THE RELATIONSHIP BETWEEN LAMPROPHYRE DYKES AND ORE DEPOSITS WITH SPECIAL REFERENCE TO BRITISH COLUMBIA

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by

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accepted

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ABSTRACT

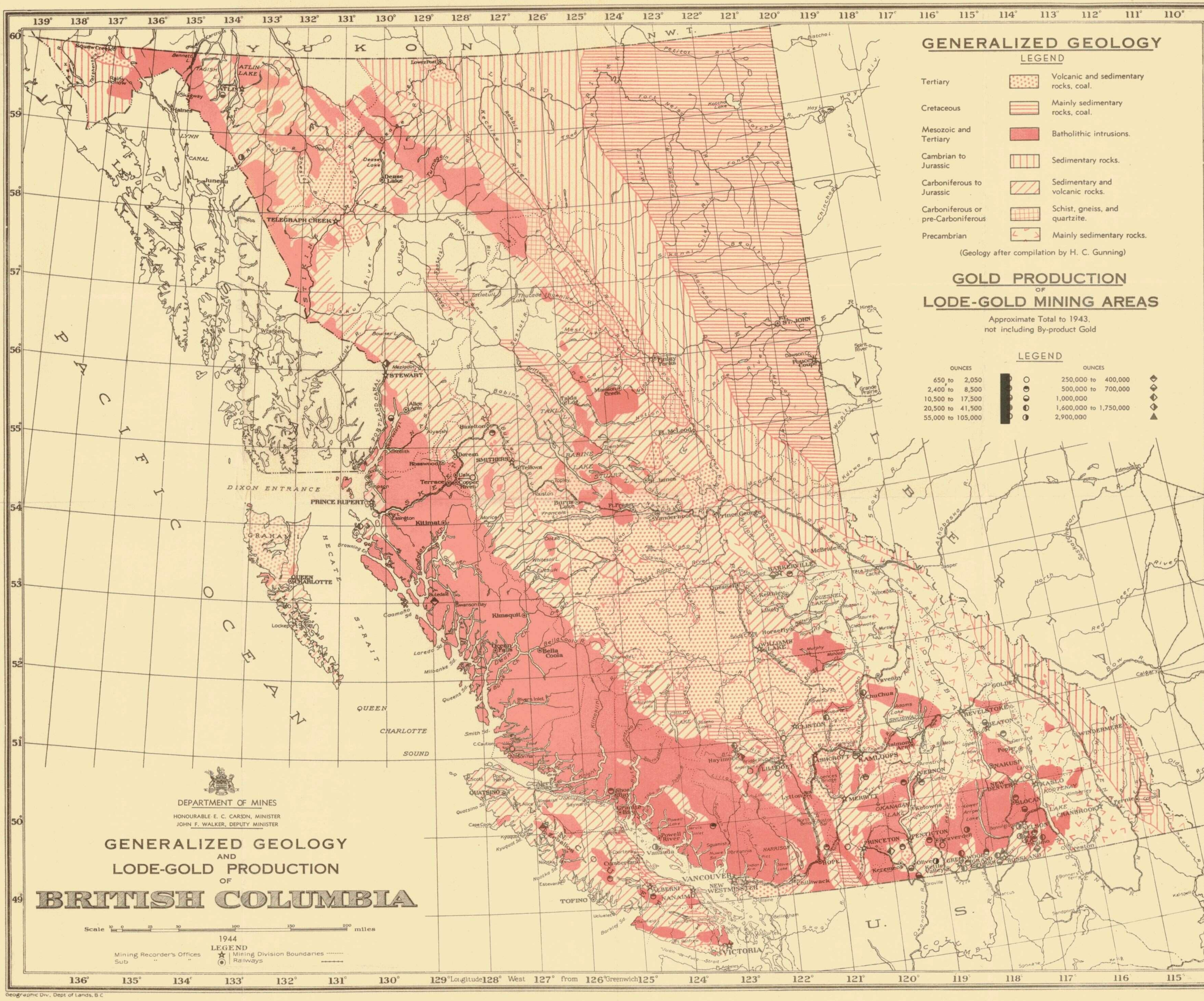
Some conceptions by Bowen regarding the processes apparently involved in the formation of ultra-basic lamprophyres have been applied to observations made on reaction-rims in the rocks of this thesis. An attempt has been made to find, in the reaction-rims surrounding basic minerals, phenomena that might indicate that reactions took place, during the time the rock was forming, between the basic minerals and an alkaline liquid. No conclusive evidence of such reactions was found but the suggestion is made that there is an unusually great development of reaction rims, especially in the more basic lamprophyres, that may be due to the effect of an alkaline liquid. Another theory by Bowen, dealing with the possible origin of ore-bearing solutions, has been amplified to present possible reasons for a close relation between lamprophyres and ore.

On the more practical side, a petrographic study of lamprophyres and associated ore has revealed an intra-mineralization age for lamprophyres whose field relations do not conclusively indicate contemporaneity with ore.

A compilation from the literature, of facts pertaining to most of the lamprophyre occurrences in British Columbia, has provided interesting statistics on the geographical and geological distribution of lamprophyres, and on their relations to different types of ore. The majority of lamprophyres occur in the Rossland-Ymir-Nelson-Slocan belt, near the eastern con-

tact of the Nelson series of batholiths, while most of the remainder are confined to the eastern contact of the Coast Range batholith. The lamprophyres of the Nelson batholith region are associated with ores which, in the Rossland, Salmo, Ymir and Nelson areas are almost half of the Pb, Zn, Ag type and in the Ainsworth-Slocan districts, entirely of the Pb, Zn, Ag type. It is in the Ainsworth-Slocan districts furthermore, that lamprophyres are perhaps most densely concentrated and show the closest time relation to ore. The lamprophyres along the east side of the Coast Range batholith provide most of the evidence indicating ~~for believing~~ that post-ore lamprophyres are predominantly associated with ores containing Au and Cu.

The conclusion seems inescapable that lamprophyres are concentrated in the two most intensely mineralized zones of the province. Furthermore, a marked affinity is shown by lamprophyres for those areas in which Pb, Zn, Ag mineralization either is prominent or, at least, is present along with other metals. These statistical facts suggest that the relation between ore and lamprophyres is not purely one of chance and they arouse our curiosity as to what reasons may exist for such a relationship.



Geographic Div., Dept of Lands, B.C.


PLAN OF PART OF
PIONEER GOLD MINE
SHOWING LAMPROPHYRE DYKES
Scale: 1" = 40'
Lamprophyre Dyke
Quartz Vein
March 1948
J. W. Young
NORTH
Specimens No. 19,20,21
Specimen No. 25, 26, 27, 28, 29
Stope
VEIN
"27"
E 14400
E 14200
MAIN VEIN
Specimens No. 30, 31, 32
Specimen No. 16, 17, 18
FOOTWALL VEIN
N 6200
N 6000
N 5800
N 5600
N 5400
E 14000

INTRODUCTION

The purpose of this thesis is to investigate lamprophyre dykes in British Columbia for evidence that may help to determine whether they are connected with ore deposits in their origin.

The method of attack has involved first, a study of the theories, put forward by various authorities, that deal with the origin of lamprophyres in the expectation that some might suggest reasons for a close time and space relationship between lamprophyres and ore. A laboratory study has been made of lamprophyres and ore from several mines and a search of the literature was undertaken to obtain a record of all the reported lamprophyres in British Columbia together with their associated ores.

DEFINITION AND CLASSIFICATION OF LAMPROPHYRE DYKES.

The term "lamprophyre" covers a large and ill-defined group of rocks which typically occur as dykes or small intrusives. In their chemical composition, lamprophyres are characterized by a medium to low silica percentage and a considerable relative quantity of sodium and potassium, the alkali metals. In addition, oxides of calcium, magnesium and iron are abundant so that the rocks are rich in ferromagnesian minerals.

The textural criteria that may assist in determining whether or not a rock is a lamprophyre are the prevalence of a porphyritic texture, the phenocrysts being most commonly the ferromagnesian minerals or, in the absence of a porphyritic texture, the panidiomorphic texture, in which the rock is holocrystalline and commonly equigranular with the component minerals all tending to form euhedral crystals.

The classification of the different lamprophyric types is dealt with by Harker[(1)] and Johannsen.[(2)] The more commonly occurring types are summarized in the following table after Johannsen. (See next page.)

(1) Harker, A.: "Petrology for Students". Page 134. (1908)

(2) Johannsen : "Petrography". Vol. III, pages 32 and 137. (1937)

Feldspar	Orth.-Felds. Predominant	Plag.-Felds. Predominant	NaCaf	Very little NaCaf
"Family"	Syenite	Diorite	Gabbro	Perknite
Biotite predominant	Minette	Kersantite		
Hornblende and/or Augite pre-dominant	Vogesite	Spessartite (Camptonite)	Odinite	Garewaite (rare)

The term "camptonite" is applied to lamprophyres of the spessartite classification which are more melanocratic than spessartite and therefore contain less feldspar. Odinite and garewaite are extremely rare. It should be emphasized that all gradations exist between these main types.

The extremely basic lamprophyres, in which no feldspar is present, are divided into three classes, in all of which olivine is a prominent constituent and alkali minerals are plentiful. Monchiquite is characterized by idiomorphic crystals of olivine and augite set in a colorless, isotropic base believed to be analcime. Hornblende and biotite may also be present. Limburgite is a type allied to monchiquite but the interstitial base is a brown glass instead of colorless analcime. Alnöites are olivine rich, biotite-monchiquites characterized by the presence of melilite and usually alkaline minerals in the groundmass. Ouachitite is an olivine-free variety of monchiquite, characterized by abundant biotite.

THEORIES AS TO THE ORIGIN OF LAMPROPHYRE ROCKS

Theories by Niggli (1),(2)

Niggli points out, as have others, the complementary relation existing between aplites and lamprophyres when compared with the granite masses from which both originate. The two may be considered as the extreme acidic and basic products of fractional crystallization of granitic or granodioritic magma. He also states that lamprophyre dykes are usually later than the related aplites in their time of intrusion.

With regard to the mechanics and chemistry of lamprophyre-formation, Niggli believes in the remelting or solution of early-formed ferromagnesian crystals to form a lamprophyric fluid, the ferromagnesians accumulating by gravitative settling towards the bottom of the magmatic chamber and the volatiles which dissolve them being forced down towards them by the progressive lowering of the solidifying batholithic hood. After the mixing of the basic crystals with the volatile fluid, the whole is forced out to form intrusive lamprophyres. Niggli points to the usually high biotite and hornblende content of lamprophyres as evidence of the importance of water vapor and other volatiles in their formation.

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(1) Niggli, "Die Leichtflüchtigen Bestandtheile im Magma" - as quoted by Spurr in Bulletin of Geol. Soc. of Am. Vol 36, p.564. (1925)
(2) Niggli, "Gesteins und Mineralprovinzen" - as communicated to the writer by Dr. K. DeP. Watson.

Theories by Grout[1] and Reynolds[2]

Grout thinks the production in granitic magmas of late siliceous residues (aplite and pegmatite), at the same time as late basic residues to be highly improbable. He is an assimilationist who considers the occurrence of partly-assimilated basic inclusions in some lamprophyre dykes as suggestive that lamprophyres may be formed by the mingling of basic material with dyke fluid of another composition. A point in his favour is that the infinite number of combinations of different kinds of inclusions and dyke fluid can account for the great variety of features found in lamprophyres. Grout is not dogmatic, however, and suggests that it is likely that several different processes account for the variety of characteristics of lamprophyres.

D.L. Reynolds goes to an even greater extreme in advocating assimilation than does Grout.

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(1) Grout: "Criteria of Origin of Inclusions in Plutonic Rocks" Bull. G.S.A. Vol. 48, No. 11, p. 1549. (1937)
(2) Reynolds, D1L.: "Transfusion Phenomena in Lamprophyre Dykes and their Bearing on Petrogenesis.

Theories by Spurr and Comments Based on the Findings of This Thesis.

Spurr[1] presents a lengthy discussion of the relation between all types of dykes and mineral veins, with special consideration of the control exerted by wall-rock temperature on the zonal arrangement of ores and the accompanying formation of contemporaneous dykes. In his view, wall-rock temperatures must be at a certain value for certain ores to form and dykes, contemporaneous with the ore, must have also required the same temperature level for their crystallization. He cites statistical evidence showing that basic dykes (lamprophyre, diabase, diorite) are more nearly contemporaneous with ore than acidic dykes and that probably a majority of the basic dykes having a close time relation to ore are lamprophyres. His compilation includes discussion of the lamprophyres of Rossland and Ainsworth, B.C.

Similar relations were noticed in the compilation of this thesis during which a rough idea was retained of the reported occurrences of dykes other than lamprophyres. It was found that acid dykes generally antedate lamprophyres and that less certainly, but generally, acid dykes are pre-ore.

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(1) Spurr, J.E.: "Basic Dyke Injections in Magmatic Vein Sequences", Bull. G.S.A. Vol. 36, 1925. p. 545.

THEORIES AS TO THE ORIGIN OF LAMPROPHYRE ROCKS

Theories by Bowen (1)

Bowen first points out the two perhaps most important characteristics of the ill-defined and inclusive group of rocks known as lamprophyres. These characteristics are, their tendency to a panidiomorphic or porphyritic texture, the phenocrysts usually being ferromagnesian minerals, and the tendency for the groundmass to be highly alkaline. Thus, there are commonly phenocrystsof olivine, pyroxene, hornblende, or biotite, or any combination of the four, in a groundmass rich in alkali feldspar or other alkaline minerals.

We shall deal in the next paragraph with the importance of the alkaline components of the magma to the crystallization processes of lamprophyric rocks and point out, for the present, that Bowen believes the prevalent porphyritic or panidiomorphic character of lamprophyres to indicate that they did not crystallize directly from a single liquid of the same composition as the rock but resulted instead from a reaction between early-formed ferromagnesian crystals and an alkaline liquid enclosing them. The assumption that mafic crystals existed in a suspending liquid is intended to account for the prevailing panidiomorphic or porphyritic character of the solidified lamprophyre. One of the reasons for suspecting that lamprophyres do not crystallize directly from a uniformly liquid magma is the absence of proof that chilled selvages of lamprophyre dykes

(1) Bowen, N.L.:"The Evolution of the Igneous Rocks", Chaps. 13 and 14. (1928).

have the same overall chemical composition as the total composition of the dyke, thereby suggesting that no liquid existed which had the same composition as that of the dyke.

For examples of rocks occurring in nature which may serve to substantiate his theories, Bowen uses the alnöites. These are non-feldspathic, peridotite-like lamprophyres containing, usually, idiomorphic olivine, augite, and biotite crystals and characteristically melilite together with alkalic minerals of different kinds. An example of such alkalic minerals is analcime, which usually forms a colorless, isotropic base. Bowen's first typical alnöite is a rock from Isle Cadieux, Quebec, the constituent minerals of which are plainly divisible into two genetic classes: augite and olivine in the first class, in crystals 1/2 to 1 cm. in diameter and in the second class, biotite, monticellite, melilite, and perovskite which make up more than one-half the rock, the liquid which deposited them attacking and replacing large amounts of olivine and augite. The other example is an alnöite from Montana in which the original minerals are olivine and nephelite with possibly augite, which have been attacked by a liquid which partly replaced them and deposited principally melilite, hauyne, and phlogopite.

Bowen now proceeds, partly on the findings of investigated systems and partly by a theoretical projection of the results of these experiments to more complicated systems, to describe the manner in which alkaline constituents may affect the crystallization of the cafemic elements in a melt, with the resultant formation of the lime-rich-mineral, melilite. He first shows, that in the ternary system CaO -MgO-SiO_2, a liquid consisting of 50 percent forsterite (2MgO.Si.O_2) and 50 percent åkermanite (2caO.MgO.2SiO_2) crystallizes in the order forsterite, monticellite, melilite; the melilite having a replacement relation to monticellite, and monticellite replacing forsterite. This description serves to call attention to the fact that melilite may replace olivine, a phenomenon already shown to occur in natural rocks. Finally, a quarternary diagram is drawn, involving CaO-MgO-SiO_2 and nephelite, to illustrate the effect of the addition of an alkali-rich liquid on the crystallization of a silica-lime-magnesium liquid. Briefly, the effect is that nephelite, being a feldspathoid, takes up silica thereby leaving the CaO-MgO-SiO_2 portion, in effect, richer in CaO and MgO. This promotes the crystallization of lime-rich melilite and olivine and retards the formation of pyroxene, which is less basic and which would ordinarily be formed if nepheline were not present to deprive the solution of silica. The reaction of silica and nephelite meanwhile results in the formation of the alkaline minerals (hauyne, phlogopite, etc.) of the groundmass.

The significance of the effect that nepheline has in promoting the crystallization of lime-rich melilite is that it is not necessary that the solutions be rich in lime in order to produce melilite. Melilite may form from an alkali-rich magma through the agency of reaction effects brought about by the alkalis. This feature is exemplified in nature by the frequent association of nephelite and melilite in rocks.

The value of discussing the foregoing ideas of Bowen lies in the fact that alkaline minerals are important in lamprophyres and it is well to have some conception of the part they appear to play in the formation of lamprophyres. From an experimental and theoretical approach to the subject, Bowen has traced a likely chain of events, involving nepheline (whose common occurrence in these rocks justifies its use in the discussion), silica and the cafemic ingredients, all of which crystallize and react to produce (1) melilite, which is characteristic of alnöites, (2) highly-alkaline groundmass minerals such as analcime, hauyne, biotite and phlogopite, and (3) the rimming of augite or olivine by melilite, one example among the many apparently noted, of reaction and replacement relations which minerals of the second genetic class have to those of the first genetic class.

A POSSIBLE CONNECTION BETWEEN ORE-FORMING SOLUTIONS AND THE ALKALINE SOLUTIONS BELIEVED TO BE IMPORTANT IN THE ORIGIN OF LAMPROPHYRES

The writer proposes to make use of the foregoing summary of the part played by alkaline solutions in forming lamprophyres to present a theory which will correlate the alkaline solutions with those that apparently form ore deposits. It will be necessary first to point out that the mechanics of formation suggested by Bowen for his olivine-bearing lamprophyres[(1)] are not adaptable to a theory that proposes a relation between alkaline, lamprophyre-forming solutions and acid, ore-forming solutions. In Bowen's lamprophyre-forming process, the alkaline liquid develops along with the basic crystals as a result of a reaction between hornblende crystals and a hotter liquid saturated with olivine, pyroxene and perhaps basic plagioclase into which the hornblende sinks. The added hornblende, due to the effect of the basic elements that it contributes, accelerates the crystallization of olivine, pyroxene and perhaps basic plagioclase from the liquid, the net effect on the liquid, consequently, being an increase in its alkalinity. If this mixture of ferromagnesian crystals and alkalic liquid be injected into colder rocks, its rapid cooling might give such rocks as the olivine-bearing lamprophyres discussed in the preceding section. Hence, it is evident that Bowen does

(1) Op. cit. Chap. XIV.

not suppose a separate and distinct existence of ferromagnesian crystals and alkaline liquid but rather, that the mafic crystals and the alkaline fluid develop together and at the same time.

The theory now to be proposed, requires a production of the alkaline liquid that will eventually mingle with the ferromagnesian crystals, by a process entirely unconnected with the ferromagnesian crystals. (A similar joining of the two phases after the separate formation of each has been proposed by Niggli.[1]) The manner of formation of the volatile, alkaline liquid in this case, however, will be different, and will be related to the processes by which ore-forming solutions apparently originate in a batholith.

Again, an article by Bowen[2] will be drawn upon for the fundamental facts and conceptions. In this article, Bowen traces what he conceives to be the successive stages in the formation of mineralizing solutions, from the time the residual magmatic liquid begins to form in a crystallizing batholith to the final disposition of the mineralizing fluids after they have deposited their valuable metals. The "pegmatitic liquid", or the residual magmatic liquid left after crystallization of the magma is well advanced, is highly alkaline. It is alkaline because hydrolytic action by water on the metallic silicates

(1) See page 4.

(2) Bowen, N.L. "The Broader Story of Differentiation, Briefly Told." Ore Deposits of the Western States - Chap. III.

produces metallic hydroxides, as shown by the following equation:

$$Na_2SiO_4 + H_2O = SiO_2 + \underline{2\ NaOH}$$

There are also acid hyperfusibles present in the liquid such as Cl, F, and S, but, due to the large quantity of water and metallic silicates present in the residual liquid, there are more than enough bases to neutralize the acids. The liquid will contain the following ions together with others of less abundance:

$$H^+,\ Na^+,\ K^+,\ Ca^{++},\ Mg^{++},\ Fe^{++},\ Fe^{+++},\ Al^{+++}$$
$$Cl^-,\ F^-,\ S^{--},\ SO_4^{--},\ OH^-$$

The next phase is the boiling of this pegmatitic liquid, brought about by the increase in its vapor pressure due to continued crystallization from the liquid. As the liquid boils, the more acid components come off first and in larger quantities than the basic constituents since they are more volatile. This is illustrated by the equilibrium between KCl, H_2O, HCl, and KOH in which H_2O and HCl are the most volatile substances and pass into the vapor phase more rapidly, leaving the residual liquid, in this case, richer in KCl and KOH. Therefore, the most abundant substances in the gas are water vapor, halogen salts, and acids. The elements most prominent in the gas are H, O, Cl, Si, F, S, B, K, Na, Fe, Ti and Al.

It is now necessary, according to Bowen, to picture a "Fractional Distillation Column" set up in the interstices of the surrounding magmatic hood and in fractures in the overlying country rock, in which the acid vapors, forced outward by the boiling at the source, selectively drop their less volatile components into the liquid phase as cooler places are reached so that the gas continuing on is successively enriched in the more volatile substances. The liquid which ultimately forms by condensation at more remote points will be high in water, halogen compounds, and acids and it is this liquid which is considered to be the agent responsible for the formation of ore deposits of igneous origin.

It is with the residual alkaline liquid or "pegmatitic liquid" left behind at the boiling source that we are most concerned. This liquid was alkaline before boiling took place and it should now be even more alkaline since the more volatile, acid portions of the original liquid have been vaporized. After continued boiling the liquid presumably contains the positive ions Na^{+}, K^{+}, Al^{+++} and much smaller amounts of Ca^{++}, Mg^{++}, Fe^{++}, and Fe^{+++} since the increase in concentration of Ca, Mg, Fe, and Al in the liquid should be retarded by their crystallization as basic aluminum silicates. The tendency of the whole process then, appears to be towards enrichment of the liquid in the alkali metals, Na and K. If the process is halted by the forcing-out of the liquid as intrusions into the surrounding rocks, aplite dykes, high in alkali feldspar and quartz will perhaps be formed. If the boiling and crystallization continue, however, it is possible that a stage might be reached at which a large part of the volatile halides, acids, and much of the water have been boiled off, the mafic constituents have been considerably reduced by crystallization with falling temperature, and the end product is a highly alkaline liquid, much enriched in K and Na and still relatively high in volatiles. Such a liquid should be capable of transporting accumulations of mafic minerals, previously formed and accumulated in another portion of the batholith, and reacting with them to form lamprophyre intrusive bodies.

If the above process be considered to take place (i.e. the production of ore deposits by acidic solutions accompanied by formation of lamprophyres by the associated alkaline solutions), it is possible to see reasons for the frequently-observed, close time-relation between ore-formation and lamprophyre emplacement. It would explain the tendency for lamprophyres to be later than the ore since the boiling process, which is believed to produce the acid ore-bearing solutions, should continue for some time before a highly alkaline residue would be produced. It is more awkward to attempt an explanation, by this hypothesis, of lamprophyre dykes which pre-date the ore. Another picture must be utilized, such as the lateral movement of lamprophyric fluid from a more remote portion of the batholith to the present locale of the ore; the ore, however, being perhaps produced by a separate and later boiling process taking place more nearly beneath the ore locality. Lamprophyres related to this later ore-forming process may or may not be formed, or if formed, they may or may not be represented in the ore deposit by post-ore lamprophyre dykes.

AN ATTEMPTED APPLICATION OF BOWEN'S ALKALINE SOLUTION REACTION THEORY TO THE PRESENT WORK

In Bowen's discussion of lamprophyres, only the ultrabasic type, alnöite, was considered and in such a rock type, his reasoning seems well-supported by phenomena observed in naturally-occurring rocks. It seems logical that, in a general way, conclusions reached involving one member of a group of rocks such as lamprophyres should have some value in any consideration of the other members of the group. Bowen did not, however, attempt to show how the supposed effect of a highly-alkaline liquid reacting with pre-formed mafic crystals in the formation of alnöite could be applied to the formation of the more common lamprophyres. It will be interesting, therefore, to attempt to find features in the rocks studied by the present writer which may indicate that similar processes took place in their formation, or conversely, to present evidence discrediting such a theory.

The Evidence of Phenocrysts and Groundmass Minerals in the Rocks of this Thesis.

Nearly all the rocks studied are porphyritic and invariably the phenocrysts persist into the chilled margins of the dykes, indicating, as in most porphyritic rocks, that the phenocrysts were crystallized and grew to a large size while the main portion of the dyke was still liquid. Regarding evidence in these rocks of reaction between the phenocrysts and the alkaline liquid in which they were supposedly suspended, the difficulty arises of distinguishing the products of such a reaction from those which might form in the deuteric reaction of crystals with a suspending liquid of a non-alkaline composition.

(a) Reeves-McDonald Specimens.

