastic rocks described above. The relationship of these tuffs to the clastic rocks has not been seen by the writer. Near Copper Creek the clastic rocks dip 90° striking northwesterly while the tuffs dip gently southeasterly and are not overturned. No evidence for tops was seen in the clastics and the contact is covered in this area. The tuffs are intruded near Copper Creek by extensive large sills of an ultramafic rock described by Cockfield as augite porphyrite. These are certainly sills and are not 'sills or flows' as suggested by Cockfield. The picrite also intrudes the tuffs as irregular dyke-like bodies like those of Miocene or later age seen around Kamloops. Both these ultramafic rock types are probably related. If the augite porphyrites were flows the tuffs would have to be contemporaneous giving an age of Miocene or later. As it is, they must be Miocene or earlier, and could of course be Cretaceous.

Kamloops Group

This group of volcanics and lesser amounts of non marine sediments, up to about 5000' thick, is very widespread, covering large areas especially north of Kamloops. The age is Oligocene-Miocene based on fossil evidence. A section of sediments in the volcanics has been called the Tranquille beds from the type locality at Tranquille. Mathews proposes dividing the Kamloops Group into lower volcanics, Tranquille beds, and upper volcanics. However, this may not be feasible as the Tranquille may be discontinuous, and beds called Tranquille may actually occur in different parts of the section in different localities. The Tranquille beds include tuffaceous sandstone and shale and minor coaly layers which can hardly be called coal beds. Due to their very soft nature, these sediments do not often outcrop and they may be more extensive than they appear.

The Kamloops volcanics are made up of basalt flows and breccias (also agglomerates?) with lesser amounts of andesite and minor rhyolite. It is usually not possible to determine attitudes, tops, etc. in these rocks. Sometimes thin flows, tuff beds, well developed columnar jointing, or other features, may be present and may indicate attitude. The sequence south and west of Kamloops indicates that Tranquille sediments are overlain by thick massive basalt flows. The sequence at Kamloops is confused by folding and faulting. It is often difficult to distinguish Kamloops volcanics from Nicola volcanics, especially near faults where Kamloops rocks are often altered and sheared.

Conglom-Cornwall Lodge

Several outcrops of red and green boulder conglomerate occur near Cornwall Lodge about 15 miles west of Kamloops along Cherry Creek. In one good exposure the conglomerate is seen to be under a gently dipping thrust fault, the hanging wall of which is agglomerate of the Kamloops Group. This conglomerate is not seen elsewhere and its stratigraphic position is unknown. It may be a lenticular bed in the Kamloops Group.

Tuff north of Afton Group

A 250' hole drilled by Cadamet Mines in December, 1959, north of the Afton Group and east of the south end of the pond south of the Trans Canada Highway on a soil anomaly, after penetrating 148' of overburden, was entirely in a fine grained reddish rock with vague green chlorite particles. A steep shear zone filled with magnetite stringers was cut by the hole also. This was thought by the writer to be intensely altered diorite but a thin section indicates that it is a tuff. It is made up mostly of laths of plagioclase Ab_6, sometimes bent, which are rudely aligned in some parts. A green mica (biotite?) occurs as pseudomorphs (?) after large and small grains of mafic mineral. These patches of

Tuff north of Afton Group (continued)

mica often contain grains of leucoxene and magnetite. The feldspar is mostly quite cloudy with dust of a brown mineral of high relief. Quartz is present as small interstitial grains, as larger patches of chalcedony with sharp irregular outline, and as a few large, perfectly rounded, clear grains, which are certainly clastic grains. This rock is believed to be an altered tuff. It has not been mapped in outcrop but may have been mapped with altered diorite which it resembles.

It is not clear just what this rock is as it is south of diorite outcrops which are part of the batholith. It is most logical to assume that this is a roof pendant of Nicola tuff although it could be a block of Tertiary tuff faulted into position.

Post Kamloops igneous rocks

Around the margins of the Iron Mask Batholith and at other localities in this area are ultramafic intrusions usually of irregular shape which have been classified as picrite. The rock in its least altered condition is a dark green porphyry containing rounded phenocrysts of clinopyroxene and also pseudomorphs after olivine. The relative abundance of pyroxene and olivine probably varies but the texture is characteristic even when altered to the extreme. The matrix is fine grained pyroxene and glass?

Alteration of these rocks is usually extreme and usually consists of complete alteration to tremolite-actinolite with lesser amounts of pyrophyllite or talc, antigorite, and chlorite (pennine?)

Occasionally phenocrysts consist of cores of clinopyroxene and in one case orthopyroxene surrounded by tremolite-actinolite. Other rounded phenocrysts containing chlorite and sometimes antigorite surrounded by rims of iddingsite, limonite and magnetite are believed to represent former olivine. Rarely in hand specimen altered phenocrysts show a network of fractures characteristic of altered olivene. It should be emphasized that this alteration is not like that seen in older serpentinized ultramafic rocks seen along the Fraser River and in the southern part of the Cariboo.

In many places around the Iron Mask Batholith, as for instance at the Makaoo property, on the highway cut north of Shumway Lake, and on the CM & S property near Jacko Lake, these altered rocks show more or less distinct outlines of closely spaced rounded bodies or fragments of the same rock, giving the rock the general appearance of an agglomerate. Dr. Gunning suggested that this structure might be due to progressive alteration outward from close spaced fractures as in orbicular

Post Kamloops igneous rocks (continued)

weathering, or that it may represent intrusion as a mush with included fragments. The rounded 'fragments' in some places have a different content (usually higher) of phenocrysts than the interstitial material tending to substantiate the idea that these do represent fragments suspended in a matrix of approximately the same composition.

On the northern slope of Coal Hill south of Kamloops altered picrite is found cutting Tranquille type sediments and volcanics of the Kamloops group. It is found also northwest of Kamloops on Gannell Creek where it apparently cuts volcanic agglomerate of the Kamloops Group. The age of these intrusions is therefore Miocene or later. The picrite described above is probably related to the 'augite porphyrite' sills at Copper Creek. The sills show little alteration at least in hand specimen. They are quite uniform over long distances, and very close examination is necessary to see that they are intrusive into the red and green tuffs and are not flows. Possibly the lack of alteration in these gently dipping sills might be explained on the basis that hydrothermal solutions more easily penetrated steep dipping dykes along vertical structures than the gently dipping sills.

Several elongate zones of buff colored carbonate rock with breccia structure cut the Iron Mask Batholith and Nicola sediments to the west. The specific gravity of this rock is higher than calcite; it is probably a mixture of siderite, magnesite, etc. Dr. Gunning suggest that this rock is a product of alteration of picrite dykes. This type of alteration is discussed by Turner and Verhoogen.

The extreme alteration of the picrite gives it very little resistance to weathering so that it seldom is found in outcrop. However, it commonly weathers to a very sticky bright green mud which is easily recognised. It probably has little strength in the altered state and is therefore the locus of shearing and faulting.

