PETROLOGY OF THE SHINGLE CREEK PORPHYRY

by

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ABSTRACT

A brief description of the geology of the Shingle Creek area southwest of Penticton B.C., together with a more detailed report on the mineralogy and petrology of the Shingle Creek Intrusion (granite porphyry) are given. The presence of flows and tuffs showing similar mineralogical features to the Shingle Creek Intrusion suggest that this intrusion was shallow rather than deep-seated.

Sanidine phenocrysts showing oscillatory zoning are described with a range in composition of from 40 to 70 percent orthoclase (based on a comparison of optical properties with those determined by Tuttle 1952). The zones often occur in pairs showing a gradation from an albite-rich inner zone to an orthoclase-rich outer zone. It is tentatively suggested here that pressure changes in the magma, by altering the liquidus - solidus relations, might provide this reversed zoning.

Plagioclase phenocrysts from the intrusion show transitional to high temperature optics when compared with the results of Bowen and Tuttle 1950.

Beta quartz phenocrysts showing rounded outlines and development of late halos are described. From evidence given it is suggested that these features are due to resorption of
quartz in a magma chamber prior to intrusion, followed by late growth after intrusion and during crystallization of the porphyry matrix.

Petrographic study of the largest dyke associated with the porphyritic intrusion has suggested that this dyke may have been intruded in several stages.
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CHAPTER I
INTRODUCTION

LOCATION AND ACCESSIBILITY

The centre of the Shingle Creek intrusion is located in the valley of Shingle Creek roughly three miles south southwest of the Penticton railway station and on the boundary between the Osoyoos District to the north and the Similkameen District to the south (see key map Figure 1). The entire intrusion is within the Penticton Indian Reserve.

The intrusion underlies an area about four miles (east-west) by one and a half miles (north-south), but some discontinuous dykes extend some two miles west of the main body.

The area is conveniently reached either by the north branch of the Shingle Creek road from Penticton or by the south branch from Skaha Warf (see key map Figure 1). Both branches are open during the entire year. Of the areas mapped in detail (see key map figure 1) the North Dyke Section may be reached by climbing up the first gully west of the abandoned farm in the central stretch of Shingle Creek Valley. The South East Contact Area may be reached by the old Shingle Creek road which is accessible to vehicles at a point directly south of the abandoned farm mentioned above. This road is passable only for vehicles of short wheel base and high undercarriage clearance.
Figure (1)

The Shingle Creek Porphyry

Scale 1 inch to 1 mile

Rock Types
- Tertiary
  - Marron Formation
  - Shingle Creek Porphyry
  - Springbrook Formation
- Post Triassic Intrusions
  - Aplite
  - Granite
  - Granodiorite
  - Diorite

Symbols
- □ 500 foot contour interval
- □ Creek
- --- Road
- --- Approximate geologic contact
-  □ Drift-covered area

Reproduced from Geological Survey Map 627A
PREVIOUS GEOLOGICAL WORK

The Shingle Creek intrusion and areas to the south and west were mapped H.S. Bostock of the Geological Survey of Canada in 1928 (published in 1936) on a scale of one mile to one inch. The geology of an area extending from the 49th parallel north to the 50th parallel, and including the Shingle Creek area, is shown on a map on a scale of four miles to the inch compiled in 1936 by C.E. Cairnes of the Geological Survey of Canada. Both maps are accompanied by a brief set of descriptive geological notes.

R.F. Flint, W.H. Mathews, S.J. Schofield and others have given accounts of the Pleistocene and Recent deposits, and of the geomorphic features of the Okanagan valley.

In his study of the etch reactions of alpha and beta quartz Meen used quartz phenocrysts from the "Quartz Porphyry" at Penticton B.C.

FIELD WORK

The igneous geology of the Shingle Creek area was suggested to the author as an interesting subject for research by H.S. Bostock in the fall of 1954. In the following winter the author spent several days in the area during which a brief reconnaissance of some of the various intrusives was made and specimens collected.

During the following spring the reconnaissance of the area was continued with the aide of air photographs
purchased from the British Columbia department of Lands and Forests. It was hoped that an intrusion of this size might show some evidence of differentiation, and some days were spent in careful search for it in the central and eastern parts of the intrusion. Although some evidence of compound intrusion was discovered, the extreme weathering of outcrop surfaces over most of the area and the lack of outcrop at crucial points made progress slow and uncertain. It was therefore decided to shift the emphasis in mapping to contact features of the intrusion and two areas (see Figure 1) were selected for detailed mapping where the rock appeared to be least altered and best exposed. These areas are:

(1) The North Dyke Section
(2) The South East Contact Area.

The North Dyke Section was mapped in the spring of 1955 at 50 feet to the inch with a 5 foot contour interval using plane table and stadia rod. The outcrops of the section occur principally on the floor and walls of a small gulley transecting the dyke at right angles. Specimens were collected, at average intervals of one hundred feet, along this gulley where the rock surfaces were fresh.

Mapping of the South East Contact Area at 200 feet to the inch with a 10 foot contour interval was begun in the last three days of the spring season and completed
during the following autumn. The rock was found to be too deeply weathered and friable for detailed sampling and only a few specimens of the least weathered outcrops were collected.

A standard elevation for each detailed map area was taken from map 627A (Okanagan Falls) of the Geological Survey of Canada.
ACKNOWLEDGEMENTS

The author wishes to express his appreciation for the guidance and encouragement given him by Professor K.C. McTaggart and the helpful suggestions of Professor R.M. Thompson. Further acknowledgment is due to Mr. P. Brock, Mr. E. Chown and Mr. R. Saunders who assisted the author in the field.

The author is grateful to Mr. E. Freeman for the use of his camera in taking photomicrographs and to Mr. J. Donnan for providing half of the thin-sections used in this study.

The author is indebted to the Ontario Research Council for the award of a scholarship grant in support of this research.
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CHAPTER II

GENERAL CHARACTER OF THE AREA

PHYSIOGRAPHY

GENERAL STATEMENT

The Shingle Creek Area is located at the southeast end of the Interior Plateau which forms part of the Interior System of British Columbia. The Shingle Creek intrusion is contained entirely within Shingle Creek valley, one of many tributary valleys which dissects the plateau rather deeply at its southern end. Relief within the area reaches a maximum of 3,400 feet with the ridges north and south of Shingle Creek attaining an altitude of slightly more than 4,500 feet above sea level.

Physiographically the area may be divided into three distinctive parts:

(1) The Mountain Slopes
(2) The Silt and Gravel Terraces
(3) The Recent Shingle Creek Flood Plain

MOUNTAIN SLOPES

From the ridge summits down to approximately 3,500 feet the mountain slopes are relatively gentle; but, from this level down to an elevation of about 2,000 feet, slopes are steeper. Here talus and gullies in glacial till are common. Low jagged bluffs commonly project above the till and slide debris. Below the 2,000 foot contour bedrock is extensively covered by alluvium, silt, and till.
SILT AND GRAVEL TERRACES

The silt and gravel deposits of Okanagan valley have been described by Flint (1935) and are well exposed at Shingle Creek. These deposits consist principally of fresh feldspathic rock flour (Flint 1935) of cream white to pale buff colour, with interbedded clay laminae near the bottom of the section and some sand and gravel near the top particularly along the course of Shingle Creek. Vertical silt bluffs and steep-sided gullies along Okanagan valley above and below the creek mouth show many freshly exposed sections with fine lamination and cross bedding.

Another group of gravel and silt benches are found in the valley at the junction of Shatford and Shingle Creeks. The upper benches of this group approach 1,500 feet above the Okanagan Valley bottom and consist predominantly of bedded gravel; however, a distinct lower silt bench was found roughly 100 feet above the present beds of Shatford and Upper Shingle Creeks.

SHINGLE CREEK FLOOD PLAIN

At their junction Shatford and Shingle Creeks are sluggish streams meandering across a nearly flat, marshy flood plain two to three hundred yards wide. Below the junction the valley steepens and the creek flows between gravel fans and silt bluffs in a gulley fifty to one hundred yards wide. At a point two miles west of Okanagan valley the creek is confined to a rock walled gorge about thirty
yards across; below this the grade diminishes and the flood plain gradually widens to its junction with the Okanagan valley.