There are numerous examples of reaction-rims in the rocks studied in this investigation, particularly in the olivine phenocrysts of rocks from the Reeves-McDonald mine, described in Appendix B. The reaction-rimming in this case, is spectacular and although the definitely-identified reaction products are those ordinarily encountered in olivine pseudomorphs, there is some doubt as to the identity of some of the reaction products, notably the "carbonate" of the outer alteration rim in thin section 1 and the unknown alteration product described in thin section 3 which, however, occurs at the center of the pseudomorph and consequently is less likely to be due to late-magmatic alteration of the type in which we are interested. Diopside phenocrysts of the rock in thin section 1 are darkened by incipient alteration which, however, is unidentified. Biotite phenocrysts of thin section 1 are irregularly penetrated or corroded (but not rimmed) by material identified as carbonate and chlorite, and andesine is highly altered to calcite, clay mineral, and possibly a little chlorite. The conclusion therefore, in regard to reaction-rimming of phenocrysts in the specimens from Reeves-McDonald is that, unless the unknown minerals secondary after olivine and pyroxene can be identified as types peculiar to a reaction of olivine with alkaline liquid, no application of Bowen's hypothesis is possible. Furthermore, the feldspar of the groundmass is predominantly andesine and the groundmass contains no alkaline minerals other than a small proportion (one percent of the rock) of alkaline feldspar and some of the smaller biotite grains, which however do not appear to be second generation crystals as they grade in size downward from the biotite phenocrysts.

(b) Mayflower Specimen.

In thin-sections of this rock, diopside composing originally 25 percent of the rock, is 50 percent altered at the unmineralized center of the dyke. The alteration product is almost all uralite which grew from the outer edge inward with parallel orientation on the diopside. There were also formed, however, apparently by alteration of diopside, small amounts of biotite, chlorite, and a little calcite. Of these products, only the biotite is alkaline, but as it is confined to the pseudomorphs, where it is enclosed by chlorite, its occurrence does not suggest reaction of the diopside phenocryst with enclosing alkaline liquid. This apparent alteration of diopside to biotite is not general throughout the rock nor does the biotite ever rim the diopside. The possibility also must be recognized that this alteration was effected by the hydrothermal mineralizing solutions which acted on the dyke, even though metallic mineralization does not extend to the dyke's center.

(c) Rossland Specimen.

Biotite of this rock is shreddy and irregular in shape, a fact which might suggest its corrosion by containing liquid. ¶ There ~~is~~ are, however, no reaction rim~~ming~~s ~~of~~ on the biotite. The colorless base and slightly-crystallized feldspar is alkalic, therefore there is no argument against an application of Bowen's theory here except for the lack of reaction rims on biotite grains.

Hornblende of the rock is highly chloritized but this is apparently due to the penetration of hydrothermal solutions along a fracture in the rock.

(d) Sullivan Specimen (unmineralized).

Biotite, comprising 80 percent of the rock, is unaltered. It comprises 97 percent of the groundmass, the other constituent, in almost negligible amount, is interstitial among the biotite grains and is a colorless, cryptocrystalline to almost isotropic base, whose refringence could not be determined as being greater or less than balsam.

(e) Bralorne and Pioneer Specimens.

The biotite and pyroxene phenocrysts are unaltered.

(f) Ruth-Hope Specimens.

There is, in these specimens, a very peculiar occurrence of large, greenish prochlorite(?) phenocrysts in a ground composed of calcite and an unknown, cordierite-like mineral. A few small shreds of apparently-residual biotite occur, but not in close association with the prochlorite(?).

(g) Premier Specimens.

In specimen 3, hornblende phenocrysts are somewhat chloritized and also frequently have long feldspar laths resting against them on all sides, the feldspar laths appearing to rim the hornblende grains. The refringence of this feldspar is apparently less than balsam, although only one place was found in which it was possible to make an observation.

Conclusions in Regard to Reaction Rims

A review of these rocks reveals no diagnostic evidence of action by unusually alkaline solutions on the basic phenocrysts. It must be remembered, however, that late-magmatic, residual fluids of any crystallizing rock are more alkaline than the minerals that have been crystallizing so that deuteric reaction effects will resemble those we have been seeking. The only suggestion that can be made, therefore, is that reaction rims are perhaps more highly developed in these lamprophyres than is usually the case in rocks subjected only to deuteric alteration.

LAMPROPHYRE OCCURRENCES IN BRITISH COLUMBIA AND THEIR RELATIONS TO ORE DEPOSITS — AS COMPILED FROM PUBLICATIONS

A perusal of most of the available geological literature dealing with B.C. has produced the information appearing in Appendix A. In compiling this information, the procedure has been to give a little general information on the lamprophyres and the geology of the map area or mining district, together with a short description of those properties on which lamprophyres occur. In describing the individual properties, the lamprophyric intrusives and their relationship to ore in time and space are first dealt with, then a brief description of the ore is given. At the end of each section dealing with a particular mining camp, there is generally a short summary giving the total number of property descriptions for the area and the number of these in which the occurrence of lamprophyres is mentioned.

Table I is intended to provide a condensation of the more important facts appearing in the descriptions. This table lists the properties in geographical order and indicates whether the lamprophyres occurring on them are pre-ore or post-ore and whether the ore is of the high, medium or low temperature type. The designation of the deposits as high-, low-, and medium-temperature is debatable except for some of the more important mines since sufficient information is not available in the descriptions of small properties. In the incompletely-described, small properties, the classification is often based on the mineralogy alone, as indicated in the list of abbreviations.

It will be noticed that the descriptions are arranged in a geographical manner, those of south-eastern B.C., from the International Boundary to the Big Bend country, being placed first, followed by those in the general vicinity of the eastern Coast Range batholith contact, from the southern extremity at Hedley, to the north end, in the Atlin district.

Memoirs and Summary Reports of the Canadian Geological Survey were found to be the best sources of information, although miscellaneous publications were valuable in some cases. All Memoirs and Summary Reports were searched and any report dealing with B.C. was examined for references to lamprophyres. The index was consulted first and then the pages of the "General Geology" section on which appear "Minor Intrusives and Dykes" ~~were read~~. If lamprophyres were described there, the "Descriptions of Properties" were read for further details. If, however, no lamprophyres were described under "General Geology" it was usually assumed that the area under consideration contained no lamprophyres and the report was set aside. It is evident, therefore, that a fairly careful search was made and that areas such as Vancouver Island, the Cariboo, etc., in which a non-existence of lamprophyre dykes is assumed in this thesis, are at least devoid of important lamprophyre concentrations although they may contain minor occurrences which have been overlooked. A complete reading of all reports, especially the "Descriptions of Properties", would be necessary in order to be certain that lamprophyres are not reported in these areas.

TABLE I

THE MORE IMPORTANT FEATURES OF LAMPROPHYRE OCCURRENCES IN MINERALIZED AREAS OF B.C.

List of Abbreviations:

E + = epithermal, high-temperature end. Based on a mineralization consisting largely of sphalerite, galena, argentite, ruby silver, native silver.

M = mesothermal. Based on a mineralization consisting largely of quartz, galena, sphalerite, pyrite, chalcopyrite.

M + = mesothermal, high-temperature end. Based on mineralization consisting largely of pyrite, galena, sphalerite, pyrrhotite.

M(?) = doubtfully mesothermal. Based on a mineralization consisting largely of quartz, pyrite, free gold.

H = hypothermal.

* = lamprophyres are considered contemporaneous with the ore.

TABLE I.

District	Property	Lamprophyre Pre-Ore	Lamprophyre Post-Ore	Lamprophyre Uncertain	Type of Ore	Chief Metals	Remarks
Boundary Creek	Snowshoe mine			x	H-	Cu	
	Jewel mine		x		E	Au,Ag	
Franklin Mining Camp	McKinley mine		x			(?)	Ore is Jurassic, lamprophyre is post-Miocene, therefore is probably unconnected with ore.
Rossland Mining Camp *	(1). Jurassic lamprophyre dykes. (2). Main, late-Jurassic period of mineralization. (3). Oligocene(?) lamprophyre dykes. (4). Miocene lamprophyre dykes. (5). Second, main, late-Miocene (?) period of mineralization (6). Pre-Pliocene lamprophyres.				H	Cu,Au and (Pb)Zn, Ag	Majority of lamprophyre dykes are later, but some are earlier than the ore and some are intra-mineralization.
Salmo Map Area	Reeves-McDonald mine *				M	Zn,Pb (Ag)	One of the two dykes is mineralized, the other unmineralized.
Ymir Mining Camp	Wilcox mine			x	M-	Au,Pb	Faulting along some lamprophyre dykes is a conspicuous feature.
	Ymir Belle			x	M-	Pb,Zn	
	Ymir		x		M-	Au,Ag,Pb	
	Porto Rico			x	M(?)	Au	Dykes are probably pre-ore.
	Fern		x		M(?)	Au	
	7 other properties	~~x(?)~~	X(?)				

TABLE I. (CONT'D)

District	Property	Lamprophyre Pre-Ore	Post-Ore	Un-certain	Type of Ore	Chief Metals	Remarks
Ymir Nelson Area	Nevada Imperial Claims			x	M-	Pb,Zn	A lamprophyre forms H.W. of vein in one open-cut.
	Second Relief mine		x		H	Cu	
	Center Star mine		x		M+	Pb,Zn	
	Dundee mine		x		M-	Pb,Zn	
	Golden Age			x(?)	M	(Pb,Zn)	Occasionally the vein wall is a lamprophyre dyke.
	Star and Alma mine		x		M(?)	Cu	
Nelson Map Area	Kootenay Gold Mines Ltd.		x		M(?)	Pb,(Cu)	
	Athabaska Mine		x		M-	Pb,Zn	Aplites are pre-ore.
	Royal Canadian Group		x		M-	?	
	Eureka mine		x			?	
	Queen Victoria Mine		x		H	Cu	Basic lamprophyre dykes. Limestone replacement ore.
	Kootenay Bonanza Mines, Ltd.			x	M-	(Ag,Cu)	
Nelson Map Area, East Half	Spokane mine		x		M+	Pb,Zn	

TABLE I. (CONT'D)

District	Property	Lamprophyre Pre-Ore	Lamprophyre Post-Ore	Lamprophyre Uncertain	Type of Ore	Chief Metals	Remarks
	Sullivan* mine				H	Pb,Zn	Most are later, some are intra-mineralization.
Slocan* Mining Camp	L.H. Mine				M+	(?)	The country rock is lamprophyre(?)
	Antoine Claim	x			M(?)	(Zn)	
	Comstock Group	x(?)				(?)	Ore occurs mainly where the lode lay between lamprophyre and granite country rock.
	Fisher Maiden	x(?)			E+	Ag,Zn, Pb	Basic biotite dyke often forms H.W. of lode.
	Mountain Con Group	x				(?)	Dyke follows lode and changes from H.W. to F.W. side.
	Richmond Eureka Group		x		M	Pb,Zn	Lodes in places turn to follow formational planes especially near basic dykes.
	Ruth-Hope* Group				M	Pb,Zn	Lamprophyres closely related in time to the period of vein deposition.
	Silversmith-Slocan-Star* Group					(?)	Lamprophyres nearly contemporaneous with ore. Intimately associated in places with the vein structure.
	Reco Group		x			(?)	
	2 other properties			x			
	Enterprise mine	x	x		M	Pb,Zn, Ag	Most lamprophyres are pre-mineral and are involved in the faulting that disrupts the lode. 2 others are post-ore.

TABLE I. (CONT'D)

District	Property	Lamprophyre Pre-Ore	Lamprophyre Post-Ore	Lamprophyre Un-certain	Type of Ore	Chief Metals	Remarks
Ainsworth Mining Camp *	Jackson* Group				M	Pb,Zn	Dykes and ore very nearly contemporaneous.
	Metlakahtla claim			x	M-	Zn(Pb)	
	Whitewater & Whitewater Deep Groups			x	M-	Zn, Pb(Ag)	In the upper levels of Whitewater mine.
	Whitewater mine	x			H-	Zn,Pb	Magnetic ore replaces basic dyke rock in lower levels.
	Star mine			x		(?)	
	Bluebell* mine					(?)	Dykes and ore are probably nearly contemporaneous.
Kootenay Lake District	Bluebell mine		x		M+	Pb,Zn, Ag	Ore is limestone replacement type.
	Kirby group		x		M-	Zn,Pb	
Upper Arrow Lake	Big Ledge (Consolidated)			x	H-	Zn	In limestone.
Field Map Area	The Waterloo mining claim	x(?)			M+	Cu,Zn, Pb	Ore is blanket type, replacing limestone.
Hedley District	Nickel Plate mine		x	x	H+	Au(Cu)	Contact metamorphic deposit.
	Sunnyside mine		x		H+	Au	the same
	Kingston group			x	H+	(?)	the same.

TABLE I. (CONT'D)

District	Property	Lamprophyre Pre-Ore	Lamprophyre Post-Ore	Lamprophyre Uncertain	Type of Ore	Chief Metals	Remarks.
Bridge River District	Bralorne		x		M	Au	
	Pioneer		x		M	Au	
Terrace Area	La Libertad	x			(?)	nil	Quartz is barren.
	St. Paul and X-claims	x			M	Au, Ag	
	Kalum Lake Mines, Ltd.		x		M	Au, Ag(Cu)	
	Golden Crown Group & Kleanza Company			x	M	Au(Cu)	
	Terrace Claim			x	M-	(Pb, Zn)	
	Rosie Group			x		(Au)	Deposit consists of pyritized country rock assaying trace in gold.
	Columario Consolidated G.M., Ltd.			x	M(?)	Au, (Cu, Pb)	
	Cordillera Mine			x		Cu	Sparse bornite and chalcopyrite in quartz veins.
Usk to Cedarvale	Lorna May Claim			x	M-	Cu, Pb, Zn	
	Grotto group			x	M+	(?)	
	Silver Basin group			x	(?)	(?)	
Hazelton-Smithers District	Great Ohio	x			H	Zn, Pb	Veins often follow small camptonite dykes and cut through them. The dykes themselves are mineralised.

TABLE I. (CONT'D)

District	Property	Lamprophyre Pre-Ore	Lamprophyre Post-Ore	Lamprophyre Uncertain	Type of Ore	Chief Metals	Remarks
	Duthie mine	x			M-	Ag, Pb Zn	Fractures in the lamprophyre dykes are mineralized.
	Rocher Deboule mine	x			H	Au, Ag, Cu	
	Silver Creek group			x	M	Zn	Limestone replacement type ore.
	Glacier Gulch Gold Group			x	E+	Au, (Bi)	
Alice Arm District	Wolf Mine		x		M-	Ag, Cu, Zn	
	Esperanza Mine			x	M(?)	Ag, Cu, Zn, Pb	
	La Rose		x		M	Ag, Cu, Zn	
	2 properties			x	(?)		
	North Star group			x	E-M(?)	Ag	
	Dolly Varden		x		E-M	Ag	
Portland Canal Area	Premier mine	*			E-M	Ag, Au, (Pb, Zn)	Lamprophyres are mostly later than ore but some are very nearly contemporaneous.
Taku River Area	Mannville Ore Body		x		E-M	Zn, Cu	

COMMENTARY ON THE COMPILED DATA PERTAINING TO LAMBROPHYRE OCCURRENCES IN B.C.

Of the 84 occurrences of lamprophyre listed in Table I, 35 are post-ore, ~~13~~ 12 are pre-ore, ~~25~~ 29 are uncertain due largely to the absence of intersections with the ore, and eight are very nearly contemporaneous with the ore, though tending usually to a slightly post-ore age. In addition, the lamprophyres of Rossland, not tabulated in detail, are post- , pre- and intra-ore with the post-ore representatives predominating.

The lamprophyres for which a very nearly contemporaneous, or "intra-mineralization" relation to the ore is postulated are in the Rossland mining camp, Reeves-McDonald Mine, Sullivan mine, Slocan mining camp, Ainsworth mining camp and Premier mine. At Rossland, Sullivan and Premier, this relation is deduced for only that small proportion of the total number of lamprophyre dykes present which cut the ore but either are mineralized by ore-solutions or delimit the later, precious-metal mineralization of the ore. In the Slocan and Ainsworth camps, the dykes are largely pre-ore, but ore-filled fractures are intimately associated with the dykes and show phenomena which indicate that the fracturing and ore formation took place almost contemporaneously with the emplacement of the dyke.

Before going on to consider the compiled data in greater detail it will be advisable to emphasize that evidence of contemporaneity or pre-ore age is not always easily observed in the field. A definite conclusion that the lamprophyres at the Sullivan and Mayflower mines herein described are earlier than some of the mineralization would be almost impossible without a careful collection and petrographical study of specimens of the dykes to determine that they are mineralized. This is something that geologists do not always do in their examinations of properties, unless they are particularly interested in lamprophyre-ore relations. Therefore in all probability, much published data on ore-lamprophyre age relations are quite unreliable. It is a well-recognized fact that the chilled edges of dykes present highly impermeable barriers to the penetration of solutions into the dyke with the result that any mineralization of the dyke may be minor and escape notice in a megascopic examination.

THE ORE-LAMPROPHYRE RELATIONSHIP IN RELATION TO THE METALS CONTENT OF THE ASSOCIATED ORES

A. Occurrences in which the Lamprophyres and the Ore are Contemporaneous.

In these occurrences it was decided, even though only a portion of the lamprophyres present show definite proof of contemporaneity, to consider that the few contemporaneous dykes link up pre-vein and post-vein lamprophyres so that all belong to the same general period of intrusion. This conception seems incorrect in the case of the Rossland camp where Drysdale[(1)] has apparently found evidence that there were four

(1) Drysdale, C.W. C.G.S. Memoir 77.

separate periods of lamprophyre intrusion all of which cannot be contemporaneous with the two mineralizing periods. Yet there is proof that some of the dykes are contemporaneous and for the purpose of the discussion that is to follow, the Rossland district will be considered a "contemporaneous lamprophyre" district.

Of the six mining centers with contemporaneous lamprophyres, the Reeves-MacDonald, Sullivan, Slocan, and Ainsworth produce Pb, Zn and Ag, the Premier produces Au, Ag, (Pb and Zn) and Rossland produced Au, Cu, and Ag. In connection with the Rossland camp moreover, it should be noted that the deposits of the south belt of Rossland, in which the Mayflower mine lies, contain important quantities of (Pb), Zn and Ag, besides variable amounts of Cu, Au and arsenopyrite. Thus, the most common metals associated with contemporaneous lamprophyres are Pb, Zn, Ag, with some Au and a little Cu. There are no examples of gold-quartz ores.

B. Occurrences in which Lamprophyres are Pre-Ore Only.

These are very few in number and are confined to the Terrace and Hazelton-Smithers areas since the six pre-ore lamprophyres of the Slocan and Ainsworth districts are arbitrarily assigned a contemporaneous age owing to the general contemporaneity of lamprophyre intrusion in those districts. There is little uniformity in the ores of this class. In the Terrace area, one deposit contains barren quartz and the other, low grade Au and Ag. In the Hazelton-Smithers area, the Great Ohio contains Zn and Pb, the Duthie Ag, Pb and Zn and the Rocher

Deboule, Au, Ag, and Cu.

C. Occurrences in which Lamprophyres are Post-Ore Only.

The majority of the tabled lamprophyre occurrences are post-ore but only 22 of them are considered under this heading since the three Slocan examples are excluded and, in the case of three others, the metals content of the ore is unknown. In general, there is a trend away from ores of the Pb, Zn, Ag type, of which there are six examples, to those of Au and Cu. Four important mines (at Bridge River and Hedley) and one small mine (the Fern) produce only Au, and three mines, in the Ymir-Nelson area, produce only Cu. Of the eight remaining, seven contain either Au and Cu in addition to their other metals (Ag, Pb or Zn). One mine, the Dolly Varden, produces only Ag.

To enlarge further, ores containing Au and/or Cu, with or without other metals are associated with pre-ore lamprophyres in three and with contemporaneous lamprophyres in two instances while there are nine occurrences in which the ore-lamprophyre relationship is uncertain. There are, therefore, only five occurrences in which the associated lamprophyre is not post-ore compared with 15 in which the lamprophyre is post-ore.

Conclusions with Regard to the Ore-Lamprophyre Relationship in Relation to the Metals Content of the Associated Ores.

With the exception of those of Rossland and Premier, contemporaneous lamprophyres belong with Ag, Pb, Zn ores, while post-ore lamprophyres in a rough way show affinities for ores containing Au and Cu, with or without other metals.

GEOGRAPHICAL DISTRIBUTION OF LAMPROPHYRES IN B.C. AND THE GENERAL CHARACTER OF ASSOCIATED ORES

It may be possible to deduce something of a general significance from the relative incidence of lamprophyres in different parts of the province. It is evident that the majority of lamprophyre occurrences in B.C. are in the south-east, along a north-south belt that includes the Rossland, Salmo, Ymir, Nelson, Slocan and Ainsworth districts. Forty-eight of the 84 properties individually listed in Table I are in this belt and this does not take into consideration the numerous properties at Rossland which all contain lamprophyres but are not individually listed in the table. Assuming 15 properties at Rossland (actually there are more), the proportion of lamprophyre occurrences in the far-east belt to the total number in the province is 63 to 94. Two-thirds of the lamprophyre occurrences in B.C., therefore, are in this belt. In this area also are found all of the lamprophyres that are contemporaneous with the ore with the single exception of those in the Premier mine. The commercial ores in this belt are predominantly of the mesothermal, silver-lead-zinc type.

Westward from the Rossland-Slocan belt, lamprophyres associated with Au, Cu ores are reported near the International Boundary in the Greenwood and Franklin districts but are not known to occur again until Hedley is reached. In the vicinity of Hedley, post-ore lamprophyres are fairly plentiful in the contact metamorphic gold deposits but are absent from the copper deposit at Copper Mountain. There are scattered occurrences of lamprophyres for which no relations to ore are described in the Coquihalla and Tulameen districts and the next major appearance of lamprophyres is in the Bridge River district where they are later than the mesothermal to high-temperature gold-quartz deposits. Lamprophyres are apparently present to a small degree in the Chilko and Taseko lake regions but no published reference to them could be found.

It is not until the Terrace-Hazelton-Smithers region is reached that lamprophyres again become plentiful and in this region the development of lamprophyres is second only to that in the south-east portion of the province, 16 properties containing them. No contemporaneous lamprophyres are reported, but the only pre-ore lamprophyres of the province, five in number, occur here. In addition, one occurrence is post-ore and the remaining ten are uncertain. The ores are not conveniently classified but the majority are mesothermal and their metallization ranges from Au, Ag, Cu to Pb, Zn, Ag.

The next lamprophyre region to the north is the Alice Arm where seven properties contain lamprophyres, all of which are either post-ore or of uncertain relative age. The ores are mainly of the epithermal to mesothermal type and produce mainly Ag with a little Cu and Zn.

In the Portland Canal area, lamprophyres are described at the Premier mine where ~~they~~ most are ~~mostly~~ post-ore but some are contemporaneous. The ore is epithermal to mesothermal and production is in Au, Ag, (Pb and Zn).

In the Taku river district the Mannville deposit, containing a medium- to low-temperature, Zn, Cu ore, is associated with probably post-ore lamprophyres. One lamprophyre dyke, with no ore within seven miles, is reported from the Atlin district.

Apparently no lamprophyres occur within the Coast Range batholith nor at its western contact on Vancouver Island where low-temperature Pb, Zn, Ag deposits are generally lacking and the higher-temperature Cu and Au deposits prevail.

No lamprophyres are present in the Cariboo district where gold deposits occur in Pre-cambrian sediments.

Regarding the Beaverdell camp, where epithermal silver mineralization is present, it was not definitely ascertained whether lamprophyres are present or absent.

The objection might be raised to the foregoing treatment of lamprophyre distribution that many small prospects, in the Portland Canal area for example, contain lamprophyres not reported here. This is true but the relative proportions should still be roughly correct since there also will be unrecorded lamprophyres at many small deposits in other districts.

Another pertinent point should be considered and that is the frequently-expressed opinion that lamprophyres only appear to be more plentiful in mineralized regions because they are exposed by mining operations, their occurrences elsewhere, meanwhile, being concealed as a consequence of their soft, easily-weathered character. Although it is true that lamprophyres weather rapidly, there are nevertheless, numerous natural outcrops in such heavily-dyked regions as Rossland and there are frequent references in the literature to lamprophyre outcrops in un-mined areas, such as those by Daly (1) along the 49th parallel, and numerous others (Franklin Mining camp, Bridge River, Atlin district, etc.). If lamprophyres are present to any important extent in an area, there will be indications of them on the surface.

Conclusions with Regard to Geographical Distribution and the General Character of Associated Ores.

Lamprophyres are twice as plentiful in south-eastern B.C., where mesothermal, silver-lead-zinc deposits predominate, as they are in all other parts of the province combined, and in addition, show the closest time relation to the ore. In the southern half of the eastern contact of the Coast Range batholith, post-ore lamprophyres are associated with the moderate- to high-temperature Au deposits there but do not really become plentiful again until the northern part of the eastern contact is reached where there is a preponderance of mesothermal deposits containing Au, Cu, (Pb, Zn, Ag). Such important mining centers as Zeballos and Cariboo apparently do not have lamprophyres and in these areas, gold is the important metal.

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(1) Daly, R.A.: C.G.S. Mem. 38. Part I, (1912)

A BRIEF SUMMARY OF THE LABORATORY WORK UNDERTAKEN AND THE RESULTS OBTAINED

Thirty-three thin sections were examined and of these, 21 are described at considerable length in Appendix B. In addition, five polished sections were studied in conjunction with the thin sections.

The most valuable specimens, for the purpose of studying lamprophyre-ore relations, were obtained by Dr. Gunning from the Sullivan, Reeves-McDonald, and Rossland mines. Most of these lamprophyre specimens are mineralized and some have pieces of the related ore attached to them. In addition, unmineralized specimens were collected by Dr. Gunning from Britannia mine. Specimens of lamprophyre and other dyke rocks from Premier mine were obtained through Dr. W.H. White, specimens from the Ruth-Hope mine were contributed by Mr. W.M. Sharp and those from the Bridge River district were collected by the writer.