Sugarloaf porphyritic diorite

Sugarloaf Hill west of Kamloops is composed, except for the northern flank, of a porphyritic diorite. This rock is quite heterogeneous, especially at Sugarloaf Hill, and often has a distinct hypabyssal texture and so should possibly be called a porphyry rather than a diorite. This is the rock called hornblende diorite by Jones. Although hornblende is usually present as prominent phenocrysts it is sometimes absent, so it is felt that the term hornblende diorite should not be used.

This rock is composed of plagioclase andesine (?) with phenocrysts of pyroxene and/or hornblende often with a little

Sugarloaf porphyritic diorite (continued)

quartz usually less than 5%. The grain size varies from coarse to fine and when present the hornblende phenocrysts may be very conspicuous. If hornblende is present this rock is easily distinguished from the plutonic rock of the Iron Mask batholith which does not contain hornblende under normal circumstances. This rock is often altered and is sometimes mineralized.

This rock cuts the pierite already described. This relationship is best shown in the gulley at the northwest corner of the Afton Group where hard, fresh looking dykes of Sugarloaf diorite stand out in extremely altered and weathered earthy pierite. In an old short adit southwest of the Afton Sugar Loaf diorite cuts pierite and contains numerous xenoliths of pierite. This rock is thus Miocene or later and younger than pierite.

Cherry Creek porphyry

This rock is a fine grained porphyry which is found in and around the Iron Mask Batholith. The best exposed outcrops of this rock are northeast of Cherry Creek near the old Copper King Mine. This rock is believed to be very closely related to mineralisation in this area.

The rock is fine grained and its porphyritic texture is not often easily seen in hand specimen. In most places it has been altered with the addition of red orthoclase; under these conditions it may be identified with certainty only in thin section. The rock is composed of about 60% quite closely packed crystals of plagioclase (Ab_6), along with phenocrysts of clinopyroxene and rarely hornblende. In thin section the feldspars often show an alignment giving the rock a trachytoid texture which is seldom seen in hand specimen. The groundmass is very fine grained and is usually very cloudy due to alteration. It probably is a mixture of orthoclase and plagioclase. Up to 5% quartz is sometimes present. The rock might be called a trachyte or soda trachyte.

The Cherry Creek porphyry occurs in various small bodies around the Iron Mask Batholith. South of Knutsford on the old Joker prospect a number of close spaced diamond drill holes show flat lying sheets of Cherry Creek porphyry in plutonic rocks of the batholith. At the Kimberley property at Knutsford there is a suggestion of a similar flat sheet in the adit. A diamond drill hole at the DM property west of Kamloops passed through about 150' of Cherry Creek porphyry and then ran into Sugar Loaf diorite. The contact of a body of Cherry Creek porphyry with overlying plutonic rock dips about 20° at Frederick. These occurrences suggest that in some places this rock tends to occur as flat sheets which would hardly be expected under these conditions. Small dykes in the Iron Mask Batholith near the Copper King mine are steep.

SECTION

		Copper Creek intrusions: stocks, dykes, granite, granochorite.
		Fine grained amphibolite dykes, unmineralized.
		Feldspar porphyry, quartz feldspar porphyry, rarely quartz porphyry dykes, buff to grey.
Miocene and/ or later		Brown weathering basalt (andesite). Thick massive flows, dykes, sills in Kamloops tuffs - Usually included as part of Kamloops volcanics, may be correlated with Valley Basalt of Merritt area.
		Cherry Creek type fine grained porphyry, trachytoid texture, dykes, stocks, often with patches of explosion breccia.
		Sugar Loaf type porphyritic diorite usually containing hornblende (porphyritic texture often not seen in hand specimen).
		Dykes, stocks and sills of ultramafic rocks, picrite, (often like agglomerate) augite porphyrite, and minor layered intrusions at Copper Creek.
		Thick massive uniform basaltic flows, sometimes showing columnar jointing. Also minor coarse grained porphyritic dolerite near Cherry Creek.
Miocene and (?) Oligocene	Kamloops Group	Volcanics - mostly agglomerates & breccias (?), with thin basaltic flows, often vesicular. Minor sediments, tuffs.
		Tranquille beds. Sandstone and shale, often light buff colored, tuff, minor coal, minor conglomerate.
		Volcanics - mostly agglomerates and breccias. Minor sediments and tuff.
	Coldwater conglomerate	Conglomerate sandstone, shale and coal. (May not be present near Kamloops).
Cretaceous (?) or Tertiary (?)		Clastic rocks and tuffs at Carabine & Copper Creeks northwest of Kamloops. Conglomerate, arkose, and sandstone (may be Coldwater).
Upper Triassic	Coast Intrusions	Quartz diorite, diorite, granodiorite, granite, minor gabbro, and pyroxenite, homogeneous and heterogeneous phases.
Upper Triassic	Nicola Group	Predominantly volcanic - Greenstone; basalt flows, breccias, agglomerates, and tuffs; limestone, limey sediments, and tuffs, argillite, quartzite, green schists.
		Probable unconformity
Permian and (?) earlier	Cache Creek Group	Black argillite, ribbon chert, limestone, tuffs, dark and light flows, quartzite, green schists, mica schists. Cherty rocks are characteristic. Limestone sometimes fossiliferous.

Cherry Creek porphyry (continued)

Interesting features of this rock type are the bodies and patches of explosion breccia which occur within it. The explosion breccia typically consists of rounded, sub rounded and angular fragments in a fine to medium grained matrix. Most of the fragments are porphyry with occasional fragments of plutonic rock and fine grained nondescript rocks. The matrix in thin section is a highly altered mixture of broken grains with occasional small rock fragments made up of several grains. The matrix typically makes up a high proportion of the rock, over 50% in some cases.

The irregular patchy nature of the breccia can best be seen in drill core where the breccia structure ranges from very clear to absent; it does not seem to have definite boundaries. Where outcrop is scarce, small, and scattered, it is quite difficult to see the breccia unless a very distinct patch of breccia occurs in outcrop. Excellent exposures occur in the Kimberley Adit, north of the DM shaft and along the CN track just east of Fredrick on the north shore of Kamloops Lake. Explosion breccia cuts a dyke of Sugarleaf diorite cutting pierite at Makaoo. Other patches of breccia have been found north of Hughes Lake and southeast of Hughes Lake. No explosion breccia has been recognized at Cherry Creek near the Copper King.

Dr. J. M. Carr of the B. C. Dept. of Mines, who has worked at Bethlehem Copper where explosion breccia of this sort is quite common, proposes an origin of the breccia in that area along the following lines. A swarm of porphyry dykes when contained by high pressure in competent rock solidifies in the normal manner. When such dyke forming magma encounters a zone of weakness caused by previous structure such as an igneous contact, the magma under high pressure may force its way into zones of lower pressure causing a sudden reduction in pressure causing volatile constituent to come out of solution and part of the liquid magma to flash into vapor with consequent rapid reduction in temperature. Under these conditions a rapid flow of magma toward the zone of lower pressure breaks up parts of the rock which have already solidified and also part of the confining wall rock to produce a breccia. The early crystallising components of the magma which form the phenocrysts flow easily as long as there is enough fluid to maintain the solids in suspension. Upon the sudden vaporizing of part of the liquid phase with consequent drop in temperature the solids and remaining liquid may either freeze as closely packed porphyry or if the pressure gradient is great enough may flow as a semi-solid material with comminution of rock fragments and early formed crystals to form a mylonite.