POST GLACIAL HISTORY

At the end of the Pleistocene a large mass of ice is believed to have occupied Okanagan Trench, and smaller masses probably remained stagnant for a while within the smaller surrounding valleys. One such smaller mass probably occupied the valleys of Shatford and Upper Shingle Creeks at their junction. Draining of melt water south along the border of the ice against the south east facing slopes may account for the upper gravel benches here.

While the ice continued to block the valley of Upper Shingle Creek, drainage from the north developed a prominent outlet fan at the mouth of Farleigh Creek which crossed the present valley of Shatford Creek and extended south toward the Marron River. Later the ice receded from Upper Shingle Creek, the Farleigh Creek outlet was abandoned and a shallow lake (herein referred to as Shatford Lake) formed at the head of lower Shingle Creek. This lake was presumably maintained at this high elevation by the high level of ice in Okanagan Valley, and probably overflowed along the edge of the ice to the east. Dry valleys along the southeast slopes above Lower Shingle Creek (e.g. the South East Contact Canyon of the South East Contact Area Map) may have acted as drainage channels at this time.
With the lowering of the ice level in Okanagan Valley a lower outlet may have been achieved in this direction, and Shatford Lake was drained into a new lake forming between the ice and the mouth of Lower Shingle Creek. At the same time Shatford Creek cut a channel through the fan formed at the Farleigh Creek outlet and adopted its present course into Lower Shingle Creek.

Development of the prominent silt bluffs above Penticton has been attributed by Flint (1935) to the formation of a lake between the ice and the valley walls which extended south to a dam below Vaseaux Lake. With the breaking of this dam Shingle Creek was able to erode its present course.

VEGETATION AND CLIMATE

The area surrounding Shingle Creek is below timber-line and the forest cover is predominantly coniferous with deciduous trees largely restricted to the Shingle Creek flood plain and some of the larger gullies. South facing slopes are dry and sparsely timbered but the sheltered north facing slopes support some thick stands of spruce and pine.

The climate at Shingle Creek is arid but considerable variations in precipitation are apparent between mountain tops and the valley. Six inches of fresh snow were encountered by the author at 3,500 feet in December when the valley bottom had a cover of less than one inch.
Consolidated rocks in the Shingle Creek area range from post-Triassic - pre-Tertiary to early Tertiary in age.

The oldest rocks comprise a sequence of post-Triassic intrusions of diorite, granodiorite, granite and aplite which were intruded in the order given. These are overlain by the Springbrook Formation of Paleocene (?) age which consists, within the Shingle Creek area, of conglomerate and sandy tuff. Contemporaneous with the Springbrook formation is a pink to grey granite porphyry (the Shingle Creek intrusion) which has been found cutting the lower beds of the Springbrook Formation. Most of the latter formation, however, contains angular fragments of the porphyry.

The Shingle Creek intrusion and the Springbrook Formation are intruded by later basic dykes probably related to the Marron Formation. The area is overlain to the west and south by the Marron basic volcanics.
TABLE OF FORMATIONS

CENOZOIC

Pleistocene and Recent
Shingle Creek alluvium, gravel and sand
glacial till, glacial lake silt

Pre-late Eocene
Marron Formation - basalt and andesite
Shingle Creek Intrusion Springbrook Formation
granite porphyry conglomerate and tuff

MESOZOIC

Post-Triassic Intrusions
Aplite
Granite
Granodiorite
Diorite

POST TRIASSIC INTRUSIONS

DIORITE

The Shingle Creek diorite is a mesotype equi-
granular medium-grained rock showing low degrees of meta-
morphism. It is situated in the area surrounding the
junction of Shatford and Shingle Creeks and extends down
the lower Shingle Creek valley for about two miles below
this junction.

Three specimens from the diorite intrusive of
slightly different appearance were examined under the micro-
scope and their content is summarized in table (1).
Specimens W11 and W14 represent typical diorite. The development of chlorite and epidote in these specimens is probably due to metamorphism which may be associated with the subsequent intrusions.

Table (1)†

<table>
<thead>
<tr>
<th></th>
<th>W11</th>
<th>W14</th>
<th>W5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potash Feldspar</td>
<td>---</td>
<td>---</td>
<td>4%</td>
</tr>
<tr>
<td>Plagioclase</td>
<td>50% An45</td>
<td>60% An43</td>
<td>69% An27-36</td>
</tr>
<tr>
<td>Quartz</td>
<td>---</td>
<td>2%</td>
<td>13%</td>
</tr>
<tr>
<td>Pyroxene</td>
<td>---</td>
<td>---</td>
<td>2%</td>
</tr>
<tr>
<td>Amphibole</td>
<td>17%</td>
<td>15%</td>
<td>7%</td>
</tr>
<tr>
<td>Biotite</td>
<td>2%</td>
<td>15%</td>
<td>5%</td>
</tr>
<tr>
<td>Chlorite</td>
<td>21%</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Epidote</td>
<td>8%</td>
<td>1%</td>
<td>---</td>
</tr>
<tr>
<td>Accessories</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
</tr>
</tbody>
</table>

Specimen W15 represents the freshest outcrop found which occurs in a recent road cut along the north west edge of the intrusion.

† To obtain the percentage given, the area occupied by each mineral was estimated in five different fields for each thin-section, the result averaged, and the residual error distributed according to the relative abundance of each mineral.
Specimen W11 represents somewhat more weathered diorite from the edge of the middle bench three quarters of a mile northwest of the junction of Shatford and Shingle Creeks.

Specimen W5 represents diorite from the slopes above lower Shingle Creek and along the southern contact of the intrusion.

Specimen W5 represents a porphyritic phase of the diorite in which larger grains of plagioclase are surrounded and replaced by a mass of fine grained quartz and potash feldspar. The overall composition of the specimen is somewhat different from W11 and W14, and suggests either a slightly chilled quartz-alkalai rich phase of the diorite, or contamination or alteration of diorite by quartz-alkalai material. Plate (1) page 17, shows a phenocryst of andesine altered to oligoclase at its periphery and in part replaced by quartz and potash feldspar.
GRANODIORITE

The Shingle Creek granodiorite is a light grey medium to fine-grained equigranular rock which underlies the upper mountain slopes south east of the junction of Shatford and Upper Shingle Creeks.

The granodiorite was not observed in contact with any of the other intrusions during a single traverse made in this area and none of its outcrops appear in close proximity to the Shingle Creek Porphyry intrusion.

The composition of the granodiorite is summarized in Table (2).
Table (2)
Granodiorite W4

<table>
<thead>
<tr>
<th>Mineral</th>
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<tbody>
<tr>
<td>Microcline</td>
<td>14%</td>
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<tr>
<td>Plagioclase</td>
<td>61%</td>
</tr>
<tr>
<td>Quartz</td>
<td>11%</td>
</tr>
<tr>
<td>Biotite</td>
<td>13%</td>
</tr>
<tr>
<td>Accessories</td>
<td>1%</td>
</tr>
<tr>
<td>Magnetite</td>
<td></td>
</tr>
<tr>
<td>Zircon</td>
<td></td>
</tr>
<tr>
<td>Apatite</td>
<td></td>
</tr>
</tbody>
</table>

Specimen W4 was taken from the granodiorite at the head of the first prominent gully parallel and east of Shatford Creek.

GRANITE

Where the granite intrusion was examined by the author (principally on the slopes north of Lower Shingle Creek) it consists of a medium-grained leucocratic equigranular rock. Bostock (1936) refers to a porphyritic phase of this intrusive at Shingle Creek but no marked porphyritic textures were observed in the outcrops examined.

