"PETROLOGY OF THE NORTH-WESTERN PART OF HOLYROOD GRANITE BATHOLITH."

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"Petrology of the North-western Part of the Holyrood Granite Batholith."

By

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A Thesis

Submitted in partial fulfillment of the requirements for the degree of Master of Science in Geology.

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Abstract

The Holyrood granite batholith is a dome-shaped igneous body, approximately 40 miles in length and 8 miles in width forming the backbone of the Avalon Peninsula. Its western part intrudes folded volcanic rocks of pre-Cambrian age, the Harbour Main Group. Its eastern boundary is defined by a fault. Petrographic studies of the north-western part of the batholith have indicated that it is biotite granite which can be divided into two main types:

1. A coarse-grained variety containing numerous inclusions, low in biotite and relatively little altered.
2. A medium-grained type with only few xenoliths, a higher biotite content and greater degree of alteration.

Intrusive contacts between the granite and tuffs of the Harbour Main Group can be seen clearly in the field, but no intrusive relationships with the sediments of the Conception Group were observed in the area studied. However, basal conglomerates of the Conception Group contain cobbles of pink Holyrood granite indicating a pre-Conception age for the granite. No definite lineation or foliation appear in the outcrops, indicating that the granitic pluton is post-kinematic. Its contacts with the country rocks are very sharp without any pronounced mineralogical changes. Studies of rocks within the contact zone adjacent to the granite indicate that there is little evidence of contact (thermal) metamorphism accompanying the intrusion. The most striking

effect of the granite on the older rocks has been the introduction of silica, water and/or carbon dioxide and to a minor extent the addition of lime.

Parts of the country rocks were incorporated in the granitic magma during emplacement; by assimilation various granodioritic and dioritic hybrid rocks have been formed. The granite was subjected to considerable stress during and after crystallization. Several pegmatite bodies associated with the granite, some containing giant quartz crystals, are poor in minerals containing volatile elements. This indicates that either the granitic residum lacked such hyperfusible constituents, or they may have escaped from a shallow intrusion through a porous or fractured roof.

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Chapter I

Introduction

Statement of Problem:

Parts of the Holyrood granite have been studied by previous investigators. These studies have been connected mainly with either regional mapping (Buddington, Rose, McCartney and Dawson) or with specialized topics, (Buddington, Vhay) and of necessity the granite has not been studied in greater detail. Recently there has been increased interest in the studies of granites in Canada and the present work was undertaken as a contribution to the studies already began. It formed partof a programmed of detailed mapping of the Holyrood granite batholith started at Memorial University. This study was undertaken to determine;

1. The nature of the Holyrood granite, and the contact features associated with it.

2. The relative ages of the intrusive rocks in the area.

Location, Size and Accessibility:

The area described in this study comprises about 25 square miles between 47° 23' 30" and 47° 27' 00" North and 53° 07' 30" and 53° 00' 00" West. The Trans Canada and the Topsail Highways provide access to the area. Secondary roads and paths connecting communities and isolated settlements were also used.

Previous Geological Work:

The first geological work on the Avalon Peninsula was carried out by J. B. Jukes in 1839 and 1840. This was followed by regional mapping by A. Murray in 1868 and by Murray and Howley in 1869-1883. These studies resulted in the first geological map of the Avalon Peninsula published in 1881. The volcanics and granites were grouped together as intrusive rocks by Jukes. Later Murray and Howley (1881) subdivided the igneous rocks of the area into a "Laurentian gneiss" which represented the main areas of the granitic rocks and "metamorphic slates and sandstones" which corresponded to the volcanics.

Walcott (1889) proposed the name "Avondale Terrane" for the Pre-Cambrian sedimentary rocks lying above the Archean gneisses and was the first to introduce the name "Conception" and "Torbay" slates for the two lowest formations of the series. A. F. Buddington in 1916 published a paper on "Pyrophullitization, Pinitization and Silicification of the rocks around Conception Bay"; and in 1919 another paper on "The Pre-Cambrian Rocks of South-east Newfoundland". In the latter report Buddington proposed the name Avondale volcanics for the Huronian series of Howell (1907), a name which was later changed to Harbour Main volcanics by Howell (1925). Buddington (1919) was the first to name and describe the Holyrood Granite as a granite batholith. Referring to the intrusive rocks in South-east Newfoundland he wrote (1919, p. 477);

> "Geographically, chemically and physically the volcanics, plutonics and the dikes of the Conception Bay region appear to be genetically related". Thus the gabbro, quartz-bearing gabbro, hornblende porphyrite with quartzose groundmass, granodiorite quartz syenite, biotite granite, granophyre and aplite form a series of rocks with an ascending silica ratio belonging to the same geographical area and very probably to the same period of intrusion."

Among more recent workers who have contributed to the geology of this map-area or parts of the granite are Vhay, Rose, McCartney and Dawson. Vhay (1937) carried out an investigation of the pyrophyllite deposite near Manuels and described parts of the granite. In a footnote on some granitic pebbles occurring in conglomerates of his "Conception Slates" he wrote (1937, p. 9); "This granite must be derived from the erosion of an older intrusion not identified in the area". Rose (1952) mapped the Torbay area to the east of the present map-area. He found the granite to be intrusive into the Harbour Main volcanic rocks and also into the Lower beds of his "Conception Group". He defined and grouped all the formations and proposed the names "Harbour Main Group" for the "Avondale volcanics" and the "Conception Group" for the "Conception and Torbay series of earlier investigators.

In 1951 and 1952 the Holyrood area of which the present work forms a part was mapped by McCartney for the Geological Survey of Canada. His preliminary report was followed by a comprehensive study submitted as a doctoral dissertation to Harvard University (McCartney, 1954, 1959). Although McCartney's work was concerned primarily with the regional geology of the area, nevertheless it forms the main basis for the study of the granitic and intrusive rocks around the east coast of Holyrood Bay. Very recently Dawson (1963) described some parts of the granite in his regional mapping of the Fox-trap-Topsail area.

Present Work:

The field work on which this study is based was carried on in the summer of 1964, from June to September. Mapping was done with aerial photographs supplied by Royal Canadian Air Force, using suitably enlarged National Topographic Map Sheet 1N/6H (Seal Cove), 1:25,000 as a base map.

Acknowledgements:

The writer is indebted to Dr. W. D. Brueckner, Head of the Geology Department and particularly to Dr. V. S. Papezik under whose supervision the Thesis was written and who gave valuable criticism. Many thanks are due to the Department of Mines and Resources who provided enlargements of the base maps. Grateful acknowledgement is extended to Mr. and Mrs.

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Chapter II

Physiography

Physiographically the map-area can be divided into two main parts. The Western portion of the map-area is a lowland, having an average elevation of 300 feet above sea-level. The rest of the map-area is a gently rolling, plateau-like area with an elevation of approximately 700 feet above sea-level. The boundary between the two sections, in the south-western part coincides with the approximate contact between the sedimentary and the volcanic rocks.

The lowland is somewhat dissected, heavily covered by vegetation and to some extent molded by ice moving northwesterly from the central portion into the sea. The central plateau is formed by northeasterly trending hills and ridges; the highest of these is the Holyrood Butter Pot Hill, 1040 feet in elevation Fig. (1). The most pronounced alignment of these hills is shown by six ridges between Butter Pot Pond and Seal Cove. The ridges commonly have very steep sides and show glacial striae on the summits.

The more rugged and irregular hills are underlain by volcanic rocks while the granite commonly shows more rounded topographic forms. It is obvious that throughout the map-area the underlying structure and rock-type has controlled the topography. This appears to be a characteristic feature of the Avalon Peninsula. Buddington (1919) describing the physiography of South-east Newfoundland wrote, (1919, p. 452);

> "The trend lines of the most impressive and marked physiographic features have been controlled for the greater part by the presence of ancient fault and fracture lines, which have to a large extent determined the distribution of the underlying rocks, with their varying degrees of resistance to erosion and weathering and the consequent parallel lineaments of the present topography".

Drainage:

The eastern plateau is poorly drained. This may be in part due to the abundant cover of impermeable glacial drift and in part to the relief. Considerable areas of bogs are commonly found. Most of the small brooks connect individual lakes and ponds, only a few flow directly into the sea. The lowland to the west is very well drained, lacks bogs and marshes but contains irregular hummocks covered with thick, short shrubs.

Glaciation:

The map-area was glaciated during the Pleistocene. The evidence of this glaciation is preserved in pronounced glacial striae on the hills and in numerous erratics precariously perched in many places. There appears to be conflicting opinions on the direction of movement of the ice. Buddington (1919) suggested that there were local ice caps flowing into individual bays in a direction perpendicular to the major outlines of the various bays.

Rose (1952) however, indicated that the ice moved radially seaward from the central part of the Avalon Peninsula. The direction of glacial striae on the hills together with the alignment of erratics indicate that around the east coast of Holyrood Bay, the ice moved to the North and Northeast.

Chapter III

General Geology

General Statement:

The map-area forms part of the Avalon Peninsula, the geology of which has been well described by A. F. Buddington (1919) and W. D. McCartney (1959). The oldest pre-Cambrian rocks are the Harbour Main volcanics, which consist of a great thickness of acid and basic flows and intercalated breccias, tuffs and minor sediments. These rocks, folded and faulted, form the core of an anticline which is exposed at the head of Conception Bay. A large granite batholith intrudes the eastern limb of this fold. Successively younger pre-Cambrian rocks are the Conception and Cabot Groups. The former consists chiefly of sediments. Cambrian and lower Ordovician rocks overlie unconformably the pre-Cambrian formations.