In the case of specimens from the Ruth-Hope, Pioneer, Bralorne, Britannia and Premier mines, in which no mineralization is present, the petrographical descriptions merely serve to classify the rocks and to record their features for future reference. The descriptions of specimens from the Sullivan, Reeves-McDonald and Mayflower mines, however, are more important as they record in addition, observations of value to a consideration of lamprophyre-ore relations. It is to the latter descriptions that most attention should be directed.

In the case of the Sullivan mine, specimen S35 from the south wall of the 3904 cross-cut consists of lamprophyre dyke material in contact with pyrrhotite-sphalerite ore (generally called "low-grade ore"), the dyke in this case being apparently later in origin than the ore (see diagram facing p. 16B). Specimen S36, from the same location, consists of lamprophyre which contains inclusions of "low-grade ore" but is mineralized by galena-rich "high-grade ore" occurring in contact with it. The conclusion from these observations is that the lamprophyre was intruded after the "low-grade ore" but prior to the galena mineralization and is therefore closely related in time to the ore. This interpretation is placed on the ore-lamprophyre relations in these specimens for reasons explained in detail in Appendix B and amounts to a confirmation of the results of previous investigations at the Sullivan mine.[1]

At the Reeves-McDonald mine, the lamprophyre 3000 feet from the portal of the River adit, from which specimen 2 is taken, cuts the ore structure so that it appears to be later than the ore yet it contains pyrite and galena in the amount of three percent of the rock and is intensely affected by carbonatization and chloritization as well. These features

(1) C.O. Swanson and H.C. Gunning: Geology of the Sullivan Mine, C.I.M.M. Bull. 402, Oct. 1945.

indicate a close time relation for the ore and dyke.

In the Mayflower mine, Rossland District (Trail Creek), a lamprophyre from the main level (thin sections M34, M35; polished sections M34, M36) cuts and is chilled against heavy-sulphide ore. The lamprophyre is however mineralized with chalcopyrite, sphalerite, pyrite, and galena but not by ~~an~~ apparently-earlier pyrrhotite and arsenopyrite occurring in the ore toward the interior of the ore band and consequently farther from its contact with the lamprophyre. Thus, it is possible ~~appears~~ that this lamprophyre too is ~~largely~~ contemporaneous with the ore, although the evidence is not conclusive and the dyke may equally well be pre-ore.

The "Rossland No.2 lamprophyre" (thin section L33) was obtained from a narrow dyke outcropping 50 feet north of a caved glory-hole in the LeRoi mine, the actual intersection of the dyke with the ore having been destroyed by mining operations. The location of the specimen is, however, aparently within the range of possible mineralization stemming from the ore. The thin-section shows accessory pyrrhotite grains and two grains of sphalerite but the evidence is insufficient for one to decide whether or not the dyke was intruded in the ore-forming period.

Of the remaining descriptions, which are less important because there is no mineralization of the lamprophyres, those dealing with Pioneer and Bralorne are of some interest as they provide petrologic data concerning colouration and apparent alteration of chilled margins of the lamprophyres. These phenomena are described in Appendix B.

The laboratory-work descriptions pertaining to the Ruth-

Hope and Premier mines have value only for determining whether the rocks are lamprophyres or not. The Premier lamprophyres studied are generally transitory between vogesite and quartz-hornblende-syenite whereas the Ruth-Hope rock is a chlorite phenocryst-bearing rock of peculiar petrographic appearance which apparently contains no feldspar.

The Britannia thin sections were not described as they are obviously not of lamprophyric material but of amygdaloidal, andesitic to basaltic, volcanic dyke rock.

APPENDIX A

COMPILATION

TABLE OF CONTENTS

49TH PARALLEL, IN SELKIRK RANGE, NEAR PEND D'OREILLE AND COLUMBIA RIVERS (1)

This memoir presents interesting and complete descriptions of the mineralogical and chemical composition of lamprophyre dykes occurring in this area together with their field relations but there is no special reference to ore deposits in the descriptions nor does Daly discuss theories as to the origin of the lamprophyre.

BOUNDARY CREEK DISTRICT (2)

This district is just north of the International Boundary in the general area surrounding the city of Greenwood. In the area, Brock states that alkali-syenite (pulaskite type) occurs as intrusives and dykes and that there are also dark lamprophyre dykes and light bostonite-like dykes which are probably connected with the alkali-syenite. All of these are of post lower-Tertiary age.

The ore is divided into two types,

(1) Large, low-grade copper deposits containing pyrite, pyrrhotite and magnetite,

(2) Gold and silver bearing veins containing chalcopyrite, pyrite, galena, sphalerite, tetrahedrite, rich silver minerals,

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(1) Daly, R.H.: C.G.S. Memoir 38, North American Cordillera, 49th Parallel, Part 1, 1912.
(2) Brock, R.W.: C.G.S. Summary Report, 1902, Preliminary Report on the Boundary Creek District, B.C. P. 90.

tellurides and native gold.

Both these types are of Tertiary age and number(1) is said to be related to the alkali-syenite while deposits of type (2) have alkali-syenite dykes associated with them and perhaps are also genetically related to the alkali-syenite.

Lamprophyre dykes are found in both types of deposit, occurring in some but not all of the mines. In detail the occurrences are:

No.(1) Type of Deposit

Greenwood or Phoenix Camp.

Snowshoe mine - some dykes of porphyry and dark lamprophyre cut the rocks.

Deadwood Camp.

Mother Lode mine - heavily dyked by the pink alkali-syenite porphyry, no lamprophyres mentioned.

No.(2) Type of Deposit

Jewel mine - Alkali-porphyry dykes occur in the mine and also small dark lamprophyre dykes. The lamprophyres are numerous, small, cut the ore and are later than the ore.

No. 7 mine - Contains many small black dykes, too decomposed for determination together with a grey syenite-porphyry dyke.

FRANKLIN MINING CAMP[1]

This camp is in the West Kootenays, on the east fork of the north fork of the Kettle River.

In this area all formations are cut by pulaskite dykes and plugs. The youngest dykes of all are lamprophyres, including minettes and augite-microdiorite, the former bearing a genetic relationship to the pulaskite. Note: the lamprophyres are later than Miocene flows, whereas the only ore deposits that have a nearby lamprophyre dyke (at the McKinley Mine), are of Jurassic age and therefore can not be connected with the post-Miocene lamprophyre.

A lamprophyre-minette is exposed on McKinley Mountain for over a mile in length. It varied from ten feet to 150 feet wide. Outcrops decompose readily (there is a photograph showing differential erosion) and specimens for microscopic study had to be collected from No. 1 tunnel of the McKinley mine where a 4½ foot dyke follows a limestone-tuff contact.

Field relations point to the close connection of the lamprophyres, geologically and petrologically, with the great Rossland alkali-syenite and granite batholiths to the east in the Granite range which probably underlie Franklin district.

There is no detailed description given of the lamprophyre occurrence in the McKinley or other mines of the district.

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(1) Drysdale, C.W.: C.G.S. Mem. 56, Geology of Franklin Mining Camp, B.C.(1915).

ROSSLAND MINING CAMP (1),(2),(3)

The Rossland camp, in which were located many important gold-copper mines such as the LeRoi, Center Star and Josie, is famous for the number and diversity of the lamprophyre dykes contained in the area. According to Barber (2) there was a greater variety of fresh lamprophyre to be found here than anywhere in North America.

Description of Lamprophyre.

Lamprophyre dykes occur by the hundreds and in some sections of the mines there is a lamprophyre dyke in every 25 feet of section. All the lamprophyre dykes trend north and south with very little deviation, and have nearly vertical dips whereas the ore trend is consistently in an east-west direction. In some sections of the mines where lamprophyre is very plentiful, the cross-cutting dykes reduce the ore proportion so much as to make the ore worthless for mining. In size, the dykes vary from the width of a knife blade to the immense Josie and Nickel Plate dykes which are up to 225 feet wide. There is often a change in character in different parts of the same dyke, mica dykes in depth becoming non-mica dykes higher up.

The principal types are minettes (Tramway and Black dykes),

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(1) Drysdale, C.W.: C.G.S. Mem. 77, Geology and Ore Deposits of Rossland, B.C. (1915).
(2) Barber, W.B.: American Geologist, Vol. XXXIII, p. 335. (1904)
(3) Bruce, E.L.: Dept. of Mines Bulletin No. 4, (1917) Geology and Ore Deposits of Rossland, B.C.

kersantites (Josie and Nickel Plate dykes), vogesites (Upper Center Star Dyke), spessartites (Spokane and White dykes) and odinites but there are also all gradations between these.

Type of Ore.

The ore is of the high temperature replacement type, consisting of veins of massive pyrrhotite and chalcopyrite with some pyrite and a little arsenopyrite in a gangue of altered country rock.

Relation between Lamprophyre and Ore.

The following table, taken from Drysdale's memoir, gives his conception of the chronological order in which the country rock formations, the intrusives and the ore were formed:

AGE OF ORE DEPOSITS

1. Marine sedimentation and igneous activity of the Carboniferous period (Mount Roberts formation).
2. Deformation at close of the Palaeozoic.
3. Triassic erosion and intrusion of augite porphyrite.
4. Jurassic mountain-making revolution, intrusion of Trail batholith and allied injections, extrusion of lavas and tuffs, intrusion of lamprophyric dykes.
5. First main period of mineralization. Replacement by sulphides along fissure and shear zones formed chiefly in the cover rocks of the Trail batholith and along formational contacts.
6. Cretaceous erosion cycle and removal of probably several thousand feet of cover rocks of batholith bringing possibly the upper extensions of some of the present veins close to the surface. Land surface brought down to one of low relief.
7. Laramide mountain-making revolution and re-elevation of Columbia range. Faulting of veins.
8. Eocene erosion and continental sedimentation. Sophie and Lake Mountain conglomerate.
9. Oligocene (?) deformation, intrusion of porphyritic monzonite stocks and lamprophyre dykes; erosion interval.
10. Miocene vulcanism. Intrusion of Coryell batholith and pulaskite porphyry dykes; intrusion of lamprophyric dykes.
11. Second main period of mineralization. Secondary enrich-

ment by ascending alkaline solutions containing free gold.
12. Intrusion of Sheppard alkalic granite stocks and dykes.
13. Block faulting and intrusion of youngest lamprophyres.
14. Pliocene erosion cycle. Production of present mature to late mature upland topography and removal of upward extensions of veins in upthrust fault block or 'horst'.
15. Late Pliocene uplift and erosion of deep valleys.
16. Pleistocene glaciation: removal of possible oxidation zone of deposits: accumulation of morainic material.
17. Recent weathering and oxidation.

It is to be noted in connection with this table that the Trail granodiorite batholith, which is identical with the Nelson granite, is apparently the ultimate source of the ore-bearing solutions. The ore-bearing solutions came in after the intrusion of the first generation of lamprophyre dykes which are also probably genetically related to the granodiorite. The two succeeding intrusive cycles (that of the porphyritic monzonite and the Coryell pulaskite batholith) are each followed by their associated lamprophyre dykes and there is a second period of mineralization which comes after the intrusion of the Coryell batholith.

In connection with the different types of lamprophyre "it seems probable that the sub-alkalic varieties (kersantite and spessartite) are genetically related to the Nelson granodiorite: the intermediate varieties correspond to the monzonite and the alkalic varieties (minette and vogesite) to the alkalic syenite or pulaskite."(1) This relationship may be deduced from compositional similarities.

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(1) Drysdale, C.W.: C.G.S. Mem. 77, Geology and Ore Deposits of Rossland, B.C. (1915), p. 243.

It was noticed that lamprophyre dykes seemed to be equally abundant throughout the area of the sheet and that their distribution gave no indication of a local origin.

The majority of the dykes are later than the ore but some are older since they are included in the ore, cut off by ore and some are mineralized.

In some places underground, where ore intersected earlier-formed dykes, the ore was bunched up against the dyke indicating a damming effect of the dyke. Also, where lamprophyres of an intermediate age were encountered, the earlier-formed sulphide mineralization was continuous beyond the dyke but the gold values, apparently introduced by mineralization of a later age, stopped at the dyke.

SALMO MAP AREA[1]

A good description of the characteristics and field relations of lamprophyre and aplite dykes in the map area together with a very satisfactory account of a specific occurrence of lamprophyre in the Reeves-McDonald Mine is contained in Walker's memoir.

In the general area, aplite dykes, associated with granite intrusions, cut the country rock and are most abundant in the most highly metamorphosed areas. Aplite dykes are cut by mineral veins and by still later lamprophyre dykes.

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(1) Walker, J.F.: C.G.S. Mem. 172, Geology and Mineral Deposits of the Salmo Map Area, B.C. (1934).

"Lamprophyre dykes cut all other rocks and also mineral deposits. They are generally fine-grained, dark grey to black rocks in which biotite and augite phenocrysts are visible to the naked eye."[1] As a rule they are considerably altered and weather rapidly.

Reeves-McDonald Mine.

Ore.

The ore consists of "low grade, disseminated replacements of limestone by pyrite, pyrrhotite(?), sphalerite and galena," occurring in the lower part of Pend Oreille Series.

A typical assay is: zinc - 6.2%, lead - 1.6%, silver - 0.5 ounces to the ton.

Description of the Lamprophyre and the Mineralization.

In his report on this mine, Walker gives a description of the River Adit from its portal to the face. The tunnel passes eastward through limestone with only streaks of zinc and lead(?) carbonates in the brown oxides in some places and in other places the limestone is barren. "At 3060 feet from the portal, pyrite occurs in a 70 foot dyke which appears to be a lamprophyre but may be an altered basic dyke of a greater age (Note: this dyke cuts and is chilled against the ore).[2] The mineralization continues in the limestone beyond the dyke, and 18

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(1) Walker, J.F.: C.G.S. Mem. 172, Geology and Mineral Deposits of Salmo Map Area, B.C. (1934), p. 18
(2) Dr. H.C. Gunning; ~~Personal~~ Oral communication.

feet beyond the dyke where a ten-foot lamprophyre dyke cuts the mineralization it consists of pyrite, possibly some, pyrrhotite, sphalerite and a little galena."

This mineralization continues east of the small dyke for 180 feet and is 50 feet wide in places. Diamond drilling showed the mineralization to continue east for a further 130 feet but thereafter very little mineralization was encountered.

In the other adits of the mine, there is good ore but there is no reference to lamprophyre dykes in them.

YMIR MINING CAMP (1)

There are many diaschistic dykes genetically connected to the Nelson batholith which grade from aplites to lamprophyres. Lamprophyre dykes occur throughout the whole area and are probably of two ages - the older related to the Nelson batholith and the younger, more alkalic, to the Coryell batholith of Tertiary age. The Tertiary and later lamprophyres are later than the main period of mineralization (connected with the Nelson batholith) and are of little economic importance.

The lamprophyre dykes are generally persistent dykes with steep dips, found chiefly in cover rocks of the batholith. Minette, kersantite, spessartite and vogesite are all mentioned. "The lamprophyre dykes bear important structural relations to

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(1) Drysdale, C.W.: C.G.S. Mem. 94, Ymir Mining Camp, B.C.(1917), p. 35

some of the ore-bodies as, for instance, in the Porto Rico and Fern mines".[1]

No mention was made of the relations of aplite dykes to ore.

The ores are gold, silver and lead ores which are divided into two types of which number one is the more important.

1. Auriferous galena, pyrite, sphalerite.
2. Quartz ore with free gold - also a little pyrrhotite, chalcopyrite, pyrite. This type is associated with intrusive dykes in the Rossland volcanics group.

<u>Wilcox Mine.</u>

The rocks are traversed by lamprophyre and aplitic dykes, chiefly the former (minettes). A very persistent 40 feet wide lamprophyre probably forms the western limit of No. 1 ore shoot. A fault of 30 feet displacement follows along this dyke.

-Fourth of July vein - No. 1 tunnel. Boundary of ore shoot delimited by a kersantite dyke but the best values in the shoot are in the end farthest away from the lamprophyre.

- No. 2 tunnel passes through 471 feet of barren ground, cutting several lamprophyres (kersantite, vogesite). The ore is encountered farther on.

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(1) Drysdale, C.W.: C.G.S. Mem. 94, Ymir Mining Camp, B.C. (1917).

The ore of the Wilcox Mine consists of pyrite, galena, Fe_2O_3 and occasionally zinc blende in a gangue of silicified country rock. The principal values are in gold, of which 70% is free gold.

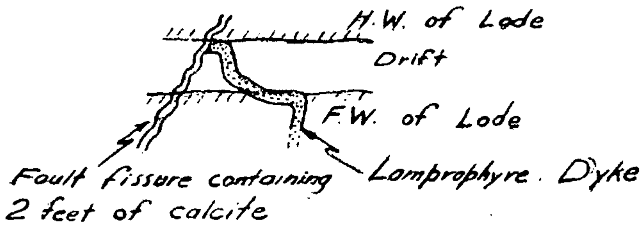
Ymir Belle.

Lamprophyres occur in this mine. The ore is pyrite, galena, zinc blende and quartz.

Ymir.

Lamprophyre dykes with branches occur through the workings.

A description is given of the intersection of a four-foot lamprophyre with the vein lode which may be summed up best by a diagram:



The extension of the dyke beyond the fault has not been located"

The ore is galena, pyrite, zinc blende and has gold, silver and lead values.

Porto Rico.

This mine had extremely rich ore. For one-half mile on the surface, the ore is opened up at intervals and invariably is against a narrow, fine-grained, cherty lamprophyre (altered augite-kersantite), about two feet wide with the same strike and dip as the vein. The dyke usually forms the hanging-wall but sometimes ore is on both sides and sometimes the lamprophyre also is put through the mill. Drysdale does not state whether the lamprophyre is mineralized or not but he does imply that the lamprophyre is pre-ore as "the mineralizing solutions followed along the underside of the dyke."

The ore is in true fissure-type veins and contains quartz, pyrite and free gold.

Fern.

The ore is along a granite porphyry dyke which usually forms the hanging-wall. The ore has terminated at a later lamprophyre-dyke which coincides with a fault plane and had not been picked up on the other side of the lamprophyre fault. In No.2 tunnel, the gold values were highest near the lamprophyre dyke.

The ore consists of quartz, pyrite and free gold in fissure veins.

Black Cock, Sterling, Iowna, Foghorn, Bluestone, Clincher, Evening Star.

Lamprophyre dykes occur on these seven properties. Apparently they are later than the ore.

YMIR - NELSON AREA (1)

There are some references to lamprophyre dykes in the detailed descriptions of properties in this memoir.

Nevada-Imperial Claims.

A shear zone is explored on the surface by open cuts. In cut 16, the hanging-wall is a mica-lamprophyre dyke and the shear-zone is well mineralized with quartz, galena, zinc-blende and pyrite. In cut 17, the dyke does not occur and the shear-zone has no defined walls but is mineralized with some pyrite and galena. There are numerous other cuts with varying degrees of mineralization on the claims but in none of them is the occurrence of lamprophyre mentioned.

Second Relief Mine.

The "Second Relief vein", which supplied almost all the production, follows the hanging-wall of a diorite-porphyry dyke. The common dykes on the property are granite-porphyry and quartz-porphyry; there are also several mica- and hornblende-lamprophyres. The lamprophyres are deemed to be the youngest of the dyke rocks and one of them cuts the Second Relief vein.

The ore consists of pyrite, pyrrhotite, chalcopyrite and possibly molybdenite in a gangue of country rock and quartz carrying some magnetite and, in places, garnet and epidote.

Center Star Mine.

A number of lamprophyre dykes occur on the 300 level. One

(1) Cockfield,W.E.: C.G.S. Mem. 191, The Lode Gold Deposits of Ymir Nelson Area, B.C. (1936).

of these cut through the vein and is distinctly younger than the vein.

The veins consist of quartz with pyrite, galena, zinc blende and pyrrhotite.

Dundee Mine.

The deposit is a fissure vein cutting Pend d'Oreille schist and small tongues of the Nelson granodiorite. The vein is intersected by, and offset by, several lamprophyre dykes.

The ore consists of fragments of country rock cemented by quartz. The sulphides are pyrite, galena and zinc blende.

Golden Age.

Several augite-kersantite dykes occur on the property. Occasionally, the vein wall is a lamprophyre dyke.

The deposit consists of poorly defined shear-zones containing stringers and bunches of quartz. The zones are mineralized with pyrite, chalcopyrite, galena and zinc blende.

Star and Alma M Claims.

A lamprophyre dyke, one foot wide, cuts across the shear.

The ore contains pyrite, chalcopyrite and malachite.

Summary of Ymir-Nelson Area.

Of 34 properties described in this report, six are described as containing lamprophyre dykes.

NELSON MAP AREA [1]

Lamprophyre Dykes.

Lamprophyre dykes have a widespread development in the whole area and are the youngest rocks. They cut the ore-bodies in contradistinction to lithologically similar dykes in the Slocan district and at Sheep Creek which are older than the vein fissures. The dykes vary from a fraction of an inch to 20 feet in width and from 100 feet to 1000 feet in length.

Ore.

The ores are of three types:

1. gold-silver
2. copper-gold-silver
3. silver-copper

Description of Properties, Nelson Map Area [1]

1. Gold-Silver Deposits

Kootenay Gold Mines, Ltd. - 5 miles west of Nelson.

The veins are cut by minettes. The ore contains pyrite mostly, with small quantities of galena, chalcopyrite and very rarely, scheelite.

Athabaska Mine.-3 miles from Nelson on east slope of Morning Mt.

A minette dyke cuts the ore and aplite dykes are present which are pre-ore. The ore consists of galena, zinc-blende and pyrite.

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(1) LeRoy, O.E.: C.G.S. Summ. Rept., (1911) Geology of Nelson Map Area.

Royal Canadian group.

A basic mica dyke cuts and slightly faults the ore.

2. Copper-Gold-Silver Deposits

Eureka Mine - 8 miles from Nelson.

Several basic mica dykes cut and sometimes fault the ore.

Queen Victoria Mine.

The ore zone is cut by basic lamprophyre dykes. The ore is of the limestone replacement type and is of fairly high-temperature origin. The minerals are pyrite, chalcopyrite, small amounts of magnetite and pyrrhotite. Gangue minerals are garnet, actinolite, epidote, quartz and calcite.

3. Silver-Copper Deposits

The Kootenay Bonanza Mines Ltd. - on Toad Mountain.

Lamprophyres occur on this property. The ore contains tetrahedrite, chalcopyrite, pyrite and galena.

NELSON MAP AREA, EAST HALF (1)

Description of Dykes.

The only dykes described, other than lamprophyre dykes, are a few small feldspar-porphyry dykes. The lamprophyre occurs in dykes and sills which are fine-grained and dark green with biotite and hornblende the most conspicuous minerals.

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(1) Rice, H.M.A.: G.S.C. Mem. 228, Nelson Map Area, East Half, B.C. (1941)

Many of them are greatly altered with the production of chlorite and epidote. Rice (1) believes them to be related to the Mc Gregor syenite intrusives of Tertiary age.

Ore.

The ore has silver-lead-zinc values and is of two types:

1. quartz-calcite veins with chalcopyrite, pyrite, pyrrhotite and a little galena and sphalerite. This type is the less important.
2. disseminated deposits of chalcopyrite, pyrite and pyrrhotite.

The better-known mines in the area are the Sullivan, Stemwinder, North Star and Bayonne. The occurrences of lamprophyre in these mines are not described in this memoir and the only reference to lamprophyre found was that in the Spokane mine. The property descriptions in this memoir are, however, quite short and incomplete so far as the detailed geology is concerned. 34 properties are described in the memoir.

Spokane Mine.

Little information is given. Four small lamprophyre dykes cross the vein fissure and have been fractured by late movement along the fissure.

The deposit consists of a quartz-bearing fissure mineralized with galena, sphalerite, pyrite and a little chalcopyrite.

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(1) Rice, H.M.A., G.S. Mem.228, Nelson Map Area, East Half, B.C. (1941).

Sullivan Mine.[1]

Lamprophyre dykes are present in the Sullivan mine but no information could be found regarding their number and size. It is stated in this article that the lamprophyres probably were intruded toward the end of the mineralizing period.

Interesting phenomena are described in connection with one biotite lamprophyre occurring in 3904 cross-cut. This dyke cuts sediments heavily mineralized with pyrrhotite and sphalerite and is later than the mineralization. However, a seam of galena occurs in the dyke along a fault plane, the galena being post-dyke in age as it partially replaces biotite of the lamprophyre. The dyke is also carbonated at the contact with galena. Therefore, the dyke has been intruded between the two types of mineralization, and as these events are considered by the authors to be probably consecutive stages in one, long-continued period of mineralization rather than two distinct mineralization epochs, it appears that the dyke and ore are, in the large sense, contemporaneous.

Note: Descriptions of other specimens of this same dyke may be found in Appendix B.

Ore.

The deposit is of the hypothermal type, pyrrhotite, sphalerite and galena, the chief sulphides present, replacing argillaceous sediments along their bedding planes.

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(1) Swanson, C.O. and Gunning, H.C.: Geology of the Sullivan Mine, C.I.M.M. Bull. 402, Oct., 1945.

WINDERMERE MAP AREA [1]

On the ridge north-east of Mount Brewer there are two small lamprophyre dykes ten inches wide. They are rotten in appearance but appear comparatively fresh under the microscope.

No description of the relationship to ore deposits was given. The ore in the area is silver-lead-zinc ore and the minerals are galena, sphalerite, pyrite, tetrahedrite, quartz, calcite, barite and siderite.