The composition of the unaltered granite is summarized in table (3) on the following page.
Table (3)
Granite #15

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potash Feldspar</td>
<td>9%</td>
</tr>
<tr>
<td>Plagioclase</td>
<td>67% An₂₂-₄₅</td>
</tr>
<tr>
<td>Quartz</td>
<td>20%</td>
</tr>
<tr>
<td>Biotite</td>
<td>2%</td>
</tr>
<tr>
<td>Amphibole</td>
<td>Tr.</td>
</tr>
<tr>
<td>Muscovite</td>
<td>Tr.</td>
</tr>
<tr>
<td>Chlorite</td>
<td>Tr.</td>
</tr>
<tr>
<td>Accessories</td>
<td>1%</td>
</tr>
<tr>
<td>Magnetite</td>
<td></td>
</tr>
<tr>
<td>Sphene</td>
<td></td>
</tr>
<tr>
<td>Epidote</td>
<td></td>
</tr>
<tr>
<td>Apatite</td>
<td></td>
</tr>
</tbody>
</table>

From the table it is apparent that the specimen, #15, might better be described as a granodiorite; however, the name granite is retained here as the specimen represents only one outcrop of a large body designated granite on Map 627A, distinctly coarser grained and containing less mafic minerals than the granodiorite to the south.

In thin section the granite is slightly porphyritic with larger euhedral to subhedral crystals of plagioclase surrounded by quartz and potash feldspar. Small grains of plagioclase are included in potash feldspar and give the rock a poikilitic appearance. Zoning in the plagioclase is

Specimen #15 was taken from a fresh outcrop of granite at the mouth of the largest gulley extending north from Lower Shingle Creek.
well developed and shows an oscillatory normal zone pattern. Three principal zones may be seen as illustrated in figure (2).

The inner zone (1) shows oscillatory normal or reverse development. The two outer zones, (2) and (3), together show pronounced oscillatory normal development.

The presence of the outer two normal zones is common to many crystals showing zoning in the section examined. This may suggest that the plagioclase crystals were not moving relative to one another during the formation of these outer zones.

APLITE

The Shingle Creek Aplite is a fine-grained pinkish
rock forming dykes and small stock-like bodies within and along the edges of the granodiorite. These bodies were designated "granite, granophyre and felsite" by Bostock (1936).

The composition of a single specimen of Aplite is summarized in Table (4).

Table (4)

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microcline</td>
<td>36%</td>
</tr>
<tr>
<td>Plagioclase</td>
<td>19% An&lt;sub&gt;36&lt;/sub&gt;</td>
</tr>
<tr>
<td>Quartz</td>
<td>44%</td>
</tr>
<tr>
<td>Muscovite</td>
<td>1%</td>
</tr>
<tr>
<td>Accessories</td>
<td>1%</td>
</tr>
<tr>
<td>Magnetite</td>
<td></td>
</tr>
<tr>
<td>Zircon</td>
<td></td>
</tr>
<tr>
<td>Apatite</td>
<td></td>
</tr>
</tbody>
</table>

Specimen W13 was taken from pink aplite where a dyke-like body of this rock comes close to the road south of Shatford Creek.
THE SHINGLE CREEK INTRUSION

The Shingle Creek intrusion or Shingle Creek Porphyry forms an elongate stock or dyke-like body approximately a mile and a half wide at its broadest section and four miles long with a series of dykes extending west of the main body for two miles. At the upper end of Lower Shingle Creek these dykes pass beneath the Marron volcanics. The general trend of the intrusion is westerly with subsidiary dykes showing a somewhat radiating pattern about the main body.

The porphyry intrudes the granite and diorite of the post-Triassic intrusions and parts of the Springbrook formation with which it is considered contemporaneous.

Specimens of the porphyry are of granitic composition and the minerals present together with their relative proportions are listed in table (4) in Chapter IV.

The most striking feature of the Shingle Creek Intrusion is its porphyritic texture. Euhedral sanidine phenocrysts up to four inches in length with smaller plagioclase quartz and biotite phenocrysts up to one half inch in length occur in a pink grey or greenish aphanitic matrix.

For a more detailed description of this rock type the reader is referred to chapter IV.
SPRINGBROOK FORMATION

GENERAL DESCRIPTION

Bostock (1936) has mapped the Springbrook Formation at Shingle Creek and in the surrounding areas to the south and west. This formation rests on a pre-Tertiary rock surface of steep relief; and is composed of lithified soils, alluvium, talus, stream and lake deposits, and tuffaceous materials that accumulated in the valleys before extrusion of the Marron volcanic rocks. Where the Springbrook Formation is thick, the basal beds are of conglomerate containing large angular and unsorted boulders. These beds grade upward into conglomerates composed of small, rounded, and sorted materials. Uppermost strata include beds of polished pebbles, tuffaceous sandstones, and siltstones.

In the Olalla area to the west these beds contain plants of early Tertiary, perhaps Paleocene, age.

THE SPRINGBROOK FORMATION IN THE SOUTH EAST CONTACT AREA

At Shingle Creek examination of this formation by the author was restricted to the South East Contact Area. Here the basal part of the formation is made up of two parts consisting of a "basal" coarse conglomeratic member showing considerable range of thickness but probably not exceeding three hundred feet, and an upper sandy tuffaceous member up to several hundred feet thick. However, a few feet of the tuffaceous member can be seen to underly the conglomerate at the north west end of the area mapped.
The coarse conglomeratic member is buff to dark grey-brown in colour and consists largely of diorite, granodiorite, and granite boulders up to several feet in diameter with some blocks exceeding twenty feet in diameter. Some outcrops show angular fragments a few of which are granite porphyry similar to the Shingle Creek intrusion. The angularity of some of these fragments is well illustrated in plate (2).

 Angular fragments of diorite and granodiorite in the Springbrook Formation

The matrix of the conglomerate consists of poorly sorted feldspathic sandy or silty material showing various degrees of cementation. Local lenses of sand within the
conglomerate provide approximate attitudes.

The sandy tuffaceous member is grey to grey-green in colour and consists largely of well cemented quartz and feldspar grains. Many angular fragments of granite porphyry up to two inches in diameter and similar in appearance to the Shingle Creek intrusion were found. The freshness of the biotite flakes and "resorbed" surfaces observed on some quartz grains in this rock also suggest that much of the material of this formation was derived from the Shingle Creek intrusion. A few patches of well rounded cobbles in a fine-grained grey sandy matrix were observed in the upper parts of this member.

A poorly preserved segmented plant fossil resembling a "horse-tail" was found in this rock but as this type of plant fossil has a wide stratigraphic range its occurrence here is of little stratigraphic significance.

MARRON FORMATION

GENERAL DESCRIPTION

The volcanic rocks of the Marron Formation were extruded over hills of pre-Tertiary rocks and into valleys partly filled by the Springbrook Formation. The volcanic rocks finally accumulated to a thickness of over four thousand feet in some places, and are believed to have covered most of the surrounding area. The formation consists mainly of lava flows ten to twenty feet thick, but in places there are large masses of agglomerate.
At Shingle Creek the Marron volcanics consist of dark greenish-brown flows containing 20 to 30 percent of plagioclase phenocrysts ranging in size up to three quarters of an inch in length, and minor amounts of relatively small mafic phenocrysts, in a fine-grained matrix.

The author examined these rocks at only two localities; one south of the South East Contact area, and the other west of the junction of Shatford and Shingle Creeks.

ASSOCIATED BASIC DYKES

Several basic dykes cut the porphyritic intrusive and the Springbrook Formation at Shingle Creek. These are fine-grained rocks of several colours including greenish black, reddish, or grey-green. Their jointed structure has made them particularly subject to disintegration, and in most places their occurrence is marked by a long coloured talus slope.

The general strike of these dykes is somewhat east of north, obliquely across the general trend of the porphyritic intrusive.
CHAPTER IV

GEOLOGY OF THE SHINGLE CREEK INTRUSION

INTRODUCTORY STATEMENT

A brief description of the geologic setting of the Shingle Creek porphyry has been given in the preceding chapter. In this chapter are described some of the more detailed features of the intrusion.

The entire intrusion, in particular that portion underlying the more heavily wooded slopes southwest of Lower Shingle Creek, has not been examined in detail. The intrusion is well exposed along its south and east margins, but the rock here is deeply weathered and unfit for microscopic study. However, on the north slopes above Lower Shingle Creek the rock is fresher and the microscopic study to follow deals chiefly with an elongated lobe of the intrusion herein referred to as the North Dyke (see key map figure 1). A few specimens taken from the main body to the southeast are generally similar though more deeply weathered.

