A PETROGRAPHIC STUDY OF CONTACT

FACIES OF GRANITIC ROCKS WITH LIMESTONE

A thesis submitted in partial fulfillment of the requirements of the course leading to the degree of Master of Applied Science in Geology at the University of British Columbia.

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ABSTRACT

A petrographic study is made of granitic rocks which are closely associated with crystalline limestone in north-west British Columbia and south-west Yukon. A description of Contact facies between the two rock types is emphasized by the author with the aim of showing endomorphic and exomorphic effects.

It was found that the chief endomorphic effect on the granitic rock was the development of pyroxene as the mafic mineral in place of the usual biotite and hornblende. No change in the composition of the plagioclase feldspar was noted except in specimens taken in close proximity to limestone contacts. In these specimens the plagioclase was found to be abnormally calcic. Considerable quartz, orthoclase, actinolite, and clinozoisite also mark the contact facies of the granitic rock.

Recrystallization, and the development of the common skarn minerals, diopside, garnet, and wollastonite have taken place in the limestone. The skarn minerals are restricted to a narrow zone adjacent to granitic rock and along joints in the limestone.

A number of hypotheses are given with evidence for and against in an attempt to explain the genesis of the various rock types. Assimilation of the schists and gneisses but not limestone is believed by the author to be the most likely hypothesis to explain the presence of the limestone
inclusions in granitic rock. It is postulated that the pyroxene developed as a replacement or metasomatic mineral after the initial stages of the intrusion by the granitic magma. In conclusion the introduction of quartz and orthoclase and the development of actinolite and clinozoisite are thought to be related to a late stage of the igneous activity.
Vancouver, B.C.
April 13, 1950.

Dr. M.Y. Williams
Head of Department of Geology and Geography
University of British Columbia
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Dear Sir:

It gives me pleasure to submit the following thesis, A PETROGRAPHIC STUDY OF CONTACT FACIES OF GRANITIC ROCKS WITH LIMESTONE, in partial fulfillment of the course leading to the degree of Master of Applied Science in Geology at the University of British Columbia.

Yours truly,

H. Gabrielse
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A PETROGRAPHIC STUDY OF CONTACT FACIES OF IGNEOUS GRANITIC ROCKS WITH LIMESTONE

INTRODUCTION

Much of southwestern Yukon and neighbouring north-western British Columbia is underlain by schists and gneisses which are intruded by granitic rocks. In places, large inclusions of crystalline limestone or marble which occur interbedded with the schists and gneisses are present in the granitic rock.

Specimens from contact facies of crystalline limestone and granitic rocks occurring in two areas were examined. The larger suite of samples was taken in south-western Yukon, in the summer of 1949 by the author. The study of these was supplemented by specimens of a similar type taken by K. DeP. Watson in 1945 about seventeen miles to the south-east, in northwestern British Columbia (see map in folder). The Yukon occurrences will be described first.

Location of Outcrop:

One of the crystalline limestone inclusions in question was examined by the writer during the 1949 field season and occurs in the south-west Yukon about three miles east of mile-post 103 on the Haines Road. The limestone outcrop is at an elevation of about 4300' on the northerly face of the mountain block south of the Unahini river. The elevation of the Unahini River is approximately 2400' in this vicinity and the mountains to the south rise to an elevation of just over
The limestone inclusion is one of several such bodies exposed along the northern slope of the mountain. The largest of these bodies, - about 400 feet in plan length, 300 feet high, and 300 feet wide - occurs at an elevation of 4400 feet and about one quarter of a mile east of the one examined. Numerous smaller inclusions ranging up to thirty feet high by fifteen feet wide occur between elevations of 4000 feet and 4500 feet. Talus and snow makes the determination of the relationship of the limestone to the other rock types somewhat difficult but several inclusions are completely surrounded by granitic rock.

With regard to the dimensions of these inclusions the first figure denotes the horizontal outcrop distance, while the second figure refers to vertical distance between the top and bottom of the outcrop.

General Geology of the Area:

Three main rock types are present in the area - crystalline limestone or marble, granitic rock, and schists and gneisses of the "Yukon Group".

Rocks assigned by Kindle (1949 - pp. 12-13) to the "Yukon Group" occur extensively to the east of the examined limestone inclusion and also as pendants in the granitic rock to the west. These rocks, which are chiefly quartz-biotite schists and quartz-biotite-feldspar gneisses, are in contact with the granitic rock about one and one-half miles east of
the area investigated. Beyond this north-south-trending and steeply dipping contact the schists and gneisses outcrop to the east for several miles. A fairly extensive pendant of schist and gneiss, the actual extent of which is not known, occurs about one quarter of a mile west of the largest of the limestone inclusions at an elevation of about 4500 feet.

The limestone inclusions consist for the most part of coarse grains of calcite, commonly strongly twinned, up to two cm. in length. In places the limestone appears to be silicified and locally skarn minerals have been developed along joints. Contorted bedding was seen in only one of the smaller inclusions. Marble associated with schists and gneiss elsewhere in the "Yukon Group", and the contorted bedding seen in one of the small inclusions, lead to the conclusion that the limestone inclusions were originally members of the "Yukon Group" rocks.

The great bulk of the outcrop along the mountain face is medium to coarse grained, gneissic, oversaturated igneous rock containing about 10% quartz, 60% feldspar, and 30% mafics. The mafics vary from all biotite to all hornblende but in general these minerals are present in approximately equal amounts. In many cases striations are readily discernable on the feldspars and from a field examination the term quartz-diorite was used for the rock type. The grain size of the quartz diorite varies considerably from place to place. Weathering of the rock has resulted in the accumulation of a considerable amount of arkosic sand in the Unahini Valley.
Relationships of Rock Types:

The main north-south trending contact between the schists and gneisses of the "Yukon Group" to the east and the quartz-diorite to the west is gradational. On crossing the contact from the granitic side to the schists and gneisses the following sequence occurs:

1. Rocks of the normal medium to coarse grained granitic type.
2. Gneissic granitic rock with mafics well foliated sub-parallel to the contact.
3. Schists, gneisses, and numerous sills and lenses of granitic rock.
4. Normal schists and gneisses.

As mentioned previously the crystalline limestone is assumed to have been a part of the "Yukon Group" rocks. A limestone inclusion on the north side of the Unahini River is associated with some quartz-biotite-feldspar gneiss and quartz-biotite schist. Most of the inclusions on the south side of the river, however, occur without any apparent associated schist or gneiss. In the immediate vicinity of the limestone the quartz diorite has a bleached appearance. The mafic mineral is light green and seems to make up less of the bulk of the rock than in the rock types remote from the inclusions. Skarn minerals are developed along a few joints in the limestone and in places a sequence - calcite, skarn minerals, altered quartz diorite, - is evident.
Detailed Description of Limestone Inclusion:

The limestone inclusion examined is roughly elliptical being about 280 feet in plan length, 120 feet high, and 200 feet wide. (See sketch map, Figure 2). The mountain slope in this vicinity is quite steep and in places precipitous.

A conspicuous feature of the outcrop is a feldspar porphyry dyke which cuts both the limestone and quartz diorite. The dyke strikes 175 degrees and dips vertically. It is composed of feldspar phenocrysts up to 2 mm. in length in a greyish-green aphanitic groundmass. The rock is heavily rust stained and strongly fractured, weathering to somewhat rounded blocks up to a foot in length, and in places to a fine rusty sand. The contact between the dyke and the limestone is undulatory and between the dyke and the quartz diorite fairly sharp and regular.

A shear zone occurs in the quartz diorite about fifteen to twenty feet east of the eastern margin of the dyke. This zone, about five feet wide has the same attitude as the dyke and contains deeply weathered and rust stained quartz diorite. Limestone along the western margin of the shear is highly brecciated.

The quartz diorite-limestone contacts are very irregular with a dyke of quartz diorite cutting the limestone in one place as shown on the sketch map. Along the western quartz-diorite-limestone contact skarn minerals, mainly garnet and green pyroxene, occur in fractures or joints which strike
and dip vertically. The skarn zones are from three to four inches wide and the transition from calcite to skarn minerals occurs within a width of about one half inch. A transition from calcite to skarn minerals to altered quartz diorite within a width of four inches was also noted in one place.

The skarn minerals consist chiefly of brown vitreous garnet up to one inch across which occurs mainly as anhedral grains. A green-vitreous fine grained mineral resembling diopside and a white vitreous fibrous to lamellar mineral generally occur between the garnet and the calcite, although the green mineral commonly is found as grains completely enclosed in the calcite or garnet.

The limestone near the eastern part of the body, which is at or near the contact with quartz diorite and the dyke, (fig. 2) is altered over a width of about six inches to a vitreous brown siliceous material. Along contacts with the dyke the limestone is altered to a whitish grey siliceous rock.

As in the vicinity of the other limestone inclusions the quartz diorite has been altered near the limestone contacts to a generally light colored rock. In the macroscopic examination the main difference between the normal quartz diorite and the altered variety is the pale green color of the mafic material in the latter. The amount of mafic material in the altered rock appears to be relatively small but varies considerable and is not as conspicuous as the
black euhedral hornblende or the glistening biotite in the unaltered variety. The overall grain size appears to be very little different from that of the normal igneous rock. The lateral extent of alteration of the quartz diorite near the limestone contacts is difficult to determine because of talus and snow and because of possible irregularities of the limestone beneath the surface of the outcrop. The alteration, however, is definitely less than twenty feet in width as the unaltered granitic rock type occurs in the shear zone at the eastern margin of the outcrop.