The present thesis area covers a part of the western contact of the granite batholith. The rocks underlying different parts of the area are the Harbour Main volcanics, the Holyrood granite batholith and minor Conception Group sediments. The Harbour Main volcanics consist predominantly of tuffs, volcanic breccia and minor flows of quartz-latite. The volcanics are intruded by the Holyrood granite batholith which consists of coarse pink biotite granite, aplite and pegmatite, and dikes of quartz-feldspar porphyry. Associated with the batholith are stocks of granodiorite, quartz-hornblende diorite and dikes of olivine gabbro. Lying unconformably on the Harbour Main and in part derived from it are the sedimentary rocks of the Conception Group, which consist of greenish-grey siltstones, conglomerates, red beds and slaty shales. Although the granite was not found in contact with the Conception Group sediments, a post-granite age is indicated by the presence of granite boulders in some conglomerate beds.

Structurally the area is quite complex, having been affected by folding and faulting. The majority of the faults can be assigned to two main groups. The first set consists of a number of strike-slip faults which trend North-North-easterly. They have affected only the volcanic rocks and do not continue into the granite and the sediments. The second set, which consists of dip-slip faults, strike North-west. These faults have affected both the Harbour Main and the Conception rocks as well as the granite. Jointing is well developed in the granite where two main systems are present. The area has been subjected to two main periods of deforemation. The first, which was early in the pre-Cambrian, preceded the intrusion of the Holyrood granite. The second orogeny which has affected the area was probably the Taconic orogeny; one of the results of this deformation is probably the most prominent fault of the region, the Topsail Fault, found to the east of the present map-area. Some of the faults in the map-area may be related to movement along the Topsail fault.

The table of formation which follows is the summary of the geology of the area as interpreted by the writer.

Table 1

Table of Formation

Period and Epoch	Formation	Lithology
	Basic Dikes	Small dikes of diabase
Intrusive Contact		
Late Proteroeoic	Conception Group	Greenish-gray siltstone, red siltstone, lime-stone lenses, slaty shale, Conglomerate
Not in contact with granite; unconformity with Harbour Main Group		
Mid Proteroeoic Pre Cambrian	Holyrood Granite Batholith	Rhyolite porphyry Olivine gabbro Granodiorite Coarse-grained granite; aplite, pegmatite. Quartz-hornblende diorite
Intrusive Contact		
Early Proteroeic	Harbour Main Group	Acid tuffs, quartz-latite and rhyolite flows, volcanic breccia.

Chapter IV

Volcanic Rocks of the Harbour Main Group

General Statement:

The rocks of the Harbour Main Group were first mapped as Huronian by Howley (1907). He described them as composed of mixed igneous and aqueous deposits in a highly metamorphosed condition. Buddington (1919) proposed the name "Avondale Volcanics" for these rocks because of their characteristic development and typical outcrops near Avondale, Conception Bay. Rose (1952) redefined these rocks and suggested the name "Harbour Main Group" for them. McCartney (1959) defined the Harbour Main Group as a "succession of volcanic and sedimentary rocks more than 6000 feet thick underlying the Conception Group on the eastern Avalon Peninsula".

In this study, all the volcanic rocks found in the map-area will be included with the Harbour Main Group as defined by McCartney (1959) because on the east coast of Holyrood Bay such rocks are unconformably overlain by sediments lithologically similar to and possibly equivalent to the Conception Group.

In the map-area, rocks of the Harbour Main Group consist predonimantly of tuffs, volcanic breccia and minor flows of quartz latite composition.

Most of the rocks are highly silicified and intricately faulted and altered to such an extent that most of the original features are completely obliterated. It must be pointed out that the volcanic rocks were not studied in detail; their intense silicification and alteration and possible recrystallization of the constituent minerals render any interpretation of textures and exact classification of these rocks very difficult. The classification suggested above is based mainly on the present mineral assemblage and texture.

Distribution and Field Relations:

Acid volcanic rocks occur in several places in the map-area. Their outcrops cover about one-sixth of the area. On the coast tuffs and minor acid flows are intruded by a ;ale-grey granite in the northern part while in the south-west the volcanics are overlain unconformably by sedimentary rocks of the Conception Group.

Near Holyrood, the volcanic rocks outcrop on the summits of Hennessey and White Hills. The outcrops display flow-banded texture. The contact between these rocks and granodiorites to the north of the rhyolites is masked by dense vegetation and not very clear, but a possible fault contact is indicated by intense crushing of the granodiorite.

Description of Rock-types

Quartz Latites:

The principal outcrops of these rocks are on the coast and on the Trans-Canada Highway, a quarter of a mile southwest of Black Mountain Pond. In hand specimen the typical quartz latite is a greenish-grey rock. It is porphyritic with feldspar phenocrysts averaging 0.3 mm - 0.4 mm in diameter embedded in an aphanitic matrix. In thin section, the rock consists of fractured phenocrysts of potash feldspar, plagioclase and biotite in a fine-grained quartzo-feldspathic matrix. One specimen from Black Mountain Pond contains a few rounded grains of quartz.

The plagioclase making up about half of the phenocrysts is albite An_8. It occurs as tabular crystals twinned mostly on Carlsbad and albite laws; chessboard twinning was seen in some grains. The albite grains are corroded and embayed at their edges; many grains are fractured, others are partly replaced by potash feldspar. Some fine-grained albite is present also in the groundmass.

Potash feldspar present in these rocks is sanidine. Staining with sodium cobaltinitrite indicated that the potash feldspar formed about 10%-15% of the rock. Sanidine occurs as euhedral phenocrysts. Some of the phenocrysts are twinned; the grains are generally clear and less altered. The mineral has low relief, a small axial angle (2V-10°), and it is optically negative.

Quartz commonly occurs in the groundmass, but one specimen near Black Mountain Pond contains a few rounded grains of quartz. The mineral forms less that 10% of the rock.

Mafic minerals account for less than 10% of the rock. The principal mafic m neral is biotite which occurs as elongated flackes, pale green in colour and weakly pleochroic; (X=brown, Y=Z=deep green). It is altered to flakes of chlorite.

The accessory minerals are magnetite and apatite. The groundmass containing the fractured phenocrysts is holocrystalline and fine-grained. It is made up mainly of potash feldspar, albite and quartz with some chlorite and sericite, and displays traces of flow-texture.

Discussion:

Quartz does not commonly form phenocrysts except for one specimen mentioned, but is confined mainly to the groundmass. Albite makes up about two-thirds of the phenocrysts. The mineral assemblage of albite, sanidine, quartz and biotite together with the flow texture indicate that these rocks are acid volcanics. In view of the relatively abundant albite they should be classified as quartz latites.

Tuffs

Distribution:

Tuffs outcrop on Hennessey and White Hills near Holyrood, and near Big Otter Pond. Some flow-banding was observed at these two localities. The colour of the tuffs varies from brick-red to greenish grey. The rocks are commonly aphanitic in texture, dense, and massive with an almost cherty appearance. Microscopically these rocks consist chiefly of crystal and rock fragments set in a holocrystalline chloritic groundmass.

Crystal Fragments:

Mineral fragments occuring in these rocks are albite, quartz, sanidine, and biotite. Quartz is most abundant in specimens from Little Otter Pond; while albite (An_8) is the most common mineral in other rocks from the other areas.

Quartz occurs as angular to subangular fragments and as fine-grained aggregates in the groundmass. Effect of strain is shown by the highly undulose extinction. It commonly forms up to 20% of the rock.

Albite (An_8) occurs as short, lath-shaped crystals showing albite and carlsbad twinning. The crystals are fractured and partly replaced by quartz. The mineral makes up about 30% of the rock.

Sanidine phenocrysts form less than 3% of the rock, but potash feldspar is common in the groundmass. The mineral is euhedral in form, clear and locally twinned.

Biotite is commonly euhedral in form, weakly pleochroic, almost invariably altered to flakes of chlorite. Common accessory minerals are magnetite and apatite.

Rock Fragments:

Rock fragments in the tuffs are angular to subangular. They are made up of abundant small altered plagioclase laths in a fine-grained chloritic matrix, suggesting a trachytic texture. The groundmass containing both crystall and rock-fragments makes about 50% of the rock. The groundmass is fine-grained; consists of mosaic aggregates of quartz, flakes of chlorite, sericite, epidote, potash feldspar and some carbonate.

Volcanic breccia:

Volcanic breccia occurs only along the coast where it is interbedded with the tuffs and quartz-latites. The breccia is made up of angular to subangular fragments of quartz and feldspar 10 mm - 15 mm in diameter set in a chloritic matrix, now stained red by hematite.

Alteration:

The volcanic rocks are highly altered. The principal types of alteration are silicification, chloritization and sericitization. The processes are discussed more fully in Chapter VII.

Structural Relations and Age:

The stratigraphic relations between the tuffs and the quartz-latite flows are obseured by faulting, silicification and discontinuity in outcrops. However, on the coast the volcanic breccias are interbedded with the quartz-latite flows.

The Harbour Main volcanics are the oldest rocks in the area. The rocks are intruded by Holyrood granite, the intrusive relationships being shown clearly by the many inclusions of this group in the granite. On the east coast of Holyrood bay, the volcanics are overlain unconformably by Conception Group sediments. Near Duffs the granite is overlain unconformably by Lower Cambrian strata. For these reasons, the Harbour Main group has been assigned to early Protezoic.