PETROLOGY

MEGASCOPIC DESCRIPTION

In hand specimen the Shingle Creek Intrusion is porphyritic with a ground mass of aphanitic appearance containing phenocrysts of sanidine, quartz, plagioclase, and mafic minerals. The proportion of phenocrysts to matrix ranges from forty to sixty percent approximately. The
quartz and plagioclase phenocrysts, and a large portion of the sanidine phenocrysts range from one eighth to one half inch in length. Some parts of the intrusion, however, contain larger than average sanidines which reach four inches in length. Biotite, hornblende and magnetite are present as phenocrysts of smaller size seldom exceeding one quarter of an inch in length; however, clots of hornblende and biotite up to one half inch in diameter were observed in one or two specimens.

The large euhedral sanidine phenocrysts are white, pink, or crimson, the last colour being peculiar to deeply weathered outcrops. Many of the sanidine crystals show a suggestion of zoning in the form of layers of cracks concentric about the crystal centres.

In some places, particularly noticeable in the North Dyke, the large sanidine phenocrysts show a poorly developed preferred orientation giving a trachytic texture to the rock as a whole; however, in most outcrops the orientation of phenocrysts is random.

Twinning, and intergrowths of two or more crystal individuals are common amongst the sanidine phenocrysts. These features are illustrated in plates (4) to (6), on the following pages.
Plate (3)
A simple Sanidine crystal showing (001), (010), (110), and (201) faces

Plate (4)
A typical Sanidine Carlsbad twin
Plate (5)

Intergrowth of two Sanidine individuals similar to that shown in Plate (3)

Plate (6)

A large block of porphyry from the North Dyke
The face exposed has dimensions 14"x6"
Plagioclase phenocrysts are white to brownish and generally are more deeply weathered than the sanidine. Quartz phenocrysts occur as subhedral bipyramids somewhat rounded by corrosion.

The porphyry matrix appears uniformly fine-grained in hand specimen but ranges from grey-buff through grey to grey-green, with the grey-buff variety occurring predominantly along the north side of the intrusion, and the grey and grey-green varieties occurring in the central and eastern parts.

MICROSCOPIC DESCRIPTION

Composition

Table (4) is a summary of the composition of several specimens representing the Shingle Creek Porphyry as a whole.

Table (4)

<table>
<thead>
<tr>
<th>Phenocrysts</th>
<th>ND52</th>
<th>ND60</th>
<th>48</th>
<th>47</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sanidine</td>
<td>2%</td>
<td>10%</td>
<td>3%</td>
<td>4%</td>
<td>3%</td>
</tr>
<tr>
<td>Plagioclase</td>
<td>35% An₁</td>
<td>24% An₁₀</td>
<td>31% An₄</td>
<td>21% An₃₇</td>
<td>35% An₀</td>
</tr>
<tr>
<td>Quartz</td>
<td>12%</td>
<td>8%</td>
<td>4%</td>
<td>14%</td>
<td>2%</td>
</tr>
<tr>
<td>Biotite²</td>
<td>3%</td>
<td>3%</td>
<td>2%</td>
<td>4%</td>
<td>--</td>
</tr>
<tr>
<td>Accessories</td>
<td>2%</td>
<td>2%</td>
<td>1%</td>
<td>3%</td>
<td>1%</td>
</tr>
<tr>
<td>Matrix</td>
<td>46%</td>
<td>54%</td>
<td>61%</td>
<td>54%</td>
<td>59%</td>
</tr>
</tbody>
</table>

(quartz and potash feldspar approximately equally represented)

² This line includes hornblende which is present chiefly in section 47.
Specimens ND52 and ND 60 represent two phases of the Shingle Creek intrusion from the North Dyke section.

Specimen 48 was taken from the south side of Lower Shingle Creek Valley opposite the North Dyke Section.

Specimen 47 was taken from a bluff in the south central part of the intrusion.

Specimen 30 was taken from the South East Contact Area.

Mineralogy

(1) Phenocrysts

(a) Sanidine-Anorthoclase

Investigation of thin-sections showed that the large potash feldspar crystals have a small optic angle and this indicates that they are members of the sanidine-anorthoclase series rather than microcline or orthoclase.

At high temperatures a continuous solid solution series is believed to exist between high albite and sanidine (KAlSi3O8) named by Tuttle the Sanidine-Anorthoclase-Cryptoperthite series. High albite and anorthoclase are triclinic but sanidine is considered to be monoclinic so that a transition occurs within the series. In an attempt to determine the crystal system of the large phenocrysts from Shingle Creek, a thin-section of a crystal twinned according to the Carlsbad law was made approximately perpendicular to the "c" crystallographic axis. The "X" "Y", 
and "Z" axes of the optic indicatrix for each twin unit, together with the pole of the composition face (010) were very carefully determined and plotted on a stereonet, and the angle between the "Z" axis and the (010) pole determined to be of the order of one degree (approximately the order of magnitude of the error of measurement). This suggests that the crystal investigated is either very slightly triclinic or else is monoclinic. No evidence of unmixing or microscopic twinning was observed in the section. The optic plane was shown to be approximately perpendicular to the monoclinic symmetry plane (010). Figure (3a) is a reproduction of the plot obtained.

Several thin-sections of untwinned large sanidine phenocrysts were cut perpendicular to the "X" axis (see figure (2b)) for the purpose of measuring the optic axial angle, \(2V\). These crystals were found to be concentrically zoned as illustrated in plates (7) and (8). The maximum and minimum \(2V\) for each of these crystals was measured, and the range found to extend from \((-)2V = 24^\circ\) to \((-)2V = 42^\circ\). A single thin-section of unusual composition (see specimen 47 table (9)) showed potash feldspar with \((-)2V = 53^\circ - 59^\circ\). Many of the zones show abrupt inner boundaries, with a gradual decrease in \(2V\) outwards toward the next zone representing a gradual increase in potash content within the zone. The zoning is oscillatory and no marked general trends either towards more sodic or more potassic composi-
Figure (3a)

Stereographic projection of the orientation of the "Y", "Z", and "Z" optic axes and the (010) pole of a sanidine Carlsbad twin from Shingle Creek.
Figure (3b)

Sketch showing the approximate relative positions of the "X", "Y", and "Z" axes, the optic plane, and crystallographic faces of a typical sanidine phenocryst from Shingle Creek.
Plate (7)
A zoned sanidine phenocryst (x 25)

Plate (8)
A zoned sanidine phenocryst (x 25)
tions were observed in one crystal. Different crystals, however, appear to vary about slightly different average compositions. Thus, of three crystals whose zoning was studied in detail, one approximated an average of \((-2V = 30^\circ\), one \((-2V = 34^\circ\), and the other \((-2V = 38^\circ\). Figure (4) is an illustration of the type of variation in \(2V\) measured in the large sanidine phenocrysts.

**Figure (4)**

An example of the type of zoning observed in the large sanidine phenocrysts.
For the purposes of measuring the indices of refraction accurately in conjunction with 2V, a slab perpendicular to the "X" axis and somewhat thicker than a normal thin-section was cut from a large sanidine phenocryst. A fragment of the slab showing a minimum of alteration and containing two well defined zones was removed and placed in an index oil closely approximating the indices of the fragment. The "Y" and "Z" indices for each zone of the fragment were then compared with the index of the oil for various wave lengths of light, using an arc lamp and monochromometer. The wave lengths for which matching was achieved were noted. The fragment was washed in benzene and placed in oil of slightly different index; the comparison of indices was repeated, and the wave lengths for which matching was achieved again noted. Graphs representing the variation in index of the oil used, with variation in the wave length of light, were plotted before and checked after each comparison using an Abbe refractometer in conjunction with the arc lamp and monochrometer. (See solid lines figure 5). The indices of the two axes of each zone in the fragment at the matching wave lengths were read from these graphs. From the data thus obtained lines were drawn representing the variation of the indices of the axes themselves with the wave length of light. The indices of the "Y" and "Z" axes of each zone in sodium yellow light were extrapolated from these lines. Figure (5) is a reproduction of the type of graph obtained.
Figure (5)

A graph showing variation in index with the wave length of light of two oils used, and of the "Y" and "Z" indices of the fragment of sanidine.
The fragment was then placed on the four axis universal stage and the optic angle, $2V$ measured as accurately as possibly for each zone. Using the $2V$ and the values of the "$Y$" and "$Z$" indices previously obtained the "$X$" index of each zone was calculated. Using this information independent estimates of the compositions of the two zones studied were made using Tuttle's curves. Tables (5) and (6) are a summary of the data obtained.