The fine grain size and the weathered nature of the dyke make it impossible to determine whether or not it has been altered. One difference, however, is the dark grey to black color of the groundmass material in the limestone contact facies of the dyke contrasted to the light grey color of the groundmass near the centre of the dyke.
Description of Thin Sections:

Thin sections were made of the various rock types, particularly of the contact facies. In a few cases it was possible to obtain the actual contact between two rock types in a thin section. For the most part, however, the thin sections represent rock types on either side of the contact. A detailed description of the individual thin sections appears in the appendix of this report.

The "Normal" Granitic Rock Type (Quartz Diorite):

Thin Sections 1, 1b, 17.

The thin sections listed above were made from specimens of the "normal" granitic rock type occurring on the mountain mass which contains the limestone inclusions. Thin sections 1 and 17 are representative of the granitic rock in the immediate vicinity of the examined outcrop, while thin section 1b was made from a specimen of rock taken about three miles south-west of the outcrop along the Haines Road. Hand specimens of the granitic rock from numerous parts of the area were also examined.

Although the grain size and amount of mafic material is quite variable in the various localities the overall mineral compositions of the rock remain constant. The rocks show the typical granitic or medium to coarse grained hypidiomorphic texture, a typical feature being perhaps the euhedral hornblende crystals which are very well developed in the coarser grained varieties. The average grain size
of the minerals is approximately 4 mm. but some of the hornblende grains are up to 7 mm. long. The mineralogical composition averages approximately as follows: about 50 - 60% feldspar, 25 - 35% total mafics (mainly hornblende and biotite) and from 15 - 20% quartz. Accessory minerals include titanite (sphene), apatite, magnetite, and possibly zircon. Apatite is fairly abundant and is characteristic of the entire group of specimens.

The main feldspar in all the examined specimens varies little from Ab₆₀An₄₀ or medium andesine. In most cases the feldspars are zoned to a greater or lesser degree. A few grains show a microantiperthitic texture but this is not a common feature in the normal granitic rock.

Orthoclase is present in minor amounts and is always present in small irregular grains. The mineral occurs for the most part wholly within plagioclase grains but in some cases cuts across the borders of several plagioclase grains.

In thin section 17 which represents the "normal" granitic rock near the limestone inclusion orthoclase has extensively replaced the medium andesine feldspar. This feature however appears to be restricted to the granitic rocks close to the limestone.

The amount of each of the mafic minerals is variable with hornblende being dominant in one case and biotite in the next. On the average, however, the two minerals are present in about equal amounts and show marked euhedral form.
Apatite, as previously mentioned, is fairly abundant in all of the unaltered igneous rock types. The mineral occurs in euhedral grains showing the typical hexagonal cross section and elongate prisms.

Zoning of the plagioclase feldspars and the characteristic hypidiomorphic or granitic texture of the rock type suggest that it is of a normal plutonic igneous origin.

According to Grout's (1932, pp. 47-48) classification of the igneous rocks, in which emphasis is placed on the composition of the feldspar the normal granitic rock type in the area should be called a quartz diorite. It is likely that specimens taken in certain areas might show that greater than 13.5% of the feldspar is orthoclase. In this case the rock would be termed a granodiorite. In general, however, it is believed that the thin sections studied are fairly representative so that the rock type will be termed a quartz diorite.

Altered Quartz Diorite:

Thin sections representing various areas in the altered quartz diorite are: 4, 5, 5(b), 5(c), 7(a), 12, 12(a), 14, 14(a), 19, 13. Specimens of altered quartz diorite were taken on or near the limestone contacts and also from an irregular dyke in the limestone.

The texture of the altered quartz diorite is somewhat like that of the unaltered rock although most of the grains in the former show much less well defined crystal
boundaries. Actually a number of thin sections show a crystalloblastic texture. Irregular inclusions and shreds of one mineral in another are a common feature and in several thin sections the replacement of one mineral by another is evident. The rock is in general medium grained but in a few instances aggregates of finer grained material occur. Very narrow filled fractures are especially prevalent in thin sections of the actual contact of the quartz diorite and limestone. In general the mineralogy is more complex in the altered granitic rock, particularly on the contacts, than in the unaltered rock type.

Description and Occurrence of Minerals:

Mafic material:

Pyroxene: The chief difference between the mineralogy of the altered and unaltered granitic rocks is the almost complete absence of the mafic minerals hornblende and biotite in the former. The mafic mineral in the altered rock is mainly the pyroxene, diopside and the presence of this mineral accounts to a large extent for the lighter colour of the altered rock in the hand specimen. The diopside which occurs in grains up to 3 mm. in length generally shows anhedral crystal form and in many cases contains small grains of plagioclase feldspar and quartz. Most of the grains of plagioclase feldspar which are enclosed in pyroxene are euhedral. The boundaries of the pyroxene with bordering plagioclase grains, on the other hand, are in many places very irregular. The composition of the plagioclase inclusions in all the
determinable grains was approximately the same as that of the surrounding plagioclase. The pyroxene is partly replaced in some instances by shreds and fibres of a light green amphibole which is probably actinolite.

The pyroxene is also altered along veinlets to an amorphous kaolin-like material and to a yellow mineral with low birefringence which is possibly a serpentine. In some sections the pyroxene is highly altered to a mixture of carbonate and an actinolitic variety of amphibole.

Thin section 13 contains grains of pyroxene in close association with and included by garnet. Some of the grains have been altered considerably along fractures to a brown, slightly pleochroic and highly birefringent mineral. This mineral which is fibrous in appearance and shows parallel extinction is possibly turgite, a secondary iron mineral.

An oil immersion method was used to determine the approximate refractive indices of the diopside. The indices $n_\lambda > 1.6679$ and $n_\gamma = 1.6901$ indicate that the pyroxene is close to diopside in composition (Winchell, 1947 p. 226).

Maximum extinction angles which in most cases are about $40^\circ$ further suggest the mineral is of a diopsidic composition.

**Plagioclase Feldspar:**

The plagioclase feldspar in the altered granitic rock is largely of the same composition as that of the unaltered rock, ie. medium andesine. Many of the plagioclase
grains show evidence of recrystallization. Sutured borders are common and the mineral may wholly enclose remnants and small grains of other minerals. Thin sections 5b and 14a have grains of plagioclase feldspar which are considerably more calcic than the normal variety. In general the more calcic feldspar determined as $Ab_{30}An_{70}$ occurs almost directly on the granitic rock-crystalline limestone contact. The grains of this material which occur as a decussate aggregate are considerably smaller on the average than the less calcic variety. Another characteristic of the calcic plagioclase is the relatively large amount of alteration as compared to the andesine type. A slight alteration of the feldspar to chiefly clinozoisite is common. In thin sections 5b and 14a, however, a large part of the feldspar is replaced by both calcite and clinozoisite.

**Orthoclase Feldspar:**

Orthoclase is fairly abundant in the altered quartz diorite. This mineral occurs as small anhedral grains which are regarded as a remaining constituent of the unaltered quartz diorite. It also occurs as small irregular veinlets which appear to have cut through and replaced the plagioclase. The orthoclase commonly is present along boundaries between plagioclase grains giving rise to irregularity of grain contacts. An insignificant amount of sericite might possibly be an alteration of the orthoclase.
Quartz:

Quartz, like the orthoclase, is especially prevalent in thin sections representing the contact between the granitic and crystalline limestone rocks. In some places quartz encloses grains of calcite and in others the calcite occurs in small fractures in the quartz. The mafic minerals are almost completely absent in the highly siliceous facies. Quartz grains include and cut the plagioclase feldspar and the mafic minerals. In no instance, however, was the quartz noted to have cut the orthoclase. Two ages of quartz are present; the later type encloses and cuts the earlier grains which were apparently a part of the original rock type. Although the quartz is especially prevalent directly on the contact between the altered granitic rock and the limestone it occurs in only very minor amounts in the altered pyroxene-bearing granitic rock. Only a few small grains of quartz are present in the latter rock type and these are commonly closely associated with the pyroxene.

Carbonate:

Calcite is a common mineral in the examined thin sections. On the contacts it occurs as disseminated grains and as a fracture filling. In places the minerals of the
granitic rock are highly fractured and the carbonate forms the cementing material between the fragments. Small veinlets of carbonate have much the same habit as some of the orthoclase. As might be expected calcite is much more common directly on the contact than elsewhere in the altered granitic rock. A small amount of carbonate occurs as an alteration of the pyroxene and in the siliceous contact facies with clinozoisite as an alteration of plagioclase.

**Clinozoisite (Zoisite)**

Clinozoisite is present in the altered igneous rock in variable amounts. In places it occurs mainly as an alteration product of the plagioclase feldspar, although minor amounts are associated with the pyroxene. In some instances, however, as particularly exemplified in thin section 15, the major amount of the clinozoisite occurs associated with actinolite in a well-defined fracture cutting both plagioclase and pyroxene alike. In general the clinozoisite decreases in abundance in the specimens taken farther from the contact. The lack of cleavage makes the determination of the mineral difficult since it is very similar to zoisite. Although a few grains show inclined extinction the latter mineral may also be present.

**Actinolite:**

Actinolite occurs, as mentioned above, closely associated with the zoisite. For the most part the mineral appears to have replaced the diopside. Mutual relations
of the actinolite and the biotite are discussed in the
description of the occurrence of the mafic minerals as a group.
It should be noted here that very little clinozoisite or
actinolite occurs in thin sections of the altered granitic
rock which contain only a minor amount of quartz.

Apatite:

Although apatite is abundant in the unaltered
granitic rock it appears to be even more abundant in the
altered variety. Euhedral grains are very common but never
attain a large size.