Mode of Origin:

Buddington (1919) who was the first to study these volcanic rocks in detail proposed a subaerial origin for them. McCartney (1959) described certain volcanic rocks on the Avalon Peninsula as ignimbrites and included the tuffs in the present map-area in this category. A survey of the literature shows a wide range of opinion as to the typical features of ignimbrites or "welded-tuffs".

Cook (1955, p. 1544) wrote:

> "Ignimbrites may be distinguished from lava flows by great extent, horizontal depositional surface, lack of vesicles, presence of compaction but not flow structure - - - abundance of glass shards as well as possible presence of incoherent basal ash, lithic fragments

through the mass."

> " Ignimbrites may be distinguished from air-fall and water laid tuffs by the absence of bedding, lack of sorting.

This definition however does not indicate any mode of origin for these rocks. Jenkes and Goldick (1956) applied the term to those rocks which show welding and advanced syngenetic recrystallization of the glass shards. Smith (1960) did not agree that crystallization is essential for the formation of ignimbrites. He wrote (1960, p. 800):

> "A welded tuff is a rock or rock-body in which vitric particles have some degree of cohesion by reason of having been hot and viscous at the time of their emplacement. Incipient, partial or complete welding are indicated by these teems - - - Crystallization may follow or accompany welding, but commonplace is not essential to that process."

Enlows (1955) studied a suite of welded tuffs from Arizona and concluded that because deposits of nuees ardents are gradational with those of ash showers and lava flows, exceptions will be found to all typical characteristics. In the present map-area, the volcanic rocks were not studied in detail. Field relationships between different members are masked by faulting and silicification, which render any interpretation of the microscopic features very difficult.

For these reasons, the writer has refrained from calling the acid volcanic rocks of the area ignimbrites or "welded tuffs", but has referred to them as tuffs, volcanic breccia and minor flows of rhyolite and quartz latite composition. However, it is possible that they have originated in the manner described by the various writers quoted above.

Chapter V

Conception Group Sediments

General Statement

The Conception Group was defined by Rose (1952) as a thick assemblage of sedimentary rocks overlying the Harbour Main Group and underlying the St. John's formation of the "Cabot Group". McCartney (1959) objected to this restriction since volcanic rocks were omitted, and applied the name Conception Group to those sedimentary rocks and rare volcanic rocks that overlie the Harbour Main Group and underlie the Carbonear formation of the "Hodgewater Group" (the Hodgewater Group being considered as the western equivalent to the Cabot Group).

Dawson (1963), working to the north-east of the present map-area, found that in certain places parts of the Conception Group are interfingered with the Harbour Main volcanic rocks. He reported, however, a unit similar in facies to the Conception Group unconformably overlying the Harbour Main volcanics and Holyrood Granite, which he called the "Blackhill sequence".

At several places west of Holyrood Bay, along the coasts of Harbour Main, Colliers and Marysvale, sedimentary rocks of the Conception Group overlie unconformably Harbour Main volcanic rocks, and basal beds of the sediments contain rounded cobbles and pebbles of the underlying volcanic rocks.

In the present map-area, along the coast, sedimentary rocks lithologically similar to the Conception Group rocks unconformably overlie silicified Harbour Main Group acid volcanics. For this reason the sedimentary rocks in the present map-area have been assigned to the Conception Group. Since neither the Cabot Group nor the Hodgewater Group outcrop in the writer's area, the upper limit as defined by Rose (1952) and McCartney (1959) cannot be established.

Distribution and Rock-types:

Rocks of the Conception Group outcrop in a narrow band along the east coast of Holyrood Bay extending inland for about a mile. The rocks of the Conception Group consist of greenish-grey siltstones, siliceous in part, and a few layers of conglomerate; both rock-types are associated with sporadic lenses and wedges or red laminated siltstones.

Conglomerates:

In addition to a true basal conglomerate that overlies the volcanic rocks and in part contains rounded pebbles of the underlying rocks, there occurs another conglomeratic member in the sedimentary succession. This conglomerate is so disturbed by intricate faulting that its position in the stratigraphic sequence cannot be determined accurately. However, it is most unlikely that it occurs very far from the bas of the Conception Group.

The upper conglomerate is made up of angular boulders of pink granite and granodiorite and reaches a maximum thickness of 100 feet. Locally the conglomerate is mixed with cherty sediments towards the top of the bed. The boulders are embedded in a green matrix which is sandy in the lower parts but cherty and silty towards the top of the bed. The siltstones underlying the conglomerate in places contain sandy beds and lenses up to 6 inches in thickness. The angularity and large sizes of some of the boulders suggest that the boulders may have been transported by either tidal waves or by heavy storm waves from a source not far away from the site of deposition, possibly from a boulder beach.

Isolated Pebbles:

In the lower part of the sequence a number of isolated pebbles were observed which lie within a relatively narrow mapable horizon. This horizon is about 1 foot thick. These pebbles need special mention because of the possibility that they might be useful as a "marker horizon" in the Conception Group west and east of Conception Bay. Similar isolated pebbles in a similar stratigraphic position were observed by the writer along the coast of Harbour Main (to the north of the present map-area) and W. D. Brueckner (personal communication) reports other occurrences at Brigus (still further north of the present area), and at Portugal Cove and Flat Rock east of Conception Bay.

The isolated pebbles in the writer's area are generally rounded and on the average about 3 cm in diameter. Their consistent occurrence in a well-defined horizon and the absence of any features in the siltstones which may be attributed to river action seem to indicate that thepebbles might have been deposited from drifting ice.

The part of the Conception Group sediments which overlies the conglomerate consists of greenish-grey siltstones. These greenish siltstones are in places interbedded with red sediments which include massive siltstones and finely laminated shales. Calcareous lenses and elongated pyrite nodules are commonly present in the siltstones but their distribution is irregular and do not follow any pattern.

Structural Relations:

Along the coast, rocks of the Conception Group unconformably overlie silicified Harbout Main volcanics. The sediments are not found in contact with the granite, but a post-granite age is indicated by granitic boulders in some of the conglomerates in the sedimentary sequence. The Conception Group sediments are intruded by a diabase dike on the coast. This diabase may be part of a swarm of diabase dikes which intrude both the Harbour Main volcanics and the granite.

Correlation:

Rose (1952) described the coarse conglomerates which outcrop on the east coast of Holyrood Bay, and which have been discussed above, and included them in the Harbour Main Group together with similar conglomerates occurring on the Witless Bay Line. Contrary to Rose's observation the conglomerates are of Conception age as they contain pebbles of Harbour Main Group rocks. Similar conglomerates were examined by the writer on the Trans Canada Highway, about 3 miles east of the Foctrap intersection. These particular conglomerates were mapped by Dawson (1963) as the base of his "Blackhill Sequence".

Also on the coast west of the town of Harbour Main beds with pebbles containing calcareous streaks were seen in the lower part of the Conception Group. It seems reasonable to assume that all these conglomerates belong to the basal part of the Conception Group. In this case the sedimentary sequence in the present map-area comprising conglomerates, red beds and greenish siltstones would belong to the Conception Group "sensu stricto" recognised on the Avalon Peninsula west of the Topsail fault. East of the Topsail fault sediments of Conception Group lithology are interbedded with Harbour Main volcanics and are hence obviously older than the Conception rocks "sensu stricto" west of the fault. For this reason a correlation with the Conception Group sequence east of the Topsail fault cannot be attempted.

Chapter VI

Holyrood Granite Batholith

General Statement

The Holyrood Granite Batholith is shown as part of the Laurentian series on the early geological maps of Newfoundland (Murray and Howley 1881, 1907). Buddington (1919) designated it for the first time as a batholith. In his paper on the Pre-Cambrian Rocks of South-east Newfoundland he wrote (1919, p. 475):

> "The backbone of the St. John's Peninsula is mapped by Howley (1907) as Laurentian. This rock in its northern half was found by the writer to bear intrusive relations to the Avondale volcanics and to constitute a granite batholith five to six miles in width and about forty miles in length."

Parts of the granite were later mapped by Vhay (1937) in connection with his geological investigation of the pyrophyllite mine near Manuels, and also by Rose (1952). McCartney (1959) objected to Buddington's usage of the term batholith on the grounds that:

a. Batholith is a structural, not a lithologic term.

b. Small intrusive bosses and stocks in the area are isolated from the batholith.

c. Part or all of the Butter Pot gabbro may have been derived in situ from older rocks of the Harbour Main Group.

Instead he applied the term "Holyrood Plutonic Series" to these rocks. In this work however, the name Granite Batholith as used by Buddington (1919) will be retained for the following reasons:

1. The writer does not agree that the Butter Pot gabbro was formed in the manner suggested by McCartney.
2. Smaller stocks of intermediate rocks in the area are considered to be related and to form an integral part of the granite.

The Central Granite

General Statement:

The Holyrood granite batholith forms the backbone of the Avalon Peninsula. It is 40 miles in length and about 6 miles in width. On its western boundary the granite cuts off and intrudes the eastern limb of an anticline, the core of which is exposed at the head of Conception Bay. (Buddington, 1919). Its eastern boundary is marked by a fault. In the map-area, granite underlies an area approximately 4.6 miles wide and 5.5 miles long. The term "Central Granite" will be used by the writer to refer to this granite.