SLOCAN MINING CAMP [2]

Salic dykes and sills, granite and acid granodiorite mostly, are in great number in the area, especially in the vicinity of metalliferous deposits. Mafic dykes, all lamprophyres, are less abundant than salic. Salic dykes strike north-west, parallel to the regional strike of the enclosing rocks, whereas mafic dykes (lamprophyres) generally strike north-east, parallel to the course of the metalliferous veins.

Description of lamprophyres.

The lamprophyres weather more readily than the enclosing rocks and the weathering, particularly of olivine, had produced a pseudo-amydgaloidal texture. The most common type is a dark-green, medium-grained lamprophyre containing essentially olivine, pyroxene and biotite in varying proportions, with accessory

(1) Walker, J.F.:C.G.S. Mem. 148, Geology and Mineral Deposits of Windermere Map Area, B.C., (1926).
(2) Cairnes, C.E.: C.G.S. Mem. 173, Slocan Mining Camp, B.C.(1934)

magnetite, limonite and pyrrhotite. Little quartz is generally present and may be partly or entirely secondary. Feldspar when present is in subordinate amounts and is calcic plagioclase. Amphibole is scarce. These lamprophyres yield dykes rarely greater than a few feet wide, though at the Slocan Sovereign they are 50 feet wide. They more commonly follow or parallel the course of the metalliferous veins than that of the enclosing rocks. Consequently they strike nearly normal to the salic dykes and in most cases cut across them. They are more abundant in the Slocan Series (of sediments) but similar mafic dykes occur in the Nelson granite.

The second type of lamprophyre, observed in granitic areas (Fisher Maiden and Comstock Mines), contains no olivine but has abundant hornblende together with biotite, calcic plagioclase and accessory quartz, magnetite, ilmenite and epidote.

The third type of lamprophyre consists almost entirely of secondary minerals. It is light to dark grey and contains numerous light green streaks and brownish spots. The light green streaks are due to the chromium-bearing mica, mariposite and the brown spots to oxidation of iron sulphides and ferruginous carbonates. Under the microscope this type is largely composed of ferruginous magnesium carbonate with associated colorless mica (mariposite), a little quartz and sometimes serpentine, chlorite, sulphides and commonly calcite. These are best seen near the Whitewater and Jackson mines. Their original composition is in doubt but they appear to grade into the dark-green lamprophyre in some outcrops.

The last type of mafic dyke is "Minette", which is found near Sandon. These dykes are a few inches wide, dark-colored and contain a large amount of black mica. In most cases they are highly altered.

Age of Dykes.

The salic dykes and most of the mafic dykes are premineral as they are cut by the fissures which provided entry for the mineral-bearing solutions. The mafic dykes, however, are on the whole the younger of the two dyke-types since they cut the salic. Salic dykes, abundant in the Slocan Series (sediments), are scarce in the granite areas whereas mafic dykes are about equally prominent in both formations. The salic dykes are considered to represent a late stage in the intrusion of the Nelson batholith since many of them bear lithological resemblance to the later members of the batholith.

The following paragraph is quoted directly from Cairnes to present the evidence for a close time relationship between lamprophyre and ore.

(1) The minor intrusives are much less deformed than the prebatholithic formations they intrude, undoubtedly because the latter were deformed before intrusion of the Nelson batholith. Developments underground have, however, shown that minor intrusives were, in places, involved in shearing that affected older formations. In a number of instances, both in the Slocan series and the Nelson granite, mafic dykes have been observed to be followed by fissures and shear zones providing access for mineralizing solutions. This feature has, in fact, appeared so significant in mining operations as to suggest some connexion between these dykes and mineralization. It appears unlikely that the mafic dykes are the source of ore mineralization, for they are free of ore minerals except where they have been frac-

(1) Op. Cit. p. 72

tured. They were, however, probably intruded during a period of deformation just before and possibly extending into the period of mineralization; in some cases, where their intrusion did not completely heal the original planes of weakness or where they themsèlves were less competent than the rocks they intruded, further fracturing or shearing occureed along them and provided channels for ore-bearing solutions. A few, small, mafic dykes of definitely post-mineral age were observed cutting across the ore-bearing fissures or shear zones as, for example, at the Enterprise and Anna mines. At the V and M property a similar dyke is intruded along a fault which displaces a vein.

Type of Ore.

The ore occurs in veins, vein lodes, fissure fillings and replacements. The production is in silver-lead-zinc and the minerals are mainly galena, blende, quartz, calcite, siderite but also grey copper, ruby silver, pyrite. Better-known mines of the district are the Silversmith, Arlington, Standard, Van Roi, Whitewater.

Description of Properties, Slocan District.

The "L.H. mine".(1)

The mine is located five and one-half miles from Silverton at an elevation of 5,250 feet. 1700 feet of drifting and cross-cutting had been done.

Lamprophyre.

The country rock of the mine is plainly an early basic differentiate, consolidated and later sheared dynamically. It is a hard, massive porphyry, similar in appearance to a sill rock found in Number 7 tunnel of the Standard mine which has the composition of a kersantite.

(1) Bancroft, M.F.: C.G.S. Summ. Rept. (1917), Investigations in Slocan District, B.C.

The lamprophyre dykes of the West Kootenay are considered to be the basic differentiates of the greater granite massives and mineralization is only another phase of this prolonged process of magmatic invasion, beginning with Jurassic.

Type of Ore.

Pyrrhotite, pyrite, arsenopyrite and quartz formed in a gangue of country rock in a zone 20 to 40 feet wide which follows the master jointing.

A. SLOCAN MINING DIVISION (1)

Antoine Claim.

A dark green lamprophyre dyke, five feet wide, is cut by the vein lode on No. 5 level.

The lode contains siderite with a little pyrite and zinc blende.

Comstock Group - 10 miles from Silverton.

The property is in the tip of a body of granite, a member of the Nelson batholith. The lode intersects fine-grained hornblende granite and follows, in places, a dyke of biotite lamprophyre.

The ore consists of brecciated granite partly cemented by quartz containing streaks of ore minerals. The ore appeared to occur mainly where the lode lay between granite and the basic (lamprophyre) dyke.

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(1) Cairnes, C.E.: C.G.S. Mem. 184, Descriptions of Properties, Slocan Mining Camp, B.C. (1935), p. 1.

Fisher Maiden - 8 miles from Silverton on Silverton Creek.

The deposit is in rocks of the Nelson batholith. A basic hornblende-biotite dyke follows parts of the lode and may have had some influence on the position of the ore bodies. Lengths of 50 to 100 feet of ore have the basic dyke as hanging-wall.

The ore contains zinc-blende, argentite, ruby and native silver and galena.

Mountain Con Group - At extreme head of Carpenter Creek.

The granite of the Nelson batholith in which the claims lie is intersected along the course of the Mountain Con lode by a lamprophyre dyke, composed of biotite, bronzite, feldspar and a little quartz, with secondary calcite, talc(?) and bastite. The dyke occurs in places on the hanging-wall, and in places on the foot-wall, side of the vein and appears to have been intruded along the course of the fissure. Subsequent movement resulted in the shearing of the dyke and deposition of the vein matter.

Richmond-Eureka Group - East fork of Sandon Creek.

The underlying sediments of the Slocan series are intersected by quartz-diorite porphyry dykes and a few basic lamprophyre and minette dykes. In places the lode turns to follow formational planes, especially near the basic dykes.

The metallic minerals are galena, zinc-blende, pyrite and a little chalcopyrite.

Ruth-Hope Group - South-west of Sandon.

The underlying rocks are massive argillaceous and quartzitic strata of the Slocan series, which in many places are calcareous. The sediments are intersected by many dykes, chiefly of quartz-feldspar porphyry but including some darker, mostly small, dykes varying in composition from minettes to basic lamprophyres. The dark dykes are notably irregular, appear to be later than the light-coloured dykes, and to be rather closely related in time to the period of vein deposition. Ore deposition was later than the acid dykes, but they exerted a structural control over the courses followed by the lodes and the location of the ore deposits.

The ore contains galena, blende, grey copper, chalcopyrite and pyrite with quartz and a little anglesite as gangue minerals.

The following discussion of the Ruth-Hope property is inserted here to present some reasons for believing that the lamprophyre is rather closely related in time to the period of vein deposition. These observations have been contributed by Mr. W.M. Sharp, M.A.Sc., who is working on the detailed geology of the mine.

Some of the lamprophyres in the mine are considered to have been intruded very shortly after the introduction of ore because they have been affected by the normal faulting that took place during the ore-forming period or shortly after. The reason for considering this normal faulting to be very close to the ore in age is that replacement ore reflects the drag-fold pattern associated with the normal faulting, with very slight brecciation of the ore. The same drag-folding in the quartz-feldspar porphyry, on the other hand, is accompanied by slight crackling of the porphyry. The inference here is that mineralization was probably going on at the same time as normal faulting, and, as the lamprophyre is cut by the normal faulting, it must therefore have been intruded during or shortly after the ore-forming period. The absence of hydrothermal mineralization of the lamprophyre in contact with the lode structure is good evidence that the lamprophyre is not completely pre-ore.

<u>Silversmith-Slocan Star Group</u> - ½ mile south of Sandon.

The sediments are intruded by acid porphyries and lamprophyres. The lamprophyres vary in composition from minettes in which biotite and orthoclase are the predominant minerals to more basic lamprophyres in which olivine and/or pyroxene and biotite are conspicuous. In contrast with the acid intrusives these basic dykes are notably irregular in their individual structures and dimensions. They appear to be younger than the acid intrusives and are smaller, averaging probably less than a foot in thickness. They are, as on other properties, intimately associated in places with the lode structures, an association that suggests that their period of intrusion was separated by no great interval from the period of mineralization.

The Remainder of the Lamprophyre Occurrences in Slocan Mining Division.

On the Reco Group there is a mica lamprophyre younger in age than the quartz-porphyry dykes.

On the Slocan King group there is a basic lamprophyre dyke.

On the Slocan Sovereign claim, a lamprophyre dyke follows rather closely the course of the lode.

Summary of Slocan Mining Division, Slocan Mining Camp.

There are 105 descriptions of different properties under the heading, "Slocan Mining Division" and of these only ten contained references to lamprophyre dykes. These references have been summarized above. There were, in addition, four or five references to "basic dykes" which presumably means lamprophyre dykes. These, however, were not considered in this compilation due to their uncertain identity.

The vast majority of the properties contain numerous quartz-porphyry and quartz-feldspar-porphyry dykes which are pre-lamprophyre in age.

B. SLOCAN CITY MINING DIVISION (1)

Enterprise Mine - 8 miles from Enterprise Landing.

The granitic rocks underlying the property are intersected by a few, small, basic dykes, varying from hornblende porphyrite to olivine and olivine-diallage lamprophyres. One at least, and probably two narrow dykes of the lamprophyre types were

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(1) Cairnes, C.E.: C.G.S. Mem. 184 (1935), Descriptions of Properties, Slocan Mining Camp, B.C. Chap. II, p. 166.

observed to cut across the lode. Others are pre-mineral and are involved in the faulting that disrupts this lode.

The ore minerals are galena, zinc blende, pyrite, chalcopyrite, grey copper.

References to "Basic Dykes".

There are references to "basic dykes" on six other properties. It is not stated whether these are lamprophyres or not. Of these six occurrences, two follow the lode, one is intersected and displaced by the lode and the remainder are not described.

Summary of Slocan City Mining Division, Slocan Mining Camp.

The total number of properties dealt with is 40. Of these, only one is stated to contain lamprophyre and six have basic dykes which may or may not be lamprophyres.

C. AINSWORTH MINING DIVISION [1]

Jackson Group.

The underlying Slocan sediments are cut by dykes and sills of quartz porphyry that are commonly closely aligned with the sedimentary formations, and highly altered greenish dykes of more basic composition that cut across the sediments more nearly parallel with the vein-bearing lodes. Underground, the association of these green dykes with the ore-bearing portions of the Jackson lode is a noteworthy feature.

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(1) Cairnes, C.E.: C.G.S. Mem. 184 (1935), Descriptions of Properties, Slocan Mining Camp, B.C.

The more productive parts of the Jackson lode are followed for considerable distances by narrow, greenish dykes. These dykes are sheared and completely altered and consist chiefly of carbonate, quartz, and a greenish micaceous mineral resembling mariposite. One such dyke, two feet wide, is overlain and underlain by ore and slightly mineralized by galena. The association of these greenish dykes with thelode and, in particular, with the more productive parts of the lode may have some genetic as well as structural significance. Here, as elsewhere in the district, such dykes have been found in close association with fissure vein deposits and though in no case have they seemed to be directly responsible for the mineralization yet their association has, in many instances, suggested that their period of intrusion closely preceded the incursion of mineral-bearing solutions; that their source has been one with these solutions; and that the fissures they have followed have been along lines or zones of weakness which, if not completely healed by the dykes or if reopened by further fracturing and fissuring involving the dykes themselves, have permitted access to the later ore-bearing solutions.

The ore minerals are galena, zinc blende, chalcopyrite, pyrite in a gangue of siderite, quartz and crushed rock.

Metlakahtla Claim - At mouth of Whitewater Creek.

The Slocan sediments are cut by a green lamprophyre dyke. At one point on the Metlakahtla claim a narrow siliceous band or vein three feet above the base of the dyke contains disseminated pyrite and galena.

Principal work on this claim has been done on a mineralized zone unassociated with the lamprophyre. The zone was mineralized with sphalerite, pyrite and a little galena.

Whitewater and Whitewater Deep Groups.

The rocks are slates and impure limestones of the Slocan series. One basic dyke, 40 feet wide, occurs underground. The dyke is very much like, if not identical with, one observed on the Metlakahtla claim. (Note: the Metlakahtla dyke here referred to is called "lamprophyre" in the preceding section.) Several other similar basic dykes of peculiar greenish hue were also observed. The greenish color is due to mariposite(?). Otherwise the rocks are composed chiefly of carbonates.

West of the raise from No. 11 level, comparatively little mineralization has been encountered on No. 10 level except near the face where the lode filling carries some ore minerals in the vicinity of one or more of the carbonate-mariposite dykes referred to above.

Note: M.S. Hedley[1] calls these Whitewater dykes lamprophyres.

The Whitewater Mine - Slocan District[1]

Upper Mine Geology - above 13 level.

Lamprophyre.

The lode here is an irregular zone of shearing and frac-

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(1) Hedley, M.S.: B.C. Dept. of Mines, Bulletin No. 22, (1945) Geology of the Whitewater and Lucky Jim Mine Areas, Slocan District.

turing in slates. A porphyritic lamprophyre, so extremely altered to carbonate, sericites and locally mariposite that identification is difficult, follows the lode on 10 and 11 levels and apparently did so on the upper, worked-out levels as well. It occurs as sheets and lenses within the lode and locally in the wall. It was intruded prior to mineralization and must originally have been a rather complex body which now is much broken up by displacements along the lode.

<u>Ore</u>.

The ore consists of galena and sphalerite and a little grey copper. There is some pyrite and chalcopyrite. The gangue is chiefly siderite but some quartz occurs.

<u>Lower Mine Geology</u> - below 13 level, the dip of the lode changes from 60 degrees to 20 degrees.

The foot-wall of the lode is slate and the hanging-wall, limestone.

<u>Ore</u>.

There are three types of ore in the lower mine.

(1) Same as in the upper mine - this type is not so important.

(2) Massive replacement of limestone by sphalerite and siderite. Galena amounts to 1/5 of the sphalerite. This is called "spathic" ore and is the most important.

(3) Magnetic ore, formed by replacement, consists of sphalerite and little galena in a gangue of magnetite, pyrrhotite, pyrite and some silicate minerals. This

ore replaces dyke rock, part of the irregular lamprophyre intrusive which extends through the mine.

The magnetite ore is mostly if not all a replacement of dyke rock. In some parts the replacement is gradational and in others it is sharply bounded by extremely altered dyke. In most instances the ore grades into rock which, although consisting almost entirely of carbonate and sericite, as a rule retains its igneous texture and is recognizably porphyritic underground. The dyke is much wider in the main magnetite ore body and for the most part, elsewhere exists as sheared remnants within the lode.

Other References to "Basic Dykes" in Ainsworth Mining Division.(1)

One property contains a "narrow, fine-grained basic dyke" which partly defines the hanging-wall of the lode.

One property contains "altered, greenish, basic dyke rock" which defines the hanging-wall of a lode.

On another property, a narrow band of highly altered, dark, micaceous rock is associated with the main lode and is probably a basic dyke.

Another property has "small basic dykes".

Finally, a property contains acid and basic dykes. The basic dykes cut across the strike of the rocks.

Summary of Ainsworth Mining Division, Slocan Mining Camp.

There are 74 descriptions of properties and of these, five

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(1) Cairnes, C.E.: C.G.S. Mem. 184 (1935), Descriptions of Properties, Slocan Mining Camp, B.C. Chapter III.

contain references to lamprophyre and five additional descriptions contain references to "basic dykes". Owing to their similarity in mode of occurrence to the lamprophyre dykes of nearby parts of Slocan Mining Camp, it seems highly probable that these "basic dykes" were originally lamprophyre dykes which are now altered too highly for identification.

Numerous acid dykes occur on the majority of the properties.

AINSWORTH MINING CAMP (1)

Description of Dykes.

Lamprophyric dykes can be traced up to hundreds of feet in length and are less than eight or 10 feet wide. There are two sets, one in the bedding and the other crosscutting the bedding. The most common dyke rock type is camptonite which contains phenocrysts of hornblende and biotite. Microscopically, hornblende is the strongly pleochroic, dark brown variety occurring as phenocrysts in a fine-grained ground of biotite and andesine. Apatite and magnetite are quite abundant accessories.

Ore.

The ore deposits are true fissure veins and limestone replacements. Most are of the true fissure vein type but both types are of the same age and have the same ore minerals.

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(1) Schofield, S.J.: C.G.S. Mem. 117 (1920), Geology and Ore Deposits of Ainsworth Mining Camp, B.C.

The minerals are galena and zinc blende in calcite, siderite, quartz, fluorite.

Typical mines in the area are the Star, Highlander, Florence, Spokane, Bluebell.

Age of Dykes and Relation to Ore.

The age of the lamprophyre is in doubt but it is not much older than early Cretaceous. The lamprophyre dykes are highly altered by the mineral-bearing solutions which are responsible for the ore deposits of the Ainsworth camp. Schofield concluded that the ore deposits are associated with Jurassic and Cretaceous batholiths and the dykes are associated with the cooling stages of the Nelson granite batholith but at a stage previous to the one in which ore deposits were formed.

Star Mine.

In the lower tunnel, a lamprophyre occurs which has very large hornblende phenocrysts and contains a great number of inclusions of Nelson granite.

Bluebell Mine.

Although the lamprophyre occurring here is so altered and rotten that its relation to ore is in doubt, it is claimed that the dyke cuts the ore. But Schofield thinks, because of the position of the dyke as a bounding wall of the ore body and its intense alteration, it must be pre-ore. Therefore, he concluded that the dykes and ore were nearly contemporaneous and he also believes that the dykes have no genetic connection with ore deposition.

KOOTENAY LAKE DISTRICT[1]

The Nelson batholith outcrops along the west edge of the map area and is post-Triassic in age. Mineralization and the intrusion of lamprophyre dykes appear to be a very late stage of the batholith intrusion.

Description of Properties

Bluebell Mine.- This is one of the oldest mines in B.C. and a great deal of lead-zinc-silver ore has been removed at intermittent stages in its lifetime. It is located at Riondel on the east side of Kootenay Lake.

The country rock is Lardeau series strata, consisting of schist, quartzite and limestone. Lamprophyre dykes are common and generally follow two pronounced systems of jointing, one, north 70 degrees west and the other, south 85 degrees west. The lamprophyre is post-ore. Several small granitic dykes are pre-mineralization.

The ore consists of irregular replacements in the upper part of a limestone band, 150-200 feet thick. Pyrrhotite, pyrite, sphalerite, galena, arsenopyrite and chalcopyrite are the metallic minerals; the gangue is quartz and limestone.

Kirby Group.- This group is one mile north-east of the Bluebell mine. Lamprophyre dykes appear to be later than the ore. The ore consists of pyrite, sphalerite, galena in bedded shear zones of quartzite, schists and calcareous schist.

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(1) Walker, J.F. and Gunning, H.C.: C.G.S. Summ. Rept.,(1928), Kootenay lake District, B.C.

BIG LEDGE (CONSOLIDATED) PROPERTY, UPPER ARROW LAKE [1]

This property is located on the west side of Arrow Lake, 17 miles south of Arrowhead. The ore consists of mineralized bands in Precambrian limestone and contains pyrrhotite as the most plentiful, followed by pyrite as the second most plentiful sulphide. Sphalerite also is present in smaller quantity.

One lamprophyre, three to four feet wide, was observed and two others of a similar character are reported to occur elsewhere on the property. The lamprophyre carries large crystals of titan augite, plagioclase near andesine, calcite, ilmenite, pyrite and an abundance of radiating masses of serpentine and chlorite. No quartz was noted. The dyke appears to cut all other rocks except, possibly, the pegmatitic intrusives. (Note: the dyke's relation to ore was not noted.)

FIELD MAP AREA [2]

There is a laccolithic intrusive of nepheline-syenite to which 12 dykes are genetically connected. The dykes are in two groups, one, the bostonite-tinguaite group and the other, the lamprophyre group. The lamprophyre group consists of minette, vogesite, monchiquite, fourchite, ouachitite, camptonite and nepheline-basalt. (Note: Allen's petrographic

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(1) Cairnes, C.E. and Gunning, H.C.: C.G.S. Summ. Rept., (1928) Big Ledge (Consolidated) Property, Upper Arrow Lake, Kootenay District, B.C.
(2) Allen, J.A.: Mem. 55, Geology of Field Map Area, B.C. and Alberta (1914).

descriptions indicate the presence of feldspar in the monchiquite and fourchite. According to both Johannsen (1) and Harker, (2) there is no feldspar in these two types of lamprophyre.)

The Waterloo Mining Claim - This is located near Moose Creek on Zinc Mountain, not far from Mount Goodsir.

The ore contains pyrrhotite, chalcopyrite, sphalerite, pyrite and galena and is a blanket-type deposit replacing limestone. The deposit is roofed by mica-porphyry (ouachitite) which has irregular streaks and fragments impregnated with pyrite crystals.

BIG BEND MAP AREA (3)

Lamprophyre dykes are sparingly developed in the Big Bend map area. Daly (4) described two small dykes of "dark, greenish-grey, somewhat porphyritic, medium grained minette" and a basaltic sill at Albert Canyon gorge on the C.P.R. main line.

There is a dark-grey, fine-grained lamprophyre dyke in Silver Creek, about 1½ miles below the forks, which consists of biotite, quartz and alteration products (calcite chiefly). Fluorite and quartz were observed in amygdales. It probably resembles the minette at Albert Canyon gorge. It is greatly

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(1) Johannsen, A.: Petrography, Vol. III. (1937)
(2) Harker, A.: Petrology for Students. (1908)
(3) Gunning, H.C.: C.G.S. Summ. Rept. (1928), Geology and Mineral Deposits of the Big Bend Map Area, B.C.
(4) Daly, R.A.: C.G.S. Mem. 68. Golden to Kamloops along the C.P.R. (1915)

altered.

HEDLEY DISTRICT [1],[2]

Description of Lamprophyre. [1]

The types of lamprophyre present are kersantites and camptonites. They are less than three feet wide, are not remarkably persistent and occupy tightly closed fissures.

Plagioclase is the most abundant constituent, both as phenoerysts and in the groundmass; hornblende or augite is second in importance. Biotite, when it is present, occurs rarely as phenocrysts, but normally is in the groundmass in small flakes where it is relatively abundant. Plagioclase, hornblende and pyroxene show as a rule, good crystal form and the texture of the rock is either porphyritic or panidimorphic. The hornblende of the kersantites is dark to light green and not strongly pleochroic.

Ore.

The ore is closely associated with the diorite-gabbro stocks which garnetized the limestone and is of the contact-metamorphic type in limestone, a high-temperature, deep-seated type of deposit. Structural control is provided by the bedding of the limestone in conjunction with the diorite-gabbro dykes. The values are all in gold which occurs in

(1) Camsell, C.: C.G.S. Mem. 2, The Geology and Ore Deposits of Hedley Mining District, B.C. (1910).
(2) Camsell, C.: C.G.S. Summ. Rept. (1907), Camp Hedley, Osoyoos Mining District, B.C.

arsenopyrite almost entirely. Other minerals are pyrrhotite, specularite and chalcopyrite.

Relation between Lamprophyres and Ore.

The lamprophyre dykes follow closely after the intrusion of the stocks of diorite or gabbro with which the ore is related. Whether the lamprophyre is later or earlier than the mineralization is not stated except in the Sunnyside mine, in which the lamprophyre is later. The ore is cut by small, black lamprophyre dykes and by dark green andesite dykes. In the Nickel Plate mine the limestone is intruded by white gabbro sheets and dykes and there are other dykes of various kinds. The most common are hard, black, lamprophyre dykes of no uniform strike, also andesite and one or two keratophyre dykes. At least one lamprophyre dyke in the Nickel Plate mine is post-ore since a section of the mine along No. 3 tunnel shows the dyke cutting the ore.[1]

The Kingston Group.

Lamprophyre dykes cut the sedimentary rocks in which the ore occurs. The lamprophyres are accompanied by a great many sheets and dykes of diorite and gabbro but apparently are later than the diorite and gabbro.

The ores are the contact metamorphic type associated with intrusions of diorite. The outcrop of a payable ore-body has

(1) Camsell, C.: C.G.S. Mem. 2, The Geology and Ore Deposits of Hedley Mining District, B.C. (1910), p. 155.

been found in the sedimentary rocks alongside a black lamprophyre dyke which strikes north and south across the side of a hill. About 600 feet of tunneling has been done on this property but no ore was shipped.