Sphene:

Sphene is abundant in all of the slides and commonly
occurs as a granular aggregate surrounding grains of magnetite.
Some of the grains of sphene, however, show a well developed
wedge shape. Both the sphene and magnetite appear to be
closely associated with the mafic minerals. The greater
abundance of sphene in the altered granitic rock as contrasted
with the unaltered variety is marked. The relationships of
sphene and biotite will be discussed later.
Mafics other than pyroxene and mutual relationships:

Biotite and amphibole occur in a few of the thin sections of rocks which apparently represent a transition zone between the altered and unaltered granitic rock types. As a result, in these thin sections the three mafic minerals, pyroxene, amphibole, and biotite, are closely associated.

The biotite occurs in frayed anhedral grains which show a marked reddish brown pleochroism. This pleochroism is very similar to that displayed by the biotite of the "Yukon Group" schists and is unlike that of the normal granitic variety. The chlorite, pennine, is present as an alteration product of the mica. Abundant small euhedral grains of sphene are associated with the amphibole and biotite. The mineral is largely concentrated along contacts between biotite grains and along cleavages in the biotite. In some instances the sphene appears to have grown by thrusting aside the mica along cleavages.

Two varieties of amphibole are present in the apparent transition zone. The first of these is a light green actinolitic variety which shows weak pleochroism. The second variety is much like the normal amphibole of the unaltered granitic rock showing pleochroism from tans to dark brown. The actinolitic amphibole appears to be later than the mica. In thin section 14 the amphibole contains shreds and remnants of biotite, many of which are in optical continuity. Cross cutting relationships suggest further that the amphibole is later than the mica.
The pyroxene in the transition zone appears to be more altered than that occurring nearer the contact. Much of the pyroxene is altered to a mixture of carbonate and actinolitic amphibole. In several instances assemblages of biotite, amphibole, and carbonate, occur without associated pyroxene. In these areas it is possible that complete alteration has taken place.

In thin section 12c the chief mafic minerals are actinolitic amphibole and biotite. A few altered grains of pyroxene and patches of actinolitic amphibole and carbonate are closely related. A few irregular, isolated, remnants of pyroxene in optical continuity seem to represent relic larger grains that have been replaced by plagioclase feldspar.

Needles and laths of actinolitic amphibole project into the pyroxene and in many cases into the plagioclase. Shreds of the amphibole occur in much of the pyroxene. As these shreds are in optical continuity the overall appearance suggests at first that the pyroxene has replaced the amphibole. This type of structure might be expected, however, as the replacement of the pyroxene by actinolitic amphibole would be controlled largely by the orientation of the space lattice in the pyroxene. The result, therefore, should normally be a common orientation of the amphibole grains. A close association of actinolitic amphibole and clinozoisite is evident, especially along well-defined fractures or veinlets.

The relationship of the pyroxene and biotite is
difficult to determine, but the evidence suggests that the mica is contemporaneous with or later than the pyroxene. In places grains of biotite, although very frayed in appearance, project into pyroxene grains. This feature and the alteration of the pyroxene suggest that the mica is later. One might expect that the biotite would also be considerably altered if it were contemporaneous or earlier than the pyroxene.

Summary of Rock Types:
A brief summary of the prominent minerals and the spatial relations of the various rock types in the area is necessary before a discussion regarding their genesis is undertaken. The description will begin with the unaltered granitic rock and then follow through the various zones to the crystalline limestone as follows: (See sketch in folder)  

1. Normal granitic rock
2. Transition zone
3. Pyroxene-bearing zone
4. Silica rich zone
5. Skarn
6. Crystalline limestone

The normal quartz diorite as described previously consists of medium andesine feldspar, quartz, biotite, hornblende, apatite, and sphene. In the vicinity of the limestone inclusion andesine is partially replaced by orthoclase. The above-mentioned rock type grades into the transition zone variety in which there is a change of the mafic
minerals. In this zone the mafics consist of actinolite amphibole, diopsidic pyroxene, and biotite. The biotite differs from that of the normal granitic rock in its frayed appearance and reddish brown pleochroism. A considerable increase in the amount of apatite and sphene is evident.

Farther towards the limestone, the rock consists essentially of medium andesine feldspar and diopside. Very little quartz is present. This is significant in that it represents the only granitic rock in the area that has a low free silica content. Beyond this zone occurs a zone which is characterized by the predominance of free silica, the high degree of alteration of the plagioclase, and the presence of wollastonite. The plagioclase is more calcic than the normal variety.

The latter zone grades into the skarn minerals, garnet, diopside, and wollastonite, and then into crystalline limestone.

It is difficult to assign definite widths to the zones described above as they appear to be variable. Minerals of the transition zone occur in the centre of the irregular granitic dyke approximately ten feet from the limestone. At the western limestone-granitic rock contact the transition zone variety occurs within two feet of the contact. The wollastonite, silica-rich zone appears to be not more than six inches wide in most cases.

The chief alteration of the limestone has probably been that of recrystallization. This is only an assumption, however, as the entire outcrop is composed of coarsely crystalline limestone or marble. Limestone occurring elsewhere in the Yukon Group schists and gneisses, however, is much finer grained. The development of skarn minerals along fissures or joints is another alteration of the limestone.

Minerals determined in the hand specimen and in thin section are chiefly brown garnet, diopside, wollastonite, carbonate, and quartz. The lateral distribution of these minerals is constant with the garnet forming the central part of the skarn bordered by diopside, wollastonite, and then calcite respectively. The transition between these minerals is not abrupt as grains of diopside occur with and completely enclosed in garnet. Grains of garnet up to 3 cm. in diameter are present in the hand specimen while the diopside occurs in grains up to 2 or 3 mm. Wollastonite bordered by the calcite on one side and diopside on the other occurs in lamellar grains up to one cm. in length. These grains in general are elongated at right angles to the walls of the joints. In this section the wollastonite is very much altered to carbonate giving the mineral a shred-like appearance.

Diopside grains are very irregular and are concentrated along the borders of the garnet grains. The diopside is embayed by and in places wholly enclosed by the garnet. Alteration of the diopside in thin section has occurred along
fractures to a mineral which is possibly turgite. A discussion of the alteration and the minerals formed will be given later.

Quartz occurs as small grains in the calcite and in most cases encloses minute particles of calcite. Small amounts of pyroxene are also enclosed by the quartz.

Specific gravity, x-ray (Bragg - 1937, p.157) and chemical tests suggest that the garnet is probably close to grossularite in composition. The approximate refractive indices of the diopside were determined by an oil immersion method and according to Winchell (1947 - pp.226) the composition of the mineral probably is close to that of diopside in the diopside-hedenbergite series. The presence of some iron in the diopside is suggested in the hand specimen by a limonitic stain associated with grains of this mineral.

Thin section thirteen is of interest as it shows a limestone-altered quartz diorite contact. This slide shows the minerals occurring in this zone including garnet, wollastonite, quartz, orthoclase, Ab\(_30\)An\(_70\), plagioclase, feldspar, zoisite, and calcite. The garnet contains a large amount of inclusions of quartz, plagioclase feldspar, and diopside, and appears to have engulfed these minerals. Orthoclase and carbonate in veinlets, however, cut across the garnet.

The calcic plagioclase feldspar is fine grained and rather extensively altered to clinzoisite. Quartz is extremely abundant in this section and has replaced the plagioclase feldspar.
Petrographic Description of the Feldspar Porphyry Dyke:

Thin sections were made representing the material of the central part of the dyke and of the contacts between the dyke with limestone and granitic rock.

Thin Sections 8, 6, 7b, 9.

Thin section 8 represents the rock type from the central part of the dyke. The rock is composed of approximately 35% plagioclase feldspar phenocrysts, a few hornblende phenocrysts, and a groundmass of plagioclase microlites.

The plagioclase phenocrysts, which average about two mm. in length, are for the most part strongly zoned and in several instances the feldspar forming the rims is more calcic than that of the central portion. One phenocryst showing both Carlsbad and Albite twinning was examined which had an outer rim of Ab$_{40}$An$_{60}$ (medium labradorite) plagioclase and an inner portion of Ab$_{65}$An$_{35}$ (sodic andesine) plagioclase. Microlites appear to be of a medium andesine composition but the exact determination of these is difficult. (Wahlstrom) The microlites display a certain amount of fluidal texture as they are somewhat lineated about the phenocrysts. Hornblende phenocrysts, which are minor in amount, and small grains of magnetite are also present in the rock. Much of the groundmass is made up of a brownish-stained, cryptocrystalline to glassy material.

Thin section 6 represents the dyke rock near the eastern limestone contact and consists essentially of the same
minerals as thin section 8. One notable difference however is the much greater abundance of euhedral hornblende phenocrysts.

Thin section 9 represents a limestone, dyke, granitic rock contact near the eastern margin of the outcrop. (See map of outcrop in folder).

Plagioclase feldspar occurs as microlites and as larger heavily fractured, unzoned, somewhat resorbed grains. The latter are commonly surrounded by microlites and cryptocrystalline to glassy material apparently related to the dyke rock. Quartz grains are abundant and have replaced some of the larger plagioclase feldspar grains. They are in turn, however, highly fractured with calcite and dyke material occurring as the filling material. Sphene is very abundant in the section in close association with grains of carbonate. Contorted shreds of biotite are quite common and appear to be associated with the dyke material. In several cases an incipient growth of needle like grains is apparent in the calcite near the contact with dyke material. The indices of refraction of the mineral appear to be slightly greater than that of the lower index of calcite. Small grains of sulfide are fairly abundant and the oxidation of this mineral has probably accounted largely to the rusty color of the weathered dyke.
Discussion and Conclusions:

The following discussion of the problems concerning the crystalline limestone occurrence in granitic rock will deal first of all and principally with, the locality in the south-west Yukon.