Field Characteristics:

The intrusive contacts of the Central granite and the acid volcanics of the Harbour Main Group can be seen clearly in the field. For example, in the south-east near Big Otter Pond the granite intrudes acid tuffs. Intrusive relationships with the Conception Group sediments were not observed in the field. However, basal conglomerates of the Conception Group on the coast contain boulders of varying sizes of pink granite and granodiorite indicating a pre-Conception are for the granite. On the east coast of Holyrood Bay a pale-grey granite is overlain unconformably by Cambrian Sediments.

The granite is generally homogeneous although there are conspicuous changes in the grain-size, biotite content and in the degree of alteration. No definite lineation or foliation appears in theoutcrops. Contacts with the country rock, where exposed, are very sharp, without any pronounced mineralogical changes.

Aplite dikes are common in the granite. They are generally but not always associated with pegmatite dikes. On the coast near Duffs, a coarse pale grey granite is associated with a pegmatite stock. This pegmatite, which contains giant quartz crystals, is conspicuous by the complete absence of minerals containing volatile elements.

Along the margins and borders of the Holyrood granite lie stocks and bosses of granodiorite, quartz diorite and other hybrid rocks. Several dikes of quartz-feldspar porphyry intrude the older rocks along the contact zones of the granite. Xenoliths are common in the granitic rocks; they are mainly angular fragments of quartz-latite and tuffs in which the original textural and flow features are still discernible.

Classification:

The classification adopted for the granite is that proposed by Tuttle and Bowen (1958). Although x-ray analyses of the feldspars were not attempted, chemical and modal analyses together with field evidemce provide the basis for the classification.

1. The granite contains both potash feldspar and plagioclase feldspar, the latter occurring as a component of perthite and as separate crystals.
2. The normative constituents of albite + quartz make up more than 90% of the rock.
3. The granite does not contain any pyroxene.
4. It shows little evidence of contact metamorphism.
5. A marginal pegmatitic "facies" is associated with the granite.
6. The modal percentages of the constituent minerals agree fairly well with those of normal granites as defined by Tuttle and Bowen (1958).

On the basis of the above data, the Central granite is assigned to Group II C (Subsolvus granite) of Tuttle and Bowen (1958 p. 129, and pp. 137-138).

Subdivisions:

While the Central granite is relatively homogeneous, nevertheless it exhibits some variations in grain size, in the biotite content and in the degree of alteration. Inclusions are irregularly distributed, being more abundant in the western parts than in the other areas. For these reasons the writer will discuss the Central granite under two subdivisions, here called "type G_1" and "G_2". $\underline{G_1}$ is a coarse-grained variety containing numerous inclusions, low in biotite content and relatively little altered. $\underline{G_2}$ is a medium-grained type with few xenoliths, a higher biotite content and a much greater degree of alteration. It must be emphasized, however, that these types represent variations within a single rock. The two rock-types are not considered to represent granites of different ages because:

1. No intrusive contacts between the two rock-types were found in the field. The area between Butter Pot Hill and the outcrop to the west of Peter's Pond is covered with thick vegetation and therefore it is difficult to trace any contact between the two rock-types.
2. A single joint pattern continues without change throughout both rock-types.
3. Late aplite and pegmatite dikes which occur in the two types are similar in their settings and in mineralogy.

Granite Type G_1

This rock-type outcrops in a narrow strip between Quarry Brook and ~~the~~ Butter Pot Hill. On the summit of Butter Pot the granite is in contact with hornblende diorite. Xenoliths are common in rock exposures. The xenoliths, mainly volcanic rocks of the Harbour Main Group, are angular to subangular, silicified and locally contain pyrite. Original flow textures are discernible in some of the xenoliths. In hand specimen, type G_1 is a coarse-grained, pale pink, equigranular rock. It is holocrystalline, with grains averaging 6 mm - 7 mm in diameter, consisting of quartz, potash feldspar, biotite and plagioclase.

Microscopic Petrography:

Under the microscope, the granite shows a holocrystalline, hypidiomorphic-granular texture. Mafic minerals and plagioclase are euhedral while the potash feldspar is subhedral and quartz occupies irregular interstices.

The potash feldspar is microcline-microperthite. The perthites are generally patchy and irregular consisting of rods and strings of albite (An_5) in microcline host. The spaces between adjacent perthite grains are usually filled with granular albite. This may represent a completely exsolved sodic component of the perthite which has migrated towards and concentrated along the grain boundaries. Some of the potash feldspar occurs as non-perthitic grains which show microcline twinning in patches, while others with similar optical properties are not twinned. By analogy the untwinned potash feldspar is considered to be microcline. The microcline occurs as subhedral tabular grains with perfect cleavage parallel to (001). It is optically negative with an optic angle of about 80°.

Plagioclase commonly occurs in euthedral, tabular crystals, polysynthetically twinned on Carlsbad and albite laws; some crystals display cheesboard type of twinning. The plagioclase is albite of composition An_{5-8}, optically positive with a large axial angle of 80°. The twin lamellae generally thin, vary in form. They are commonly bent, fractured and microfaulted, some lamellae showing evidence of drag-folding adjacent to a fracture. See Fig. (iii). The albite crystals are generally cloudy and alter to a scaly aggregate of sericite, and granules of epidote.

Quartz is irregular in form and occupies space between earlier formed minerals. The mineral displays undulose extinction and contains inclusions of minute flakes of mica.

Biotite is the principal mafic mineral in the granite. It occurs as short, subhedral crystals; most grains are distorted and twisted. The mineral is olive-green in colour, and weakly pleochroic; (X=yellowish green, Y = Z = deep green). It alters to flakes of chlorite and secondary magnetite. Minor accessory minerals include spatite, magnetite and zircon. A modal and chemical analysis of this rock is given in Table II.

Granite Type G_2

Distribution and Field Relations:

This type of granite covers a wider area than that of granite type G_1, forming about 70% of the Central granite outcrop. The principal outcrops are found between Pegwood and Big Otter Pond to the south, White Hill Pond to the north and the Round Pond to the east, the Butter Pot Hill being the western boundary of the area. Near Big Otter Pond rocks of this type of granite intrude tuffs of the Harbour Main Group. The rock is essentially similar to type G_1, but differs in its grain size, (G_1 = 6 mm - 7 mm, G_2 = 3 mm - 4 mm), in its higher content of biotite and in the greater degree of alteration; generally it contains fewer xenoliths. It is homogenous, although some variations were observed in fault and in shear zones. In these zones the granite is crushed to angular fragments of quartz and feldspars aligned with their long axes in the direction of movement. These fragments are set in a finely granular aggregate of epidote and chlorite, locally stained red by hematite. Thin fractures and veinlets in the granite are filled with calcite and epidote. Pyrite is notably conspicuous in the crushed zones.

Petrogfaphy:

In hand specimen the rock is a medium-grained biotite granite. It is commonly light pinkish-grey in colour, equigranular with grains nearly 3 mm - 4 mm in diameter. The rock consists essentially of quartz, potash feldspar, plagioclase and biotite. Microscopically the granite is medium-grained, holocrystalline, and hypidiomorphic-granular in texture. However, the granites from crushed zones exhibit mortar textures.

Quartz, which forms 30% - 35% of the rock, forms large compound units showing varying degrees of wavy extinction. It corrodes and embays plagioclase and potash feldspar suggesting replacement of these minerals.

Potash feldspar is microcline-microperthite, forming 30% - 35% of the rock. Microcline commonly occurs as subhedral crystals, usually cloudy due to incipient alteration to clay minerals. The perthites are made of of rods and strings of albite (An_5) in a microcline host. The strings and rods of albite are thinner and more regular, lacking the patchy discontinuous nature characteristic of granite type G_1.

Plagioclase commonly exhibits euhedral to subhedral tabular crystals, always polysynthetically twinned, some crystals display cheesboard twinning. The plagioclase is albite, An_{5-7}, forming 18% - 20% of the rock. It is generally cloudy and alters to fine-grained aggregates of sericite.

Biotite is more abundant in this type of granite, forming 10% - 15% of the rock. It occurs as euhedral, tabular crystals, locally bent and twisted. It is olive-green in colour and weakly pleochroic; (X = brown, Y=Z = deep green). The mineral is optically negative with an optical angle of 15° - 20°; it alters to chlorite.

Accessory minerals include magnetite, apatite and zircon.

Modal Analysis of the Central Granite:

Modal analysis was made on six specimens of type G_1. The thin sections were etched in hydrofluoric acid fumes for one minute, then stained with saturated sodium cobaltinitrite solution (60 gram/100 gms. of water) to identify the potash feldspar. Mechanical stage traverses were spaced 1 mm apart, and about 3000 points counted. Quartz, alkali feldspar, plagioclase and biotite were recorded separately whereas the accessory minerals were grouped together. Plagioclase lamellae in the parthites were recorded separately and later included with the total plagioclase content. The average results are given in Table II. The amount of modal quartz and orthoclase does not differ appreciably from the normative values but plagioclase shows some difference between the normative and the modal values (normative = 33; mode = 20). This difference may be due to the amount of soda held in solid solution in the potash feldspar.

Normative albite - orthoclase - quartz:

The normative amounts of albite + orthoclase + quartz for the granite were calculated from a chemical analysis. The rock from which the analysis was made was collected by the writer from the summit of Butter Pot Hill. The results show that the granite contains about 90% of the normative constituents. This figure is above the minimum value of 80% required to satisfy the normal granites as defined by Tuttle and Bowen (1958).