Other Properties

Two other properties dealt with in Memoir 2 had no lamprophyre.

TULAMEEN DISTRICT (1)

"Small dykes of generally basic composition but varying constituent minerals will be described under the general name of lamprophyres". They are all dark-colored, the chief constituents identified in the field are feldspar, hornblende, and sometimes biotite and augite. The dykes are all of small size and are not limited to any area or formation. The majority show slight porphyritic tendency, most of the phenocrysts being the ferromagnesian minerals, less often the feldspars.

The lamprophyre dykes have no definite age, they cut all other rocks except that they have not been seen to cut olivine-basalt. The youngest must be at least Miocene in age.

The ore deposits in the district are gold ores and gold-copper ores, the latter being more important.

Note: This report gives no description of ore deposits in relation to lamprophyre dykes.

(1) Camsell, C.: C.G.S. Mem. 26, Geology and Mineral Deposits of the Tulameen District, B.C. (1913).

COQUIHALLA AREA [1]

This is the region immediately to the east of Hope, B.C. There are dykes of diorite porphyry and lamprophyre. Some of the dykes are called lamprophyres because of an abnormally high percentage of dark constituents and alteration products, although the mineral constituents are similar to those of the more plentiful ordinary dykes.

Typically, the lamprophyres intersect Cache Creek rocks in the railway section. There are examples near Jessica. These contain brownish hornblende and oligoclase with magnetite and apatite as prominent accessories.

Gold ores are the most important deposits of the district. Arsenopyrite (with which gold is associated), pyrite, chalcopyrite and pyrrhotite are the ore minerals. There are also some economic deposits of silver, copper and molybdenum.

Note: This report gives no descriptions of ore deposits in relation to lamprophyre dykes.

ALNÖITE DYKE NEAR SEMLIN, ON THOMPSON RIVER [2]

This is an occurrence of alnöite, a rare type of lamprophyre, two miles east of Semlin on the north side of the Thompson River. It is in Nicola volcanics (Jurassic-Triassic) and

(1) Cairnes, C.E.: G.S. Mem. 139, Coquihalla Area, B.C.(1924).
(2) Drysdale, C.W.: C.G.S. Summ. Rept., (1912), Geology of the Thompson River Valley below Kamloops Lake, B.C.

there are no ore deposits nearby.

The alnöite dyke is of Mesozoic or Tertiary age. It is four feet wide. It consists of "....large phenocrysts of biotite, olivine, and augite in a fine grained groundmass of the same minerals. The augite shows zonal structure and the olivine has largely broken down to serpentine. Perovskite is present in small, dusty square outlines and melilite occurs in lath-shaped forms which show obscurely the pegged-in structure. The melilite is partly decomposed to calcite. Magnetite is disseminated in small grains through the groundmass. Feldspar is entirely wanting in the rock."

BRIDGE RIVER DISTRICT

The writer visited the Bridge River district in November, 1947, in order to collect specimens of lamprophyre occurring underground at Bralorne and Pioneer. A description of these lamprophyres and their mode of occurrence is ~~will be~~ given in Appendix B ~~later~~.

Lamprophyre Dykes.

In the literature, McCann,(1) Cairnes,(2) and others refer to the presence of lamprophyre dykes in Bralorne and Pioneer mines but do not give much detail regarding their relation to the ore beyond stating that they are later. Outcrops of spessartite are to be found on the south side of Bridge river

(1) McCann, W.S.: C.G.S. Mem. 130, Geology and Mineral Deposits of the Bridge River Map Area, B.C. (1922).
(2) Cairnes, C.E.: C.G.S. Mem. 213, Geology and Mineral Deposits of the Bridge River Mining Camp, B.C. (1937).

near Rexmount and elsewhere in the valley. In dealing with the Bridge River mining camp in general, Cairnes presents a geological time-table which places the lamprophyre and basaltic dykes in Tertiary time, immediately following intrusives of the Bendor batholith. It is possibly from intrusives related to the Bendor batholith that the ore solutions originated although this is not accepted without question as there is at least one distinct period of pre-Bendor intrusion of which there arerepresentative intrusive bodies in the district from which the ore may have originated. The lamprophyre dykes are, however, together with basaltic dykes, the latest igneous intrusive activity in the area and follow the Bendor intrusive with which the ore solutions are believed to be associated.

Ore.

The important ores of the district are gold-quartz veins belonging to the high-temperature end of the mesothermal group. The quartz is very lightly mineralized with chiefly pyrite and arsenopyrite. Free gold often occurs in the quartz and is later than the sulphides. There is some scheelite at Bralorne and Pioneer.

Bralorne Mine.

Two parallel biotite-lamprophyre dykes, probably minettes, intersect the Empire vein nearly at right angles to it and are later than the ore. Quartz-albitite or aplite dykes are often associated with veins, especially in the King mine, and may be mineralized so that they constitute ore.

Pioneer Mine.

At least two hornblende-lamprophyres, probably vogesites, occur underground and there are three or four other intersections with lamprophyre that probably represent separate dykes. The lamprophyre is all later than the ore.

Note: Detailed field descriptions of the lamprophyres at Bralorne and Pioneer are given elsewhere.

TERRACE AREA (1)

On Thornhill mountain, granodiorite country rock is cut by lamprophyre dykes. These are cut by quartz-orthoclase porphyry dykes which in turn are cut by quartz-diorite dykes. There are two other types of salic dykes, later in age than the lamprophyre. There are an unusually large number of examples of veins following the walls of dykes but these dykes are always quartz-albite or porphyry dykes.

Description of Individual Properties:

On Thornhill Mountain:

La Libertad -

Lamprophyre dykes are older than quartz-diorite dykes and both are older than the quartz. The quartz is barren.

St. Paul and X claims -

Quartz veins occur for 3000 feet along the wall of a

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(1) Kindle, E.D.: C.G.S. Mem. 205, Mineral Resources of Terrace Area, Coast District, B.C. (1937).

quartz-albite dyke. Lamprophyres also occur and these are older than the quartz-albite dyke. The quartz veins carry low gold and silver values and are mineralized with pyrite, chalcopyrite, galena and sphalerite.

Kitsumgallum Lake:

Kalum Lake Mines Ltd. -

Altered diorite dykes were intruded prior to vein formation but the lamprophyre dykes are later than the ore and one is seen cutting the ore. A small diabase dyke cuts the diorite on the Lucy O'Neil claim and forms the hanging-wall of the vein.

The ore consists of quartz, pyrite, chalcopyrite and has gold and silver values. The location is at the contact between the Coast Range diorite and the sediments.

ZYMOETZ RIVER AREA (1) (Terrace Vicinity)

Lamprophyre dykes occur everywhere. Alaskite dykes and sills are as widely distributed and there are also granite, granodiorite, aplite, etc. dykes. The lamprophyres are usually less than four feet wide and appear to be the youngest of the dykes. "...Most of the dykes (of all types) are probably of about the same age as the Coast Range batholith." Most of

(1) Hanson, G.: C.G.S. Summ. Rept. (1925), Reconnaissance in Zymoetz River Area, Coast District, B.C.

the alaskite dykes and sills have quartz veins along both walls; some of these veins contain galena and sphalerite, and others, gold and pyrite.

The area is very well mineralized but the veins are narrow and not sufficiently rich to produce mines. The valuable metals and minerals present are silver, gold, lead, copper and zinc in the east grading to copper and scheelite and molybdenite to the west towards the batholith. No information is given as to the relative amounts of lamprophyre dykes in different parts of the area.

Descriptions of Properties:

Golden Crown Group and Properties of Kleanza Company.[1]

These are on the east side of the Skeena river, three miles below Usk. The country rock is granodiorite which is cut by lamprophyre dykes. The Golden Crown vein consists of quartz sparingly mineralized with pyrite, chalcopyrite and perhaps some arsenopyrite. The main value is in gold.

Terrace Claim.[2]

On the surface a vein is exposed which contains quartz, pyrite, a little galena and sphalerite. A cross-cut 75 feet long driven in below the outcrop found no ore but cut occasional lamprophyre dykes in the granodiorite.

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(1) Hanson, G.: C.G.S. Summ. Rept. (1925), Reconnaissance in Zymoetz River Area, Coast District, B.C.
(2) Kindle, E.D.: C.G.S. Mem. 205, Mineral Resources of Terrace Area, Coast District, B.C. (1937).

Rosie Group.

At foot of West slope of Kleanza Mountain.

The country rock is granodiorite cut by occasional lamprophyre dykes. There is no ore, just altered rock containing pyrite and assaying only a trace in gold.

Columario Consolidated Gold Mines, Ltd. - West slope of Kleanza Mountain.

About 8000 feet of development work was done and a 75-ton mill operated for eight months. The ore consists of quartz veins mineralized with pyrite and gold. Small amounts of chalcopyrite and galena are present in some places.

Country rocks are cut by quartz albite, diorite and lamprophyre dykes.

Cordillera Mine - One mile south-west of Usk.

A number of small lamprophyre dykes intrude the country rocks. The mineralization consists of sparsely distributed bornite and chalcopyrite in quartz veins.

Summary of Terrace Area.

44 properties are described in Memoir 205, of which eight are described as containing lamprophyre dykes.

USK TO CEDARVALE (1)

There are a large number of salic dykes of a great variety described in this area. Examples are andesine-diorite porphyry, albite-quartz diorite and granodiorite dykes. Very many examples are given of ore following acid-porphyry dykes of various types. Lamprophyre dykes are present but are distinctly in the minority.

Lona May claim.

The quartz-albite dyke, which forms one wall of the vein, is altered and cut by a younger lamprophyre dyke. The ore contains a sparse dissemination of pyrite, chalcopyrite, galena, sphalerite and tetrahedrite.

Algoma Group - Two miles east of Pitman flag station.

A pit sunk on a three-foot lamprophyre dyke, which cuts a granodiorite dyke failed to reveal any minerals.

Grotto Group.

A quartz vein occurs along the contact of a 12-foot andesine diorite porphyry dyke in andesite. The quartz is heavily mineralized with pyrite and a little specularite. A two-foot dyke of lamprophyre occurs on the surface 30 feet from the adit but the relation to ore is not known.

Silver Basin Group.

Several small quartz-albite and lamprophyre dykes occur here.

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(1) Kindle, E.D.: C.G.S. Mem. 212, Mineral Resources, Usk to Cedarvale, Coast District, B.C. (1937).

Summary.

39 properties are described of which four had lamprophyres.

HAZELTON-SMITHERS DISTRICT[1]

The Bulkley eruptives, composed of Jurassic-Cretaceous granodiorite, are represented at the Rocher Déboulé and Hudson Bay mountains and the Babine range. The ore occurrences in the region are associated with them. Associated with the Bulkley eruptives also are dykes of granite porphyry and quartz porphyry. A few lamprophyre dykes were also noticed but these are clearly of a later age, perhaps Tertiary, since they are seen to be chilled against quartz porphyry dykes. The mineralization in the Hazelton district seems to be connected with the intrusions of the quartz porphyry dykes.[1]

Descriptions of Properties:

Great Ohio Property.[2]

This property is on Juniper Creek. The veins often follow small dykes of camptonite cutting through them on either wall; and the dykes themselves are somewhat mineralized. The ore is of the fairly high temperature type since the veins contain quartz and actinolite as the chief gangue minerals and the metallic minerals include arsenopyrite, pyrite, pyrrhotite and mercassite. There are also zinc, copper and lead minerals

(1) Malloch, G.S.: C.G.S. Summ. Rept. (1912), The Groundhog Coal Field, B.C., Omineca District.
(2) O'Neill, J.J.: C.G.S. Mem. 110, Preliminary Report on the Economic Geology of Hazelton District, B.C. (1919)

which are younger than those already mentioned. The gangue also includes younger calcite and siderite.

Duthie Mine (1) - Seven and one-half miles west of Smithers.

One diorite dyke, a quartz-albite porphyry dyke and numerous lamprophyre and albite porphyry dykes intrude the volcanic rocks. Most of the lamprophyres are less than ten feet wide but widths up to 35 feet do occur. Nearly all the lamprophyres are almost at right-angles to the veins. There are many narrow lamprophyre dykes underground, intersected by, but sometimes followed by, the vein lodes, the dykes in some cases being fractured like the lode and the fractures, 1/8 inch to two inches wide, being mineralized with sphalerite, galena, tetrahedrite, quartz, carbonate and pyrite. From the descriptions it appears that the dykes are pre-ore. The ore is a silver-lead-zinc ore, containing galena, sphalerite, tetrahedrite, ruby silver, pyrite, arsenopyrite and chalcopyrite.

Rocher Déboulé Mine - On Rocher Déboulé Mt., six miles south of New Hazelton.

Lamprophyre dykes intrude the granodiorite on the Delta property and are older than the deposits.

This is a moderate to high temperature deposit in fissures containing hornblende and actinolite as alteration products and chalcopyrite, magnetite, pyrrhotite, arsenopyrite, pyrite, tetrahedrite, safflorite and molybdenite as vein minerals.

(1) Kindle, E.D.: C.G.S. Mem. 223 (1940), Mineral Resources, Hazelton and Smithers Areas, B.C.

There is also lesser mineralization of a later age which involves mesothermal minerals. Production of gold, silver and copper is recorded.

Silver Creek Group - Eight miles north-west of Smithers.

A granodiorite stock intruding bedded rocks is cut by a lamprophyre dyke 30 feet wide, which has a flat dip. The ore is the limestone replacement type containing pyrrhotite, sphalerite and pyrite.

Glacier Gulch Gold Group - Five miles north-west of Smithers.

The mineralization occurs in tuff in a series of coal-bearing sediments. No intrusive rocks were seen in the immediate vicinity of the mineral deposits. The volcanic rocks at the foot of the glacier are intruded by lamprophyre dykes up to 20 feet wide and joint planes in these dykes contain seams of calcite and molybdenite up to 1/2 inch wide.

The ore minerals are native gold, tetradymite and bismuthinite which replace altered tuffs.

Summary.

52 properties were described by Kindle in Memoir 223, dealing with the Hazelton-Smithers area. In these, there were five references to lamprophyre dykes.

ALICE ARM DISTRICT (1),(2)

Narrow lamprophyre dykes are common in the Alice Arm district. They penetrate Jurassic sediments and are of upper Jurassic age or younger. South of Alice Arm, lamprophyre dykes are rare but dykes and sills of granodiorite and quartz-diorite are plentiful. The mineral production of the district is mainly silver with also a little copper and zinc.

Descriptions of Properties:

Wolf Mine.

This mine is located on the mountain slope north of Alice Arm village. The country rock consists of argillite and quartzite which is intruded by many lamprophyre and diorite dykes. There are three narrow silver-bearing veins and 220 feet of underground development work has been done on the center vein. A narrow lamprophyre dyke less than one foot wide accompanies and intrudes the center vein. In addition, the vein is cut by many lamprophyre dykes one to six feet wide and by a diorite dyke 30 feet wide. Two of the cross-cutting lamprophyre dykes offset the vein several feet.

The ore consists of white quartz in narrow veins which carries sulphides, chiefly in bands, along the foot-wall of the vein. The minerals are pyrite, chalcopyrite, sphalerite, galena, tetrahedrite, ruby silver and native silver.

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(1) Hanson, G.: C.G.S. Summ. Rept. (1923) Part A, Reconnaissance between Skeena River and Stewart, B.C.
(2) Hanson, G.: C.G.S. Summ. Rept. (1928), Mineral Deposits of Alice Arm District, B.C.

Esperanza Mine.

This mine is on the west side of the Kitsault river, one mile from Alice Arm. It has produced ore from stopes. The country rock is argillite intruded by narrow lamprophyre dykes which all strike north-east.

The ore consists of quartz veins which follow the fold axes and contain arsenopyrite, pyrrhotite, pyrite, chalcopyrite, sphalerite, galena, tetrahedrite, ruby silver and native silver. Some scheelite occurs in the ore but there has been no production of tungsten.

LaRose Mine.

This mine is on the east slope of Haystack mountain, on the west side of Kitsault river, eight miles from Alice Arm. Small amounts of ore have been shipped by prospectors.

The ore deposit, which is a vein in a shear zone, is cut by lamprophyre dykes. The minerals are arsenopyrite, pyrite, chalcopyrite, pyrrhotite, sphalerite, galena, tetrahedrite, native silver.

Alice Group and Tiger Group.

Both these properties have lamprophyres.

UPPER KITSAULT VALLEY[1] (Alice Arm District)

The lamprophyre dykes are black and resemble diabase but very few typical diabase dykes are present. No type-names for

(1) Hanson, G.: G.G.S. Summ. Rept. (1921) a, Upper Kitsault Valley.

for the lamprophyre were given but the constituent minerals are oligoclase-andesine laths and well-formed hornblende and augite crystals. Some of the lamrpophyres are cut by mineral veins, others cut the veins but are themselves cut by faults. Others are later than both veins and faults.

The Coast-Range batholith is a few miles to the east.

Descriptions of Properties:

North Star Group.

The country rock is grey breccia. Lamprophyre dykes parallel the vein and in some places form its foot- or hanging-wall. The ore consists of a quartz-pyrite vein which contains the rich silver minerals and barite.

Dolly Varden.

Numerous reverse faults and late normal faults cut up the vein. At the main vein, "...Lamprophyre dykes cut the vein, some of which antedate and some postdate the faults." The mine was a producer. The main vein was traced for 1500 feet and was 8 to 20 feet wide. It is a silver-bearing quartz-pyrite vein essentially, with rare sphalerite, galena, chalcopyrite and tetrahedrite. Quartz is the predominant gangue mineral, with also calcite, barite and jasper in small amounts.

PORTLAND CANAL AREA [1],[2]

The commonest dykes are known as lamprophyre dykes. They are younger than the quartz-diorite dykes and commonly also younger than mineral deposits. Some are very like the felsites of the district and are presumably related to them. Most of the so-called lamprophyres are narrow, dark-colored dykes such as are commonly present along the ast border of the Coast Range batholith and most of them may be related to the Coast Range intrusives. An uncommon type, a minette, occurs in the Silver Chord group. It is two feet wide and contains biotite, orthoclase and albite.[1] Note: There is a variety of silver, copper, lead and zinc ores in the district but the descriptions do not present any relationship of the ore to the lamprophyres.

Narrow, dark lamprophyre dykes are fairly common and are the youngest rocks in the area. Some are older and some younger than the ore deposits with which they are occasionally associated. The ores are veins and replacement deposits containing gold, silver and copper and are of the epithermal type.[2]

PREMIER MINE[3],[4]

Ore.

The deposit is intermediate between epithermal and meso-

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(1) Hanson, G.: C.G.S. Mem. 175, Portland Canal Area, B.C. (1935)
(2) Hanson, G.: C.G.S. Mem. 159, Bear River and Stewart Map Areas, Cassiar District, B.C. (1929).
(3) Langille, E.G.: Some Controls of Ore Deposits at the Premier Mine, Western Miner, June, 1945.
(4) Burton, W.D.: Ore Deposition at Premier Mine, B.C. Economic Geology, Vol. 21, No. 6. (1926)

thermal in type and the ore minerals are primarily pyrite, galena, sphalerite and the rich silver minerals. The most productive ore is that occurring as fairly solid sulphide in replacement type veins ten to 30 feet wide in feldspar porphyry. The feldspar porphyry constitutes a stock of the Coast Range batholith which has been intruded into volcanics of the Jurassic Hazelton group. The ore solutions are believed to have originated from later granodiorite of the Coast Range batholith which intrudes the earlier feldspar porphyry and volcanics.

The Lamprophyre Dykes.

The majority of lamprophyre dykes occurring in the mine are post-mineral but a few are definitely mineralized, so that some, at least, are pre-mineral. The lamprophyre dykes have a fairly constant attitude, generally striking North 60 degrees West and dipping 50 degrees south-easterly and appear to be the result of a period of north-west fracturing at the closing stages of the emplacement of the Coast Range batholith. The lamprophyre dykes are related to a north-west set of shear zones in which much of the ore occurs since they both have the same general strike and dip.

The close time relation that some of the lamprophyre dykes have to the ore is illustrated by some observations by Burton[1] who states that"...some earlier dykes intersect the min-

(1) Op. cit. p 587

eralized zone in a number of places and are slightly mineralized near the edges as well as showing similar alteration effects to those induced in the porphyry and greenstone as a result of the action of mineralizing solutions." Burton states further that hypogene mineralization commonly spreads out on the hanging-wall and foot-wall of the cross-cutting dykes. It appears then, that some of the lamprophyre dykes are later than the main part of the mineralization period since they cut across the ore zone but that continuing circulation of solutions in the ore zone have mineralized the solidified dykes. This is good evidence that the intrusion of some of the lamprophyre dykes is nearly contemporaneous with the formation of ore.

It has also been observed (1) that some post-ore dykes delimit silver and gold values in the vein. The vein may continue on the other side of the cross-cutting dyke with the same structure and, megascopically, the same mineralogy that it had before encountering the dyke, but with the silver and gold values reduced very considerably. Similar phenomena have been described at Rossland (2) where they were attributed to intrusion of the dyke after vein formation but prior to the later mineralization which formed the gold.

Other Dykes Present.

Aplite and coarse-grained diorite dykes also occupy the

(1) Dr. W.H. White: ~~Personal~~ Oral Communication.
(2) Drysdale, C.W.: C.G.S. Mem. 77. (1915), Rossland, B.C.

north-east fractures. The lamprophyre dykes cut the diorite type, indicating their relative ages. Furthermore, the diorite dykes occurring within the batholithic rocks tend to merge with the host rock whereas the lamprophyres, in the same environment, present distinct, extremely fine-grained, chilled edges showing that the host rock was comparatively cool at the time it was intruded by the lamprophyre dykes. "It would seem, therefore, that the lamprophyre dykes and the contemporaneous Premier mineralizing period or periods were very late phases of batholithic action. Although the lamprophyre dykes do not appear to exert a direct control on Premier ore-bodies, it is not surprising that, considering their similarity in age, origin and attitude, with the mineralized north-west shear zones, they are often associated with ore-bodies."[1]

TAKU RIVER AREA[2]

The only occurrence of lamprophyre described is that at the Manville ore-body, where basic dykes of lamprophyre type cut both the rhyolite and the andesite and are the youngest rocks of the series. The only effect they seem to have on the ore-bodies is to cause their shattering and impoverishment with included dyke rock in the areas of intersection.

The ore is probably a medium to low temperature type of deposit formed at appreciable depth. Zinc blende, chalcopyrite,

(1) Langille, E.G.: Some Controls of Ore Deposits at the Premier Mine, Western Miner, June, 1945.
(2) Mandy, J.T.: B.C. Dept. of Mines, Bull. No 1, 1930, Report on the Taku River Area, Atlin Mining Division.

and pyrite with minor quantities of galena occur in very fine-grained texture. A decided banding is characteristic of these ore bodies.(1)

ATLIN DISTRICT(2)

Only one lamprophyre occurrence is described. This is on Mt. Clive, on the west side of Taku Arm, just north of Graham Inlet. No ore deposit is related to it and the nearest deposits to it, referred to in this memoir, are seven miles away.

"In places, as on the north-eastern corner of Mt. Clive, basic differentiation products of the grano-diorite occur as dykes cutting the granodiorite and the surrounding Laberge beds." One such dyke on microscopic examination was described as a hornblende kersantite, a typical hypidiomorphic dyke rock consisting mainly of plagioclase, biotite and hornblende. The plagioclase occurs in long, lath-like, allotriomorphic or hypidiomorphic forms. Biotite and hornblende occur as allotriomorphic particles scattered between the feldspars which form a sort of web or base containing them.(2)

The descriptions of the mining properties, including the Engineer mine do not mention lamprophyres. There is one example of silver ore composed of mineralized diabase dyke.

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(1) Op. cit. p. 15.
(2) Cairnes, D.D.: C.G.S. Mem. 38, Portions of the Atlin District, B.C. (1913)

NO. 8 OREBODIES, BRITANNIA MINES[1]

The dykes present in No.8 orebody are:

1. Andesite dykes. These cut the ore but some are mineralized.
2. Felsite porphyry dykes. These are probably later than the mineralization.
3. Lamprophyric dykes.

There are a number of narrow lamprophyric dykes which strike north-west and dip steeply to the west. They cut both the andesite and the felsite dykes and are later than all of the mineralization.

Note: During a visit to Britannia in 1947, Dr. Gunning collected specimens of dykes indicated to him as being the lamprophyric dykes described by Irvine. Thin sections of these specimens have been examined. The rocks do not appear to be lamprophyric but, instead, are fine-grained, amygdaloidal, andesitic rocks containing andesine laths,).1 mm. long, as the largest-grained and most plentiful constituent, together with augite, minor amounts of quartz and accessory magnetite.

As Mr. Irvine was not present at the time of Dr. Gunning's visit, there is a possibility that those present at the mine then were not familiar with the correct location of the lamprophyric dykes which Mr. Irvine describeds and that the wrong

(1) Irvine, W.T.: Geology and Development of the No.8 Orebodies, Britannia Mines, B.C., C.I.M.M. Bulletin, 1946.

dykes were pointed out to Dr. Gunning.

B.C. COAST AND ISLANDS BETWEEN THE STRAIT OF GEORGIA AND QUEEN CHARLOTTE SOUND (1)

There are dykes of aplite, pegmatite, granophyre and felsite in the area. Also, there is a vast number of dark dykes whose intrusion marked the close of igneous activity in the district. They cut the ore-bodies and although they have a thin selvage of pyrite, they played a subordinate part, if any, in mineralization. They are lamprophyric in appearance (greyish-green to black), yet plagioclase enters into their composition to a greater extent than in those dykes to which Rosenbusch applies the term "lamprophyre". The phenocrysts are usually plagioclase, less frequently orthoclase, hornblende or augite. Biotite is very rare. These rocks might be called diabases and diorite porphyrite.