The first problem is that of the occurrence itself. As previously stated it is believed that the crystalline limestone or marble is a part of the "Yukon Group", rocks. Contorted bedding seen in another outcrop of limestone and associated schist and gneiss with similar outcrops in the area are supporting evidence for this theory. Other occurrences of crystalline limestone associated with gneisses, schists, and granitic rocks have been described by Kindle (1949, pp. 12-13) in the Dezadeash Map Area. The question then is why the particular limestone inclusion in question has no closely associated schist or gneiss.

Several possibilities concerning the present position of the limestone inclusion might be considered. First of all the Yukon Group rocks may have been invaded by a granitic magma with large blocks of limestone sinking into the magma. Secondly, the schists and gneisses presumably originally associated with the limestone, were readily assimilated by the granitic magma whereas the limestone, unsuitable chemically was not assimilated. Thirdly, the schists and gneisses may have been granitized. The limestone was little affected, on the other hand, because of the great chemical change it would have to undergo to change it to the
composition of granitic rock.

The possibilities will be discussed in the order given. The overall specific gravity of the limestone would probably be slightly less than that of the granitic rock because of the mafic materials in the latter. (Calculations based upon the normal granitic rock type show this to be the case - sp. gravity of granitic rock approx. 2.8 and of the limestone - approximately 2.7). It must be remembered, however, that the specific gravity of a magma would be considerably less than that of the crystalline rock type. Pirsson and Knopf (1946, p. 131) point out that in the change from glass to granite a decrease in volume of about 10 percent takes place. They show further that the volume of a magma is somewhat greater than when cooled to a glass. In the above case, then, allowing for a 10 percent decrease in volume the quartz diorite magma would have a specific gravity of slightly over 2.5. This figure would be increased somewhat if it be regarded that the magma contained a small percent of crystalline material.

The difference in specific gravity of the two rock types does not rule out the possibility that the limestone sank into the granitic magma. The predominantly upward pressure exerted by the magma would tend to counteract the sinking tendency of the intruded rocks to some extent. This hypothesis does not explain, however, why the limestone would sink into the magma unaccompanied by some schist or gneiss.
Shand (1943 - pp. 365-366) believes that a large block of
dolomite associated with foyaite in Sekukuniland, South
Africa has actually been floated up a distance of
approximately three miles from the underlying Transvaal system
through the Pretoria series and Bushveld complex to its present
position. In summary, it seems probable that the limestone
inclusions are not the result of blocks of limestone sinking
into an enclosing magma.

The other possibility is that of the assimilation
of the schists and gneisses and the chemical unsuitability
of limestone for assimilation. Lacroix (1943, pp. 103-104)
describes an interesting example in the Pyrenees in which a
granitic mass has invaded schists, quartzites, and limestones.
He believes that the massif rose by dissolving the sediments
away, the schists yielding readily to dissolution and the
limestone being more resistant. The result has been that great
masses of more or less altered limestone are included in the
granite. He goes on further to describe the change of
composition of the granite through assimilation of the limestone
with the production of more abundant and more basic mafic
materials and in places more calcic feldspar.

The nature of the schists and gneisses in the
general area of the limestone in the Dezadeash Area occurrence
lends itself quite well to the above hypothesis. A study of
the gneiss and schist in the area suggests that in overall
composition they are like that of the normal granitic rock.
The main difference is in that biotite is the chief mafic mineral. It might be worthy of note that in the granitic rock near the limestone inclusion biotite is considerably more abundant than hornblende. Some colorless garnet is also present in the metamorphic schists and gneisses but appears to be quite minor in the area.

The composition of the schists and gneisses therefore is that which would certainly have been favourable for assimilation without markedly changing the composition of the granitic magma. Assimilation of the crystalline limestone was apparently restricted as the zone of alteration in the granitic rock around the limestone body is less than ten feet in width.

Thus the possibility of the limestone inclusion having resulted from the assimilation of the schists and gneisses by a granitic magma seems reasonable. Some movement of the limestone mass after its inclusion in the granitic material might result if the magma were still mobile. This could presumably lead to a breaking up of some of the limestone masses and account for the number of small inclusions present in the area. The occurrence of the marble as lenses in schists and gneisses of the Yukon Group could, however, explain their present discontinuity. The final stage involving igneous activity in the area was the intrusion of the feldspar porphyry dyke. It is conceivable that the dyke was injected along a zone of weakness controlled by the presence of the limestone inclusion.
Field and petrographic evidence do not appear to support the hypothesis involving granitization. This hypothesis would involve an addition and subtraction of elements or ions to and from previous rock types with the result that they approximate a quartz diorite in composition. Since limestone would require a great exchange of components to change it to a granitic rock it might be expected to be altered with difficulty.

No partially granitized or 'ghost' inclusions were noted in the quartz diorite. In places lenses of quartz diorite in the schist have contorted schist bands adjacent to them and give the impression that they have been forcefully injected. A petrographic study of the schists and gneisses shows that although they are similar in composition to the quartz diorite the plagioclase is more sodic than that in the 'granitic rock. The plagioclase grains in the quartz diorite, moreover, show fairly well-defined zoning and those in the schists and gneisses do not.

Sequence of Events Leading to Alteration of Granitic Rock and Limestone:

The alteration of the granitic rock has involved chiefly a change of the mafic minerals from biotite and hornblende to diopsidic pyroxene. The question arises as to whether the pyroxene is a primary mineral in the zone of alteration, whether it has formed as a result of alteration of biotite and hornblende, or whether it is simply a skarn
mineral. The term skarn as used in this text refers to minerals which have formed during contact metamorphism of limestone and includes metasomatism. The presence of wollastonite in the contact facies appears to embrace the same possibilities.

**Direct Crystallization:**

In the first case the origin of the pyroxene might be attributed to the magma being enriched in calcium derived from the limestone. The acquisition of lime would probably increase the tendency of a magma to precipitate pyroxene rather than hornblende or biotite. The reason for this lies in the fact that the ratio of Mg : Ca in pyroxene which contains the two elements is commonly about 1:1 whereas in amphiboles the Mg : Ca ratio is much higher or approximately 3:1. Thus an increase in lime would seem to favour the crystallizing of pyroxene from a magma.

A study of the thin sections throws light on the nature of the pyroxene. Most of the pyroxene grains have irregular boundaries although some remarkably euhedral cross sections are present. In all of the thin sections in which pyroxene is present small remnants and grains of subhedral to euhedral medium andesine feldspar and quartz occur enclosed within pyroxene grains.

Relationships of the pyroxene to the plagioclase feldspar and quartz suggest that if the diopside were a product of magmatic crystallization it crystallized later
than other two minerals. If this were not the case it would be difficult to explain the subhedral to euhedral grains of plagioclase and quartz included in the pyroxene. A number of euhedral cross-sections of diopside, however, do not suggest that the mineral has formed in interstices left by the crystallization of the other minerals.

Diag. 1

Diag. 1 is a ternary equilibrium diagram after Bowen, in which the three components are diopside, anorthite, and albite. Although the diopside in the altered granitic rock actually contains some of the hedenbergite molecule, a small percentage of this molecule would not probably alter the equilibrium diagram to any great extent. Any liquid having an original composition lying within the hatched area of the diagram will crystallize plagioclase feldspar before diopside regardless of the final feldspar composition. Thus a
relatively late crystallization of the diopside might be explained.

![Diagram]

Diag. 2, also after Bowen, is termed Bowen's reaction series. This sequence of mineral formation is that which might be expected to normally take place in magmatic crystallization. From this diagram it can be seen that pyroxene should form before quartz. Thus even though it might be argued that the pyroxene could have crystallized later than the plagioclase there does not appear to be the same possibility concerning the quartz.

Another feature which seems to be difficult to explain if this hypothesis is true is the composition of the pyroxene. Diopside is characteristically a metamorphic mineral and one might expect an aluminous pyroxene rather than the non-aluminous diopside to be precipitated from a
magma. The presence of wollastonite occurring in a similar manner along the limestone contact suggests that the mineral has a similar origin as it is also a typical metamorphic mineral.

If the crystallization of the pyroxene and diopside is the result of a quartz-diorite magma being enriched in lime the question arises as to why the plagioclase feldspar is not much more calcic in the contact facies. Admittedly a small amount of calcic labradorite occurs almost directly on the limestone contact but the major portion of the feldspar associated with the diopside is medium andesine. This plagioclase appears to have an almost identical composition with that of the normal quartz diorite.

G.D. Osborne (1932, pp. 227-232) has described an occurrence of limestones and contaminated igneous rocks of the Carlingford district in Ireland. In this area - pegmatites consisting normally of microperthite, albite, oligoclase, quartz, magnetite, pyrite, biotite, and hornblende, have invaded and are contaminated by limestone. The contaminated or altered pegmatites consist of wollastonite, andradite, hedenbergite, labradorite, orthoclase, sphene, apatite, magnetite, and pyrite. Osborne concluded that the pegmatites reacted with the limestone and took Ca O into solution. Before this reaction, however, metasomatic replacement of the limestone by solutions derived from the approaching pegmatite resulted in the formation of skarn minerals. The lime enriched
liquid began to crystallize wollastonite and labradorite feldspar while at the same time the mechanical action of the liquid separated garnet and pyroxene from the neighboring skarn. Finally Osborne attributed the euhedral habit of the garnet and pyroxene to a recrystallization due to the influence of the magma.

In the above instance it is clear that the magma assimilated lime because of the composition of the feldspar in the altered rock. It is not clear, however, why Osborne chose to attribute the wollastonite and hedenbergite to different modes of origin.