The optical properties of the large phenocrysts from the porphyry are in agreement with the results obtained by Tuttle for the Sanidine-Anorthoclase-Cryptoperthite series and indicate that the crystals are zoned over a range Or$_{40}$, Ab$_{60}$ to Or$_{70}$, Ab$_{30}$, with extreme zones somewhat beyond these values. The smaller phenocrysts present throughout the porphyry are considered to be members of the same series. Thin-sections made of these crystals, however, were of normal thickness and proved to be too thin for accurate determination of $2V$. 
### Table (5)**

<table>
<thead>
<tr>
<th>Zone (1) (1)</th>
<th>Zone (2) (1)</th>
<th>Zone (2) (2)</th>
<th>Zone (2) (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;X&quot; index</td>
<td>1.5201</td>
<td></td>
<td>1.5108</td>
</tr>
<tr>
<td>(calculated)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;Y&quot; index</td>
<td>1.5255</td>
<td>1.5257</td>
<td>1.5264</td>
</tr>
<tr>
<td>&quot;Z&quot; index</td>
<td>1.5260</td>
<td>1.5260</td>
<td>1.5270</td>
</tr>
<tr>
<td>(-)2V</td>
<td>29° 2°</td>
<td></td>
<td>33° 2°</td>
</tr>
</tbody>
</table>

### Table (6)**

<table>
<thead>
<tr>
<th>Zone (1)</th>
<th>Zone (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composition derived from &quot;Y&quot;</td>
<td>Or 71</td>
</tr>
<tr>
<td>Composition derived from &quot;Z&quot;</td>
<td>Or 69</td>
</tr>
<tr>
<td>Composition derived from 2V</td>
<td>Or 71</td>
</tr>
</tbody>
</table>

** Columns (1) and (2) of table (5) represent independent readings on the same zone, and column (3) represents the average of columns (1) and (2).

In table (6) the figures given represent percentage of orthoclase as read from Tuttle's curves. The remaining constituents are assumed to be Albite (Ab) and Anorthite (An).
(b) Plagioclase

Euhedral to subhedral plagioclase phenocrysts up to one quarter inch in length are more or less uniformly distributed throughout those parts of the intrusion visited by the author. The plagioclase phenocrysts were examined in standard thin-sections made from specimens from some of the fresher outcrops at various points in the intrusion, and from a detailed set of specimens collected across the North Dyke section. For each crystal examined the Anorthite-Albite (An-Ab) content was determined using Van Der Kaaden's curves for normal plagioclase, and the optic axial angle, 2V, measured. Only grains with Albite twin lamellae, and with the "X" axis nearly normal to the slide were used in these measurements. The An-Ab content was checked with index oils. Variation in 2V was plotted against An-Ab composition on the diagram of Bowen and Tuttle here reproduced as figure (4).

From figure (4) it is apparent that the plagioclases of the intrusion may be divided into two main groups, one approximating the composition An_{10}-Ab_{90} with a relatively small (-)2V close to 70°, and a second group approximating the composition An_{2}-Ab_{98} with a larger (-)2V between 74° and 92°. A suggestion of a third group is present but this is represented by one specimen only (taken close to an internal contact in the west central part of the intrusion, (see table (9)). This latter group is distinct from the former two in
In Figure (6) points marked:

- $\times$ represent crystals from the North Dyke Section.

- $\circ$ represent crystals from other parts of the porphyritic intrusion

- $\triangle$ represent crystals from the plutonic post Triassic intrusions

(curves after Bowen and Tuttle, 1950)
showing a well developed oscillatory normal zone pattern, and a relatively higher An percentage.

In figure (4) the line CB (after Bowen and Tuttle) represents the variation of 2V for "low temperature" plagioclase. The line AB (also after Bowen and Tuttle) represents the variation of 2V with composition for "high temperature" plagioclases. Thus the group of crystals approximating An$_2$-Ab$_{98}$ shows transitional (-)2V towards the "low temperature" range of Bowen and Tuttle and the group approximating An$_{10}$-Ab$_{90}$ shows transitional optics towards the "high temperature" range of Bowen and Tuttle. The crystals belonging to the third group from a single specimen appear to belong to the "high temperature" range. Five crystals from the post-Triassic Intrusions were investigated for the sake of comparison and their plots fall well below the "low temperature" lines.

(c) Quartz

Quartz occurs as phenocrysts up to one half inch in length throughout the intrusion. In many places the rock is severely weathered and the quartz phenocrysts may be broken out quite readily. The forms observed on these crystals are typically somewhat corroded bipyramids.

Quartz phenocrysts from the "Quartz Porphyry at Penticton B.C." were investigated by Meen (1934) and determined as beta quartz on the basis of crystal form, fracturing due to inversion, and twin pattern developed by etching.
Some doubt has been cast on the value of these criteria for distinguishing between alpha and beta quartz by Frondel (1955). He states that:

(1) The extent of twinning and cracking of quartz crystals at the inversion point tends to be reduced on slow cooling.

(2) The beta quartz habit (equal development of rhombohedrons with no prismatic faces) may be found in alpha quartz deposited from iron rich solutions.

Some of the quartz phenocrysts from Shingle Creek examined in thin-section are only slightly fractured (see plate (9)) but others show many fine fractures (see plate (10)). The notably iron poor environment in which the quartz phenocrysts formed at Shingle Creek would seem to suggest that these crystals are beta quartz as concluded by Meen.

(2) Matrix

In thin-section the matrix of the Shingle Creek porphyry consists of allotriomorphic grains of quartz and feldspar ranging in diameter from 0.0005 inches to 0.003 inches in different specimens.

Quartz comprises about half of the matrix and consists of uncracked grains of relatively high relief. The feldspar consists chiefly of allotriomorphic potash feldspar (sanidine or orthoclase cryptoperthite) distinguishable from quartz by its low relief and (-)2V of 40° to 50°.
Quartz phenocryst showing slight development of cracks (x 50)

Quartz phenocryst showing development of many fine cracks (x 50)
Some plagioclase is present as shown by the presence of multiple twin lamelae observed in one grain.

(3) Accessory Minerals

The accessory minerals consist of biotite, hornblende sphene, apatite, magnetite and pyrite. Biotite crystals are ubiquitous in the intrusive being found in approximately similar quantities (2 to 3 percent) in almost all thin sections examined.

Hornblende was found in greatest abundance in the section showing the most calcic plagioclase (An$_{37}$) where it occurs as euhedral phenocrysts up to one quarter of an inch in length. The crystals are pleochroic and show two prominent zones. On one crystal measured the centre zone showed $(-)2V=74^\circ$ and the outer zone $(-)2V=80^\circ$. The obtuse bisectrix "Z" makes an angle of $15^\circ$ with "c".

Sphene and apatite occur in trace amounts in almost all the specimens examined. Sphene shows the typical wedge shaped crystals of high relief and is noticeably concentrated with hornblende in specimen (47). The apatite is a fluorescent variety and glows dull white under the ultraviolet lamp.

Textures

(1) Phenocrysts

(a) Protoclastic Structure

The phenocrysts of the porphyry are undeformed in
most specimens examined. A few specimens, however, in-
cluding those from a relatively narrow dyke at the west 
extramity of the intrusion, show a marked protoclastic 
structure. This structure is particularly evident in the 
quartz phenocrysts which were perhaps severely cracked pheno-
crysts which were perhaps severely cracked by inversion before 
consolidation of the matrix. Slight movement in the still 
mobile magma after inversion caused an incipient "stringing 
out" of quartz fragments. This feature is illustrated in 
plate (11).

Plate (11)

Protoclastic structure of quartz in a narrow dyke (x 25)
(b) Resorption and Secondary Growth

Quartz, plagioclase and sanidine phenocrysts all show effects of resorption to some extent.