Table II

Chemical Analysis of Holyrood Rocks

	B-79	B-83
SiO_2	74.25	76.01
TiO_2	0.12	0.12
Al_2O_3	13.51	12.54
Fe_2O_3	0.62	0.38
FeO	0.42	0.64
MnO	0.04	0.02
MgO	0.18	0.16
CaO	0.31	0.44
Na_2O	4.10	4.30
K_2O	5.47	4.42
P_2O_5	0.02	0.03
CO_2	0.11	0.12
H_2O^+	0.41	0.30
H_2O^-	0.03	0.05
	99.59	99.53

B-79: Coarse pink granite from Summit of Butter Pot Hill - G_1

B-83: Rhyolite porphyry from Butter Pot Hill
Analyst: H. Dehn, University of Pittsburgh..

Norm

	B-79	B-83
Q	26.99	31.32
Or	33.0	26.5
Ab	37.0	39.0
An	0.43	0.43
Di	0.34	0.34
Hy	0.53	0.69
Mt	0.20	0.42
Hm	0.30	0.06
Il	0.73	0.16
C	0.05	0.63
Ap	0.20	0.05
Cc		0.40
	99.97	100.00

Mode

Quartz	32
Microcline	38
Albite	20
Biotite	8
Others	2
	100.0

Aplite Dikes

Distribution and Field Relationships:

Aplite dikes occur throughout the whole of the Central granite, usually in close association with pegmatite dikes. The aplite dikes vary in thickness from a fraction of an inch to several feet. Where individual dikes can be traced for considerable distances, they are observed to follow the general directions of the two mail joint systems in the granite, north-west and north-east. Contacts of the aplite dikes with the granite are generally sharp.

Petrography:

In hand specimen, the rock shows an even, fine-grained sugary texture; it is commonly pinkish and consists of anhedral quartz, potash feldspar and plagioclase with few ferromagnesian minerals. Microscopically the rock shows micrographic to allotriomorphic-granular texture. The dominant minerals are quartz and microcline-microperthite with some albite and biotite.

Quartz forms about 40% - 45% of the rock. It occurs as composite grains of irregular shape showing wavy extinction. Locally, quartz appears to replace the earlier formed constituents.

Microcline-microperthite forms 35% - 40% of the rock. The perthites consist of fine continuous strings of albite

(An_5 in microcline. Microcline.occurs as short anhedral crystals showing the characteristic albite and pericline twinning. The mineral is optically negative with optic angle of 80°. Besides the thin lamellae in perthite, albite forms lath-shaped subhedral crystals. These show well-developed polysynthetic albite twinning and have an optic angle of about 78° - 80°. The twin lammellae are commonly curved and fractured. The mineral is relatively fresh except for minor sericite alteration, and it forms about 10% - 15% of the rock.

Biotite forms 2% - 5% of the rock. It occurs as subhedral to euhedral platy crystals. The mineral is greenish brown in colour and weakly pleochroic; (X = light brown, Y=Z = deep green). It is partly altered to chlorite and magnetite.

The intimate association of the aplite dikes with pegmatite suggests that both rock-types may have originated in the same way. They probably represent granitic residua. The composition of the aplites does not appear to differ significantly from that of the host-rock, the Central granite. The dikes probably represent a late-stage injection of the same magma into the solidified granite.

Pegmatite

Besides the smaller interior pegmatites that are found in the Central granite, a coarse pegmatite body is exposed on the coast of Holyrood Bay, near Duffs. The two rock-types are basically similar in mineralogy except that giant quartz crystals occur in the latter. The smaller pegmatites are g generally but not always associated with aplite dikes. They are less frequent in occurrence and variable in width, ranging from 2 inches to 6 inches. The typical "interior" pegmatite consists chiefly of pink potash feldspar anhedral quartz, plagioclase (An_5) and muscovite.

On the coast pegmatite is associated with a pale grey granite which locally merges into a coarse-grained pink granite. The pegmatite occurs in a zone shich starts about 130 feet south-west of an unconformity overlain by Lower Cambrian sediments and extends further to the south-west for 500 feet. Within this zone giant quartz crystals are embeded in irregular aggregates of coarse pink microcline and quartz. The giant quartz crystals are euhedral and prismatic in habit, about 10 inches in diameter, and each crystal contains thin concentric films of potash feldspar.

The groundmass and the giant quartz crystals usually form elongated blocks about 15 feet wide and 40 feet long. These blocks are oriented subparallel to each other and trend in a north-easterly direction. A typical block consists generally of 3 rows of quartz crystals, regularly spaced, usually not more than 4 crystals in each row. Individual crystals in these rows are aligned with their long axes to the general trend of the blocks. The spaces between crystals are filled with aggregates of microcline, quartz and minor plagioclase. Ferromagnesian minerals are notably absent within the blocks but they tend to be concentrated at the borders of the blocks, forming thin dark bands which grade into the surrounding granite. A very significant feature of the pegmatite is the total absence of minerals containing volatile elements normally concentrated in the last fractions of crystallizing magma.

Petrography:

The mineralogy of the pegmatite is simple. Microcline-microperthite is the dominant mineral, associated with albite and quartz. Biotite and muscovite occur in minor amounts.

Microscopically, quartz occurs in the form of irregularly shaped composite grains, some interstitial to feldspar, others with "caries" texture suggesting replacement. A striking textural feature of the rock consists of intergrown quartz and microcline, the former occurring as isolated "hieroglyphs" or as lamellae which have grown at right angles to the faces of the feldspar "phenocryst" and which expand in girths. The "hieroglyphs" within each area are in optical continuity.

The microcline - quartz intergrowths are roughly rounded and the quartz "hieroglyphs" have a radial arrangement. Quite often microcline crystals are intimately penetrated by "tongues" of quartz leaving corroded, and embayed residual patches of these crystals.

Grains of Microcline-microperthite are severely strained and display very extreme undulose extinction; they form less than 20% of the rock.

Albite (Ab_5) forms 10% - 15% of the rock. It occurs as lath-like crystals, polysynthetically twinned, optically positive, with an optic angle of about 80°.

The rock containing the quartz crystals is holocrystalline, micrographic in texture; replacement of microcline-microperthite by quartz is common in many thin sections.

Possible Origin and Age

Pegmatites and aplites are generally considered to have originated either by replacement or by crystallization from a granitic residuum or by a combination of the two processes. Where pegmatite and aplite are closely related, bear close genetic relationship to the granites in which they occur and show dilational emplacement, they are considered to have been of magmatic origin. They represent granitic residua which were injected into the partially crystallized rock. Field observations together with microscopic evidence indicate that the aplite and pegmatite dikes which occur in the Central granite (interior aplite and pegmatite) are of magmatic origin and are related to the granite.

However, the origin of the marginal pegmatite on the coast poses a problem. It is characterized by the absence of minerals containing volatile elements, but contains giant quartz crystals and rare vugs lined with prismatic crystals of smoky quartz. Any theory proposed for the origin of the pegmatite must take into account these observations.

The literature on giant crystals occurring in pegmatites shows a wide range of conflicting opinions on the origin of these minerals. Replacement and magmatic crystallization processes are the two main theories that have been proposed to explain their origin. Schaller (1927) attributed the development of large crystals of potash feldspar to hydrothermal replacement. Landes (1928) suggested a replacement origin for large individual crystals of spondumene in the pegmatite of the Black Hills region. Other investigators have regarded all giant crystals as products of crystallization from a pegmatite magma. Jahn (1955), reviewing the published data on pegmatites and field occurrences wrote: "Convincing direct evidence that the giant crystals grew by replacement of other minerals appears to be lacking". He proposed instead that giant crystals do crystallize directly and rapidly from pegmatite liquid that was rich in hyperfusible constituents. An explanation of the absence of these constituents may lie in the fact that either the granitic residuum lacked such constituents, or they may have escaped from a shallow intrusion through a porous or fractured roof. However, microscopic data indicate that quartz replaces microcline-microperthites and plagioclase. On the strength of this evidence the writer believes that hydrothermal replacement has been active in the development of the giant quartz crystals.

Granodiorites and Quartz Diorites

General Statement:

Within the interior and near the margins of the Holyrood granite lie stocks and bosses of granodiorites and quartz diorites. Generally the contacts of these rocks with the granite are gradational. The rocks are variable in texture and in colour but their mineralogy is basically similar. They consist of dominant plagioclase, potash feldspars, quartz and abundant accessory sphene. Because of the relative abundance of plagioclase and minor amounts of quartz, they have been classified as granodiorites and quartz diorites.

Distribution:

The principal occurrence of the rocks are found on the coast, on Brophy's Hill and near Kelly Pond. Near Duffs, quartz diorite for numerous inclusions in the granite. The inclusion, which show gradational contact with the enclosing granite, contain more mafic minerals than the granite. Half a mile South-west of this outcrop, pink granodiorite is in contact with volcanic breccia of the Harbour Main Group; the South-western boundary is defined by a fault. At the summit of Brophy's Hill a pale green granodiorite forms an irregular stock, while near Kelly Pond quartz diorites show gradational contact with the granite.

Petrography: The rocks are pinkish to pale-green in colour; commonly medium-grained, holocrystalline; some types display subporphyritic texture with phenocrysts averaging 2 mm - 4 mm in diameter. The typical granodiorites consist of plagioclase, potash feldspar, hornblende and quartz with accessory sphene and magnetite.