This idea proposed by Carr is better able to explain the erratic, patchy distribution of breccia than the more widely

Cherry Creek porphyry (continued)

held idea that breccias of this sort are created by a separate source of energy situated at depth.

The relative age of this rock is not known exactly. It cuts Sugarloaf diorite at the Makaoo and flat lying Tertiary rocks south of the Afton Group. It is believed to be older than brown weathering basalt yet to be described.

Other Tertiary dyke rocks

Small dark fine grained dykes are seen occasionally; these are usually less than 10' wide and do not seem to have much strike length. They cut the Cherry Creek porphyry and are not mineralized when they cut mineralized rocks. In thin section one of these was seen to consist of a felt of long hornblende crystals with interstial fine grained minerals, probably mostly orthoclase, containing fine hairlike crystals, which may also be amphibole. A little quartz also occurs as small grains. This might be classed as amphibolite.

Buff colored fine grained dykes with variable amounts of coarse feldspar and glassy quartz phenocrysts occur in this area. The quartz is absent in some of these. The glassy mineral which Jones and the writer believe is quartz is believed to be leucite by Burton on the basis of grain shape. These dykes occur in the Afton area where they are not over 20' wide and in a body over 500' long and at least 200' wide, south of Sugarloaf Hill. The relative age of these dykes is not known, only in that they cut Sugarloaf diorite.

Brown Weathering Basalt

This rock is a fine grained homogeneous rock which is usually not vesicular but is quite vesicular in some places. It is made up of a felt of andesine - labradorite (Ab_5) plagioclase composing about 80% of the rock with interstitial grains and phenocrysts of clino-pyroxene probably augite quite corroded and altered. Rare phenocrysts of zoned calcic plagioclase are also seen. No quartz was recognised in the fine grained interstitial material. This rock should probably be called andesite because of the high content of plagioclase but it was first called brown weathering basalt by Jones so this name has been retained. This rock weathers a characteristic brown color, hence the name. It often shows concentric close jointing on weathering which results in some cases in small isolated knob like forms.

This type of rock occurs along the north and eastern contacts of the Iron Mask Batholith and also in areas of Tertiary

Brown Weathering Basalt (continued)

sediments and tuffs on the north side of Coal Hill and between the DM Group and Kamloops Lake. The same rock forms the uppermost massive flows of the Kamloops Group in the area south of Kamloops Lake. Flows of this type are found near Inks Lake southeast of Sugarloaf Hill. This rock is seen to occur as dykes on the Afton Group cutting the batholith and as dykes cutting soft tuffs of the Kamloops group. Outcrops on the Kimberley and DM properties are isolated and it is not known whether these are dykes or flows although it seems more likely that they are dykes than flows.

One of these dykes cuts mineralized Sugar Loaf diorite on the Afton, and the dyke is also mineralized, so these dykes are pre-mineralization in age. If the brown weathering basalt is properly correlated with the top flows of the Kamloops Group this would indicate that the top flows of the Kamloops Group are post-Sugar Loaf diorite age, and indicates a time interval between the deposition of Tranquille sediments and the overlying flows. Thus the soft buff-colored weathered-looking tuffs under the top Kamloops flows may be a regolith.

It is possible that this brown weathering basalt may be related to Cockfield's Valley basalt found around Merritt which is clearly younger than the Kamloops group in that area. The composition of the two are about the same but this is not much help in correlation as there are probably other rocks in the Kamloops group of about the same composition. In any case, whether the rocks extruded and intruded in the Merritt and Kamloops areas are the same or not, they may well have originated during the same episode. It might be mentioned here that post-Pliestocene volcanic activity is well known north of here, at Quesnel Lake, southeast of Horsefly, and west of the North Thompson River near Clearwater. The Valley basalt-brown weathering basalt, although not post-Pleistocene may be as recent as Pleistocene.

Copper Creek granite

The best example of this rock is in the riprap quarry just east of the CN tunnel at Copper Creek. Here a small stock of granite cuts tuffs and ultramafic rocks. This stock has not been unroofed by erosion and the rounded top of the stock is well exposed in the quarry. The dark green rocks have been partly digested to green micaceous minerals over a zone averaging about 30' thick. The only occurrence of Copper Creek rocks south of Kamloops Lake is in 2 dykes reported by Jones to cut brown basalt (brown weathering basalt?) northwest of the Afton Group. These have not been seen by the writer. Jones' correlation is based on an examination of thin section(s). This indicates that the

Copper Creek granite (continued)

Copper Creek granite is post-Kamloops in age and not pre-Kamloops as Cockfield suggests. Stocks of Copper Creek Granite are shown on Cockfield's map to the northwest cutting the conglomerate which occurs at Copper Creek.

Other intrusive rocks

A small elongate stock along Cherry Creek is composed of pyroxene gabbro which may cut Kamloops rocks or may be in fault contact with them. There is the possibility that the volcanics may be part of the Nicola Group, although they look like typical rocks of the Kamloops Group. This stock is cut by a large quartz-feldspar porphyry dyke as described above, indicating that the stock is at least older than these dykes. If it were not for the presence of surrounding Kamloops volcanics one would not hesitate to correlate it with the Iron Mask Batholith which is quite heterogeneous in character. This is probably the best correlation assuming fault contacts with Kamloops volcanics which are so common around the main batholith. This gabbro may therefore be a small horst or some other structural feature.

At the old Maid of Erin workings (part of Iron Mask Mine) the dumps contain much porphyry quite different than porphyrys seen on surface. This rock is a grey feldspar porphyry.

A stone wall near Knutsford contains numerous blocks of a coarse feldspar porphyry much like the Blue Creek Porphyry at Poison Mountain. This rock is reported to be local.

The old Allies (Gold Ridge) prospect shows dykes of a grey feldspar porphyry cutting soft pierite which intrudes Kamloops volcanic agglomerates. This porphyry is cut by quartz veins containing pyrite and chalcopyrite and carrying gold. This area is believed to be the source of placer gold and platinum found in Tranquille and other creeks in that area.

A body of intrusive rock north of Kamloops near Ramage section on the CN railway has been mapped as a Coast Range type intrusion. The northern part at least, which has been examined by the writer, is not normal coast range type rock but is a coarse grained reddish close-packed plagioclase porphyry quite different from other rocks in this area. It may well be related to other porphyrys of Tertiary age. Gold, iron and copper showings occur near it.

Structure

The structure of this area is quite complex. Folding and faulting have involved all the rocks in the area with the possible exception of the Copper Creek intrusions.

Structure (continued)

The structure of the Cache Creek rocks is unknown but is certainly fairly complex. Dips are usually steep and the rocks have been involved in severe shearing and faulting in many places. Along the North Thompson within a few miles of Kamloops Cache Creek argillite has been converted to graphitic schist along a large north trending regional fault. In most places in the Kamloops district metamorphism has been rather slight.