Recrystallization of the minerals due to metamorphism could presumably explain the present relationship between the pyroxene and plagioclase grains. The composition of the pyroxene and of the plagioclase as previously mentioned, does not seem to favour a primary crystallization of these minerals from a magma enriched in lime. Wollastonite and Ab$_{30}$An$_{70}$ plagioclase occurring at the contacts of limestone and granitic rock may possibly be products of crystallization from a magma enriched in lime.

**Metamorphic Origin of Pyroxene:**

If the diopside is not a product of normal crystallization it may have formed as a metamorphic mineral. In the latter case two processes might be examined. First of all the diopside and wollastonite formed as metamorphic minerals as the magma approached the limestone. These
minerals were later engulfed by the magma and as a result attained their present relationships. Secondly the normal mafic minerals originally crystallized in this area and the diopside formed largely as a replacement of these minerals. The foregoing hypotheses will be discussed in the order given above.

Wollastonite and Diopside as Skarn Minerals:

The first hypothesis involving diopside and wollastonite as skarn minerals, is similar to that proposed by Osborne, as mentioned previously. The wollastonite is associated with a plagioclase feldspar which is more calcic than the normal variety. It might be postulated that both minerals crystallized from a lime enriched liquid. Since the diopside, however, is not associated with an unusually calcic plagioclase it does not seem that the zone in the magma in which diopside occurs was enriched in lime.

The order of the zones occupied by the wollastonite and pyroxene near the limestone contact has the same spatial relation to the limestone as those which occurred in the bands of skarn minerals along the joints in the inclusion. If the diopside and wollastonite were included by a magma after their formation, a considerable amount of associated garnet would be expected, as it is the predominant skarn mineral. No garnet occurs in the altered granitic rock excepting directly on the limestone contact. This latter feature appears to be the major objection to the formation of the skarn minerals prior to inclusion by the magma. An
inclusion of skarn minerals by a magma not enriched in lime also does not explain why biotite and hornblende are not present in the pyroxene-bearing granitic rock.

Another fact to be explained is the occurrence of subhedral to euhedral grains of quartz and plagioclase in the pyroxene. This apparently could be brought about only by a considerable recrystallization of the minerals involved.

**Pyroxene (and Wollastonite) as a replacement:**

A replacement origin of the diopside and wollastonite would involve a diffusion of lime across the contact from the limestone to the granitic rock. The constant composition of the plagioclase suggests that very little lime was assimilated by the magma prior to its initial crystallization. If this were the case there seems to be little reason why the normal mafic minerals, biotite and hornblende, should not have formed. Thus in the early stages of magmatic intrusion the granitic rock may have been similar to the present normal variety. A minor amount of calcic plagioclase occurring along the limestone contact might represent crystallization from a locally lime-enriched portion of the magma.

Later, as the magma completely engulfed the inclusion the temperature could have increased. During this stage a diffusion of lime from the limestone into the granitic rock promoted a replacement of the original mafic minerals by pyroxene. This change would involve a release of
H₂O, aluminum, and probably some iron and magnesium. The last three elements are present in the diopside and garnet of the skarn zones. In this way the exchange of elements which has apparently taken place between the limestone and granitic rock might be explained.

The actinolitic amphibole of the transition zone may also represent a replacement of earlier formed rock minerals. In the formation of actinolite the Mg; Ca ratio would be considerably greater than that for diopside. This zone then might represent a dropping off in the amount of available lime as the lime diffused farther and farther from the limestone.

In the pyroxene zone the alteration has resulted in a certain amount of desilication. Possibly much of the free silica in this area moved into the skarn zone to form part of the skarn minerals.

At this period of maximum mobility of the various elements a minor recrystallization of the plagioclase feldspar would result in the sutured irregular borders displayed by this mineral.

Recrystallization of the biotite could also have occurred at this time. Metamorphism of a titano-biotite with the introduction of lime from the limestone may account for the large amount of sphene occurring along cleavages in the biotite and along the contacts of biotite grains. It has been noted that aggregates of sphene grains occur around grains of magnetite. This suggests that the magnetite may
have been a titaniferous variety. Harker (1932, p 281) has a diagram showing an albite-epidote-hornblende schist in which abundant sphene has formed around grains of iron ore. Probably the available titanium was closely related in both of the above cases to the iron-bearing mineral.

Whether or not a titanium-bearing magnetite is unstable in a lime-rich environment is questionable. Large bodies of titanium-bearing magnetite occur associated with anorthosites. On the other hand large masses of magnetite related to contact metamorphism of limestones appear to contain little titanium.

Now let us assume a normal cooling of the area associated with the introduction of a considerable amount of highly siliceous material now represented largely by quartz and orthoclase. One suggestion is that this fluid represented a late differentiate of the parent magma similar in composition to normal pegmatitic fluids related commonly to large granitic masses. This migration of this liquid was restricted mainly to the limestone-granitic rock contact.

In the highly siliceous environment pyroxene and medium calcic plagioclase would be unstable. As a result saussuritization of the feldspar and uralitization of the pyroxene took place. Turner (1946 - p. 121) states that saussuritization and uralitization are sometimes intimately connected, with the two processes taking place simultaneously. In fact, one equation suggested by Turner to represent the
saussuritization of a calcic plagioclase involves an addition of lime, silica, and alumina, all of which could be the by-products of uralitization.

Swanson (1924 - P.124-A) shows a similar type of alteration in a tonalite which intrudes limestone rocks on Texada Island in British Columbia.

Replacement of the medium andesine of the "normal" feldspar by orthoclase was probably contemporaneous with the saussuritization and uralitization. Fractures in the altered granitic rock containing clinozoisite and actinolite also contain orthoclase.

The myrmekitic structure displayed by the plagioclase feldspar represents a somewhat unusual type of occurrence. Small irregular blebs of quartz in numerous instances occur within plagioclase grains similar in composition to the plagioclase of the normal granitic rock. In a few places these blebs protrude into the bordering orthoclase and some blebs occur wholly within orthoclase grains.

The close relationship of the orthoclase and the myrmekite suggests that the structure is connected to the replacement of the medium plagioclase. The potash-rich liquid probably contained a high percentage of silica and the corrosive effect of this liquid resulted in the resorption of some of the plagioclase after the initial formation of a myrmekitic structure. Thus the isolated blebs of quartz in orthoclase probably represent the remnants of a previous plagioclase
myrmekite. Resorption of the plagioclase would then result in the presence of the blebs in orthoclase.

A similar occurrence is cited by T. Strand (1949, p. 21-22) in which potash feldspar appears to have replaced plagioclase. The formation of myrmekite in this manner is the reverse of the process generally ascribed to the normal formation of myrmekite. This latter process involves the replacement of orthoclase by a plagioclase feldspar. The released silica forms blebs which appear around the borders of the orthoclase. Tyrrell (1942 - pp.94) attributes the structure in most cases to a thermal metamorphism under uniform pressure.

The type of replacement involving the alkali and medium andesine feldspars appears to be different from that involving the replacement of diopside by actinolite. In the latter case the relationships of the two minerals suggests an ion for ion substitution during which neither of the minerals were ever in a liquid form during the replacement period. The relationship of the two varieties of feldspar suggests, however, that replacement took place at a sufficiently high temperature as to allow a certain degree of fluidity. This is shown by the bulbous protruberances of the medium andesine into the orthoclase and vice versa.

Serpentinization of the pyroxene as mentioned previously may have taken place before the formation of the metamorphic biotite. This relationship is suggested by the lack of alteration of the biotite to any great extent, in the zones containing partially serpentinized pyroxene. The
possibility exists, however, that biotite, being a hydrous mineral, would not be as readily altered as the pyroxene. A definite weakness in the above hypothesis is that no relics of amphibole and biotite occur in the pyroxene. A preservation of these relic structures would be expected, however, to occur in the transition zone, if at all. Admittedly the relationships of the minerals in this zone are complex and certainly anything but clear.

The hypothesis seems to fit the evidence more satisfactorily than those discussed previously and as a result is favoured by the author.
Discussion of Feldspar Porphyry Dyke

Alteration caused by the intrusion of the feldspar porphyry dyke appears to be restricted to a narrow border of silicification where the dyke is in contact with the limestone. No apparent alteration of the dyke by the limestone was noted in the thin sections.

Many phenocrysts of plagioclase, as noted in the description of the thin sections, show a reversal of normal zoning. This is brought about by the presence of a more calcic plagioclase near the margins of the grains than in the central portions. The presence of an ill-defined trachytic texture suggests that the liquid has been in motion after the formation of some of the crystalline material. Movement of a plagioclase crystal into an area of higher temperature than that at which it was formally in equilibrium would result in a reversal of normal zoning.

Lack of significant alteration with the exception of minor silicification, along the dyke-limestone contact suggests that the dyke was intruded at a temperature lower than that at which the main igneous mass was intruded.

![Diagram](attachment:image.png)
Diagram 3 shows the P-T diagram for calcite, quartz, and wollastonite. It can be seen that even at a relatively great pressure the temperature at which wollastonite would form is approximately 800°C. This seems to rule out the possibility that the plagioclase phenocrysts crystallized in the vicinity in which they are now found. It appears probable then that the plagioclase phenocrysts crystallized in an environment of higher temperature and were injected as ready-formed crystals into their present position. Further evidence to support this theory is that there appears to be very little difference in grain size of the plagioclase phenocrysts at the centre of the dyke as compared to those along the margin.

It might be noted that an incipient crystallization of fibrous to lath-like mineral occurs in some of the calcite grains. The refractive index of this mineral appears to be of the same order as that of wollastonite. Possibly these grains represent the initiation of wollastonite formation. In any case, with the exception of minor silicification no evidence is present of endomorphic or exomorphic effects produced by the intrusion of the dyke into the limestone inclusion.
Description of British Columbia Occurrences:

A second location of granitic rock in contact with crystalline limestone is in British Columbia about eighteen miles southeast of the first described occurrence.