The Plagioclase is Oligoclase (An_{25-28}). It occurs as long euhedral crystals showing Carlsbad and albite twinning. It is optically negative with an optic angle of about 78°. The twin lamellae are severely fractured and distorted, the fractures are filled with chlorite and sericite. The mineral shows normal zoning with highly saussuritized cores rimmed by relatively unaltered albite (An_8).

Potash feldspar is microcline-microperthite. Microcline shows the typical polysynthetic twinning but some grains are clouded by clay minerals and thus do not show the twinning clearly. The microcline host contains irregular films and rods of albite (An_{5-8}). Radiating from the edges of the microperthites and in places replacing plagioclase are myrmekitic intergrowths.

Quartz occurs as anhedral grains generally interstitial to the feldspar. It displays pronounced wavy extinction and in highly fractured rocks it is reduced to mosaic aggregates.

<u>Hornblende</u> is the principal mafic mineral. It occurs as long euhedral prismatic crystals, greenish in colour and weakly pleochroic; (X = yellowish green, Y = olive green, Z = dark green).

<u>Sphene</u> occurs in euhedral crystals which show high relief and rhombic sections with distinct partings. It is positive with optic angle of about 35°.

Other accessory minerals are magnetite and apatite.

Modal Analysis of Granodiorite

Table III*

Quartz	10%
Potash feldspar	24
Plagioclase (An_{25-28})	45
Hornblende	15
Accessories	6
Total	100.0

*Average of four thin section determinations.

3000 points counted.

Quartz Diorite:

The occurence and field relations of this rock-type have been described in previous chapters. In the field the quartz diorite is distinguished from the granodiorite by its darker colour and to some extent by the higher degree of alteration.

It is less widespread in occurrence than the granodiorite. The rock is holocrystalline, medium-grained, consisting of plagioclase, potash feldspar, quartz and hornblende. Microscopically the texture is hypidiomorphic-granular. The mineralogy is basically similar to the granodiorite and will not be discussed in great detail except to point out that hornblende is more abundant (forming about 20% of the rock) than in the granodiorite. Plagioclase is similar in composition (An_{28-30}) and occurs as lath-shaped crystals. Quartz which forms less than 10% is mostly interstitial to the feldspar. Potash feldspar is usually perthitic, consisting of irregular films and rods of albite (An_{5-8}) in microcline. The microperthites are commonly cloudy die to alteration to clay minerals and sericite.

Possible Mode of Origin of Granodiorite and Quartz Diorite

The granodiorite and the quartz diorite display certain characteristics commonly associated with hybrid rocks. Incipient development of myrmekite and mortar texture, features generally associated with hybrids have been observed in the sections from these rocks. The rocks are also notably variable in texture and in colour although their mineralogy is similar. The writer believes that the granodiorite and quartz diorite are of hybrid origin, formed through contamination of the granitic magma by digestion of mafic rocks.

Evidence for this observation lies in the fact that they are lower in potash and in quartz, but richer in plagioclase and in mafic and accessory minerals, than the Central granite. They generally occur at the margins of the Central granite, an association which furnish further evidemce for some genetic relation with the granite.

McCartney (1959) who made fairly detailed study of the Holyrood granite concluded that the granite was contaminated along its margins by assimilation of mafic rocks forming granodiorites and quartz diorite. The writer is in essential agreement with this view.

Feldspars

General Statement:

The feldspara occurring in the granite show features which have inportant bearing on the interpretation of the crystallization history of the granite. A complete study of the thermal history of the feldspars would require chemical and x-ray analyses as well as detailed optical work. However, only optical data were obtained. Thus any conclusions based on this evidence must be treated with caution.

Potash Feldspar

Orthoclase or Microcline:

Granites normally contain either orthoclase or microcline or both minerals. For example Johannsen (1932, p. 137) wrote; "Not only may orthoclase and plagioclase be present, but orthoclase and microcline may occur together". Marmo (1958) distinguished between orthoclase and microcline granites and stressed the importance of studying them separately. In a later paper (1960, p. 6) he wrote; "In the Pre Cambrian granites ... the microcline is by far the most predominant form of the potash feldspar". Felix Chayes (1952) concluded from a study of New England granites that the potash feldspar in those granites is microcline. In the present map-area, microcline usually occurs as a component of perthites, but some sections showed the characteristic polysynthetic twinning typical of microcline, while other thin sections showed untwinned potash feldspar.

While it is evident that some of the potash feldspar is microcline, the question whether all of the potash feldspar is microcline is difficult to answer without chemical and x-ray analyses. The most obvious criterion - the presence or absence of the typical microcline twinning - is clearly not a reliable guide as untwinned microcline is common. However, the twinning observed in some of the grains is suggestive that all the potash feldspar is microcline; e.g. Tuttle and Bowen (1958, p 98) believe that if some of the grains show a microcline twinning then probably all of the potash feldspar is microcline. Careful measurements of the optical angle

(2V) may furnish further evidence. A number of measurements (24 in all) were made on the untwinned potash feldspar on a Leitz Four-Axis Universal stage. The results are given in Table IV. The extinction angle on (001) varied from +11° to +14°.

Table IV

Optical Angle Determination of Potash Feldspar

No.	2V*
B - 28	87°
B - 4A	88°
B - 22B	88°
B - 94	86°

Optical plane (010)

*Average of 6 readings on each thin section.

It must be pointed out that the 2V of potash feldspar is dependent on the soda content and on the degree of inversion to microperthite or crytoperthite as well as on the structural state of the potash feldspar itself. For this reason the significance of the 2V should not be overemphasized. However, when the data are correlated with Tuttle's (1952) diagram they indicate the potash feldspar to be microcline. This agrees with the observation of Tuttle and Bowen (1958) quoted above. On the basis of these data the writer believes the potash feldspar in the Central granite is microcline.

Plagioclase

General Statement:

Plagioclase in the granite occurs in several forms, all of them albite in composition, (An_{5-8}). Besides the albite lamellae in perthite and the small euhedral crystals mentioned previously, the rock contains large euhedral grains of sodic plagioclase showing a patchy interrupted twinning pattern known as "chessboard albite". The chessboard albite will be discussed in some detail because of the conflicting opinions on its mode or origin and its importance for the crystallization history of the Central granite.

Chessboard albite occurs as complex pattern of short alternating twin lamellae, twinned on the albite law; but unlike the usual albite twins, the lamellae do not continue through the entire crystal. It is commonly, but not always, associated with fractured and distorted plagioclase crystals, deformed flakes of biotite and fracture zones. This intimate association indicates that the development of the chessboard albite may be related to stress. This is in agreement with the observations of Starkey (1959) reported in his study of chessboard albite in some porphyries of New Brunswick.

There is evidence that the Central granite was subjected to considerable stress during and/or after emplacement. The occurrence of microbreccia (near Duffs) in which the fragments are cemented by granitic material points to deformation early in the granite history which affected the oilidified portions. Undulose extinction of quartz, fractured plagioclase twin lamellae and deformed biotite flakes indicate the effect of post-crystallization stress on the granite. It is safe to conclude from the above evidence that development of the chessboard albite is probably related to this late-stage stress.

Other Intrusive Rocks

Introduction:

In addition to the granite and its related aplites and hybrid rocks, there are occurrences in the map-area of smaller stocks of hornblende diorite and dikes of gabbroic composition. The relationships of these rocks to the granite are clearly exposed at the summit of Butter Pot Hill. Here the basic rocks present interesting problems. Earlier investigators, notably Buddington (1919) and McCartney (1959) both referred to the rocks as gabbro. However recent studies by the writer have shown that there are two rock-types, different in composition and age. For reasons to be given later, the writer will refer to the two types as hornblende diorite and olivine gabbro. The former represents the "quartz bearing gabbro" and the latter the dense "basaltic" rock of the above investigators.

Hornblende Diorite:

The typical occurrence of this rock is at the summit of Butter Pot Hill and ½ mile south-east of Seal Cove. In the latter case, the outcrop is about 300 feet in length and 200 feet in width. It is intimately penetrated by branching apophyses of granite and by epidote veinlets which are common along the joint planes. At the summit of Butter Pot Hill the rock is intruded by the granite and by the olivine gabbro; the outcrop itself is cut by many aplite dikes.

Megascopically the rock is medium-grained, dark coloured, consisting essentially of anhedral, pale-green saussuritized plagioclase and elongated subhedral hornblende, 0.5 mm - 2 mm in size. In thin section, the rock is holocrystalline, allotriomorphic-granular in texture; quartz fills spaces between theother constituents.

The plagioclase is Andesine (An_{40}), forming about 50% of the rock. The mineral occurs as lath-shaped crystals, showing both albite and Carlsbad twinning, combined in some crystals with Pericline twinning. It shows normal zoning, with a highly altered core (An_{45}) and a relatively clear rim (An_{35}). The mineral is mottled with minute aggregated of sericite and is partially replaced by quartz and epidote.

Hornblende is the principal mafic mineral. It occurs as elongated prismatic crystals, weakly pleochroic; (X = light green, Y = yellowish green, Z = bluish green). It is altered an to aggregate of uralite fibres, flaky grains of chlorite and granules of epidote. It forms about 30% of the rock.