Structure in the Nicola rocks is also quite complex but in most places due to the massive character of the volcanics it is difficult to determine attitudes. Where the Nicola consists of sediments or waterlain tuffs it is of course possible to determine the attitude of these rocks; in these cases dips are usually found to be steep. No attempts have been made to work out structure of the Nicola rocks around the Iron Mask Batholith. Burton suggests that the Nicola rocks have been arched up in a northwest trending anticline over the Iron Mask Batholith. However, a drill hole by Noranda which should be on the southwest limb of this anticline shows overturning with dips 30° to 60° which hardly substantiates the presence of this anticline. Mathews suggests that the Iron Mask Batholith intrudes a northwest trending syncline with the axis trending northwest through Edith Lake. Since Mathews' work involved regional mapping with an opportunity to observe the Nicola Rocks over a large area this is probably the best opinion to date.

The contact of the Iron Mask batholith with Nicola rocks has not been seen but evidence at the Kimberley suggests a fault contact. In fact, the Iron Mask batholith seems to have been a center for faulting and folding. The fact that many of the picrite intrusions in this area are located around the margins of the batholith suggests a zone of weakness along the contact. There is little doubt that faulting has taken place along this contact up to post Kamloops time. All the contacts of the batholith with the Kamloops Group are not faulted. A flow is seen overlying the batholith near Edith Lake.

As might be expected the picrite intrusions around the batholith have been the loci of numerous faults. At the south end of the batholith the large picrite intrusion is faulted against the Cache Creek rocks on the east and against the batholith on the west. The fault zone against the Cache Creek rocks is very well exposed in the road cuts along the Merritt highway at Cardo Hill just north of Shumway Lake. Here the fault zone is in the order of 500' wide. About 2 miles north of Cardo hill drilling at the old Grey Mask showings shows intense shearing in the peridotite and a tectonic breccia in the batholith. The breccia zone seems to extend into the batholith for at least 700'. A small exposure

Structure (continued)

directly east of the Grey Mask shows a fault contact of the east side of the picrite with the Cache Creek argillite. Very little is known about the Iron Mask batholith contact between the Grey Mask and the Makaoo property. At the Makaoo the contact is well exposed in the two adits and in trenches and drill holes. Here a picrite intrusion about 5-600' wide separates the batholith from Kamloops volcanics. Both sides of the picrite and especially the north side show very intense shearing. Here there is some evidence to suggest the direction of movement on the fault. The picrite occurs along a steep north facing hillside with the large fault at the foot of the slope. The hill is composed of the rocks of the batholith while the valley is Kamloops volcanics. A vertical hole drilled at the foot of the slope in the Kamloops rocks stopped in volcanics at over 300'. The top of the hill is about 3600' in elevation while the volcanics extend below 2100'. Although one may assume considerable pre Kamloops topographic relief, this evidence indicates that the Kamloops rocks have been faulted down relative to the batholith. The attitude of the Kamloops rocks at this point is unknown.

Faulting along this contact probably continues westward north of the Afton where this fault may somehow join the Cherry Creek fault which the writer believes is a regional fault running north westerly near Copper Creek. Numerous signs of faulting are apparent along Cherry Creek from Cornwall Lodge to the vicinity of the Copper King. Kamloops flows and bedded tuffs have dips up to 70° with some evidence for overturning. Feldspar-quartz porphyry dykes trend along Copper Creek and show intense shearing. One or more small gabbro stocks on the southwest side of Cherry Creek are intensely sheared along the Creek. Kamloops volcanics are thrust southward (?) over conglomerate along Cherry Creek. Dips in the Kamloops rocks on the northeast side are northeast and decrease gradually away from Cherry Creek. The intense folding and shearing of the thick Tertiary section along Cherry Creek would seem to be more severe than would be expected with simple normal faulting, but normal faulting with northeast side down is indicated by most of the evidence.

The extensive tectonic breccias which appear in this area are interesting structural features. The best known of these at the Afton has been called Pothook breccia by Burton. It may be seen in outcrop and in core from drilling in this area. It is mostly in the Iron Mask diorite but less extensive breccia in Sugar Leaf diorite seems to be continuous with it and is probably of the same age. The Pothook breccia is at least 2 miles long and seems to be at least several hundred feet wide. A very similar breccia zone at the old Grey Mask prospect south of Knutsford has been cut by drill holes drilled in 1956 by Commercial Minerals.

Structure (continued)

Due to lack of outcrop in this area its extent is not known. It seems to be located along the contact of the Iron Mask diorite and a large pipsite intrusion lying to the east. Small dykes of Cherry Creek porphyry in this zone are also brecciated and altered. Small breccia zones of this type are exposed in the Makaoo upper adit. There no control is apparent; the breccia occurs in irregular patches with rather sharp boundaries. It does not lie along the contact with pipsite but is several hundred feet away from it. These breccia zones do not generally outcrop, so it seems likely that other breccia zones of this type occur in this area.

The breccia consists of a more or less cemented rubble always quite intensely altered. The alteration which penetrates the fragments consists of dark chlorite and carbonate with variable amounts of epidote and sericite. The color is usually quite dark. Some outcrop at the Afton shows intense 'crackling'; this is believed to be on the borders of the main breccia. Drill holes 13 and 14 at the Afton pass in and out of breccia in the Pothook breccia zone showing that the breccia is not one large continuous mass.

The origin of this breccia is not apparent. Carr suggests that such breccia zones may be controlled by a contact of competent, brittle intrusive rock with intrusive pipsite which flows under stress causing the more competent rock to become brecciated. From our present knowledge it seems that breccia zones do occur near outside boundaries of the Iron Mask Batholith and are probably related to movement on the contacts.

The age of the brecciation is indicated by certain evidence at the Afton and at the Grey Mask. At the Afton dykes of brown weathering basalt cutting the Pothook breccia are unbrecciated. At the Grey Mask Cherry Creek porphyry in the breccia zone seems to be brecciated to about the same degree as the diorite. These breccias may of course be of different ages but it is not unreasonable to assume that they are associated with the same event. This evidence indicates that brecciation took place between the emplacement of the Cherry Creek porphyry and the brown weathering basalt.

Structure in the Tertiary Rocks

With the exception of the Coldwater Beds the Tertiary rocks of this area are mostly quite flat lying and almost structureless. Around the north side of the main part of the Iron Mask batholith and along Cherry Creek the Kamloops rocks have been involved in folding. Dips over 30° are common and in one place 90° dips occur. These structures trend northwesterly and are

Structure in the Tertiary Rocks (continued)

probably part of a belt of folding extending through the Copper Creek area where the conglomerates of Eagle hill have 90° dips northwest of Copper Creek station. At Copper Creek the Copper Creek granite well exposed along the railroad does not show any faulting on its contacts. A competent stock of granite intruding soft tuffs might be expected to be a center of structural activity in case of movement so lack of shearing is evidence that the folding may be pre-Copper Creek in age. Steep dips observed in flows of brown weathering basalt indicate a post basalt age for the folding.