(1) Bancroft, J.A.: C.G.S. Mem. 23, Geology of the Coast and Islands between the Strait of Georgia and Queen Charlotte Sound, B.C. (1913).

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APPENDIX B

MEGASCOPIC, PETROGRAPHIC AND FIELD-RELATION DESCRIPTIONS OF THE DYKES STUDIED

TABLE OF CONTENTS

REEVES-MCDONALD MINE

DYKE ±100' FROM PORTAL OF "RIVER ADIT"

- unmineralized -

Megascopic Description

This specimen consists of fine-grained, black-coloured, fresh-appearing rock which contains glistening biotite phenocrysts and oval pseudomorphs after olivine. Pseudomorphs after olivine have a maximum length of 1/5 inch, but most are 2 mm. long or less. Inclusions, up to two inches in diameter, of both quartz and a fine-grained, siliceous rock are contained in the lamprophyre.

Thin Section No. 1.

The approximate mineralogical composition of this rock prior to alteration was:

Olivine..................	35 %
Biotite..................	30 %
Diopside.................	2 %
Andesine.................	20 %
Alkali Feldspar.........	1 %
Quartz...................	10 %

with accessory apatite and opaque mineral. Alteration has been extensive, olivine undergoing 50 to 100% change and andesine 15-30%.

The texture is porphyritic, with olivine and biotite phenocrysts occurring in a groundmass composed mainly of andesine.

Lesser amounts of alkaline feldspar, interstitial quartz, diopside, apatite and opaque mineral are also present in the groundmass.

<u>Olivine</u> -

The most striking feature of the rock is the presence of large phenocrysts of olivine and pseudomorphs derived from olivine (Plates 1 and 2). They are the largest grains in the slide, being up to two mm. long and they show remarkable alteration effects. Unaltered, fractured olivine remains in the center of the pseudomorph, with its borders roughly parallel to the original outline of the phenocryst, surrounded by two distinct, concentric zones of alteration products. The outer zone, much the larger of the two, consists of a brownish-black pulverulent mass which is white in reflected light. Although individual grains in the mass are too small to be distinguished, the material appears to have a high birefringence and the refractive index as obtained by the use of immersion oils is between 1.58 and 1.59. The mass shows a faint concentric banding which is due to four or five repetitions of alternating dark and light colored layers. Fine secondary magnetite particles are disseminated near both the inner and outer edge of this zone. It is possible that the material in this outer zone is a carbonate, the lack of a great range in its measured indices being perhaps due to the extremely fine-grained aggregate nature of the material.

The outer zone grades rapidly into the colorless, low-relief material of the inner zone which has a sharp, smooth contact with olivine. The mineral of the inner zone is colorless antigorite which under crossed nicols shows a fibrous structure, birefringence up to firt order yellow, and parallel extinction. It is biaxial negative with 2 V varying from 30 degrees to 50 degrees. Its index of refraction as determined with immersion oils is between 1.55 and 1.56.

Olivine in this lamprophyre has a negative optic sign and a large 2 V, between 85 degrees and 90 degrees. The negative sign indicates that the olivine is a ferriferous variety.

Biotite -

Biotite occurs predominantly as phenocrysts which are up to two mm. long but approximately 20 percent of it is in the form of smaller grains around 0.3 mm. in size. All the biotite grains, both large and small, are well-formed, although their borders are often irregularly penetrated by blebs of mixed calcite and chlorite, giving them a corroded appearance. It is possible that some of this calcite developed through alteration of small augite grains which frequently occur enclosed partially or wholly by biotite. There is a fairly well-developed splitting of biotite plates along cleavage planes with a development of elongated calcite bodies in the cracks.

Biotite is brown and the laths always have narrow, dark-brown borders and relatively light brown interiors.

Andesine -

Andesine occurs in fairly large grains which average 0.2

mm. in length. The crystals are fairly zoned and twinning after the albite law is present to a small degree. Andesine is about 50 percent altered. The alteration products are:

1. calcite in the form of large, pure grains.
2. calcite, clay-mineral and possibly chlorite intimately mixed together.
3. clay-mineral alteration in the form of dust-like patches on the surface of the andesine.

<u>Alkali Feldspar</u> -

There are a few small grains of a feldspar which has an index definitely lower than balsam. The grains are too small to give a satisfactory figure.

<u>Quartz</u> -

Quartz occurs as clear grains, generally between 0.1 and 0.3 mm. in dimension, which take their angular shape from the feldspar grains between which they have grown.

<u>Diopside</u> -

A colorless pyroxene resembling diopside is scattered in the groundmass in the form of small, rectangular prism and four or eight-sided cross-sections. Very frequently, small diopside grains are crowded together, around and in contact with olivine pseudomorphs. Deopside is frequently darkened by incipient alteration.

<u>Apatite</u> -

Well formed, large apatite grains up to 0.2 mm. long are plentiful. A few grains are 0.6 mm. long.

Opaque Mineral -

Angular grains of a mineral which is black and opaque in transmitted light are scattered sparsely through the rock. In reflected light they are almost black in color but have a faint bronze tint.

DYKE 4100' FROM PORTAL OF RIVER ADIT
- with adhering granitic inclusion -

Thin Sections Nos. 3 and 4.

Another specimen of the lamprophyre dyke 4100 feet from the portal was examined in which a portion of a granitic inclusion several inches in diameter is adhering to the lamprophyre. This specimen was taken from a location in the dyke only a few feet away from that of the specimen studied in thin section No. 1. Therefore, the lamprophyre is almost identical in the two specimens but there are some slight differences which perhaps are due to some extent to the presence of the granitic inclusion. These differences will be described below.

Alteration of Olivine.

Pseudomorphs after olivine are of the same large size as in Section 1 but the alteration is different. In section 3, no residual olivine remains and although the two distinct outer zones of antigorite and carbonate(?) are present, they are in much smaller amount. The interior area surrounded by the two rims contains a talc-like material in two of the pseudomorphs, whereas the remaining pseudomorphs contain a different material.

The talc-like mineral has the following properties in thin section. It is nearly colorless but has a slight greenish-grey tinge, its relief is low to fair and varies distinctly as the stage is rotated. The structure is fibrous but the fibers are sufficiently broad to give interference figures which are negative and either uniaxial or biaxial with 2 V very close to zero. The fibers have parallel extinction and are length slow. The maximum birefringence is 0.035. These properties agree with talc except for the slight color and variable relief.

The unknown mineral more commonly occurring in the central portion of pseudomorphs is colorless, has a very low relief which does not vary appreciably on rotation and an index greater than balsam. The structure is also fibrous but the fibers are very fine and no interference figure was obtained. The fibers have parallel extinction and are length fast. The maximum birefringence is 0.03.

In thin section No. 4 of the same rock specimen, considerable residual olivine does remain, the two outer concentric zones of antigorite and carbonate(?) are present to a small degree and there are also the two products, talc(?) and the unknown, described in section 3 but they are not so plentiful as they were in section 3.

Biotite.-

In both sections 3 and 4, the biotite shows beginning stages of chloritization. Green borders on the biotite grains are well developed and this effect is most pronounced near the contact with the granitic inclusion. Chloritization of the biotite in thin section 1 was almost entirely lacking.

REEVES-MACDONALD MINE

DYKE 3000'FROM PORTAL OF RIVER ADIT

- mineralized -

In the hand specimen, this rock is very similar to that of the dyke 4100' from the portal, (described above) except that it has a greyish-green color and contains black rather than grey-colored pseudomorphs after olivine. These differences are due to alteration of the dyke by mineralizing solutions which also deposited grains of metallic minerals, barely visible to the naked eye, in the groundmass of the rock.

Thin Section No.2.

Polished Section No.2(a).

This lamprophyre dyke has been mineralized with pyrite and galena. In thin section No. 2, its composition is:

Talc-Hematite Pseudomorphs............	30 %
Biotite................................	15 %
Carbonate..............................	40 %
Feldspar...............................	5 %
Quartz.................................	2 %
Sulphides..............................	3 %
Apatite	accessory
Magnetite.......................	accessory

The original olivine has been completely altered and the original feldspar almost completely altered.

The rock seems to be similar to that of "River Adit 4100' from portal" except that:

1. diopside is absent
2. apatite is more plentiful
3. biotite is bleached and chloritized slightly and has a greater development of calcite along cleavage planes.
4. alteration of the groundmass to carbonate is much more complete.
5. sulphides have been introduced.

Talc-Hematite Pseudomorphs -

The pseudomorphs, 1 to 2 mm. in size, have a roughly oval shape similar to that of the large olivine phenocrysts in the lamprophyre 4100' from the portal. No residual olivine remains, the transformation to talc and hematite has been complete and none of the alteration products are present which were found in the altered olivine of the dyke 4100' from the portal.

The talc is colorless and occurs in broad fibers which have parallel extinction and are length slow. 2 V is 20 degrees and the optic sign is negative. The maximum birefringence is 0.04 and the indices as determined by the use of immersion oils are $N_p = 1.55$, $N_g = 1.58$. This small range for the indices is probably due to the constant orientation of cleavage flakes in the immersion oils.

The pseudomorphs have a distinctive appearance in hand specimen and on polished surfaces. They have a dark red color which is especially noticeable in polished section under indirect reflected light. This color is due to the very fine grains of a metallic mineral, apparently hematite, which are bright red in indirectly reflected light and occur in the talc with an arrangement suggesting "mesh-structure". Most of the hematite grains are opaque in transmitted light but a few of the thinnest grains are translucent and red in transmitted light. Associated with the hematite are a few magnetite grains.

Grains of pyrite and galena such as occur abundantly in the groundmass of the rock are extremely rare in the pseudomorphs.

Biotite -

Biotite has a pale, bleached-brown color and about 20 percent of the grains have a green color and lowered birefringence indicating a transformation to chlorite. There is splitting and calcite growth along the cleavage to a greater degree than in the 4100' lamprophyre, some of the grains being split into separated shreds.

Carbonate -

Carbonate is very plentiful and is the largest component of the groundmass. It is, no doubt, in part derived from the late-magmatic alteration of feldspar. However, as the carbonate is so much more extensive than is usually the case, it is most probable that a large proportion is due to carbonatization by mineralizing solutions. Feldspar was the mineral most affected by this metasomatism.

Carbonate contains intermixed clay mineral, apatite, quartz and residual feldspar. In addition, the sulphide grains which apparently have been introduced by mineralizing solutions, are closely associated with the carbonate and most often occur between the carbonate and residual feldspar or quartz grains.

<u>Clay Mineral</u> -

There are, among the calcite grains, fine-grained masses of clay mineral which are brownish by transmitted light and white by reflected light.

<u>Feldspar</u> -

Very little feldspar is left and it is much clouded by alteration. No twinning could be seen although there were shadowy suggestions of it. The refractive index appears to be greater than balsam but this too is in doubt. One interference figure with 2 V = 90° was obtained.

<u>Quartz</u> -

A few grains of quartz are scattered in the matrix. The grains are fresh but contain small inclusions which have been altered.

<u>Apatite</u> -

Unaltered, euhedral apatite grains are extremely plentiful.

<u>Magnetite</u> -

Very few small grains of accessory magnetite occur in the groundmass.

<u>Sulphides</u> -

The metallic mineralization of the lamprophyre consists primarily of a scattering of pyrite and galena grains in the carbonatized groundmass. Very rarely do sulphides occur in the pseudomorphs after olivine. The two sulphides are in the approximate ratio of two pyrite to one galena and together comprise about three percent of the rock. In size, the grains are .05 mm. on the average but a few grains are up to 0.5 mm. in maximum dimension.

Occasionally pyrite and galena are in close association with each other, one mineral enclosing the other, or a grain of galena may occur in contact with and have a smoothly curved contact against a grain of pyrite. In the majority of cases, however, individual pyrite and galena grains occur independently of each other, being widely separated from mutual contact by the carbonate-feldspar-quartz groundmass in which most of them occur.

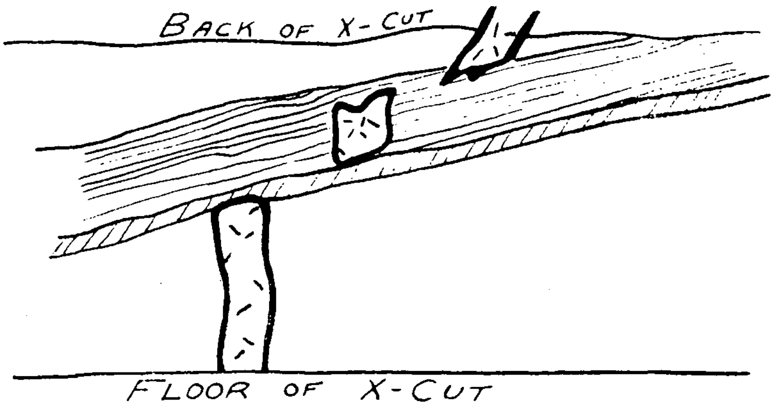
It is difficult to judge from the appearance of the sulphide grains whether or not they were formed by replacement of rock minerals, nor is there any concentration of sulphides along fractures or towards any particular portion of the slide. The quite uniform dissemination of the sulphides in the groundmass is not unlike that of original opaque mineral grains crystallizing directly from the rock magma. However, no euhedral grains were seen as would be expected in crystallization from a magma; the grains are generally irregularly rounded and quite commonly send out curved, tapering tongues into the enclosing material.

Usually, the sulphide grains are found between areas of carbonate on one side and a relic of feldspar on the other side. Sometimes the sulphide also projects into biotite grains and, in one case, pyrite cut right through a biotite grain in a direction perpendicular to the biotite cleavage. There is, however, no replacement of biotite along the cleavage or around the edges of the grain as is the case in the mineralized lamprophyre from the Sullivan mine.

The most probable interpretation of the occurrence of sulphides in this lamprophyre is that the whole dyke mass was soaked with mineralizing solutions, causing the extreme alteration of the olivine, carbonatization of the groundmass, chloritization of the biotite and deposition of the sulphides.

SULLIVAN MINE

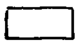
3904 Crosscut, South Wall
(Δ6 + 13')

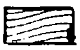


Scale: 1" = 6'

Looking South

KEY


Argillite and siltstone beds


"Low-grade" rock - bedding diagrammatic


Galena, along bedding slip-plane?


Minette

Note: The 18-inch rectangular column of minette, shown completely enclosed by mineralized rock, appears in the same position on the opposite side of the crosscut and has the same size there.

— After diagram by Dr H.C Gunning

SULLIVAN MINE

DYKE 3904 CROSSCUT, SOUTH WALL

- in contact with "low-grade" ore -

Thin Section No. S.35.

The Relation Between the Lamprophyre and the Ore.

This specimen from the Sullivan mine is of biotite lamprophyre to which a piece of banded "low-grade" sulphide ore is firmly attached (Plate 3). The lamprophyre dyke is later than the ore as is attested by its quarter-inch chilled border against the ore and by the flow- and eddy-lines traced in the lamprophyre by biotite and sulphide grains. It is even possible to deduce the direction in which the lamprophyre fluid travelled by observing the ripple-mark-like eddies produced in the lamprophyre by promontories and embayments of the ore surface.

There is some increase in the sulphide content of the lamprophyre at the contact but this added material occurs as fine (.04 mm.) pyrrhotite particles arranged in streamer-like bands which lie parallel to the contact. Such an appearance does not suggest impregnation of the solidified lamprophyre by sulphides from the ore solutions but rather suggests that the particles had disintegrated and been plucked from the solid ore by moving lamprophyric fluid. Another feature which indicates that the ore is pre-dyke is the apparent absence of any replacement of lamprophyre by ore minerals. There is no embayment and no veining of the dyke by ore, the pronounced sedimentary banding in the ore continues.without deviation right up to the contact where it suddenly stops. It is possible however, if one wishes to postulate a post-dyke age for the ore, that the ore solutions replaced the host rock constituents but were in equilibrium with the minerals of the lamprophyre at the conditions obtaining during ore formation. It is more likely, though, in the light of all the evidence, that the lamprophyre is post-ore.

Description of the Ore

The ore of this specimen is composed mainly of sulphides (70 percent). The sulphides are pyrrhotite, sphalerite and a little galena, with quartz, feldspar and biotite as the chief gangue minerals together with minor amounts of amphibole and chlorite. The ore is strongly banded, a result of preferential replacement along bedding planes of the sedimentary host rock. There is a large amount of calcite in the ore adjacent to the contact, whereas there is very little or no calcite in the ore elsewhere and no comparable amounts of calcite in the lamprophyre. The presence of this calcite may be due to either the metasomatic effects of emanations from the fluid lamprophyre or to solutions of another origin travelling along the contact.

Description of the Lamprophyre

The lamprophyre itself is unique among the specimens so far studied in that it is so largely composed of biotite with almost negligible amounts of cryptocrystalline, colorless base.

Its composition is:

Phenocrysts	
Biotite	7 %
"Amphibole Aggregations"	10 %
Groundmass	
Biotite	80 %
Colorless Base	2 %
Apatite	accessory
Pyrrhotite	accessory

Biotite, euhedral both in phenocrysts and in the groundmass, is very bleached, pleochroic from straw-yellow to colorless and has dark rims. It has not been chloritized. The phenocrysts are up to 0.6 mm. long but there are all gradations from this size down to cryptocrystalline.

There are only three areas, all except one being at the contact, in which could be detected material which might contain feldspar. This material is colorless, shows no discernible graining but gives spherulitic effects under crossed-nicols.

The only other major element in the lamprophyre consists of aggregates, of various minerals grouped together in masses which are variously tabular, rhombic, hexagonal or partly rounded in shape and up to 2 mm. in size. Some of these contain a dozen or more colorless amphibole grains but the majority have varying amounts of calcite, chlorite, quartz, biotite and pyrrhotite as well. The chlorite, and possibly the calcite, are derived from amphibole by alteration. The quartz occurrences are rare and the origin of the quartz is in doubt. These aggregations may be altered inclusions of country rock picked up by the lamprophyric fluid.

The amphibole grains have characteristic diamond-shaped cross-sections and cleavage. They are colorless but very faintly pleochroic to a feeble yellow color. The amphibole is optically negative, has 2 V = 85°, maximum extinction angle of 22 degrees and upper first-order interference colors. There appears to be no colorless amphibole individuals in the groundmass, they all occur in the aggregations.

Chlorite, which is after amphibole, is colorless but very faintly pleochroic and has anomalous brown and blue interference colors.

Pyrrhotite, where it occurs in the aggregates (Plate 3), has a long, ramifying, blade-like habit which may be due to crystallization between angular grains of an earlier age or the pyrrhotite may be pseudomorphic after replaced amphibole or biotite crystals. Pyrrhotite in the groundmass of the lamprophyre is very sparsely distributed as 0.04 mm. grains. No magnetite was seen.

Apatite is plentiful in the groundmass.

DYKE, 3904 CROSSCUT

- contains inclusions of "low-grade" ore
and is mineralized -

Thin Section S.36.

Polished Section S 36.

In this specimen, biotite lamprophyre contains three-quarter-inch inclusions of "low-grade" sulphide ore and, in addition, appears to be itself mineralized by galena-rich ore of an age later than that of the lamprophyre.

Description of the Lamprophyre.

The description of the lamprophyre of specimen S 35 applies equally well to the rock of this specimen with the exception that the sulphide contained in the calcite-quartz-chlorite aggregates is pyrite instead of pyrrhotite. In addition, a few small galena grains are associated with the pyrite. The "aggregations" have the same size (0.3 mm. to 2 mm.) as those in the previous specimen and as before are distributed irregularly through the section. No amphibole was observed in them in this case but some chlorite is pseudomorphic after amphibole and indicates that amphibole was originally present.

"Low-Grade" Ore Inclusions.

In addition to the small aggregations described above, there are large (½ - 2 inch diameter) inclusions of ore. These consist of sulphides primarily (70 percent), but contain also calcite, tremolite, chlorite and quartz in that order of abundance. The sulphide is mostly pyrite and sphalerite but smaller amounts of galena are also present. No pyrrhotite was seen. Rough banding due to the replacement of sedimentary beds is discernible in the inclusions. The presence of these inclusions in the lamprophyre is proof that the lamprophyre is younger than the "low-grade" ore.

Judging from the similarities in the non-metallic minerals occurring in both the large ore inclusions and in the smaller aggregations, the two might be of the same origin. But the metallic minerals present are different and their crystal form is different. In the large ore inclusions, pyrite, sphalerite and galena are present whereas the small aggregations contain only pyrite and sometimes a few specks of galena. Also, the pyrite in the aggregations is crystallized in long, narrow blade-like forms totally unlike the normal cubic habit prevalent in the ore inclusions. It is possible that the small aggregations, as suggested for specimen S 35, are inclusions of mineralized country rock which were picked up by the lamprophyric fluid.

The "High-Grade" Ore Band.

The feature of the specimen which arouses special interest is the presence of a thin coating of "rich" ore along one side of the lamprophyre. This layer is 1/16 inch or less in thickness and consists primarily of galena. There are also smaller amounts of sphalerite and pyrite with the galena. This is the only place in the specimen in which galena is more plentiful than the other two sulphides. The gangue minerals present are colorless chlorite, carbonate, quartz and very little biotite. The proportion of gangue in the ore is considerably higher than it is in the "low-grade" ore inclusions since the percentage of sulphides present is less than 40 percent. The sulphides are not crystallized in such a massive form as they are in the inclusions, the galena particularly occurring in fine grains of irregularly rounded, sometimes twisted habit.

Description of the Contact Zone.

At the contact with the "high-grade" ore, the lamprophyre appears to have flow structure parallel to the contact. It is, however, imperfectly developed, the biotite phenocrysts showing some tendency to be parallel to the contact but the problem being somewhat confused in the thin section by the fact that the contact is sharply bent with the result that some biotite laths do not fall into line. However, it seems fairly clear in the polished section that there is lineation parallel to the contact. A chilled margin against the ore is not evident in this specimen.

The galena mineralization seems to be post-lamprophyre. In the polished section, there is a tapering tongue of galena 1/8 inch in length which projects into the lamprophyre near one of the "low-grade" inclusions. This seems to be very good evidence that the galena is later in origin than the lamprophyre. Another phenomenon, which can be observed in both the thin section and the polished-section, is the presence of small galena and some pyrite grains in the lamprophyre which are definitely confined to a narrow zone along the contact. This zone is one-quarter inch thick and although it is somewhat lighter in color, it is recognizably lamprophyre due to the presence of brown biotite laths. The galena grains are generally less than .02 mm. in size and very irregularly rounded in shape.

On studying the galena grains in thin section it can be seen that they do not replace biotite crystals to any extent. Three or four instances were seen, however, in which narrow galena bands are localized along the edges of biotite grains. This type of occurrence suggests that the contact between the biotite crystal and the fine groundmass was a focus for the deposition of galena. The galena also appears to cut into the biotite to a slight extent. One example was seen of a different relation between biotite and galena in which a narrow, transverse crack in the biotite was filled with galena. Replacement of biotite along cleavage planes was not seen.

Practically all the galena (and the small amount of pyrite associated with it) occurs in the extremely fine-grained groundmass of the lamprophyre.

It does not seem feasible to explain the presence of galena grains in the lamprophyre by assuming a mechanical process of plucking of galena from the solidified ore by supposedly younger lamprophyre. If this had occured, the galena grains should be more angular than they are, and in addition should be accompanied by sphalerite and pyrite, both of which are plentiful in the adhering band of ore. In this connection, it is extremely important to note that the galena in the ore band itself has a replacement relation to the chlorite and biotite of the ore and also, but less conclusively, to the pyrite and sphalerite of the ore.

The above observations lead one to the fairly certain conclusion that the thin ore band had solidified prior to the intrusion of the lamprophyre but contained only pyrite and sphalerite at that time. At a subsequent stage, after the lamprophyre had solidified, galena mineralization took place, causing the replacement of previously formed minerals of the ore band by galena and an introduction of galena into the lamprophyre in a thin zone along the contact.

The presence of galena in the low-grade inclusions must be explained by postulating a small amount of galena mineralization before the introduction of the lamprophyre. It is to be noted here that there is very much more galena in the "low-grade" inclusion nearest to the "high-grade" ore band than in those farther away from the contact. With the polished section microscope, this galena can be seen to replace pyrite of the inclusion.

ROSSLAND DISTRICT - MAYFLOWER MINE

MAIN LEVEL

Thin Section No. M34 - contact against ore.

Polished Section M34 - lamprophyre at contact.

Thin Section No. M35 - middle of dyke.

Polished Section M36 - the ore at contact.

INTRODUCTION.

A study was made of specimens from a lamprophyre dyke which cuts and is chilled against heavy sulphide ore. The lamprophyre, a black, fresh-appearing kersantite, with biotite phenocrysts, appears to have been mineralized along its contact with the ore.

Microscopically, the lamprophyre in the middle of the dyke is seen to contain phenocrysts of biotite and diopside, about 0.6 mm. long, in a holocrystalline, equigranular groundmass composed primarily of euhedral feldspar and biotite. The grain-size of the groundmass in the middle of the dyke averages 0.15 mm. but at the dyke's edge the grain is much finer and occasionally the feldspar is cryptocrystalline and spherulitic.