Augite occurs as short prismatic crystals, highly altered to fibrous aggregated of actinolite. Rarely, augite crystals are rimmed by a pale-green compact hornblende.

Quartz forms less than 10% of the rock. The mineral is interstitial to the other constituents, locally associated with chlorite and uralitic hornblende. Magnetite, ilmenite and apatite are the common accessory minerals. A chemical and normative analysis of the rock is given in Table V.

Discussion:

This rock was originally referred to as quartz bearing gabbro by Buddington (1919) and as Butter Pot gabbro by McCartney (1959). A calculation of the normative composition from chemical analysis on a sample collected by the writer showed 2% quartz and only 20% of the anorthite "molecule" giving a plagioclase of composition An_{36}. This rock composition falls into Calss 2, Order 2 and Famile 12 as defined by Johannsen (Vol. I, p. 156). The writer therefore proposes to call the rock hornblende diorite. It is further suggested that the outcrop near Seal Cove together with the one on Butter Pot Hill represent the two oldest intrusive rocks in the map-area. Probably the rocks were originally gabbros which have been modified by the granite. Evidence for this assumption lies in the development of uralitic hornblende from augite, and the further alteration of the mineral to chlorite, the highly saussuritized condition of the plagioclase, reaction rims around augite and the presence of granitic dikes in field exposures.

Olivine Gabbro:

Olivine gabbro outcrops on the summit of Butter Pot Hill where it is intruded by a rhyolite porphyry. Dikes of similar composition cut sedimentary rocks of the Conception Group near Holyrood. Megascopically it is a dense, black holocrystalline rock, consisting chiefly of subhedral plagioclase and short stubby pyroxene crystals set in an aphanitic matrix. In thin section, the rock displays porphyritic texture with euhedral phenocrysts of pyroxene and lath-shaped plagioclase in a holocrystalline groundmass. The groundmass shows subophitic texture and consists of plagioclase laths, granules of augite, and magnetite.

The plagioclase is labradorite An_{50-52}. It occurs as lath-shaped crystals showing broad albite twin lamellae, commonly combined with Carlsbad and/or pericline twinning. The laths are generally shorter than the predominating augite phenocrysts. The mineral is optically positive, 2V-80°; it is relatively unaltered and forms about 55% of the rock.

Augite is present as euhedral phenocrysts and also as granules in the matrix forming about 40% of the rock. Some of the crystals are twinned with (100) as twin-planes, while others show basal idiomorphic sections. The mineral is pale greenish in colour. It is optically positive with optic angle of about 45°.

Olivine forms less than 5% of the rock. Crystals are short stubby in form and are generally rimmed by granular aggregates of augite, which is in turn surrounded by a thin ring of pale-green hornblende. It is partly altered to talc and secondary magnetite which are common along irregular fractures. Accessory minerals are magnetite and apatite.

A chemical analysis of the rock is given in Table V.

Discussion:

This rock was included with the Butter Pot gabbro by Buddington (1919) and McCartney (1959). It is intruded by a rhyolite porphyry but is not found intruded by the granite. It nevertheless cuts the hornblende gabbro stock on the summit of Butter Pot Hill. Normative calculation from chemical analysis on a sample from the above hill shows 26.85% of anorthite "molecule", giving An_{44}, and 4.53% olivine. On the basis of the mineralogy and chemical composition, the rock should be classified as olivine gabbro. It is definitely younger than both the granite and the hornblende siorite and represents a later basic intrusion following the emplacement of the granite.

Table V

Chemical Analysis of Basic Rocks from Butter Pot Hill

	$B\text{-}80^A$	$B\text{-}80^C$
SiO_2	50.50	51.05
TiO_2	0.97	0.87
Al_2O_3	18.69	17.04
Fe_2O_3	3.18	2.44
FeO	6.24	6.13
MnO	0.11	0.09
MgO	4.65	5.72
CaO	8.38	8.83
Na_2O	3.75	3.70
K_2O	1.20	1.18
P_2O_5	0.22	0.17
CO_2	0.14	0.30
H_2O^+	2.33	2.44
H_2O^-	0.05	0.07
	100.41	100.03

Norm

	$B\text{-}80^A$	$B\text{-}80^C$
Q	2.0	-
Or	7.0	7.10
Ab	34.5	33.80
An	20.0	26.85
Di	16.0	11.80
Hy	9.4	10.96
Mt	4.2	2.59
Hm	0.1	-
Il	1.4	1.24
Ol	-	4.53
C	4.4	-
Ap	0.5	0.35
Cc	0.4	0.78
	99.9	100.00

$B\text{-}80^A$: Hornblende diorite from Butter Pot Hill
$B\text{-}80^C$: Olivine gabbro from the summit of Butter Pot Hill
Analyst: A. Dehn, University of Pittsburgh.

Rhyolite Porphyry

Distribution and Field Relations:

Besides the aplite and pegmatite dikes occurring in the Central granite, there are dikes of a fine-grained acid porphyritic rock referred to here as rhyolite porphyry. This rock is particularly interesting because of its scarcity and restriction to the contact zones of the granite. It was found in only two places, near Big Otter Pond and at the summit of Butter Pot Hill. In the former case, the rock cuts both the granite and the acid tuffs of the Harbour Main Group with very sharp contacts. At the summit of Butter Pot Hill, the intrusive relations of the rock with an olivine gabbro body are clearly exposed; the same dike extends into and cuts the granite nearby. The dikes vary from 6 inches to 18 inches in width and in most cases cannot be traced for more than 20 feet along the strike.

Petrography:

The colour of the rock varies from pale-pink to yellowish-brown; it weathers chalky white, with the quartz crystals standing out. The rock is fine-grained, holocrystalline in texture and consists chiefly of euhedral to subhedral phenocrysts, 2 mm - 4 mm in diameter, of potash feldspar, quartz, albite and biotite in an aphanitic matrix. The quartz phenocrysts are well-developed. They are about 1 mm - 2 mm in size, euhedral to subhedral, with hexagonal cross-sections. In a thin weathered zone at the surface of the outcrops, the crystals can be recognised as well developed hexagonal dipyramids without any prismatic forms. This crystal habit is characteristic of high temperature quartz. (Dana, System of Mineralogy, Vol. 3). In thin section, the phenocrysts make about 45% - 50% of the rock (quartz 10%, sanidine 15%, plagioclase 10%, biotite 8%, and accessories 2%); the groundmas (50% - 55%) consists of quartz spherulites and few mafic minerals.

Sanidine occurs as euhedral phenocrysts 2 mm - 3 mm in diameter. It is relatively unaltered but is slightly corroded at the edges. It is optically negative with a low optic angle.

Quartz occurs as phenocrysts and as spherulitic forms in the groundmass. The phenocrysts are generally short stubby hexagonal crystals, some of which are surrounded by very thin rings of spherulites.

The plagioclase is albite of composition An_5. The mineral appears as lath-shaped phenocrysts and as minute grains in the groundmass. It is cloudy due to flakes of sericite and minute scaly aggregates of clay minerals. Twin lamellae are generally straight, thin and continuous. The mineral is optically positive, with optic angle of 80°.

The only common mafic mineral in the porphyry is biotite.

It occurs as subhedral tabular phenocrysts, 0.5 mm in size. It is strongly pleochroic; (X = light buff, Y=Z = deep green). Fine grained chlorite is the common alteration product of the mineral; magnetite is a minor accessory.

In addition to the common rock-forming minerals, a red-brown mineral identified tentatively as allanite is present in the rock. The mineral occurs as short tabular crystals, some grains show twinning with (100) as the twin-plane. It is distinctly pleochroic; (X = red, Y = yellow, Z = dark reddish brown). It is biaxial negative; 2Vx varies from 86° to 88°.

Discussion:

On the basis of its chemistry the rock is a "rhyolite porphyry". A chemical analysis of the rock is given in Table II. The field occurrence, chemical composition and mineralogy of the rock indicate that it is related to the granite. A calculation of the normative constituents from chemical analysis of a specimen collected by the writer from Butter Pot Hill shows 26.5 orthoclase, 39.0 albite (An_1) and 31.32 quartz. These figures do not differ significantly from those of the granite given in Table II. It is suggested therefore that this rock represents a later intrusion of acid material after the emplacement of the granite.

Origin and Age of the Granite

Two possible modes of origin for the granite were considered, magmatic and metasomatic. The writer believes that the granite is of magmatic origin for the following reasons:

1. It intrudes the acid volcanic rocks of the Harbour Main Group with very sharp contacts; locally (Big Otter Pond) dikes and apophyses from the granite are seen cutting the country rock.
2. Numerous xenoliths in the granite are angular in shape.

The relative scarcity of contact metamorphic and metasomatic features in the intruded rocks could be taken relatively low temperature. However a more probably explanation may lie in the fact that the intruded rocks are acid volcanics (quartz-latite) which would not undergo any striking changes even at normal magmatic temperatures. The granite has a relatively uniform structure, without any pronounced foliation or lineation. This is usually taken as evidence of post-kinematic origin (Buddington 1959, Marmo 1962).

Intrusive relations of the granite with the Conception Group sediments were not seen in the present map-area; however, a pre-Conception age is indicated by angular boulders of pink granite and rounded cobbles of granodiorite occurring in basal conglomerates of the Conception Group.