At the old Allies (Gold Ridge) prospect about 16 miles northwest of Kamloops Tertiary structure is evident. Here a pierite intrusion is in fault contact with agglomerate of the Kamloops Group. Grey feldspar porphyry which intrudes the pierite is severely faulted with numerous remarkable curved slickensides.

Thus our limited evidence indicates the following tectonic and intrusive sequence in the Tertiary. 1. Faulting and shearing along the boundaries of the Iron Mask Batholith localized in pierite when pierite is present. This event probably produced the extensive breccias. 2. Emplacement of brown weathering basalt flows and dykes. 3. Folding and faulting of the Tertiary rocks along the Cherry Creek 'fault zone' and along the north side of the Iron Mask batholith. 4. Intrusion of the Copper Creek granite.

Mineral Deposits

The most interesting mineral deposits found to date in this area are in and around the Iron Mask batholith, although a number of prospects are found in other parts of the area.

They may be classified as follows:

I Placer deposits of gold and platinum.
II Quartz veins.
III Mercury deposits in carbonatized zones.
IV Contact metamorphic deposits.
V Copper in breccia and shear zones in Iron Mask Batholith.
VI Disseminated copper deposits associated with porphyrys.
VII Magnatite veins.

The placer deposits have been of some interest in the past but are probably of little interest at the present time. Tranquille Creek produced both gold and platinum. Gravel reserves

Mineral Deposits (continued)

were small and most of the mining was carried out by hand. The gold and platinum are probably from the vicinity of Cannell Creek where gold in quartz occurs in one or more pierite intrusions.

The writer visited a small placer operation northeast of Kamloops on McGillivray Creek which has since gone broke. Here coarse gold occurs with many large boulders in a steep narrow creek. Gold bearing gravel ends abruptly going up-stream at a steep dipping bed of conglomerate crossing the Creek. The same situation is reported on another Creek to the south east. The conglomerate, probably part of the Cache Creek Group, may be the source of this gold.

Placer gold on the lower part of Louis Creek north of Kamloops was worked intermittently until the late 1930's. Above the old workings is a stretch of the Creek which carries some coarse gold and shows a fair reserve of gravel. No information is available on the grade of this gravel. The source of the gold on this creek may be the same as that on McGillivray Creek, as McGillivray Creek is a tributary of Louis Creek.

Quartz veins

A number of quartz veins are known in this area but production from them has been very limited. The most work has been done at Stump Lake at the mine of Comm. Nicola Goldfields which is inactive at the present time. This property produced at several times in the past, apparently going broke each time. According to Cockfield the total production has been 77,600 tons grading .19 oz Aug, 3.26 oz. Ag, 1.43% Pb, .2% Zn, with a little copper and scheelite. The widths were generally narrow. This property has not been seen by the writer.

An interesting gold property with quartz veins in porphyry dykes is the Allies (Gold Ridge) about 16 miles northwest of Kamloops. Here an intrusion of pierite into Kamloops volcanics is cut by dykes of grey feldspar porphyry which is cut by quartz veins carrying gold and chalcopyrite. The problem here is lack of outcrop as the pierite is altered and weathers rapidly to a sticky green mud, described by Cockfield as boulder clay. Certain zones of overburden carry much porphyry float and some rough gold which may be recovered by panning. The porphyry dykes are known to extend over a zone at least a mile long but all the work has been done in a small area.

A quartz vein up to about 6' wide with chalcopyrite occurs in Kamloops volcanics about half way between the Trans Canada Highway and Kamloops Lake northwest of the Iron Mask Mine. This vein is of no economic interest but is mentioned here as it gives some evidence that the age of copper mineralization is post Kamloops.

Mercury in carbonatized zones

A number of mercury mines and prospects are located west and northwest of Kamloops, particularly near Copper Creek. These occur in buff colored ankeritic carbonate zones mostly in Nicola rocks; the replacement by carbonate is complete. The cinnabar occurs as stringers and disseminated grains. Production has been insignificant. Carbonate zones of this type are known throughout the area and most of them carry no mineralization of any kind. They are not known to cut Kamloops Group rocks unless the tuffs east of Copper Creek are of Kamloops age. A large carbonate zone with breccia structure occurs in Nicola rocks southwest of the Afton Group. Similar carbonate zones have already been mentioned as occurring in the Iron Mask Batholith where they are believed to be altered pierite. If the alteration of the pierite and the carbonate zones described above are of the same age this gives evidence as to the age of this alteration. Since the pierite cuts Kamloops volcanics this alteration must be post Kamloops in age.

Contact Metamorphic Deposits

In spite of the large and widespread plutonic intrusions in this area zones of contact metamorphisms are rather rare but may be economically important as in the case of Craigmont at Merritt which is outside the area discussed in this report. Here the large magnetite hematite chalcopyrite ore body lies near the contact of steep dipping limey sediments and/or tuffs of the Nicola Group and the Guichon Creek batholith.

Only one prospect of this type is known in this area. This prospect, called the Iron Range, is near Heffley Lake and consists of a narrow skarn zone in limestone of the Cache Creek Group. The skarn is of the garnet-pyroxene type. The only igneous rocks in the vicinity are dykes of grey hornblende-feldspar porphyry. The skarn zone strikes toward barren limestone on the north and runs into an extensive area of overburden on the south.

To the east of the Kamloops area on the northwest side of the Salmon River valley southwest of Westwold is an old prospect called the Yokahama. This is a molybdenum prospect in a band of skarn in Cache Creek limey sediments. Here the pyroxene-garnet skarn completely replaces a single bed of limestone a few feet thick. In numerous old trenches the skarn has been traced for over ½ mile but interesting amounts of molybdenum occur only over a length of less than 50'. Here some shipping grade ore was mined. No plutonic rocks are exposed near the showings but a small stock is shown on the map.

Contact Metamorphic Deposits (continued)

Also out of the area under discussion is the contact metamorphic type mineralization west of Little Fort at the Lakeview on which we did some work in 1957. Here a wide irregular skarn zone occurs along the contact between plutonic rocks and limestones and volcanics of the Cache Creek Group. Here the mineralization consists of magnetite and pyrrhotite with chalcopyrite and minor arsenopyrite. Spotty gold values and a trace of nickel are also present. This area has very little outcrop and has not been covered by regional mapping of the government surveys.

Breccia & Shear zones in the Iron Mask Batholith

Afton Group

This property, formerly known as the Pothook, has been described in reports by Gunning, Jones, Burton and the writer. It has been mapped by Noel (Kennecott), Jones (Graham Bousquet), Burton (Noranda), and the writer (twice). It has been covered by a soil sampling program (Graham Bousquet) EM surveys (Kennecott, N.J.Z.), a magnetometer survey (N.J.Z), an IP survey (N.J.Z.) and a limited amount of self potential work (Noranda). Fourteen diamond drill holes were drilled in 1952 by Kennecott and four more in 1958 by Noranda. In spite of all this the geology is not well understood. Much more would be known about this prospect if Kennecott had split their core for sampling instead of assaying the whole core; the location of the holes is far from systematic. For these reasons the interpretation of the underground situation from the old Kennecott logs and a few fragments of core is pretty sketchy.