The rock types in the area as described by K. DeP. Watson (1948, pp.27-28) are very similar to those which have already been described, consisting of quartz, diorite and granodiorite with inclusions of gneiss, schist, and lenses of grey marble. The schists and gneiss are chiefly rusty-weathering staurolite-bearing varieties which contain sills of granitic material.

The grey marble is in places metamorphosed to form wollastonite skarn, brown garnetite, and skarn consisting of green pyroxene and brown garnet. These metamorphosed rocks are mixed with abundant metamorphosed granitic rock which consists of white feldspar, green pyroxene, and which locally contains bands and nodules of brown garnet.

In general the unaltered granitic rock types in this vicinity are similar to those which occur to the north-west. A somewhat higher percentage of orthoclase was noted in some specimens, however, and some of the rock types are properly classed as granodiorite.

Description of thin sections 530 and 50.

Thin section 530 is a slide made of a specimen which might be regarded as being of the typical altered "granitic" rock type of the area.
The mafic material which is a diopsidic pyroxene occurs as porphyroblasts up to two cm. in length in the feldspar. The porphyroblasts include small grains of feldspar in a few places. Orthoclase and medium andesine plagioclase feldspar are present in approximately equal amounts with the former clearly cutting and including remnants of the latter. The feldspar is in general equigranular occurring in grains up to three mm. in length. No quartz is present and the only other mineral noted in thin section was apatite which occurs in small euhedral grains.

Thin section 50 which contains both quartz and orthoclase shows both these minerals cutting and containing remnants of plagioclase feldspar and pyroxene. Also in the thin section a small amount of actinolitic amphibole has replaced portions of the pyroxene grains around the grain boundaries.

In the hand specimen some of the garnetiferous altered granitic rock is made up of brown garnet, creamy feldspar, and large crystals of orthoclase and carbonate. Other specimens contain a considerable amount of clear quartz.

In general, then, the mineralogical composition of the crystalline limestone and altered granitic rock in the vicinity is similar to that of the first mentioned locality. The main difference appears to be the greater amount of orthoclase which in places occurs as euhedral grains up to three cms. in length at the British Columbia locality. The minerals zoisite and clinozoisite were not noted in the thin sections representing the above occurrence.
Discussion and Conclusions:

No transition zone has been described in the locality between the contaminated or hybrid igneous rock and the "normal" granitic rock of the area. The close association of the pyroxene-bearing diorite with limestone, however, suggests that the genesis of this rock type is similar to that of altered granitic rock type previously described. There is a remarkable similarity not only in the mineral assemblage present but also in their paragenesis.

Porphyroblasts of diopside are well developed and as a result the mineral is more conspicuous in the hand specimen than it is in the other occurrences. In thin section the diopside does not seem to contain many inclusions but those that do occur are subhedral to euhedral. A metamorphic origin of the pyroxene seems to be the most likely postulate.

The similarity in composition of the plagioclase feldspar in the "hybrid" rock type and that of the unaltered granitic rock, to which the former rocks are presumably related, does not suggest an assimilation of much lime by the magma. Thus a theory involving the crystallization of pyroxene from a lime enriched magma hardly seems justifiable.

Whether the pyroxene has formed as a replacement of the original rock-forming minerals or was included as an already-formed skarn mineral is controversial. The latter hypothesis has some support in that garnet and wollastonite also occur in parts of the altered granitic rock.
Recrystallization could then produce relationships of the plagioclase grains including grains of plagioclase.

Certainly no evidence is present that pyroxene has replaced amphibole or biotite in these specimens. It is questionable, however, whether the lack of relic fragments of the other mafic minerals is sufficient proof to rule out a hypothesis involving the replacement of these minerals by the pyroxene.

The original altered "granitic" rock in this area contained little if any quartz. The quartz which is present has been introduced as a replacement of earlier minerals with the orthoclase. Presumably the free silica of the original magmatic material combined with lime and other available elements to form the skarn minerals. Some of the large, subhedral to euhedral grains of orthoclase have obviously formed in vugs or cavities allowing a more or less unrestricted growth.

A myrmekitic structure involving quartz blebs in plagioclase feldspar has resulted from the replacement of the plagioclase by the orthoclase and quartz. The origin of this structure appears to be similar to that of the myrmekite previously described.

In conclusion the remarkable similarity of the altered granitic rock types in the two localities and a corresponding similarity between the unaltered types suggests that their genesis is probably closely related.
Fig. 1. Replacement of andesine by orthoclase with development of myrmekite

Fig. 2 Same as above
Fig. 3 Sphene occurring along boundaries and cleavage in biotite grains

Fig. 4 Actinolitic amphibole grains projecting into pyroxene and andesine grains
Fig. 5
Inclusions of andesine in pyroxene

Fig. 6
Concentration of pyroxene along border of garnet grain. A few isolated grains of pyroxene occur in carbonate
Photos showing inclusions of crystalline limestone (white weathering) in quartz diorite on the north side of the Unahini Valley.
BIBLIOGRAPHY

Bowen, N.L.  
"The Evolution of the "Igneous Rocks."  
Princeton University Press, 1937, p. 47  
and p. 60.

Bragg, W.L.  
"Atomic Structure of Minerals". Cornell  
University Press, 1937, p. 157

Grout, F.F.  
"Petrography and Petrology." McGraw-Hill  

Harker, A.  
"Metamorphism". Methuen, 2nd Oct. 1939,  
p. 281

Kindle, E.D.  
"Dezadeash Map-Area, Yukon". 2nd Prel.  

Lacroix, A.  
See Shand - pp. 103-104

Osborne, G.D.  
"Metamorphosed Limestones and Associated  
Contaminated Igneous Rocks of the  
Carlingford District". Co. Louth, Geol.  

Pirsson and Knopf  
"Rocks and Rock Minerals". Wiley, 3rd  
Ed. 1946. p. 131.

Shand, S.J.  
"Eruptive Rocks". Murby, 1943, 2nd Ed.  
pp. 365-366, pp.103-104

Strand, T.  
"On the Gneisses From a Part of the North-  
Western Gneiss Area of Southern Norway."  
Norges Geologiske Undersokelse, No. 173  
1949, pp. 21-22.
<table>
<thead>
<tr>
<th>Author</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rept. 1924, part A. pp. 106A-144A.</td>
</tr>
<tr>
<td>Turner, F.J.</td>
<td>&quot;Mineralogical and Structural Evolution of the Metamorphic Rocks&quot;. G.S.A.</td>
</tr>
<tr>
<td></td>
<td>Mem. 30, 1948</td>
</tr>
<tr>
<td>Wahlstrom, E.E.</td>
<td>&quot;Igneous Minerals and Rocks&quot;. Wiley and Sons, 1947, p. 73</td>
</tr>
<tr>
<td>Watson, K. deP.</td>
<td>&quot;The Squaw Creek-Rainy Hollow Area, Northern British Columbia&quot;. B.C.</td>
</tr>
<tr>
<td>Winchell, A.N.</td>
<td>&quot;Elements of Optical Mineralogy&quot;</td>
</tr>
</tbody>
</table>
Introduction to Appendix:

The appendix includes a detailed description of the more important thin sections studied for this report. The method of identification of the individual minerals is given only for the thin sections in which a particular mineral was first encountered. Thin sections which were examined but which are similar to other thin sections are not included.
Thin Section 1
Quartz Diorite 50' east of eastern Is. contact

Minerals Present:
1. Med. Andesine feldspar \((\text{Ab}_{60}\text{An}_{40})\) - (55-60)%
   Optical properties
   Albite twinning
   N'S > balsam
   low birefringence
   low relief
   symmetrical extinction angles \(\approx 23^\circ\)
   Z \(\wedge 001\) - Sect. cut 1X - 25°

2. Quartz (15-20%)
   Optical properties
   low biref
   N'S > balsam
   no twinning
   Uniaxial \(\text{\pm}\)

3. Biotite (15%)
   N'S > balsam
   high birefringence \(\approx .030\)
   good cleavage in one direction
   parallel extinction
   pleochroic - browns - light tan
   maximum absorption parallel to P P.

4. Hornblende (10%)
   N'S > balsam
   Medium relief
   Good cleavage at 56°
   Birefringence \(\approx .020\)
   Pleochroic - greens to light brown
   maximum extinction 20°

5. Orthoclase (very minor amount)
   low relief
   N'S - balsam
   no twinning
   low birefringence
   pink tinge in thin section.

6. Accessory minerals,
   Apatite
   Sphene

Texture
Medium to fine grained, hypidiomorphic; plagioclase
feldspar shows weak zoning; irregularity of some of feldspar
grains suggests minor recrystallization.

Inferences

The irregular plagioclase-quartz contacts and oriented inclusions of plagioclase in quartz indicates a minor amount of replacement or resorption of the plagioclase has taken place.

The mineral assemblage, texture, and zoning of the plagioclase feldspars, suggest that the rock is a normal plutonic igneous type. According to Grout's classification of igneous rocks, the rock type is a quartz diorite.

Thin Section 1B

Quartz-Diorite - 3 miles east of Ls. on Haines Road.

Minerals Present:

1. Medium Andesine (Ab\textsubscript{60}An\textsubscript{40}) - 50%
   - Biotite 20%
   - Hornblende 15%
   - Quartz 15%
   - Orthoclase (minor)

2. Accessory minerals
   - Apatite
   - Sphene
   - Magnetite

Texture

Medium to coarse grained hypidiomorphic average grain size approximately 4 mm. Feldspars show fairly well-defined zoning. A very minor amount of myrmekite is present.