The outlines of quartz crystals range from subhedral to severely rounded and embayed, and in any one thin-section both subhedral and anhedral quartz may be found. Deep embayments in the quartz phenocrysts appear to contain feldspar and quartz in proportions similar to those in the matrix, though some embayments contain feldspar with very fine myrmekitic intergrowths. In the North Dyke these resorption effects are considered to have been formed prior to emplacement of the dyke because:

1. Around many of the embayed crystals resorbed silica appears to have been redistributed throughout the matrix.
2. Highly resorbed grains are intermingled with only slightly resorbed grains in the same thin-section.
3. The degree of resorption shows no relation to the grain size of the matrix.
4. As resorbed quartz phenocryst was found included in a large sanidine phenocryst.

Quartz phenocrysts from the porphyry also show evidence of growth after resorption. In the North Dyke section secondary growth phenomena have been examined in detail and the following generalizations may be made.
Secondary growth halos approximate the form of resorbed phenocrysts and not that of quartz euhedra (see plate 12).

Plate (12)
A quartz phenocryst with growth halo following resorbed outlines (x 50)

(2) Secondary growth halos consist of an interlocking mesh of quartz grains which show extinction parallel with the central phenocryst. Interstitial material consists of feldspar. (see plates 13 and 14).

(3) The grain size of the halos is directly related to the grain size of the surrounding matrix (compare plates 15 and 16).
(4) The thickness of the halo appears to be independent of the grain size of the matrix.

(5) Where two or three quartz crystals of non parallel orientation occur in contact with each other the halo surrounding the group is oriented parallel with its adjacent quartz crystal giving a radiating pattern as shown in plates (13 and 14).

From these data it is considered that the halos represent secondary growth of quartz after emplacement of the North Dyke. Quartz grains of the matrix crystallizing adjacent to quartz phenocrysts were oriented parallel with the adjacent quartz crystal. A single section (ND 54) shows unusually wide fine-grained halos surrounding quartz phenocrysts in a fine grained matrix. This feature may be a deuteric effect in the vicinity of an internal contact (see figure 9) and discussion of the intrusion of the North Dyke.

In concluding the description of the resorption and secondary growth of quartz it is interesting to note that Misch (1949) describes some features of very similar appearance to those observed in the quartz phenocrysts from Shingle Creek, in quartz "porphyroblasts" from "granitized redbeds" near Sheku, Northwest Yunnan. These rocks are described as containing large phenocryst like quartz grains which grade from rounded grains resembling pebbles to bi-pyramids.
Plate (13)

Slide (ND54) showing four quartz phenocrysts of non parallel orientation with a single encompassing halo. Various parts of the halo can be seen to be at the same stage of extinction as the nearest quartz phenocryst. (x 25)

Plate (14)

Central portion of plate (13) enlarged, (x 250)
Plate (15)

Slide (ND54) showing a fine-grained halo in a fine-grained matrix. (x 50)

Plate (16)

Slide (ND55) showing a coarse-grained halo in a coarse matrix (x 50)
Misch advances "two general arguments" against resorption of the quartz crystals described:

(1) "It is hard to conceive how a residual magma exceedingly rich in silica from which the quartz-rich groundmass would have to be derived could have resorbed earlier formed quartz phenocrysts.

(2) It is difficult to understand why magmatic corrosion should form narrow embayments instead of attacking the quartz crystals in a more uniform manner along their surfaces and first rounding off any crystal edges which might have been present." (Misch suggests uneven growth to account for this feature)

In response to these arguments applied to the Shingle Creek Porphyry the reader is first referred to the section of this report entitled PETROGENESIS, for a suggested explanation for the resorption of quartz in a silica-rich environment.

If, as in the second argument, it is assumed that embayments formed in quartz as a result of irregular growth, one is led to wonder why the growth of other "porphyroblasts" was not similarly effected. A second problem arises when the secondary growth halos are considered for these show no tendency to develop preferentially on the most exposed portions of the crystal (thus perpetuating the embayments).

It should, perhaps, be added that, on the basis of cross cutting structure, uniformity of composition in different host rocks, and small but systematic variations in grain-size of the matrix, there is no question of the intrusive origin of the Shingle Creek Porphyry.
Many of the sanidine phenocrysts show effects of repeated resorption parallel to the zoning. Plate 17 illustrates a sanidine carlsbad twin showing resorption rims parallel to the faces of the phenocryst, (the zoning is not visible in standard thin-section). Other crystals show resorption only on the outer surface as shown in plate 18.

Resorption is less obvious in the plagioclase phenocrysts but is evident in the rounding of the outer boundaries of most of these phenocrysts.

(c) Secondary Alteration

Secondary alteration consists chiefly of sericitization and kaolinization of the feldspars which is intense in the South East Contact Area and elsewhere where the intrusion is well exposed. A thin-section from the dyke at the west end of the intrusion shows plagioclase completely replaced by friable white kaolin.

One section, (30), from the South East Contact area shows minute fractures filled with secondary quartz and small amounts of calcite transecting both phenocrysts and matrix.

Small amounts of calcite, believed of secondary origin, occur at grain boundaries or replace previous minerals in the more altered specimens through the intrusion.

Biotite crystals are remarkably fresh and show no evidence of alteration to chlorite which is common in the surrounding plutonic rocks.
Plate 17 shows a sanidine phenocryst twinned according to the Carlsbad law (upper left) with inclusions of plagioclase. Dark outlines within the crystal are believed to be resorption rims (x 25).

Plate (18) illustrates a sanidine phenocryst (left centre) showing evidence of resorption only on its outer surface. (x 25)
Paragenesis

Table (7) is a suggested paragenesis for the phenocrysts and matrix of the Shingle Creek Porphyry based on the presence or absence of inclusions of various minerals in each other.

Table (7)

<table>
<thead>
<tr>
<th>Phenocrysts</th>
<th>Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Accessories</strong></td>
<td>—</td>
</tr>
<tr>
<td><strong>Biotite</strong></td>
<td>—</td>
</tr>
<tr>
<td><strong>Plagioclase</strong></td>
<td>—</td>
</tr>
<tr>
<td><strong>Quartz</strong></td>
<td>—</td>
</tr>
<tr>
<td><strong>Sanidine</strong></td>
<td>—</td>
</tr>
</tbody>
</table>

One small inclusion of plagioclase, identified by its polycrystalline twinning, was found in a small uncracked quartz phenocryst. Many other inclusions in cracked quartz have been altered beyond recognition but may include plagioclase. Biotite and some small sanidine inclusions were found in quartz as well.

Plagioclase and biotite form numerous inclusions in sanidine. One large resorbed quartz phenocryst and several small ones were also found in sanidine.
Plate (19)

This pair of plates shows the appearance of the secondary growth halos of quartz under high and low magnification. Dark grey cusps in the quartz phenocryst contain feldspar. The specimen represents the porphyry with coarse grained matrix.

(Plate (20) (x 250)
This pair of plates shows the appearance of secondary growth halos of quartz in section ND 54 under high and low magnification. This specimen represents porphyry with fine-grained matrix and shows the widest halos observed. Plate (21) was taken in non polarized light.

Plate (21) (x 50)

Plate (22) (x 250)
Métamorphisme

In all natural outcrops examined by the author the country rock has been so deeply weathered near the intrusion that it disintegrates at the stroke of a hammer.

Recent blasting in conjunction with widening of the road at Lower Shingle Creek has exposed some sound rock at the contact between granite and the porphyry. This road cut is within a few feet of the creek bed and is one of the deepest exposures within the intrusion. The granite here is jointed into large irregular blocks which show a reddish brown stain several inches deep along joints. The unstained central parts of the blocks are grey, and a narrow yellow-orange transition zone exists between the grey centre and the red-stained rims. In hand specimen the biotite and hornblende of the normal granite have been replaced by magnetite and a green micaceous mineral.

In thin-section the red and grey zones were found to be essentially similar, the red colouration being due to finely disseminated specks of hematite in the altered feldspars. Plagioclase grains show similar composition and zone relations to those found in the normal granite. Potash feldspar crystals are severely sericitized and some large quartz grains are present.

At the contact with the porphyry the texture of the granite is different from that of the normal granite, and is somewhat similar to that observed in specimen W5 of
altered diorite close to its contact with granodiorite. A fine mesh of equant quartz grains has developed between the larger crystals, and a few of these smaller quartz grains appear within the borders of the plagioclase crystals giving the rock a poikilitic appearance (see plate (1)). All the mafic minerals with the exception of magnetite have been replaced by calcite and a hydromica of low (-)2V.