The mineralized zone here is in a tectonic breccia, called by Burton the Pothook breccia, in the Iron Mask batholith close to an irregular contact with a younger intrusive of Sugar Loaf diorite lying to the south. This contact in the zone which was drilled seems to dip at about 45° northward under the batholith. Highly altered irregular bodies of pierite are found near the contact and intruding the batholith.

The Pothook breccia zone is extensive and most of it is not mineralized. The Sugar Loaf diorite is brecciated also but with less intensity. The control of the mineralization is not known although the irregular configuration of the contact between the Sugar Loaf diorite and Iron Mask diorite may be significant. Burton's interpretation of the Kennecott drilling suggests one or more west dipping zones of better than average grade striking perpendicular to the contact. Burton's estimate of 1 million tons of 1.1% Cu ore based on this interpretation seems high.

Geophysical methods have not been very helpful so far. The magnetic map shows a 'rug pattern' over the breccia zone with lower average intensity than the unbrecciated Iron Mask diorite. This may be due to redistribution and partial destruction of magnetite in the propylitic alteration of the breccia zone or it may be caused by rotation of fragments of the breccia causing a random distribution of directions of polarization of magnetite in the fragments.

Breccia & Shear zones in the Iron Mask Batholith (continued)

Another prospect of this type is the property of Makaoo Development Company, formerly the Python, on the northeast flank of Coal Hill just south of Kamloops. Here mineralization occurs in breccias in small veins on shear zones and along the sheared contact of Iron Mask diorite with pierite. Considerable work has been done on this property. Several thousand feet of adit have been driven on two levels, bulldozer trenching has been carried out over a large area, and a number of drill holes have been drilled from surface and from the upper adit. This work has not found a mineralized zone of economic size.

Here a body of pierite in the order of 500' wide separates the Iron Mask Batholith from Kamloops volcanics on the north. The pierite is sheared on both sides, particularly on the north side, against the volcanics where the lower level went through a gauge zone over 60' wide. The diorite is cut by numerous faults and contains several breccia zones several hundred feet from the contact south of which is the heterogeneous diorite described previously in the section on the Iron Mask batholith.

The mineralized shear zone along the contact between pierite and diorite has been called the 'Copperhead Zone'. This has been explored to the northwest and southeast by bulldozing and drilling. The mineralization seems to be confined to a length of not more than a few hundred feet near the upper level where the zone averages less than 10' wide with a grade of not more than 1% Cu. The mineralization is in both the diorite and the sheared pierite.

The breccia zones where the best mineralization is found were apparently encountered by chance in the driving of the upper adit; they do not show in the numerous bulldozer trenches on surface above. The breccia zones have rather sharp contacts and do not show any obvious relation to the numerous shear zones in that area. The breccia is fairly well cemented and is quite similar to the Pothook breccia. Mineralization is not confined to the breccia but the best zones are in, or close to it. The upper level was mapped by us with the idea of trying to trace some of the numerous faults between various parts of the workings, the drill holes, and surface exposures. This project was quite unsuccessful and showed that the faults, although they are quite prominent features, are quite discontinuous and can not be followed for any distance.

The ore reserve of 300,000 tons of 1.1% Cu seems quite unrealistic. Our sampling and sampling by Granby Mines confirms the grade; not more than 50,000 tons is indicated.

Another prospect probably of this type is the Grey Mask south of Knutsford near Separation Lake. We have very little information on this other than the results of the drilling carried out in 1956 by Commercial Minerals. The old shaft and surface cuts mentioned by Cockfield have been filled in by bulldozing. The drill holes show

Breccia & Shear zones in the Iron Mask Batholith (continued)

a breccia zone in Iron Mask diorite along a contact with sheared pierite. One hole about 700' west of the contact was in breccia, indicating that the breccia zone is at least 700' wide. Most of the holes showed no mineralization. The best mineralization consisted of about 1' of pyrite-chalcopyrite which had not been sampled. The holes were drilled apparently at random and do not cover much of the strike length of the contact. There is no outcrop on this breccia zone to indicate its extent.

Our IP survey showed IP and low resistivity anomalies in this area but they are of unknown origin. The anomalies are long and sinuous and may be related in some way to the breccia zone mentioned above.

Disseminated copper deposits associated with porphyrys

D. M. Group

This group of claims held by Cadamet Mines (formerly Graham Bousquet) covers a large area surrounding, and lying to the north of the Afton Group. We refer to the showings northeast of the Afton, south of the Trans-Canada Highway, as the DM showings; this was called the Truth Group in old reports. Here disseminated chalcopyrite occurs in Cherry Creek Porphyry of unknown extent, and in Sugar Leaf diorite, both of which intrude the northern part of the Iron Mask batholith. There are old workings, consisting of a shaft 50' deep, an adit toward the bottom of the shaft, and numerous pits and trenches, all dug between 1899 and 1907. The Graham Bousquet soil sampling program covered this area; soil anomalies at the DM showings are not extensive but correspond with surface showings. Sampling of surface cuts, outcrop, and the shaft dump by Graham Bousquet showed Cu values between .3 and 1.2%. The property was mapped by Jones for Graham Bousquet in 1957 and by the writer in 1959. It was covered by several lines in the IP survey in the fall of 1959. An IP anomaly mostly south of the known mineralization is weak.

Late in the fall in 1959 Cadamet Mines (formerly Graham Bousquet), drilled a hole just northeast of the shaft and cut about 150' of Cherry Creek Porphyry grading .46% Cu after which the hole ran into Sugar Leaf diorite of lower grade to about 233' where the hole entered a barren dark dyke ending in this at 247. As described previously, the Cherry Creek Porphyry contains gradational patches of explosion breccia, but the mineralization seems to be unrelated to this as it is quite uniform whether in the breccia or not. Exposures of explosion breccia to the northwest are practically unmineralized. Numerous quartz stringers show in the core but seem to be lacking in unmineralized outcrop. The chalcopyrite and pyrite are not concentrated in the quartz. The mineralization in the core is all primary.

Disseminated copper deposits associated with porphyrys (continued)

Another zone of the same kind or an extension of the above is found in old trenches and cuts about 1700' northeast of the DM shaft. This zone is not well exposed on surface but it appears to be of lower grade. The Iron Mask diorite around these zones is unmineralized.

Magnetometer and IP surveys have not been carried out on this property.

Kimberley Group

The Kimberley group southwest of Knutsford is quite similar to the DM but is not as well exposed. An adit and several large open cuts were made just after 1900. No work has been done since, except for mapping magnetometer and EM surveys done by us. Here a Cherry Creek porphyry intrusion of unknown extent is located near the contact of the batholith with Nicola volcanics. This contains patches of explosion breccia as at the DM but this shows up well only in the old adit. The mineralisation is pyrite and chalcopyrite restricted to the porphyry. Here the situation is complicated in the northwest by brown weathering basalt which may be intrusive or extrusive, probably both. Sampling in the adit over about 140' of wall (not true width) showed a grade of .39% Cu. Sampling of 70' of an open cut showed the same grade. As there is very little exposure of the Cherry Creek intrusive the extent of both the mineralisation and the rock is not known.