Inference

The rock type represented appears to be a normal plutonic quartz-diorite. The minor amount of myrmekite around
the borders of a plagioclase grain appears to be related to irregular grains of orthoclase which contact the plagioclase.

Thin Sections 4 and 12

Altered Quartz Diorite.

T.S. 4

Minerals Present

1. Medium Andesine (Ab$_{60}$An$_{40}$) - 35%
2. Quartz - 30%
3. Diopside - 20%
4. Clinzoisite (possibly some zoisite)
   N'S > balsam
   medium high relief
   anomalous blue birefringence - also yellowish green
   cleavage 1 direction
   extinction commonly parallel
   but in one instance - 7°
5. Actinolite
6. Orthoclase

Accessory minerals

Apatite
Sphene

Texture and Relationship of Minerals

The texture is crystalloblastic with the average grain size being approximately 3 mm. As in thin section 5 the diopside grains contain numerous inclusions.

Alteration

Actinolite and clinzoisite have formed as alteration products of diopside. The clinzoisite also occurs as
an alteration of the plagioclase. Both clinozoisite and actinolite are concentrated along a fracture which cuts both plagioclase and pyroxene. The actinolite is restricted to that part of the fracture crossing the pyroxene but the clinozoisite occurs throughout.

Orthoclase is also present in the veinlet.

Inferences

The close association of actinolite and clinozoisite suggests that these minerals were produced contemporaneously and thus in the same environment. The presence of orthoclase in the fracture indicates that the alteration is closely related to the period when the orthoclase was introduced.

Thin Section 12

Altered Quartz Diorite

Thin section twelve is identical with thin section four in most respects but does not contain clinozoisite or actinolite. In places plagioclase feldspar seems to have replaced plagioclase. This is thought to be the result of intensive recrystallization which has also left isolated grains of pyroxene in optical continuity surrounded by plagioclase.

Thin Section 5

Typical altered Quartz-diorite.
Minerals Present:
Medium Andesine (Ab$_{60}$An$_{40}$) - 70%
Diopside - 15-20%
(Indices of refraction - oil immersion method)
\[ n_{\alpha} = 1.6679 \]
\[ n_{\beta} = 1.6901 \]
Carbonate - 10%
Quartz - 5%
Orthoclase (minor)
Actinolite (minor)

Accessory Minerals
Apatite
Sphene - not abundant.

Texture
The texture is predominantly crystalloblastic with the average grain size being about 1.5 mm. In general the pyroxene grains are quite irregular but a number of almost euhedral grains are present. Subhedral to euhedral inclusions of plagioclase are present in grains of diopside. In a few cases quartz inclusions also occur in the pyroxene.

A very ill-defined zoning is displayed by a few plagioclase grains.

Alteration
Minor alteration of the pyroxene has resulted in a black amorphous kaolin-like material along fractures, and a minor amount of actinolite.

Inferences
Inclusions of plagioclase and quartz in the diopside indicate that the diopside grew later than the former minerals. The small amount of sphene and the lack of biotite seems to
be evidence to support the view that the titanite is closely related to the biotite in origin.

**Thin Section 5b**

Altered Quartz Diorite close to limestone contact.

Minerals present:
- Quarts - 45%
- Wollastonite - 20%
  - Colorless in thin section
  - N'S > balsam = 1.6
  - Birefringence = .012
  - Nearly parallel extinction
  - Good cleavage parallel to length of grain
  - On cross section cleavage in three directions - two nearly at right angles
  - Biaxial 2V = 30°
  - Optic plane at right angles to length of grain and cleavage
  - Length slow and length fast
- Diopside - 5%
- Calcic Labradorite - 20%
- Carbonate
- Zoisite

Accessory minerals
- Apatite
- Sphene

**Texture and Relationship of Minerals**

The texture displayed by this slide is controlled largely by the replacement of the plagioclase by zoisite and carbonate. As a result most of the grains are anhedral and remnants of the various minerals are common. Some of the wollastonite grains are subhedral to euhedral but alteration to carbonate has also resulted in shreds of this mineral being present. Wollastonite occurs in grains up to 0.5 mm. whereas the diopside is present only as very small anhedral grains.
Alteration

Much of the plagioclase has altered to zoisite and carbonate. The carbonate has also formed as an alteration of the wollastonite.

Inference

The presence of wollastonite appears to be restricted in this suite of specimens to the near-contact facies of the altered granitic rock.

Thin Section 12a

Transition zone - altered 'granitic' rock

Minerals Present

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Abundance</th>
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<tr>
<td>Medium Andesine</td>
<td>(Ab$<em>{60}$An$</em>{40}$) 50%</td>
</tr>
<tr>
<td>Biotite</td>
<td>15%</td>
</tr>
<tr>
<td>Quartz</td>
<td>5%</td>
</tr>
<tr>
<td>Orthoclase</td>
<td>minor</td>
</tr>
<tr>
<td>Actinolite</td>
<td>15%</td>
</tr>
<tr>
<td>Pleochroic</td>
<td>light greens</td>
</tr>
<tr>
<td>$N'S &gt;$ balsam</td>
<td>medium relief</td>
</tr>
<tr>
<td>birefringence = 0.025</td>
<td></td>
</tr>
<tr>
<td>max. extinction = 15%</td>
<td></td>
</tr>
<tr>
<td>max. absorption parallel to length of grain</td>
<td></td>
</tr>
<tr>
<td>length slow i.e. Vibration direction making smaller angle to cleavage</td>
<td></td>
</tr>
<tr>
<td>good cleavage at 56°</td>
<td></td>
</tr>
<tr>
<td>optically negative</td>
<td></td>
</tr>
</tbody>
</table>

| Diopside         | 15%       |
| $N'S >$ balsam   | medium high relief |
| birefringence = 0.028 |
| good cleavage at right angles |
| maximum extinction angle = 42° |
| Biaxial $\phi$   |
| $2V = 60°$       |

Accessory Minerals

- Magnetite
- Sphene
- Apatite
- Carbonate
Texture

The overall texture displayed by the slide might be termed crystalloblastic. Almost all of the grains are anhedral and only laths of actinolite show any tendency to regular grain boundaries. Biotite, especially, occurs in extremely anhedral grains. Some of the plagioclase feldspar grains show a very faint zoning.

Alteration

Minor carbonatization has occurred in the plagioclase along small fractures and has also affected pyroxene to some extent. The alteration of pyroxene to actinolite is evident in a number of cases.

Inference

The actinolite has evidently formed as an alteration of the pyroxene. This fact is indicated by the fresh-looking laths of actinolite which project into the pyroxene grains and also project from the ends of pyroxene grains into the plagioclase.

The relationships of the three mafic minerals, diopside, biotite and actinolite is spatially very close. It is difficult to determine, however, the paragenetic relationship of the biotite to the pyroxene. That the biotite is a metamorphic variety is suggested by its strong reddish pleochroism.

Sphene is extremely abundant along cleavages of
biotite and along borders of this mineral. This close spatial relationship indicates that the formation of sphene may be related to the metamorphism involving the biotite.

Thin Section 12b

Transition zone - altered granitic rock.

Minerals present
- Sodic andesine (Ab₆₅An₃₅) - 70%
- Hornblende - 15%
- Quartz - 10%
- Orthoclase
- Actinolite
- Carbonate
- Pennine

Accessory minerals
- Sphene
- Apatite

Texture

The texture is similar to that of thin section 12a.

Alteration

The biotite has partly altered to the chlorite, pennine.

Inference

The minor amount of actinolite and pyroxene in this thin section serves to indicate further that actinolite in section 12a has formed largely by a replacement of the pyroxene. Patches of carbonate and shreds of actinolite may represent alteration of pyroxene grains but no remnants remain.
Thin Section 12c and 14

'Transition' zone - altered quartz diorite.

Minerals present
1. Medium Andesine (Ab60An40) - 50%
2. Actinolite - 15%
3. Biotite - 10%
4. Quartz - 20%
5. Orthoclase (minor)
6. Pyroxene (minor)

Accessory Minerals
Apatite
Sphene

Texture
The texture is similar to that shown by thin section 12a. Many inclusions of plagioclase are present in the amphibole. Replacement involving the introduction of quartz and minor orthoclase is evident.

Inference
On the whole a rather extensive recrystallization is suggested by the irregular grains and numerous inclusions. Inclusions of plagioclase by amphibole indicate that the latter was the later mineral to grow.

Thin Section 14

'Transition' zone - altered quartz diorite.

Thin section 14 is similar in almost every respect to thin section 12c. The importance of this section, however, lies in the fact that good relationships showing the replacement of biotite by actinolite are present.
Thin Section 14a

Altered Quartz-diorite close to the limestone contact.

Minerals Present
1. Quartz - 55%
2. Diopside - 15%
3. Sodic Bytownite
   N'S > balsam
   fair relief
   low birefringence
   Albite twinning
   maximum symmetrical extinction angle - 41°
   Extinction - 41°
   Angle from trace of 001^ to X in section
   cut normal to Z - 49°
   in same section 010^ to X - 41°
4. Zoisite
   Similar properties as clinozoisite
   Shows anomalous blue but not yellowish green
   birefringence
5. Orthoclase

Accessory Mineral
Sphene

Texture and Relationships of Minerals

In places the plagioclase grains occur in a crystall-
oblastic decussate arrangement—the individual grains averaging
about 0.2 mm. Larger grains of plagioclase up to 2 mm occur
but appear to have been fractured considerably. Orthoclase is
present along most of these fractures. Quartz has extensively
replaced the feldspar and occurs in grains up to 3 mm.