Description of the Lamprophyre (Thin Sections Nos. M34 and M35)

The composition of unmineralized lamprophyre is as follows:

Phenocrysts

Diopside................25 % (50 percent altered to uralite, biotite, chlorite)

Phenocrysts (cont'd)

Biotite................	20 %

Groundmass

Feldspar...............	30 %	(majority is plagio-clase)
Biotite................	15 %	
Quartz.................	5 %	
Calcite................	5 %	
Magnetite..........	accessory	

Diopside.-

Diopside occurs as phenocrysts which commonly are in the form of rectangular longitudinal sections and eight-sided cross-sections. It is colorless, and non-pleochroic with a maximum extinction angle of 43 degrees. At the center of the dyke, diopside is 50 percent altered, primarily to a green, pleochroic, non-fibrous uralite which commenced to grow at the edges of diopside grains, spread toward the interior and formed in parallel position on the diopside. There also appears to be some alteration of another kind, to biotite, chlorite and a little calcite, since pseudomorphs after pyroxene contain minute shreds of biotite surrounded by chlorite. At the contact with ore, where the alteration of pyroxene is almost complete, there are pseudomorphs after diopside which contain pennine, quartz, a pulverulent white material, pyrite and very little residual pyroxene, all of which are intimately mixed together.

Biotite -

At the center of the dyke, biotite of both phenocrysts and groundmass is uniformly dark brown in color and strongly pleochroic from very dark brown to grey, but near the contact with ore, it is bleached to a brownish-grey color and is highly chloritized.

Feldspar -

The majority of the feldspar grains are twinned and the maximum extinction angle of 23 degrees indicates an andesine compositon for the plagioclase. It is but slightly zoned. Both at the middle of the dyke and at the contact, there is moderate alteration to both calcite and pulverulent clay material.

Quartz -

Clear quartz grains are interstitial to and have been formed later than the feldspar and biotite of the groundmass.

Calcite -

Calcite occurs both as large (0.2 mm.), pure grains which in some cases seem to have replaced entire feldspar grains, and as small, contorted grains inside plagioclase crystals.

Opaque Minerals -

At the dyke center, nearly all the opaque grains are magnetite although there are a few pyrite grains.

Description of the Ore - Polished Section No. M36.

The ore in contact with the lamprophyre consists primarily of massive sulphides with possibly 20 percent of gangue. The most plentiful sulphides are pyrrhotite, arsenopyrite and chalcopyrite, each amounting to approximately 20 percent of the ore. In addition, lesser amounts of pyrite and sphalerite are present, each composing about five percent of the ore. A few grains of galena are also present.

There is a rough banding of the sulphides parallel to the contact with lamprophyre. This banding results from the localization of chalcopyrite in a zone parallel to and immediately adjacent to the contact, the pyrrhotite and arsenopyrite, meanwhile being confined to the interior of the ore specimen. The minor amounts of pyrite, sphalerite and galena which occur in the ore, are in the chalcopyrite zone. Towards the interior of the ore specimen, the only sulphides present in appreciable amount are pyrrhotite and arsenopyrite. This zoning of the sulphides in the ore appears to have some significance in the light of the fact that, as will be seen later, the only sulphides occurring in the lamprophyre are those of the chalcopyrite zone.

Description of the Mineralized Lamprophyre near the Contact with Ore.

Thin Section No. M34.

Polished Section No. M34.

The piece of massive sulphide ore originally in contact with the lamprophyre in the specimen has been separated from the lamprophyre and the contact is seen to be a slightly convoluted surface with a somewhat polished appearance due to the presence of calcite and probably chlorite along the contact plane.

The following description is best illustrated by polished section No. M34. This section shows the lamprophyre for a distance of one and one-half inches in from the contact. Biotite phenocrysts have a rough orientation parallel to the contact and this is probably well enough developed to constitute evidence of flow banding. In addition, there is a quarter-inch wide, darkened zone at the contact, followed by a quarter-inch wide, lighter-colored zone which separates the dark zone from the dark-green main mass of the lamprophyre. As far as can be seen in the polished section, the grain size of the lamprophyre does not diminish appreciably towards the contact. The grain size at the middle of the dyke, however, is greater than that at the contact, as can be seen by a comparison of thin sections M34 and M35.

The alteration of the lamprophyre at the contact consists largely of chloritization which can be seen to have especially affected biotite. There is also a considerable darkening of the slide by dust-like black material which is not white in reflected light. Carbonatization is nearly absent.

The lamprophyre definitely appears to be mineralized as there are grains of chalcopyrite, sphalerite and galena in the rock which are most plentiful at the contact but which persist in diminishing quantity for a distance of one and one-half inches away from the contact. This distance is the total thickness of the specimen available so it is likely that sulphide grains occur even farther from the contact. They are not, however, present in the specimen from the dyke center.

Two large grains, one of chalcopyrite and the other of sphalerite, occur in the lamprophyre right at the contact (see polished section M34). They are one-eighth of an inch long and are much elongated parallel to the contact. The appearance of the chalcopyrite grain suggests that it is a tongue-like intrusive of the sulphide into the lamprophyre, making a flat angle with the contact. To support this conception is the fact that a thin separation, apparently of lamprophyre, exists between the chalcopyrite and the actual contact plane.

Lesser amounts of galena and pyrite also occur in the two large grains in association with the chalcopyrite and sphalerite. In addition, smaller grains of all these sulphides are disseminated in the lamprophyre. Pyrite, chalcopyrite, sphalerite and galena is probably the order of their abundance, pyrite having the most widespread and uniform distribution. The grains are irregular in shape but are usually rounded and average .05 mm. in size.

The disseminated sulphide grains, as seen in thin section, do not replace any original mineral of the lamprophyre but rather occur in the fine-grained, altered groundmass. In some cases, sulphide grains are partially surrounded by a very small amount of quartz but more commonly there is no associated quartz and the sulphide is surrounded by indefinite, chloritized material. This manner of occurrence may suggest a primary, magmatic origin in the case of pyrite grains and it may well be that some of the pyrite is due to its crystallization as an original component of the lamprophyre. However, pyrite is more plentiful near the contact than in the specimen from the dyke center, an indication that some of the pyrite was introduced from outisde the lamprophyre. Furthermore, the appearance of the chalcopyrite, sphalerite and galena grains in polished section, in which the three minerals are intergrown, very much resembles sulphide occurrences formed by mineralizing solutions.

Another, more minor occurrence of pyrite is that inside penninized pseudomorphs which are probably after diopside. The pseudomorphs contain quartz and a pulverulent white material as well. This occurrence is found in the vicinity of the larger fracture in thin section No. 34.

In addition to the occurrence in disseminated grains, the same sulphides are to be found in two thin fractures less than 0.1 mm. in width which penetrate the lamprophyre at an angle of about 45 degrees to the contact and are filled primarily by quartz and some chlorite.

From a consideration of the foregoing description and the fact that pyrrhotite and arsenopyrite were not seen to be present in the lamprophyre, the conclusion might be drawn that the lamprophyre was subjected to only the later stage of the mineralizing period, in which only pyrite, chalcopyrite, sphalerite and galena were crystallizing. The sequence of events could, therefore, be:

1. Formation of pyrrhotite and arsenopyrite ore in the lode.
2. Intrusion of the lamprophyre with consequent flow banding and slight chilling against the ore.
3. The later mineralizing period in which chalcopyrite, sphalerite and galena formed in the ore lode and also penetrated the lamprophyre, the alteration of the lamprophyre (chloritization) preceding or accompanying the introduction of sulphides.

The evidence presented above does not, however, prove an intra-mineralization age for the dyke since it is equally possible that the lamprophyre had completely solidified before the ore solutions arrived and that it had then been selectively mineralised by only those minerals that now appear in the dyke. A comparable process is the impregnation of wall rock by some of the minerals present in a vein while others take no part in the wall-rock alteration.

ROSSLAND DISTRICT - LEROI MINE

ON THE SURFACE - 50' FROM A LODE

-"Rossland - No. 2 Lamprophyre"-

A short description of the field occurrence of this dyke appears on page 41. Megascopically, the rock is extremely fine-grained, dense, unusually hard and black in color. Large biotite phenocrysts up to 1/5 inch in length produce good flow foliation.

Thin Section No. L33.

This rock, although lamprophyric in composition, lacks in its ferromagnesian crystals (biotite) the euhedral quality which is usually found in lamprophyres (Plate 5). The biotite grains, especially those of the groundmass, are very irregular although it is usually possible to make out the elongation direction of longitudinal sections. It differs also, from the lamprophyres so far studied, in that it contains no apatite. It also contains no calcite even though the presence of chlorite disseminated through the rock indicates that the rock is not entirely fresh.

The composition is:

Biotite phenocrysts	3 %
Doubtful Pseudomorphs	2 %
Groundmass:	
Biotite	35 %
Hornblende (chloritized)	15 %
Colorless base (feldspar and near-glass)	40 %
Unknown	a few grains
Pyrrhotite, sphalerite	accessory

<u>Biotite</u> -

Biotite phenocrysts average 1.5- 2 mm. in size, are uniformly brown and contain no inclusions. In the groundmass, the average grain size is .06 mm. but it grades down to cryptocrystalline. A good deal of the biotite is concentrated in brownish areas and streaks as aggregates of grains some of which give a spherulitic effect with crossed nicols. The majority of the biotite is, however, uniformly distributed in the groundmass as irregular, shreddy grains.

<u>Doubtful Pseudomorphs</u> -

Doubtful Pseudomorphs -

There are about a dozen pseudomorph-like areas, 1.0 mm. in size, which contain either dark green chlorite or serpentine together with some pyrrhotite grains. The shapes of the areas are dot diagnostic of any mineral therefore they may not be pseudomorphs.

Chloritized Hornblende -

Green hornblende which has been highly chloritized is sparsely distributed through the rock but there is a heavy concentration of it in and near a microscopic fracture. It is pleochroic (dark green to yellow-green) has a maximum extinction angle to cleavage of 26 degrees and its highest interference color is first-order yellow. A few small cross-sections were seen which still show the 60 degree cleavage but most of the grains have lost this characteristic through chloritization.

Colorless Base -

About half of the colorless ground is nearly isotropic and is therefore indeterminate although its refringence is less than balsam and its relief is low. The remaining half of the colorless base has weak anisotropism, low first-order grey interference color and forms grains which have the rectangular shape of feldspar. The index is less than balsam and the relief is low. The grain size is .06 mm. A very little albite twinning can be seen and it was possible to get an extinction angle to the twinning of 17 degrees, also one positive, biaxial figure with 2 V approximately 60 degrees. Therefore albite is apparently present but its proportion to the alkali feldspar which probably is present in the finer grains could not be determined. Owing to the alkaline character of the rock and the scarcity of twinning, the feldspar is likely to be predominantly alkalic and the rock may be a minette.

<u>Unknown</u> -

An undetermined clear, colorless, uniaxial negative mineral with index greater than balsam, very low relief and bright first-order white interference color occurs in clusters of a dozen or so rounded to broad tabular grains, each .03 mm. in size which are usually slightly separated from each other. A distinctive feature is the presence in individual grains of very thin, widely spaced, perfectly straight inclusions all of which are parallel to the straight side of the grains. The extinction is parallel to these inclusions. No cleavage is evident although in some instances the inclusions are regular enough in their spacing to suggest that they occupy cleavage traces.

<u>Opaques</u> -

No magnetite is in the rock and nearly all the opaque grains appear to be pyrrhotite. Two grains of sphalerite were seen. There is no localization of the opaques in any particular part of the thin-section.

BRALORNE MINE

FIELD AND MEGASCOPIC DESCRIPTION OF LAMPROPHYRE DYKES.

Two lamprophyre dykes are known to occur in the Bralorne mine, both in the Empire section. They have about the same attitude and are about 1000 feet apart. The more westerly of the two dykes was examined. It is a biotite lamprophyre, usually two feet wide, which strikes nearly north and is nearly vertical but dips slightly to the east. It is later than the ore and cuts across the east-west trending Empire vein almost at right angles. Where examined, in 1151 East drift, the dyke is displaced about one foot by late movement along the vein fracture. The ore at this point is low-grade, probably sub-commercial, and consists of quartz and gougey, silicified, albitized country rock in a narrow shear zone, one foot wide.

The lamprophyre has a very dark, greenish-grey color and contains many glistening, black biotite phenocrysts up to 1/10 inch in diameter. There is excellent flow foliation of the biotite phenocrysts in a band extending four or five inches in from the wall. The groundmass at the margins is strongly chilled but the phenocrysts in the chilled margins are only very slightly smaller and slightly less plentiful than in the dyke interior. The dyke contains irregular inclusions of silicified "albitite".

There is a seam of soft, very black, biotite-bearing, lamprophyre about one-half inch wide which occurs between the main lamprophyre dyke and the vein material on one wall and appears to be distinctly different from the main lamprophyre dyke. This material is largely cryptocrystalline and is probably chloritic in composition. (Thin sections 15 and 15a) Extensive groundmass chloritization such as this does not seem to be a common product of ordinary deuteric alteration, nor of alteration by weathering solutions in lamprophyres of this kind. The highly chloritized material as it occurs here, suggests alteration of the lamprophyre by hydrothermal solutions passing along the contact between the ore and the lamprophyre. As this lamprophyre dyke is strongly chilled against the ore, it would seem that the suggested liquid cannot belong to a late phase of the mineralizing period which produced the ore, although there is a less-marked chilling present in the "contemporaneous" lamprophyre specimen from the Mayflower mine. It is also difficult to conceive the alteration of the groundmass of a lamprophyre to form chlorite without any alteration of the enclosed biotite and pyroxene phenocrysts as is the case here, although this too may be possible. Therefore, in view of the rather sharp contact between the narrow black band and the main mass of lamprophyre it appears most likely that this black seam is a later lamprophyre of a highly mafic composition which came in along the wall of the main dyke. It was not noticed whether this dark seam was also present between the main lamprophyre dyke and the country rock.

PETROGRAPHIC DESCRIPTIONS

1151 East Drift

Thin Sections Nos. 11 and 13.

A lamprophyre dyke, two feet wide, intersects a sub-commercial silicified shear in "albitite". The dyke cuts through the vein and is therefore younger and has been displaced two feet horizontally by post-dyke movement along the shear.

Two sections were studied microscopically; number 11, of lamprophyre at its immediate contact with albitite and number 13, at the center of the dyke.

This rock is a biotite-lamprophyre (minette or kersantite) but the nature of the feldspar cannot be accurately determined since it is in a glass in Section 11 and is in the form of small sheaf-like spherulites in Section 13. It is most likely, however, that the rock is minette rather than kersantite because the refringence of the sheaf-like feldspar crystals is less than balsam in all the cases observed. A uniform groundmass composed mainly of granophyre and small biotite hornblende laths makes up 80 percent of the rock. The phenocrysts are biotite, pyroxene and apatite.

The composition of Thin Section No. 13 is:

Felsite ~~Granophyre~~..................	40 %
Hornblende of groundmass....	12 %
Biotite of groundmass.......	20 %
Biotite phenocrysts.........	5 %
Pyroxene phenocrysts........	5 %

Apatite......................	1 %	
Calcite......................	2 %	(excludes the vein-
Pyrite.......................	8 %	lets)
Magnetite.............	accessory	

Groundmass

The distinctive feature of this rock is the ground, comprising 80 percent of the rock, which contains:

biotite	25 %
hornblende	15 %
granophyre	50 %

Biotite crystals, in the form of well-shaped, equigranular laths less than 0.2 mm. long and six-sided cross-sections are enclosed in the granophyre accompanied by hornblende. The small biotite and hornblende laths show flow lineation which is most pronounced near the contact and grades to less and less pronounced lineation away from the dyke-wall until, at the dyke center, lineation is no longer evident. The biotite and hornblende grains have a remarkably dense and uniform distribution in the groundmass, although the proportion of biotite in relation to hornblende varies a good deal in different parts of the slide.

Hornblende. Dark brown hornblende occurs in the form of needles and diamond-shaped cross-sections with the same size range as the biotite. The maximum extinction angle to longitudinal sections is around 13 degrees and some twinning is present.

Felsite ~~Granophyre,~~ occurring only in Section 13, most commonly consists of sheaf-like groupings of radial fibers which are thinner than the slide but show parallel and nearly parallel extinction, grey interference color and no twinning. The glass of Section 11 is colorless though slightly darker than balsam and has an index usually less than balsam.

Phenocrysts

The biotite phenocrysts (0.2 to 1 mm. long) are the largest grains of the rock. Biotite (of both ground and phenocrysts), is brown-colored and fresh-appearing, has no dark-brown resorption rims nor green chloritic borders. Inclusions of large apatite grains in biotite are extremely common and there is also a good deal of penetration of biotite crystals by pyroxene grains.

Pyroxene, occurring in grains averaging 0.5 mm. in dimension, is colorless. The characteristic pyroxene habit (squares, rectangles and eight-sided sections) is much in evidence but the pyroxene cleavage does not show up very well, though it was observed in two or three cases. This lack appears to be due to the loss of a large part of the pyroxene (as well as some biotite and some questionable olivine) in grinding the slice, with the consequence that extinction angles to the cleavage of pyroxene could not be properly measured. Twinning is frequently present in pyroxene.

Some remnants remain of large grains which had the poly-

-41B-

gonal outline commonly associated with olivine. One such remnant (in Section 11) showed parallel extinction to cleavage and 2 V = 90°.

Apatite forms some very large crystals, up to 0.3 mm. in diameter, which are comparable to phenocrysts in their size. These give uniaxial negative interference figures. Apatite is closely associated with biotite, occurring either as inclusions in or as grains penetrating, contacting or neighbouring the biotite.

Calcite is almost absent from the groundmass since it occurs mainly as large grains. It is apparently in part secondary after pyroxene, completely filling apparent pseudomorphs after pyroxene. In another type of occurrence, seen in Section 11, there are both large and small calcite bodies, very elongated, oriented parallel to the lineation of the biotite needles. These elongated grains do not appear to be secondary after an original dyke mineral. The absence of secondary calcite from the groundmass is in keeping with the general freshness of the rock.

Two seams containing mostly calcite but some pyrite as well traverse Section 13. These seams may have been formed by a post vein-mineralization process involving the circulating ground-waters. However, the presence of pyrite in them suggests the faint possibility that the latest-appearing hydrothermal solutions of the ore period had acted upon the dyke.

Opaque Minerals

In Section No. 13, there is a little magnetite among the smaller grains of metallics, but all of the large grains (0.1 - 0.3 mm.) and nearly all the smaller grains (less than 0.1 mm.), are pyrite. Most of the pyrite is in the form of irregular grains scattered without any definite arrangement in the groundmass. Some, however, appear to replace biotite crystals (again without any apparent localization in any part of the slide), as they partially rim biotite crystals, with slight penetration, and occasionally vein the biotite.

In section No. 11 from the contact with country rock, however, there is no pyrite; the only opaque mineral is magnetite, most of which occurs as innumerable small (0.02 mm.) grains of generally rectangular habit, uniformly disseminated in the lamprophyre. Therefore, it is highly probable that the origin of pyrite in section No. 13 is connected with the four or five roughly parallel fractures which traverse that section and are filled with calcite and pyrite. In this connection, it is also significant that calcite grains are more plentiful in Section 13 than in Section 11.

Thin Sections No. 15 and 15(a).

These are sections of the same lamprophyre dyke as that from which sections 11 and 13 were made but, in sections 15 and 15(a), vein material consisting of quartz, sericitized feldspar, calcite and pyrite is attached to the lamprophyre. The vein material is not of commercial grade.

The lamprophyre is extremely fine-grained at the contact but minute biotite crystals are plentiful and there are also a few grains of apatite, pyroxene and biotite as large as those occurring in the interior of the dyke and these are not altered. Biotite crystals show flow lineation parallel to the contact (Plate 4).

The contact between the dyke and ore seems to have been a channel for solutions because the lamprophyre is highly serpentinized and/or chloritized there, resulting in the formation of a green, orange, yellow and colorless, non-pleochroic cryptocrystalline mass which shows flow banding due to color variations parallel to the contact. The material immediately adjacent to the vein has a yellow color and seems to be the most highly altered material. The color changes from yellow through brown to green away from the contact where the alteration becomes less intense.

There are no changes in the vein material towards the contact. Serpentinous lamprophyre sends out projecting tongues into the vein material in one place. Inclusions of vein material occur in the lamprophyre and these do not appear to have been altered by the lamprophyre fluid.

PIONEER MINE

FIELD AND MEGASCOPIC DESCRIPTION OF LAMPROPHYRES

There are at least two lamprophyre dykes occurring underground at Pioneer. These are 400 feet apart and are believed by the mine engineers to be two separate dykes. In addition, there are tunnel and drill-hole intersections with lamprophyre dykes in two other parts of the mine but it is not known for sure whether these are continuations of the two known dykes.

The dykes at Pioneer are post-ore as they cut across and are chilled against the vein-quartz. They are unlike the Bralorne dykes in that they intersect the ore structures at a flat angle and frequently follow along the wall of the vein for distances up to 40 feet before cutting through the quartz to the opposite side. The attitudes of the lamprophyre dykes and the veins are shown in the plan (back pocket). The widths of the dykes vary from six inches to two feet.

All the lamprophyres contain hornblende as the most plentiful ferromagnesian mineral. It occurs only in the groundmass, however, and the smaller amounts of biotite and occasionally pyroxene, occurring as phenocrysts, are more conspicuous. Accurate feldspar identification was impossible as feldspar is usually contained in glass or granophyre and the rarely-occurring crystals are too small to give interference figures. Indices of refraction of feldspar crystals, glass and granophyre were less than balsam in all observed cases, therefore the dykes are most probably vogesites.

Pioneer lamprophyres are very soft, crumbly and grey in color, especially along the walls and especially in the older workings where they have been exposed to the air for a longer time. Relatively recently-exposed rock was obtained near the new 27 vein on 20 level (specimen 25) and in this, the dyke is black and coarse-textured at its center. Biotite phenocrysts up to 1/10 inch in diameter are plentiful in all the dykes, and there is pronounced flow banding due to parallelism of the biotite phenocrysts. The grain size of the groundmass is much smaller and the rock more dense near the walls but the biotite phenocrysts do not change much in size nor in quantity as the wall is approached.

Pronounced color banding in the chilled edges, parallel to the contact foliation, is a remarkable feature in nearly all Pioneer lamprophyres. The color bands vary from 1/2 to 1 1/2 inches in width and in the chilled edge of specimen 25, where the colors are best developed, the sequence is: a light greenish-grey color at the wall, then a reddish and finally a dark green color that grades into the intensely black, fresh-appearing lamprophyre of the dyke interior. This color banding was not found in the dykes from other properties. It is probably due to a combination of the effects of primary, flow-banded, compositional variations of the lamprophyre and selective alteration by solutions moving along the contact, the more mobile constituents penetrating the dyke more deeply and producing changes there different from the changes produced elsewhere by less penetrative constituents. Thin sections showed the compositional differences between the interior and the outer portions of the dyke to be minor, amounting at most to five percent less of both biotite and hornblende at the wall and 15 percent more calcite.

The extreme chilling against the ore in these dykes militates against a theory that late, vein-forming solutions caused the alteration yet the color banding is so marked and the penetration is so deep (three inches), that fairly potent solutions must have been responsible. A more careful study in the mine might reveal a connection between the presence of color banding and the association of ore with the dykes.

PETROGRAPHIC DESCRIPTIONS

15 F.W. Vein. Sta. 1543

- Middle of dyke -

Thin Section 17.

Specimen 17 is most likely a vogestie, as hornblende is more plentiful than biotite and the feldspar is most probably an orthoclase-feldspar.

The approximate mineralogical composition is:

Biotite Phenocrysts.................... 5 %

Groundmass

Feldspar........................ 65 % (probably majority is orthoclase-feldspar)

Hornblende...................... 25 %

Quartz.......................... 1 %

Calcite......................... 2 %

Magnetite....................... 3 %

Apatite, pyroxene..........accessory

Biotite is restricted to the phenocryst phase in which it occurs as crystals up to 4 mm. long which are very much larger than the grains of the groundmass. There are some smaller biotite grains but the smallest of these are still slightly larger than the hornblende needles of the groundmass. There does not seem to be any small biotite grains in the groundmass; if there are any, they are very inconspicuous and could not be definitely identified. Biotite phenocrysts are brown, do not show chloritic borders nor dark resorption rims but do contain numerous apatite inclusions. Hourglass structure near the extinction position is very prominent.

Hornblende - The groundmass contains as its largest grains, hornblende laths up to 0.3 mm. long. Although they range in size down to specks which are discernible only with the high power objective, the majority are of the large size which under low power show great uniformity in size and distribution in the groundmass. Hornblende crystals are strongly euhedral, forming clear-cut laths and diamond-shaped cross-sections which have not suffered interference during their growth. The maximum extinction angle measured to longitudinal sections was 17 degrees. A single twinning line bisecting the lath is frequently seen.

Feldspar - The most abundant component of the groundmass is feldspar which forms parallel, branching and radial aggregates of coarse fibers. The refractive index is quite definitely less than that of balsam and it was possible to obtain one fairly satisfactory interference figure which had 2 V near 90°. Simple, Carlsbad-type twinning is frequently seen but there is no polysynthetic twinning. Therefore, it is most probable that the feldspar is an orthoclase-feldspar.

Quartz - There are a few curving grains of quartz up to 0.2 mm. in size among the feldspar fibers of the groundmass. They do not appear to be intergrown with feldspar. A uniaxial positive figure was obtained from several of the grains.

Calcite - There is one mass of pure, coarse-grained calcite, four and one-half mm. in diameter, completely surrounded by a narrow zone which lacks the usual hornblende concentration of the groundmass but is composed entirely of spherulitic feldspar fibers. Calcite also occurs scattered throughout the groundmass as irregularly rounded, impure grains approximately 0.2 mm. in size.