Frederick

In a low railway cut just east of Frederick on the CN Railway north of Kamloops Lake is an exposure of Cherry Creek porphyry with explosion breccia mineralised with chalcopyrite. The porphyry (unmineralised) extends eastward along the track for some distance, where it is in contact with Iron Mask diorite under a fault with a gentle north dip. No mapping or other work has been done by us in the Frederick area.

Copper King Mine

This property is a few hundred feet northeast of the Trans Canada Highway, about 1½ miles above the mouth of Cherry Creek. It was mined intermittently between 1906 and 1940 during which time 7,500 tons of ore grading .158 oz./ton Au .291 oz/ ton Ag and 2.61% Cu was mined. This is by far the best grade ore mined in any quantity in this district.

The workings are situated in a body of Cherry Creek porphyry of unknown extent intruding Iron Mask diorite. Much of this rock, especially around the mineralisation, is a brick red color; other places it is green or grey. No explosion breccia has been seen. Outcrop is plentiful in this area in contrast to

Disseminated copper deposits associated with porphyrys (continued)

most of the other properties in the Kamloops district. The underground workings were mapped and sampled, and mapping of the surface was started but not completed; a magnetometer survey was run over a small area around the ore body.

The ore body was mined out from underground through to surface leaving a 'glory hole' at surface. From the shape of the old diggings one gets the impression that the ore body was lens shaped in plan up to 40' wide plunging along its long axis northeastward. Down the plunge the grade apparently decreased and mineralization underground is sparse. The ore body from old reports and from remnants left in the glory hole consisted of disseminated chalcopyrite, bornite, pyrrhotite, and magnetite. The ore was partly radioactive; in the present workings radioactivity is restricted to a small cross cutting shear which has yielded specimens of uraninite. This shear can not be followed with a geiger counter for any distance on either side of the glory hole, so the radioactive zone was probably restricted to the ore body. A pile of low grade ore dumped at the portal is quite radioactive. Controls of the mineralization are not apparent. The walls of the ore body along strike show close spaced vertical joints along the strike of the ore body, but these do not seem to persist and other zones of much stronger jointing in the vicinity show no mineralization. An inspection of the magnetometer map which covers only a small area shows that the strike of the ore body is parallel to the magnetic grain but it does not seem to be related to any prominant features; however, the magnetic map covers such a small area that it is not possible to conclude much from it. One IP line was run northeast of the glory hole to try to pick up a down plunge extension. No anomaly was found there, but an anomaly was found about 500' to the southeast where there is nothing showing on surface.

Other Deposits

Iron Mask Mine

This property operated intermittently from just after 1900 to 1928 and produced about 189,000 tons of ore grading 1.37% Cu .0192 oz./ton Au and .22 oz/ton Ag. The property was promoted as Kamloops Copper in 1951 and was optioned to Berens River in 1952 when an EM survey was carried out and a few holes were drilled. In 1956 Kamloops Copper did some shaft sinking and diamond drilling. None of this work was successful and the property has been idle since. We have never examined this property except for very brief reconnaissance mapping. Geologically, the most helpful information available is the description by Carr in 1956, Report of Minister of Mines Brit. Col.

Disseminated copper deposits associated with porphyry (continued)

In spite of extensive underground work and exploration very little is known about the geology. The workings are all inaccessible at present. Part of the core from the recent drilling is on the property but some is mixed up and partly lost. Outcrop in the area is very scarce except east of the property.

The geology is apparently quite complex and an examination of such outcrop as there is and the various dumps shows that several rock types are present. The large dumps at the Iron Mask shaft are almost entirely pierite from which Carr infers that the exploratory 750 level to the northwest must have been in pierite. The dumps at the Erin shaft consist of several types of porphyry with diorite. On Carr's map the micro monzonite is our Cherry Creek Porphyry. It seems unlikely from descriptions of their size and shape that the ore bodies were mineralized Cherry Creek porphyry for our limited knowledge of this type of deposit indicates that this type of mineralization is usually on a larger scale. It is more likely that these were associated with zones of brecciation and shearing as at Makmee.

GWA 8 property near Jacko Lake

The best information we have on this property is Carr's description in the 1956 Minister of Mines report. From brief visits to the area we can say that an intrusion of Sugar Loaf diorite occurs south of the Monte Carlo diggings; this does not show on Carr's map. The outstanding feature of this area is the widespread replacement by white albite over large zones. This is well shown near the pipe-line and in some of the core.

From Carr's report and a brief look at some of the core it seems apparent that the mineralisation occurs as a number of parallel zones, none of which are very large. We have no definite information on the grade but it certainly is not high.

Galaxy

This property is described in a report by the writer dated March, 1958; it was formerly known as the Evening Star Group and was explored between 1903 and 1917. The present company promoted the property and did some drilling and trenching and renovated the old shaft in 1956. We mapped this property and did some geophysics in the spring of 1958.

The showings are in an inclusion or roof pendant of volcanic rocks, probably Nicola, partly in a body of micrograniteite already described. The best showings are on the northeast side of a brackish pond near the contact between the volcanics and the micro-granite. Here the volcanics are sheared and intruded by irregular dykes of diorite and mineralized with chalcopyrite and a little magnetite which occurred underground as nodules. From the magnetometer survey it is evident that the magnetite must be present in very small quantities. The work done by the recent operators has done little to explore this zone of mineralisation. Other zones

Disseminated copper deposits associated with porphyry (continued)

of mineralization occur to the northeast, some exposed in recent bulldozer cuts and others in old pits; these, too, have not been explored. A strong EM anomaly probably tabular with a steep dip occurs in the northwest trending topographic depression partly filled by the pond. This is probably the contact between the microgranite and the volcanics. The anomaly may be due to a shear filled with conducting fluids, but the possibility of a sulphide zone can not be ruled out, considering the proximity of the mineralization on the northeast side.

Other Showings

In addition to the properties described above there are numerous other old showings in the Kamloops area, many of which have not been seen by the writer. Most of these are veins in various rocks of this area, carrying copper and in some cases gold, lead, zinc, and silver. Most of these are small but some are quite large. In old descriptions most of these do not sound very attractive. However, experience has shown that many of the old descriptions are rather inadequate.

A new prospect found two years ago west of Little Fort, called the Mager group, is unique in this area as far as we know. It is described in a report by the writer in the spring of 1959. It is a zinc lead replacement in a bed of black argillite sedimentary breccia of the Cache Creek Group near dykes (?) of diorite. Although the grade is low and the bed thin (about 10') this type of mineralization could with better grade and thickness make a large ore body. The area is one of very sparse outcrop. Strong magnetic anomalies reported by the owners were found to be non-existant.

Copper Creek

About ½ mile north of the east end of the Copper Creek tunnel on the C.N.R. is an old showing known as the Tenderfoot owned by K. R. Rousseau of Alberni, B. C. The property consists of one small crown granted claim staked in 1889 covering the main showings. A number of cuts and short adits are now in bad shape and do not give much information. The showings are in tuffs cut by ultramafic sills. A sloping shaft on a shear zone at the northwest end of the diggings is still accessible but is inhabited by porcupines. This shows a shear zone up to 5' wide mineralized with copper. The most interesting feature of this property is the dump of a cross cut driven below and toward the shaft mentioned above. The rock on this dump which is presumed to be waste is impregnated with chalcocite. The writer has not examined this prospect but visited it very briefly, while examining the relations between the sills and tuffs of this area.