In the Southeast Contact Area the Springbrook conglomerate has been stained dark reddish-brown for a distance of three or four feet from its contacts with the porphyry. The conglomerate is very friable and the reddish colour lends a baked appearance to the rock.

A thin-section was made from a red stained cobble from the large conglomerate inclusion. The cobble itself was found to be friable and had to be impregnated with Canada balsam to permit grinding of the section. The mafic minerals of the cobble were found to be entirely altered to a brownish-green chlorite of very small (-)2V. The feldspars have been partly altered to sericite and kaolinite, and are readily powdered with a needle point. Some narrow myrektitic zones were found between quartz and plagioclase and incipient development of a poikilitic-like texture of quartz in plagioclase similar to that found in the altered granite was observed. These textures, however are not extensively developed in the section and may have been part of the original texture of the diorite.
The conglomerate adjacent to the largest basic dyke (see Southeast Contact Area Map) is thoroughly indurated over a width of several feet in striking contrast to the friable condition of the conglomerate contact with the porphyry. This might be the result of a higher temperature of intrusion associated with the basic dykes.

Plate (23) shows a two foot wall of indurated conglomerate at the contact of a basic dyke in the South East Contact Area. The dyke (left) has disintegrated as a result of close jointing.
STRUCTURAL FEATURES

GENERAL CONFIGURATION

The intrusion is elongated in an east-west direction and narrows to a group of discontinuous dykes to the west. In the east, however, it passes beneath the alluvium of the Okanagan Valley at what appears to be its widest section, and does not reappear on the opposite side of the valley. This suggests that the intrusion may be structurally related to the Okanagan Trench.

INTERNAL FEATURES

Internal Contacts

Outcrops of the central and eastern part of the intrusion were examined in detail for internal variations. Large outcrops were found to be essentially homogeneous with some variation in size of phenocrysts and colour of matrix. One internal contact was found in an isolated group of bluffs in the western central part of the intrusion (see Key map figure (1)). The contact strikes approximately parallel to the general trend of the intrusion, and shows a sinuous but fairly regular surface along an exposed length of several hundred feet. Jointing present shows no relation to the contact (see plate (24)) on following page. Table (8) is a summary of the compositions of two specimens taken one on either side of the internal contact. (see following page).
Plate (24)

Plate (24) shows an internal contact with large phenocrysts in the rock to the left of the hammer head and small phenocrysts in the rock to the right. The contact itself is not clearly visible in the picture but follows a line parallel with the hammer head passing just to the right of the two large sanidines (upper left). Joints show no relation to this contact.

Table (8)

<table>
<thead>
<tr>
<th>Specimen (47) N.E.Side</th>
<th>Specimen (45) S.W.Side</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phenocrysts</strong></td>
<td><strong>Phenocrysts</strong></td>
</tr>
<tr>
<td>Description</td>
<td>Description</td>
</tr>
<tr>
<td>Gr. Size</td>
<td>Gr. Size</td>
</tr>
<tr>
<td><strong>Sanidine</strong></td>
<td>(-)2V 53°-59° max. 2&quot;</td>
</tr>
<tr>
<td>(-)2V 53°-59° max. 2&quot;</td>
<td>(-)2V 43° max. 0.25&quot;</td>
</tr>
<tr>
<td><strong>Plagioclase</strong></td>
<td>An35-An46</td>
</tr>
<tr>
<td>&quot; 0.2&quot;</td>
<td>An8-An11</td>
</tr>
<tr>
<td><strong>Quartz</strong></td>
<td>Resorbed</td>
</tr>
<tr>
<td>&quot; 0.1&quot;</td>
<td>Resorbed</td>
</tr>
<tr>
<td><strong>Biotite</strong></td>
<td>minor</td>
</tr>
<tr>
<td>dom. acces.</td>
<td>dom. acces.</td>
</tr>
<tr>
<td><strong>Hornblende</strong></td>
<td>dom. acces.</td>
</tr>
<tr>
<td>minor</td>
<td>minor</td>
</tr>
<tr>
<td><strong>Matrix</strong></td>
<td>0.0005&quot;</td>
</tr>
<tr>
<td></td>
<td>0.0005&quot;</td>
</tr>
</tbody>
</table>

Potash feldspar in the two slides may be either sanidine-anorthoclase-cryptoperthite or a potash rich orthoclase-cryptoperthite on the basis of these data.
Inclusions

(1) Inclusions of Granite

Numerous granite inclusions are exposed in the North Dyke and a few of these have been mapped in detail as part of the North Dyke Section. These inclusions are found in two zones on either side of the dyke leaving a central zone forming roughly one half of the dyke free of inclusions. As can be seen in figure (9) there is a direct relation between the presence of inclusions in the dyke and the grain size of the matrix, the latter being finer grained in the zones of inclusions and towards the margins because of chilling.

The inclusions were found in a wide range of sizes and show rough irregular surfaces. Small apophyses and dykelets of porphyry commonly penetrate the granite. The inclusions are well jointed, and many sharp embayments in the contacts are thought to be the result of plucking of jointed blocks by the intrusion. Features of this type are illustrated in figures (7) and (8). (Following page)
Alteration of the granite inclusions by the intrusion is not pronounced, and has been obscured by shearing and deep weathering along the contacts.

(2) Inclusions of the Springbrook Formation

(a) Major Inclusions

A large inclusion of the Coarse Conglomerate member of the Springbrook formation lies in the porphyry in the South East Contact Area (see map). This inclusion forms a triangular section with its entire periphery exposed to view on a cliff face at the north end of the area mapped. The sides of the inclusion are sheared as shown in plate (25) and figure (9).
Plate (25) and figure (9) illustrate the shearing which occurred at the contacts of the large conglomerate inclusion.
The inclusion probably represents the end of a tongue of conglomerate extending east down the north side of the South East Contact Canyon and has probably not been moved to any great extent by the intrusion. It is likely that the conglomerate between the inclusion and the neighbouring conglomerate outcrops has been eroded leaving a large block apparently surrounded by porphyritic intrusion.

(b) Cobble Inclusions

In two instances outcrops of porphyry were found to contain rounded granodiorite and diorite cobbles presumably derived from the overlying Springbrook Formation. One such outcrop was found in the intrusion at the top of the ridge forming the north wall of the Southeast Contact Canyon about one hundred yards from the contact. A similar occurrence was found at the top of a hill in the central part of the intrusion near the internal contact described above.

EXTERNAL FEATURES

Contact Features

Some parts of the contact between the North Dyke and the granite are uniform and straight. In several gullies along the northern slopes above Lower Shingle Creek the porphyry at the contact rises as a wall ten to twenty feet high overlooking deeply weathered granite. Plate (26) shows porphyry to the left, rising along a fairly even contact with sheared and deeply weathered granite.
A granite-porphry contact showing porphyry (upper left) and sheared granite (centre right).

Other parts of the contact are irregular with sharp local changes in strike as illustrated by the north end of the North Dyke section. The general trend of the contacts of the North Dyke, however, form a wide arc or crescent concave to the south.

In the Southeast Contact Area the contact features are somewhat different from those already described. The general trend of the contact is irregular, being interrupted by at least three dykes which strike south to southwest from the main intrusion. Much of the wall-rock conglomerate appears to lie on top of the intrusion and shows a pattern of block faults of small movement extending down towards the surface of
the intrusion. These faults are thought to represent loci of minor adjustments in the roof during intrusion which allowed some blocks of conglomerate to rise or settle slightly with respect to others.

Southeast of the intrusion, outcrops of white or greenish rocks containing large potash feldspar crystals were reported by H.S. Bostock. These are exposed in cliffs between conglomerate beds and show structures typical of flow rocks.

STRUCTURAL CONCLUSIONS

The following section will attempt to interpret the structural environment at the time of intrusion of the Shingle Creek Porphyry.

Several features in the central and southeast part of the porphyry intrusion suggest that the intrusion reached the contemporaneous (Paleocene) surface which was not far above the present level of bedrock in this area. These features are enumerated as follows:

(1) In spite of the size of the intrusion there is no appreciable variation in grain size from the walls inward suggesting that the present surface of the intrusion underwent fairly uniform chilling.