Magnetite is abundant. Euhedral to subhedral grains with square cross-sections are very uniformly disseminated in the groundmass. They are black in reflected light.

Apatite occurs mostly in or in contact with biotite crystals although there are a few grains disseminated in the groundmass. Grains are .05 to 0.1 mm. in diameter, an unusually large size in comparison with the size of the other grains of the slide.

Pyroxene - Three colorless, highly birefringent grains resembling pyroxene or olivine are to be found in this slide. They are partially altered to calcite and it is possible therefore that many of the calcite blebs of the groundmass were derived through the alteration of the same material that occurs in these three grains.

Crystallites - Curved, branching crystallites which are black in transmitted light are visible in the feldspar.

2351 South Drift. Sta. 2341

Thin Section No. 32. F.W. contact against quartz.

This is either a vogesite or a spessartite but it is probably the former as the clear glass which contains the feldspar has an index considerably less than balsam, about 1.50. It is a remarkably fresh rock, no calcite whatever occurring in the slide and all the minerals being practically unaltered. All crystals are euhedral.

The mineral percentages are:

Biotite phenocrysts........... 10 %

Diopside phenocrysts.......... 10 %

Groundmass

Hornblende laths.............. 25 %

Glass groundmass.............. 50 %

Glass globules................ 3 %

Granophyre globules........... 2 %

Apatite................ accessory

NOTE: magnetite is almost entirely lacking.

Biotite is similar to that in the other occurrences of Pioneer lamprophyre. It is brown, has no dark borders, contains numerous apatite inclusions and is almost entirely restricted to the phenocryst phase, the grains being generally 0.2 to 1 mm. in size. There are a few scattered basal plates 0.03 mm. in diameter in the groundmass.

Diopside occurs as clear, colorless phenocrysts (0.2 to 1 mm.). There is slight alteration to white pulverulent material, but no calcite. A few 0.03 mm. grains can be seen in the groundmass.

Hornblende laths, 0.2 mm. long, and diamond-shaped cross-sections which are too small to give a figure, are confined to the groundmass, being uniformly disseminated in the glass where they produce very good flow lineation. It is a very dark brown barkevitic hornblende showing fair pleochroism and occasional twinning.

The glass is colorless and clear although it has a faint brownish tinge in thicker portions of the slide. If contains very fine, colorless, needle-like cryptocrystals. There are no granophyric phases in this slide except in the globules described in a later paragraph. The index of the glass is less than balsam.

Glass globules, 0.1 to 0.3 mm. in diameter, occur throughout the slide. They consist of clear, colorless glass with index number less than balsam (n = approximately 1.45), which contains crystallites. There are no hornblende crystals in the globules but the groundmass crystals abut against the globules and there is a concentration of very few magnetite grains occurring in the slide, against the borders of the globules. Some globules contain a smoky brown stain.

Granophyric globules, averaging 1 mm. in diameter, are outlined by a tire-like layer of pulverulent white material. Hornblende crystals of the groundmass penetrate into the globules, occur inside the globules and maintain therein the same lineation which they have in the surrounding groundmass. The groundmass of the globules is a darker brown than that of the main rock but is granophyric rather than glassy.

Apatite occurs occasionally in the main mass of the rock as well as inside the biotite phenocrysts.

Thin Section No. 31. Center of dyke.

This thin section is of material from the center of the dyke; thin section No. 32 being from the foot-wall of the same dyke. The material in thin section No. 31 differs from that in No. 32, as would be expected, in that it has less colorless glass and more granophyre. A more surprising difference, however, is that, in the center of the dyke, diopside phenocrysts are almost completely altered to calcite whereas there is no calcite whatever in the thin section from the foot-wall of the dyke. This feature must not be considered a characteristic of this dyke, however, since only two thin sections were examined and the calcite content of the rock may be highly variable.

The composition of this thin section is:

Phenocrysts

Biotite..........................	5 %
Calcite (after pyroxene)..........	5 %

Groundmass

Hornblende.......................	30 %
Brownish Felsic Material ~~Granophyre~~.............	50 %
Colorless Granophyre Nodules.....	3 %
Iron Ore, apatite...........	accessory

Biotite - Biotite phenocrysts have the same characteristics as those in section 32 except that they are larger, being up to 2 mm. long.

Calcite - The majority of the calcite in the slide is in large grains up to 1 mm. long, some of which have a form which suggests that they are pseudomorphs after pyroxene. However, as the calcite is clear and is not accompanied by another mineral which could account for the iron and magnesium of the original pyroxene, there is considerable doubt that these bodies are actually pseudomorphs after pyroxene. Some of the "pseudomorphs" are surrounded by a darkened rim consisting of dark, dusty material and a compressed mass of hornblende laths. This gives the impression that either expansion has occurred in the original mineral of the "pseudomorph" during its crystallization or that hornblende laths floating in the residual magmatic fluid had come to rest against the original mineral.

Hornblende - The hornblende, as in section 32, is confined to the groundmass, and is in all respects similar. It occurs in grains, the largest of which are 0.3 mm. long. The grains exhibit flow lineation around the large biotite phenocrysts.

Felsic ~~Salic~~ material - About one half of the slide is composed of slightly crystallized salic material which, most commonly, is nearly a glass or, at best, is faintly anisotropic with no visible crystal structure. Occasionally though, there are sheaf-like aggregates of crystals with refringence below that of balsam. This felsite ~~salic material~~, throughout the slide, has a light-brown color under moderate magnifications but the color is apparently produced by minute, dark brown grains, probably of hornblende, which lie between adjacent microcrystals of the aggregates.

Colorless Granophyre - There are, scattered through the rock, some nodules, 0.04 mm. in diameter on the average, of clear, colorless granophyre. The nodules are composed of very small, equigranular grains, some appearing to be quartz and others, with refringence less than balsam, appearing to be alkaline feldspar. The grains are, however, too small for proper identification. The granophyre shows spherulitic crosses with the nicols crossed.

Apatite - Apatite is the same as in section 32. Grains are .04 mm. wide and 0.3 mm. long and give uniaxial negative interference figures. Apatite is especially associated with biotite.

<u>Magnetite</u> - Accessory magnetite is plentiful.

PREMIER MINE

9 C STOPE

<u>Thin Section No. P3 - Interior of dyke</u>.

This is a specimen of dyke rock from the 9 C stope, on the second level from the bottom of the mine. It is a fine-grained, greenish-grey rock with a carbonatized appearance, containing small hornblende phenocrysts visible to the naked eye.

The composition of this thin section is as follows:

Feldspar..................	60 %
Quartz....................	5 %
Hornblende................	20 %
Chlorite..................	10 %
Carbonate.................	5 %
Pyrite, magnetite.......	accessory

The <u>texture</u> is porphyritic. Idiomorphic hornblende phenocrysts are present in a matrix composed largely of small feldspar laths (Plate 6). Only a few of the feldspar crystals are large enough to be classed as phenocrysts.

<u>Feldspar</u> - Feldspar forms a felted mass of crystals which in some portions of the slide comprises 70-80 percent of the rock and in other places only 40-50 percent. On the average, the proportion of feldspar is about 60 percent. Most of the laths are less than 0.2 mm. in length. Simple Carlsbad-type

twinning is present as well as a little polysynthetic twinning. Polysynthetic twinning, however, is rare and is obscured by kaolinization with the result that no extinction angles were obtained. The refractive indices of the majority of feldspar crystals were below that of balsam, a fact which, in conjunction with the scarcity of polysynthetic twinning, indicates a sodic and possibly a potassic composition for the majority of the feldspar. The feldspar grains are kaolinized, especially the interior portions of the larger grains.

Quartz - Quartz occurs as small, interstitial grains among the feldspar crystals.

Hornblende - Hornblende occurs as prominent, euhedral phenocrysts averaging 0.6 mm. in length but ranging up to 2 mm. in length. It is pleochroic, brown to greenish-brown and is somewhat chloritized. Long feldspar laths frequently rest against the straight edges of hornblende grains with an attitude parallel to the edges suggesting that early-formed feldspar laths had come to rest against the hornblende crystal when most of the rock was still fluid.

Chlorite - A green chlorite, some of which is pennine, comprises 10 percent of the rock. It occurs in partly altered hornblende grains, and in both large and small grains, some of which appear to be pseudomorphs after hornblende. In the latter occurrence it is usually associated with carbonate.

Carbonate - Carbonate occurs mostly as pure grains associated with the feldspar of the groundmass but also as rounded, irregular grains inside chlorite grains.

Name of the Rock.

This rock may be classed as a vogesite lamprophyre although it has perhaps, too low a proportion of ferromagnesian constituents for a typical lamprophyre. Nevertheless, it has a high alkali proportion, since the majority of feldspar is alkalic, and it therefore fulfills the requirements for a lamprophyre in regard to its chemical composition. The rock might be classified as a hornblende-quartz-syenite except that the proportion of ferromagnesian minerals is too high for a typical syenite. In view of the lamprophyric texture of the rock, together with its relatively high proportion of ferromagnesian minerals and its alkalic composition it is perhaps best to call the rock a vogesite lamprophyre. This designation should be qualified with the statement that the rock is transitional to a quartz syenite.

910 DRIFT

Thin Section No. Pl - Interior of dyke.

This specimen of dyke rock is from the 910 drift at Premier, the second level from the bottom, in the recently-worked part of the mine. The rock is aphanitic, has a distinctly green color and appears to be carbonatized.

The composition of this specimen is as follows:

Feldspar...................... 75%

Quartz........................ 3%

Chlorite...................... 20 %

Carbonate..................... 5 %

Magnetite, pyrite........accessory

This rock consists primarily of a mass of small feldspar laths, together with lesser amounts of both large and small, green chlorite grains. Some of the larger chlorite grains appear to be pseudomorphic after hornblende and there are instances of feldspar laths resting against the large chlorite grains in a manner similar to the "wrapping-around" of the hornblende phenocrysts by feldspar laths seen in thin section No. 3. The rock has certain similarities in appearance to that in thin section No. 3 but has a still higher proportion of feldspar.

Feldspar - The feldspar laths average 0.2 mm. in length and form a groundmass of interlocking laths. They are less clouded by alteration than those in thin section 3 and it could be seen that about five percent of them are polysynthetically twinned. The twinned feldspar is albite and the remaining untwinned feldspar also has a refringence less than balsam and is orthoclase.

Quartz - Quartz occurs interstitially.

Chlorite - Chlorite occurs mostly as small, irregularly-shaped grains (less than 0.1 mm. in size) scattered through the groundmass but also in lesser amount as large (0.3-0.4 mm.) grains which may be pseudomorphic after hornblende phenocrysts. As there is no identifiable residual hornblende or biotite, it is not known for sure what mineral was altered to form the chlorite.

<u>Carbonate</u> - Most of the carbonate is scattered among the feldspar grains but some of it is in association with chlorite.

<u>Opaque Spots</u> - Small dark-grey, powdery, opaque spots averaging 0.02 mm. in size are uniformly distributed in large number through the rock. They are white in reflected light.

Owing to the fact that chloritization of the original mafic minerals has largely destroyed any euhedral quality they may have had, it is impossible to judge accurately the original textural characteristics of the rock. There is a fairly strong suggestion, however, that prior to chloritization this rock was somewhat similar, texturally, to specimen No. 3. In view of the fact that the majority of the feldspar is orthoclase-feldspar, the rock might be called a vogesite but as the ferromagnesian proportion is so low (20 percent) and as the texture is not clearly lamprophyric it is perhaps better to classify this rock as a syenite. In this case, also, the name should be qualified by stating that it is transitional to a vogesite since the proportion of ferromagnesian minerals is large for a syenite.

<u>Thin Section No. R11. - Contact of dyke with mineralized porphyry.</u>

This is a specimen, from Dr. W.H. White's collection, of dyke rock such as is termed lamprophyre at the Premier mine. Megascopically, it is a very fine-grained, almost aphanitic, dark greenish-grey rock which contains small whitish grains of carbonate and small particles of pyrite. It is in contact with porphyry which is mineralized with pyrite.

Microscopically, the dyke is seen to be largely (65 per-cent) composed of an indeterminate, grey-colored groundmass which is clouded by alteration so that it appears white in reflected light. The groundmass shows no anisotropism in its present state. Under high magnification there can be seen colorless, needle-like crystals, 0.01 mm. thick to almost sub-microscopic in size, very thinly distributed in the groundmass, giving it, in places, a felted appearance.

The only essential minerals which could be identified are calcite, feldspar and quartz. They generally occur in grains of .05 mm. dimensions. Feldspar is the only euhedral mineral in the slide, the largest crystals of which rank as micro-phenocrysts.

The composition of the rock is:

Calcite..................	20 %
Feldspar.................	10 %
Quartz...................	5 %
Isotropic Groundmass.....	65 %

Apatite, pyrite, magnetite - accessories.

Quartz - Quartz is uniformly distributed in the form of rounded grains, .05 mm. in diameter.

Feldspar - Feldspar laths are up to 0.2 mm. long and are untwinned; no interference figures nor refractive indices could be obtained for it.

Calcite - Calcite has formed by groundmass alteration, which was most effective around edges of quartz and feldspar grains, and by partial or complete replacement of feldspar laths by calcite. Calcite is profusely scattered through the rock in grains of .02 to 0.1 mm. diameter, which often have clear interiors and cloudy, incompletely transformed outer zones.

Isotropic Groundmass - The very fine colorless needles which sometimes give a faintly discernible felted appearance to the groundmass seem at first glance to be the smallest representatives of feldspar grains grading downward in size from the micro-phenocrysts. However, the interference color of these tiny needles is too high for feldspar as it is first-order white in grains which are less than .01 mm. thick. The needles have parallel extinction and they may therefore be biotite or some other ferromagnesian mineral. The ferromagnesian constituents of this rock, which must be in appreciable amount to give the rock such a dark color, are contained in the groundmass where they are insufficiently crystallized to permit identification.

Apatite, pyrite, magnetite - Occasional euhedral grains of apatite can be seen as well as 0.15 mm. grains of pyrite and .05 mm., square and diamond-shaped, euhedrons of magnetite.

A tear-shaped inclusion or amygdule, 1.5 mm. in diameter, occurs in the section. It contains small calcite and sericite grains poikilitically enclosed by a grain of a nearly colorless mineral which is biaxial and has dark grey interference color.

The rock has flow structure due to alignment of feldspar laths and some elongated carbonate grains.

The specimen is, unfortunately, from the chilled edge of the dyke, and is insufficiently crystallized to permit a determination of its composition or its identification as a lamprophyre. Its dark green color suggests that it is fairly basic in composition, yet there are no ferromagnesian crystals present. It has been observed, in all lamprophyres studied, that their chilled edges invariably contain ferromagnesian crystals which are only slightly smaller than phenocrysts occurring in the center of the dyke, even though all the salic constituents be uncrystallized. The lack of ferromagnesian crystals in this specimen is therefore indirect evidence that the rock is not a lamprophyre but it must be discounted owing to the possibility that a non-porphyritic, very fine-grained lamprophyre might have no mafic crystals in its chilled borders even though they occur at the center.

RUTH MINE, SLOCAN DISTRICT

LAMPROPHYRE SILL - 5 LEVEL

A dsicussion of the field relations is given in Appendix A.

Thin Sections Nos. 1 and 2.

Specimen No. 1 is from a lamprophyre sill near its contact with the Ruth lode and specimen No. 2 is from the same sill, four feet away from the contact. The only difference between the two specimens is that No. 2 has very many large, elliptical, carbonate aggregations, all oriented normal to the sill walls whereas in No. 1, there are only three such bodies. Megascopically, the rock has a grey color due to intense carbonatization. No constituent minerals are discernible other than calcite.

The outstanding feature of this rock is the occurrence in it of large, pale-green chlorite crystals up to 1 mm. long which constitute about 45 percent of the rock and are the only ferromagnesian crystals present except for a few small shreds of biotite. This chlorite may have been formed through alteration of original biotite since there are small biotite shreds in section 2 and because the chlorite laths resemble biotite in their shape. On the other hand, as these shreds of biotite do not show particularly close association with the chlorite, it is not certain that chlorite is after biotite.

No feldspar could be found in either section.

The composition of thin section 2 is:

Chlorite...........................	45 %
Calcite, in Oval Aggregations....	20 %
Calcite in the Rock..............	20 %
Unknown..........................	10 %
Quartz...........................	3 %
Biotite, phlogopite........	a few grains

<u>Chlorite</u> - This mineral is probably prochlorite. It has a pale-greenish color, distinct pleochroism, first-order white interference color, one perfect cleavage and an extinction angle of 2^{o}-5^{o}. The laths are length fast, the optic sign is positive and the figure either uniaxial or biaxial with 2 V less than five degrees. The mineral occurs in biotite-like laths and large, irregular basal sections which are almost black under crossed nicols. The refringence as determined with immersion oils is between 1.59 and 1.66.

The chlorite laths show a distinct tendency to lineation similar to that of the carbonate ellipsoids but not to such a high degree. In addition, chlorite may also occur in radiating groups of large crystals which usually show spherulitic extinction effects. The occurrence of chlorite in this rock is very novel and is the more remarkable since it is accompanied by no other ferromagnesian mineral except the few grains of biotite.

<u>Calcite</u> - Calcite is present in two forms. One, as clear,

coarse grains scattered through the rock and the other, as large (up to 1/3 inch long) ellipsoidal aggregations, each composed of a granulated mass of small calcite grains. These ellipsoids have parallel orientation in a direction normal to the walls of the sill. The calcite in the ellipsoids is darkened by material which is white in reflected light. The calcite in the ellipsoids is thought[1] to have been formed by secondary solutions moving through a system of parallel fractures, which was intersected by another set of fractures, thus causing the formation of oval-shaped oriented masses wherever two fractures meet.

Unknown - A mineral very similar to cordierite in appearance but with a definitely positive optic sign is irregularly distributed in the rock in anhedral grains, 0.4 mm. in diameter. Very many fine sericitic grains are invariably contained in the mineral. The optical properties are: colorless, no visible cleavage, relief very low, index very close to balsam but probably a little greater than balsam, interference color first-order grey, uniaxial or 2 V very small, optic sign positive. The mineral may be a feldspar but it is very hard to prove it.

Quartz - Quartz occurs as interstitial grains among the calcite and chlorite crystals.

Biotite - Biotite grains, seen best in section 2, definite-

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(1) Sharp, W.: Personal Communication.

ly appear to be relics of alteration as they are never euhedral but are usually in the form of small shreds. Biotite, however, rarely occurs inside grains of chlorite as would be expected if the chlorite were a result of biotite alteration. The color of the biotite is brown. In thin section 1, the chloritic material frequently has a birefringence too high for chlorite. This occurrence may represent the transition stage between biotite and chlorite.

Phlogopite - A few grains, tentatively identified as phlogopite, occur in thin section 2. They are lath-shaped, almost colorless, have parallel extinction and are length fast. The highest interference color observed was second-order blue and the interference figure is almost uniaxial, negative with one ring.

Opaque Minerals - There are very few, irregularly distributed black opaque grains which are probably magnetite.

Inclusions - A few inclusions consisting of granulated quartz grains together with a little muscovite and carbonate occur in the rock. These are up to one-quarter inch in diameter and have no specific orientation such as that of the calcite aggregations.

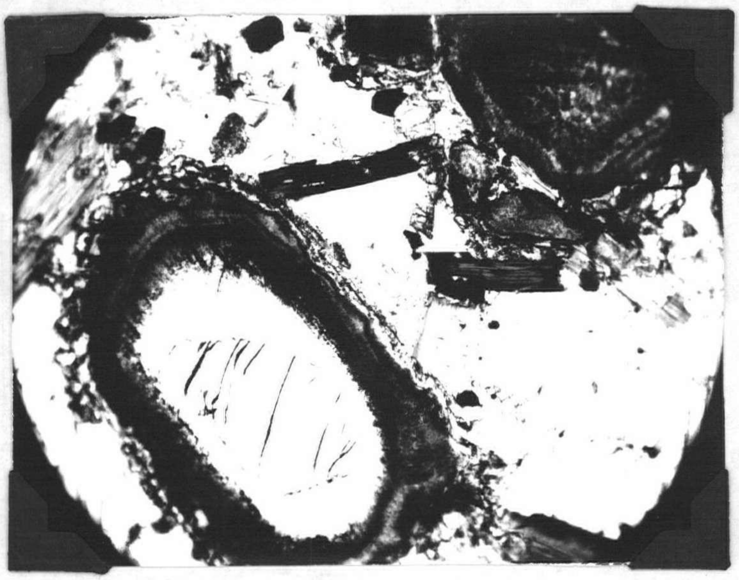

Plate 1.   x 50

Reeves lamprophyre, T.S. 1. Shows the two zones of alteration surrounding residual olivine. Also visible are biotite, diopside, apatite and metallic grains in a ground of feldspar, carbonate and quartz.

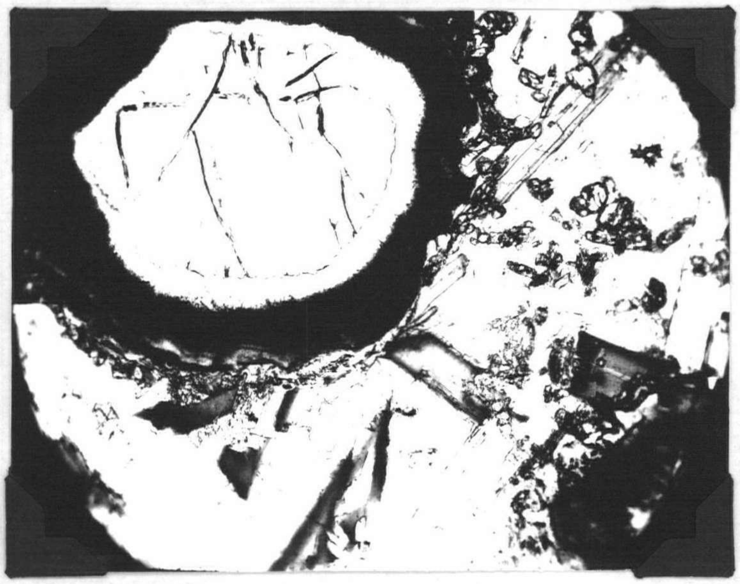

Plate 2.   x 50

Reeves lamprophyre, T.S. 1. Similar to Plate 1. Partly altered diopside grains are more plentiful and are concentrated around edge of altered olivine grain.

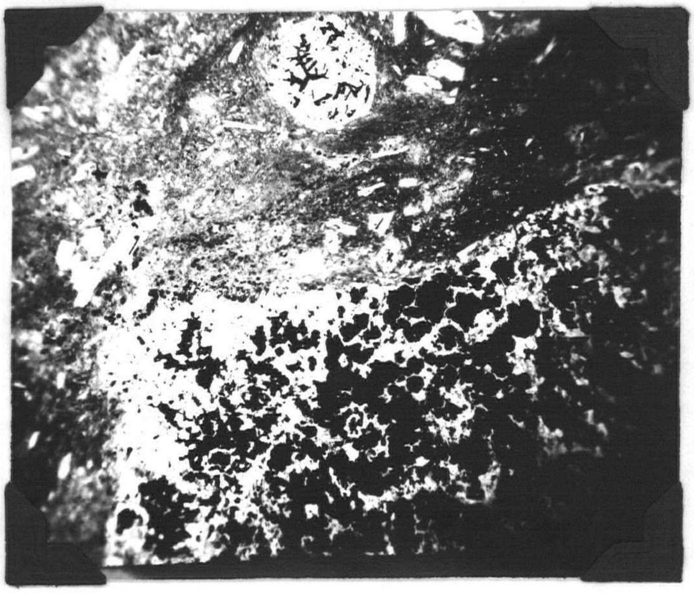

Plate 3. x 20

Sullivan, 3904 cross-cut. T.S. S35. Biotite-lamprophyre at top in contact with earlier "low-grade" ore at bottom. Illustrates flow-banding in the lamprophyre.

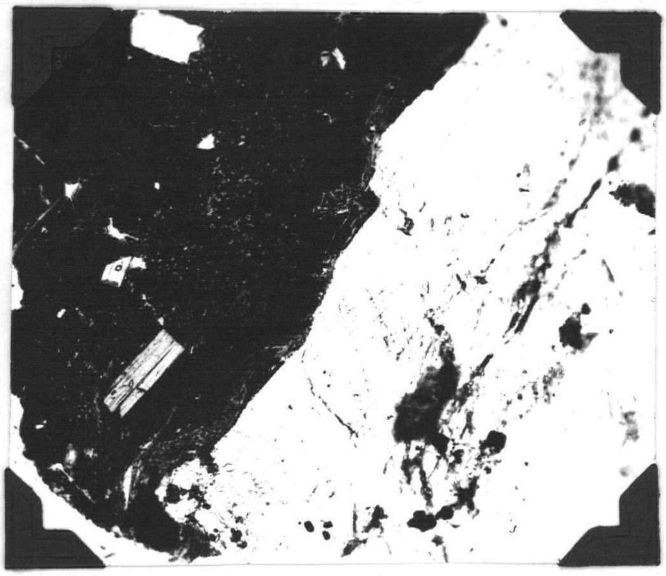

Plate 4. x 55

Bralorne, 1351 East Drift. T.S. 15(a). Chloritic lamprophyre (black) in contact with vein quartz (white). Biotite phenocryst and flow-banding are visible in the lamprophyre.

Plate 5. x 60

"Rossland No.2" lamprophyre. T.S. R33. Anhedral biotite (dark) with feldspar (white). Biotite phenocryst on the right.

Plate 6. x55

Premier, 9C stope. T.S. P3. Kersantite containing hornblende phenocrysts in a groundmass of kaolinized feldspar, carbonate, chlorite and a little interstitial quartz.