Magnetite veins

A number of magnetite veins of mineable width are known in this area and small veinlets are common. The veins of any size seem to be restricted to the Iron Mask Batholith but they are found also cutting the Cherry Creek Porphyry and tuff north of the Afton. The two magnetite veins on which the most work has been done are the Glen Iron Mine near the mouth of Cherry Creek and the Moose, Magnet, etc. northeast of the Afton Group. Magnetite from the Glen Iron was mined for smelter flux. None has been shipped for iron ore because of the high phosphorous content of the ore; this phosphorous occurs as apatite in fine and coarse crystals resembling feldspar.

The magnetite veins which range in character from disseminated to massive magnetite in diorite with apatite are up to about 25' wide, but pinch, swell, and split up along strike. The magnetometer survey in the Afton area shows that the veins occur in a zone more or less continuous for at least a mile. Although a little chalcopyrite is reported with the magnetite northeast of the Afton it is very difficult to find. This magnetite does not seem to be related in any way to the copper mineralization in this area.

There is no doubt that if the magnetite were free of phosphorous it would be of considerable economic interest at this time.

Age of Mineralization

The mineralization is probably of more than one age. The contact metamorphic deposits are presumably of the same age as the Coast Range type intrusions, namely Jura-Cretaceous. The quartz veins at Stump Lake and others in this district in Nicola rocks are of unknown age and may be also of Jura-Cretaceous age.

The deposits of most economic interest, those around the Iron Mask batholith, are all or mostly all, of Tertiary age. The Galaxy could be older than the others although there is nothing to indicate this. All the other properties described around the Iron Mask batholith involve rocks more or less proven to be Miocene or younger in age. The mineralization is believed to be younger than the brown weathering basalt as a dyke of this rock at the Afton is mineralized with pyrite and chalcopyrite. The only intrusive rock found in bodies of any size, younger than the brown weathering basalt, is the Copper Creek granite. In following the usual line of reasoning in correlating widespread hypogene mineralization with an igneous episode, one is inclined to correlate the copper mineralization in the Kamloops area with the Copper Creek intrusions.

Conclusions

In spite of all the work which has been done in this area the geologic picture is rather sketchy. The recognition of Tertiary intrusives and structures has helped to clear up some problems and offers some explanation for the control of some of the mineral deposits. However, the structure along the northeast side of the Iron Mask batholith, along Copper Creek, and through Jacko Lake, is not understood. A better knowledge of these structures might indicate structural controls for mineral deposits in these areas. Our present knowledge does enable us to classify the more important mineral deposits into types. This is helpful in planning exploration in this area.

Of the several types of mineral deposits seen in this area the types which seem to have the greatest economic potential are those associated with the Cherry Creek intrusions, as the Kimberley, DM, and Copper King, and those related to the tectonic breccia zones as at the Afton. In both these types the host rock, namely Cherry Creek, intrusives and tectonic breccia are found in large enough masses to contain large ore bodies.

Conclusions (continued)

Up to the present mineralization of these types, where it is exposed, has proved to be of too low a grade to be of economic interest. However, in an area such as this which has been thoroughly prospected one should not expect to find a good grade ore body exposed on surface. Exploration under these conditions must endeavor to find new mineralized zones and to ascertain whether exposures such as those at the DX and Kimberley may be part of large zones of economic grade.

Our work here so far has failed to find an effective geophysical method of locating this type of mineralization under overburden. EM can not be expected to work on the disseminated mineralization found here. Numerous anomalies which show up are believed to be caused by conducting overburden; however, nothing has been done to check this. I.P. results have not yet been thoroughly evaluated but so far this method (using McPhar equipment and technique) does not appear to be very effective. The magnetometer may be the best geophysical tool in showing up zones of interest. Mineralised zones show a 'rug pattern' which may be related in some way to mineralisation. This can only be seen well when the spacing of stations is reduced to 100' x 100'. More magnetometer work and further exploration of known mineralized zones must be carried out before this method can be evaluated with any certainty. A statistical analysis of distribution of magnetic intensity (distribution of magnetite) in two areas seems to indicate that a rug pattern may be spotted by this method without reducing the spacing of stations to 100' x 100'.

We have not tried soil sampling in this area, but the experience of Graham Bousquet in the Afton area would indicate that it should be helpful. This soil survey involving several thousand samples shows that known mineralization produces anomalies. However, strong spurious anomalies were also found in areas where overburden was over 100' thick (in one case 170'). The cause of these anomalies, which are unrelated to topography, is not known.

In evaluating soil anomalies data on depth of overburden may be valuable. Experience here so far indicates that it is not possible to estimate thickness of overburden from topography as the bedrock surface is probably one of considerable relief.

Before considering exploration in this area for possible hidden ore bodies by geophysical and geochemical methods, it would seem to be essential to first get more data about the mineralised zones of which we already know, such as

Conclusions (continued)

the DH, Kimberley and Afton. Any decision on whether to proceed further here must be based on evaluation of the economic possibilities, physical characteristics, (size, continuity, uniformity, controls, etc.), and geophysical correlations on the known zones, which one must assume are similar to possible hidden zones. If this work should indicate that the known zones (even if they are not ore bodies) have enough favorable characteristics and have geophysical and/or geochemical expression plans could then be made to explore the geologically favorable zone along the margin of the Iron Mask Batholith.

Other parts of the Kamloops district are also worthy of consideration for further exploration. The area west of Little Fort where Cache Creek volcanics and sediments are cut by an irregular batholith is interesting. Here showings include skarn zones with magnetite, pyrrhotite, copper, gold, and traces of nickel, a zinc-lead replacement in sedimentary breccia, and quartz molybdenite showings. This area is a plateau of rather low relief with relatively little outcrop; it has not been covered by geologic mapping. Following reconnaissance mapping a program of airborne geophysical surveys would seem to be the best approach.

Another area of some interest is on the west side of the north part of Okanagan Lake where a number of bodies of feldspar porphyry of probable Tertiary age have been mapped. The Goodenough prospect on which we did some work in 1956 is a skarn zone on the border of one of these intrusives. In doing some soil sampling in an area of little outcrop north of the showings a soil anomaly was found and subsequently trenched by a bulldozer. The rock which was mineralized with disseminated chalcopyrite over a large area was not recognized as porphyry at that time on account of intense alteration. An examination of thin section of this rock in the fall of 1959 by the writer found the mineralized rock to be a highly altered and bleached porphyry.

This area is rapidly becoming more accessible because of widespread logging operations. A new G.S.C. map of that district (Vernon map area No. 1059A) is in press. Further soil sampling, stream sediment sampling and reconnaissance mapping could be done in this area. The presence of the highly magnetic skarn zone at the Goodenough may be significant.