(2) The upper member of the Springbrook formation in the Southeast Contact area consists of several hundred feet of rhyolitic tuff similar
in composition to the porphyry and distinctly different from the succeeding basic flows.

(3) Southeast of the area white or greenish rocks containing large potash feldspar crystals are exposed in cliffs between conglomerate beds and are reported to show structures typical of flow rocks.

West of the main body of the intrusion and along the north slopes above Lower Shingle Creek the rock surface contemporaneous with the porphyry intrusion may have been considerably higher than at present. This is suggested by the fact that a large proportion of the cobbles and boulders of the conglomerate in the Southeast Contact Area are of rock types represented by the plutonic intrusions to the north and west. The size and angularity (see plate (2)) of some of these boulders present testify to the ruggedness of this topography.

South and southeast of the Southeast Contact Area the late Mesozoic surface is overlain by several thousand feet of Tertiary sediments and volcanics and does not outcrop even in the creek valley one mile south of, but at about the same present elevation as, the Southeast Contact Area. The land surface to the southeast at the time of intrusion of the porphyry may thus have been considerably lower than the surface to the north and west, and in this southeasterly direction (from the intrusion) are located the remnants of tuffs and
flows which appear to be related to the intrusion. To the east, Okanagan valley (Lower Eocene of Schoefield) was probably in the early stages of formation and a major portion of the volcanic products of the intrusion may have been deposited on low ground in this direction.

The Shingle Creek Porphyry may thus be interpreted as marking the site of an early Tertiary volcano with a vent located west of Penticton in the central part of the intrusion. Possibly during an explosive phase in the life of this volcano the North Dyke and other dykes were intruded along fractures showing somewhat curved outlines simulating roughly an extended ring pattern.
PETROGENESIS

In the following paragraphs the data discussed and the conclusions arrived at apply specifically to the North Dyke Section which has been studied in detail. Many of the conclusions, however, may apply to other parts of the intrusion as well.

CRYSTALLIZATION OF THE PHENOCRYSTS

Without a chemical analysis it is not possible to state accurately the composition of the North Dyke, but an approximation can be made. From the estimates, made earlier in this chapter, of the relative compositions of two specimens the composition of the North Dyke may be reduced to three principal components: quartz, albite, and orthoclase. The albite content of the sanidine-anorthoclase is added to the albite of the plagioclase. Mafic minerals, accessories, and anorthite come to less than ten percent and may be disregarded in this approximation. Table (9) gives the estimated amounts of each of these three components as accurately as the method of calculation will allow:

Table (9)

- Quartz ....... 40%
- Albite ........ 40%
- Orthoclase ..... 20%

When this composition is plotted on a ternary diagram representing the albite-orthoclase-silica system
(J.F. Schairer and N.L. Bowen—see figure (10) it is seen to fall very nearly on the cotectic line dividing the diagram into tridymite and feldspar fields. This may suggest that the Shingle Creek Porphyry magma represents the product of an earlier differentiation or of selective fusion.

Considering figure (10), a melt of composition such as that represented in table (9) (see figure 10, point A), on slow cooling, might be expected to precipitate potassium poor high albite first. This would be followed early by beta quartz with concentration of potassium in the residual magma. When the melt reached the ternary eutectic, V, sanidine would begin to crystalize. This sequence (up to the first appearance of sanidine phenocrysts in the melt as suggested by small sanidine inclusions in beta quartz) is born out by the paragenesis presented earlier in the chapter.

At this time, however, beta quartz became unstable in the magma and began to be resorbed. This resorption may be accounted for if the cotectic trough, CD, is lowered and shifted toward the silica apex of figure (10) (analogous to the shifting of the diopside-anorthite-eutectic with increased water vapor pressure. (Yoder, 1954).

With further cooling under the new conditions (increased water vapor pressure to account for resorption of quartz) the potassium rich residual magma would begin to crystallize a potassium rich sanidine which was the last mineral to form phenocrysts.
Figure (10)

Phase diagram for the system nepheline-kaliophilite-silica (after J.F. Schairer and W.L. Bowen) Point "A" represents the composition of the Shingle Creek Porphyry approximately.

Key to Figure (10)

1. Cristobalite field
2. Tridymite field
3. Na-K-Feldspar field
4. Leucite field
5. Na-K-Nepheline field
6. Carnegieite field
The sanidine phenocrysts formed at this time show an intricate oscillatory zone pattern described earlier in the chapter. Many of the zones occur in pairs with abrupt contacts between pairs, in some cases marked by resorption (see plate (17)), and gradual increase in potash content from the innermost to the outermost members of the pairs. This gradation is in the reverse sense to what might be expected for phenocrysts of the present composition crystallizing under constant pressure. However, the configuration of the liquidus and solidus curves for the albite-orthoclase system (Bowen and Tuttle) varies with the vapor pressure of water in the system. The data are incomplete so it is only very tentatively suggested here that pressure changes in the magma, by altering the liquidus - solidus relations, might provide the reversed zoning observed in the sanidine. A repeated sequence of gradual buildups of pressure followed by sudden releases would be required. In some cases the pressure release was sufficient to cause some resorption of sanidine by shifting the cotectic line, CD, of figure (10) away from the silica apex. However, beta quartz shows no evidence of intermittent resorption so that this shift was probably never large enough to cause resumed crystallization of beta quartz.

**INTRUSION OF THE NORTH DYKE**

It is suggested that the crystallization of the phenocrysts described above took place in a magma chamber at
depth and that the initial increase in pressure associated with the beginning of resorption of beta quartz was probably a major change as beta quartz remained unstable in the magma up until just before final consolidation. This postulated increase in pressure may have been responsible for the beginning of the intrusive and volcanic stages in the history of the magma. The increased pressure in the chamber, however, did not remain constant and is thought to have oscillated in the manner suggested by the zoning in the sanidine phenocrysts. These oscillations in pressure may have been related to eruptions or to intrusion of the dykes surrounding the intrusion.

Petrographic variations in the rocks of the North Dyke Section suggest that the intrusion of the dyke occurred in several phases. In order to illustrate these variations figure (11) has been constructed showing the variation of each feature described as ordinate, and the relative position within the dyke as abscissa. From the data presented in figure (11) it is suggested that the intrusion of the dyke at some stage in its history reached a maximum of intrusive activity during which the walls were actively plucked and inclusions were incorporated in the dyke. The composition of the plagioclase phenocrysts being supplied by the source chamber was then $\text{An}_2\text{-Ab}_9\text{B}_8$ approximately, and the matrix of the intrusion was chilled to a more or less uniform fine grain size.
Figure (11) illustrates petrographic variations in a group of specimens taken from the North Dyke. The grain-size of the matrix is measured in thousandths of an inch.
Intrusive activity then waned and movement of magma occupied a lesser central portion of the dyke which now contains no inclusions. When the intrusion finally ceased the wall rock (formed now to a large extent of recently consolidated porphyry) was somewhat hotter than the walls had been during the phase of maximum activity and permitted the matrix of the intrusion to reach a somewhat greater size. The plagioclase supplied during the final stage of intrusion was approximately An_{10}-Ab_{90}.

With normal differentiation in the source chamber calcic plagioclase would be expected to form first with more albite plagioclase crystallizing as crystallization progressed. The later central phase of the North Dyke is thus out of harmony with a simple process of differentiation. The higher anorthite content of the central section of the dyke cannot be explained by assimilation of the dyke walls as the plagioclase of the earlier phase of the dyke is practically pure albite. However, progressive assimilation of granite (see table (3)) from the walls of the source chamber might account for the enrichment of the magma in anorthite.

As can be seen from figure (9) the composition of plagioclase in section ND 49 (taken close to the upper contact of the North Dyke) corresponds with the plagioclase of the central part of the dyke. The matrix, however, is fine-grained similar to the adjacent dyke rock. This may be
explained if it is assumed that the later phase of the intrusion was not entirely confined to the centre of the dyke but sent dykelets into the surrounding rocks along structurally susceptible planes. The contact between the granite walls of the dyke and the recently consolidated initial phase of the dyke may have provided such a structural plane. The temperature at the granite walls was probably considerably less than the temperature of the inner walls of the first phase of the dyke intrusion so that the fine-grained texture of the matrix in section ND49 is to be expected.