Alteration

Zoisite is the major alteration product and has almost
completely replaced some of the larger plagioclase grains.
Inference

The composition of the plagioclase indicates a definite increase in lime content in this particular area. The high quartz content is obviously the result of a relatively later introduction of this mineral.

Thin Section 17

Slightly altered Quartz Diorite 50' west of Is. inclusion.

Minerals Present

Sodic Andesine (Ab$_{65}$An$_{35}$) 30%
Hornblende 20%
Biotite 15%
Quartz 10%
Orthoclase 20%
(Determined by K. DeP. Watson with use of universal stage)

Accessory Minerals

Apatite
Sphene

Texture

The texture is largely medium grained, hypidiomorphic but in numerous cases highly irregular grains have formed by the replacement of plagioclase by orthoclase.

Myrmekite is present near the borders of plagioclase grains where they are in contact with orthoclase.

Inference

An introduction of potash feldspar and silica has resulted in resorption of some of the plagioclase and apparently has been a factor in the origin of the myrmekite.
Thin Section 19b

Typical gneiss of 'Yukon Group'
(Quartz-feldspar-biotite-garnet-gneiss)

Minerals Present
Sodic Andesine ($\text{Ab}_{70} \text{An}_{30}$) 45%
Sodic Andesine ($\text{Ab}_{65} \text{An}_{35}$) 45%
Quartz - 30%
Biotite - 20%
Garnet
Magnetite
Apatite
Chlorite

Texture
Crystalloblastic

Structure
Gneissose

The minerals display the typical mosaic arrangement characteristic of metamorphic rocks. Only the mica, apatite, and garnet, show any crystal form with the mica giving the rock its directional properties.

Inference
The rock type seems to be the product of regional metamorphism. An abnormally high content of soda, as might be noted by the mineralogical composition, is present.

Thin Section 50

Altered granitic rock east of Blanchard Lake.

Minerals present
Quartz - 40%
Sodic Andesine 20%
Orthoclase - 20%
Diopside - 15%
Apatite
Texture and relationships of minerals

All of the minerals occurring in this thin section are anhedral with the average grain size being approximately $2\frac{1}{2}$ mm.

Replacement of plagioclase and diopside by orthoclase and quartz is evident.

The pyroxene is remarkably fresh and shows no alteration.

Thin Section 13

Altered Quartz Diorite - limestone contact

Minerals present
- Garnet - 20%
  - High relief - N'S greater than balsam
  - Colorless in thin section
  - Isotropic
- Diopside - 10%
- Quartz - 30%
- Plagioclase (Ca Labradorite - 25%
  (Na Bytownite
- Carbonate
- Clinozoisite
- Orthoclase

Accessory Minerals
- Apatite.

Texture and Relationships of Minerals

The texture is typically crystalloblastic with much of the feldspar, diopside, and considerable quartz occurring in grains averaging about .4 mm. Irregular grains of quartz up to 3 mm. are present but the largest grains are those of garnet which display a sieve structure. The garnet contains grains of quartz, feldspar, quartz, and plagioclase.
Orthoclase and carbonate veinlets cut all the other minerals present in the section. Quartz has replaced much of the plagioclase.

**Alteration**

Clinzoisite and carbonate have formed as alteration products of the plagioclase and of diopside. Diopside has altered along fractures to a dark brown, fibrous material which is possibly an iron-bearing mineral.

**Inference**

The calcic plagioclase appears to be restricted to areas close to the contact. It is apparent that the garnet has formed later than the diopside, plagioclase, and at least some of the quartz. The crystalloblastic texture and decussate arrangement of the minerals indicates the influence of predominantly thermal metamorphism.

**Thin Section K-530**

Altered granitic rock east of Blanchard Lake

**Minerals Present**
- Diopside - 10%
- Med. Andesine (Ab$_{60}$An$_{40}$) 45%
- Orthoclase 45%
- Apatite

**Texture**

Porphyroblastic - in the hand specimen porphyroblasts of diopside occur up to 2 cm. in length.
Structure - Granulose

The orthoclase has replaced the plagioclase and in a few cases myrmekite has developed near the borders of the plagioclase being replaced. Very little diopside occurs in the thin section and it is difficult to determine its relationship to the other minerals.

Thin Section 15

Skarn occurring along joints in limestone.

Minerals Present

1. Calcite - 15%
2. Wollastonite - 10%
   - N'S oil immersion method
     - n d > 1.6111
     - n r near 1.6190

   low birefringence
   biaxial ⊕ 2V = 30°
   length fast and length slow as optic plane
   almost perpendicular to length
   good cleavage in one direction
   extinction parallel - not in all cases (up to 26°)

3. Diopside - 20%
   - N'S> balsam - oil immersion N d > 1.6901
   - high birefringence
     - Nr = 1.7290
   - good cleavage at right angles
   - Biaxial ⊕ 2V = 65°
   - maximum extinction = 44°
   - polysynthetic twinning
   - slight greenish tinge in thin section

4. Garnet - 50%
   - Colorless in thin section
   - high relief
   - isotropic
   - N > balsam ≠ 1.75 - oil immersion
   - contains Ca, Al, Fe, Mn, Mg, SiO₂
   - spectrograph chemical tests show only trace of Fe
   - cell edge - 11.80 X-ray pattern

5. Quartz.
Texture and Relationships of minerals

The garnet occurs in large grains up to one inch in diameter in the hand specimen. The mineral which is restricted to the centre of the fracture encloses all the other minerals present in the slide. The diopside is concentrated in a narrow band on either side of the garnet band but many small inclusions are present in the garnet. The diopside grades into wollastonite which in turn grades into calcite. The latter two minerals occur in grains up to 2 mm. in length with the diopside tending to smaller grains of the order of about 1 mm. Wollastonite grains are elongate at right angles to the banding.

Alteration

Wollastonite has altered considerable to carbonate with the result that only shreds of the former mineral remain.

Inference

The indices of refraction of the pyroxene suggest that it is diopside containing some of the hedenbergite molecule. (Winchell, 1947, pp.226)

Various tests on the garnets indicate that this mineral is made up largely of the grossularite molecule.

The order of formation of the skarn minerals appears to be related to their spatial distribution. Thus the order seems to have been wollastonite, diopside, and garnet respectively.
Thin Section 5c

Altered quartz diorite near dyke

Minerals present
Medium andesine - 70%
Quartz - 10%
Carbonate - 15%

Accessory minerals
Muscovite (a few shreds)
Sphene
Apatite

Texture and relationships of minerals

Subhedral plagioclase grains occur up to 3 mm. in length but have been considerably fractured. The angular fragments are cemented by carbonate which has also replaced plagioclase to a certain extent.

Inference

The fracturing of the feldspar grains is apparently the result of the intrusion of the dyke. The subsequent filling by carbonate suggests the latter mineral was fairly mobile at the time of the emplacement of the dyke.

Thin Section 8

Centre of Feldspar Porphyry dyke

Minerals Present
Plagioclase phenocrysts - strongly zoned - 30%
vary from Ab$_{65}$An$_{35}$
to Ab$_{45}$An$_{65}$

Plagioclase microlites - Ab$_{50}$An$_{40}$ - 40%
Hornblende phenocrysts (minor)
Cryptocrystalline material - N'S > balsam - 20%
Magnetite - 5%
Texture and relationships of minerals

The texture is distinctly porphyritic with plagioclase phenocrysts up to 2 mm. occurring in a groundmass of microlites and cryptocrystalline material.

Most of the plagioclase phenocrysts show marked zoning and in a number of cases the borders are more calcic than the centres. The microlites show a trachytic texture which is especially marked around the phenocrysts.

Some of the plagioclase phenocrysts have been resorbed considerably by the groundmass material.

Inference

The reversed zoning of plagioclase-phenocrysts indicates a change in environmental conditions during their crystallization. Apparently they were moved into a warmer area after having partially crystallized.

Thin Section 6

Dyke near eastern limestone contact

Thin section 6 although representing a border facies of the dyke is identical with thin section 8 except for an approximate 15% content of remarkably euhedral hornblende phenocrysts.

Thin Section 9

Western limestone dyke contact
**Minerals present**

- Calcite - 40%
- Plagioclase - 20%, microlites and a few larger grains - medium andesine Ab$_{60}$An$_{40}$
- Quartz - 30%
- Zoisite
- Biotite
- Hornblende - minor
- Sphene
- Unidentified small needle-like grains in calcite

**N'S** 1.55 - 1.67

**Texture and Relationships of minerals**

With the exception of the microlites the minerals present show very irregular outlines. Much of the quartz occurs as a mosaic of anhedral grains up to 1 mm. Fragments of calcite vary greatly in size with the largest being about 1 mm. Carbonate stringers cut all minerals and have apparently filled fractures in these minerals. The dyke material occurs between the calcite and quartz grains.

The small needle-like grains in the calcite occur where the calcite is in contact with dyke material.

**Inference**

This thin section indicates that the dyke was intruded at a temperature sufficiently low to prevent the formation of skarn minerals.
GEOLOGIC MAP
SHOWING
YUKON GROUP ROCKS AND ASSOCIATED GRANITIC ROCKS
IN SOUTH-WEST YUKON AND NORTH-WEST BRITISH COLUMBIA
SKETCH MAP OF LIMESTONE INCLUSION
IN SOUTH-WEST YUKON TERR.

LEGEND

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<th>Description</th>
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<td>CRYSTALLINE LIMESTONE</td>
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<td>UNALTERED AND ALTERED QUARTZ DIORITE</td>
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<tr>
<td></td>
<td>DYKE-FELDSPAR PORPHYRY</td>
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</tr>
</tbody>
</table>

Figure 2

Scale: 1" : 36"
DIAGRAMMATIC SKETCH OF ZONING