McCartney (1959) reports an age of 910$\pm$ 10% million years for the Holyrood granite. This is based on K/Ar ratio determination carried out by H. W. Fairbairn. The sample for the determination was collected by McCartney from Duffs, where a pale grey granite is overlain unconformably by Lower Cambrian sediments. This is the only absolute age available for the granite, and must therefore be treated with caution. The Geological Survey of Canada is currently working on a new age determination of the granite by the Rb/Sr ratio. Until the results of these determinations are known, the age of the Central granite will be fixed tentatively as Mid-Proterozoic.

Chapter VII

Metamorphism, Metasomatism and Alteration

General Statement:

Although the total changes along the granite contacts are relatively inconspicuous, the granite intrusion and the accompanying hydrothermal activity have produced various physical and chemical changes in the volcanic rocks of the Harbour Main Group. The principal types of alteration observed along the granite contacts are silicification, sericitization and pyrophyllitization. The occurrence and frequency of the above types of alteration have been determined mainly by three factors:

a. The proximity of the volcanic rocks to the granite.
b. The composition of the original rock.
c. Shearing, which may have preceded or accompanied the intrusion of the granite.

In highly to moderately sheared zones the acid volcanic rocks have been altered to pyrophyllite - $Al_4(Si_8O_2°)\ (OH)_4$. Near Manuels, large quantities of pyrophyllite have been formed by hydrothermal alteration of sheared rhyolitic rock. This deposit, which is currently being mined, lies outside the boundaries of this thesis area but has been described by Vhay (1937) and Dawson (1963).

In the present map-area the intruded rocks show very little, if any, contact metamorphic effects. This is because the intruded rocks are acid volcanics of roughly the same composition as the granite. However, the metasomatic effects of the granite involve silicification, sericite alteration of feldspar, chloritization of mafics and some introduction of calcite and epidote.

Silicification is the dominant alteration process in the area. The colour and texture of the silicified rocks vary considerably. The colour is generally greenish-grey or creamy grey depending on the original rock. The silicified rocks are generally cherty in appearance and break with a conchoidal fracture. The most intense silicification was observed in tuffs ½ mile south of Harding Hill, where the rock is altered to a nearly white quartzose rock. The less intensively altered rocks are darker in colour, and show numerous quartz veinlets.

Thin sections show that quartz replaces both rock and mineral fragments in the tuffs. Spaces between individual minerals in the rock fragments are permeated by milky-white, cryptocrystalline quartz; many mineral fragments are embayed extensively at their edges, resulting in some cases in a complete replacement of the original minerals by finely granular silica. Numerous fractures are also filled with white milky quartz. Veinlets of quartz are very common in the rocks.

Chlorite occurs mainly as minute flakes, less commonly as granular aggregates; it is pale green in colour and weakly pleochroic; (X = pale yellow, Z=Y = green). Some flakes show abnormal blue colours. The mineral is usually disseminated irregularly throughout the rock, commonly associated with pale yellow epidote and anhedral magnetite. The chlorite appears to be an alteration product of biotite and hornblende; this is indicated by some remnants of the original prismatic crystals of hornblende and the tabular flakes of biotite, now completely replaced by chlorite.

Sericite commonly occurs as minute shreds or as fine scaly aggregated in the plagioclase. When associated with clay minerals they give the feldspar a cloudy appearance.

In addition to the major secondary minerals of quartz, sericite and chlorite, some altered grains of calcite and veinlets of epidote are present in the rocks from the contact zones.

It is evident that the principal types of metasomatism which have affected the volcanic rocks in the present map-area have involved an addition of silica, water and/or carbon dioxide and probably some introduction of lime (carbonate, epidote). The dominant secondary minerals are quartz, chlorite and sericite; with the exception of quartz these minerals are hydrous while carbonate and epidote are often present in considerable amounts. The types of alteration which have affected the rocks may be attributed to late-stage hydrothermal solutions derived from the crystallizing granitic magma. The affected rocks were roughly of the same composition as the granite, therefore the total effect is of minor importance.

Chapter VIII

Structure

General Statement:

The general structure of the Avalon Peninsula has been well summarized by Buddington (1919) and McCartney (1959). According to these authorities the oldest pre-Cambrian rocks have been folded and extensively faulted. Folds which generally trend northeasterly are close and commonly steeply dipping. The core of a major anticline comprising faulted and folded volcanic rocks is exposed at the head of Conception Bay. Cutting across the eastern limb of the anticline is the Holyrood granite batholith which together with the volcanics forms a stable comples on which younger pre-Cambrian and Paleozoic rocks have been deposited. Bordering the eastern flank of the granite is a succession of volcanic and sedimentary rocks which are overlain by successively younger beds, until the trough of a syncline in the Cabot group is reached near St. John's.

The most striking structural features in the present map-area are:

1. An angular unconformity separating the Lower Cambrian sediments from the Holyrood granite.
2. An unconformity between acid volcanics of the Harbour Main Group and sediments of the Conception Group.
3. The intricately faulted condition of the rocks.

In addition jointing is common in the granite and fracture cleavage is well developed in the sedimentary rocks.

Unconformities

Unconformable relations between the different rock formations occurring in the map-area were observed in two localities. Near Duffs, Lower Cambrian sediments unconformably overlie the granite. Greenish-grey shales and nodular crystalline limestones rest on angular to sub-angular granite blocks of varying sizes. The sediments occupy hollows between the granitic blocks, and fill narrow deep spaces between the joint planes. One and a half miles south-west of this unconformity, acid volcanic rocks of the Harbour Main Group are overlain unconformably by sediments of the Conception Group. Basal conglomerates of the latter carry rounded cobbles and pebbles derived from the former, but because of the lack of any observable primary structures in both groups it is difficult to know whether a structural discordance or disconformity is present.

Faults:

The rocks in the present map-area, especially the volcanics and the sediments, are intricately faulted to such an extent that it is difficult to determine any stratigraphic sequence between the different units. Bedding faults, strike-slip faults and dip-slip faults are all present but most of the faults fall into the last two categories. Strike-slip faults which trend north-northeasterly to northerly have affected only the volcanic rocks of the Harbour Main Group and do not continue into the granite and the sediments; they may thus be pre-granite in age. The dip-slip faults trend northwesterly and have affected both the granite and the Harbour Main rocks as well as the sediments. They are generally open and show well-developed slickensides. Faults of both types are commonly steeply dipping.

Jointing and Cleavage:

Other secondary structural elements present in the rocks are jointing and fracturing. Jointing is most pronounced in the granite where two main joint systems are present. The first system consists of northeasterly-trending joints, with a general strike of N 70°E and dipping 60°SE. The second system strikes N 20° W and dips 60°NE. Most of the aplite and pegmatite dikes in the central granite generally strike in the direction of the two main joint systems.

As a result of intense silicification and other types of alteration together with intricate faulting to which the acid volcanic rocks have been subjected, primary structures are generally lacking. However, rare flow-banded texture was found in the tuff outcrops on the summits of Hennessey and White Hills. Most of the outcrops are fractured, with numerous quartz and epidote veinlets. Fracture cleavage is well developed in the sedimentary rocks. It is generally at an angle of 45° to the bedding and is confined mainly to the more incompetent shaly beds.

Chapter IX

Geological History of the Granite Batholith

The literature on granitic plutons and various aspects of the granitic problem has been concemned mainly with magmatic and metasomatic petrogenic concepts. Solid diffusion, grain boundary and fluid diffusion have been proposed to account for the origin of granitic rocks according to the metasomatic theory. Under the magmatic theory, the granitic magma originates from either partial or complete fusion of rock material. The granitic pluton is then emplaced by mechanical displacement of the country rocks. Where the pluton is charged with numerous xenoliths, piecemeal stoping is cited as a possible mechanism of emplacement.

Careful examination of field and labDratory evidence relating to the Holyrood granite suggests a magmatic origin. The following facts are clearly established.

1. The Central granite is a composite body; the two types (G_1 and G_2) referred to in earlier chapters are similar in mineralogy and in texture and represent variations within one unit.
2. Each of the two types is relatively uniform.
3. Intrusive contacts between the granite and the country rock is clearly demonstrated.
4. Xenoliths which occur in the granite are angular to subangular fragments of quartz-latite and tuffs.
5. Apophysis from the granite are seen cutting the country

rocks.

The angularity and concentration of the xenoliths along the margins of the granite may be taken as evidence supporting emplacement of the granite by piecemeal stoping. However, there is no proof that such a process actually did operate in the map-area. Earlier investigators, Rose (1952) McCartney (1959) concluded that the granite cuts across folded sedimentary and volcanic rocks of the Harbour Main Group. This observation, to some extent supported by the present study, shows that the intrusion of the granite followed the folding and the faulting of the Harbour Main Group rocks. The granite has a relatively uniform structure, without any pronounced foliation of lineation, which provides further evidence of post-kinematic origin.

The occurrence of undulatory extinction of quartz, bent and fractured plagioclase twin lamellae and the development of chess-board albite are the effects of later-magmatic and possibly post-magmatic deformation.

Studies of rocks within the contact zone adjacemt to the granite indicate that there is little contact (thermal) metamorphism occompanying the intrusion. The explanation of this may lie in the fact that the intruded rocks are quartz-latites which would not have undergone any striking changes even at normal magmatic temperatures. However, there is evidence of metasomatic effect of the granite on the intruded rocks. The most pronounced feature of these rocks is the intense silicification to which they have been subjected. This is common in all rocks from the contact zone. Ferromagnesian minerals have been altered to chlorite, sericitization is commonly observed in the feldspars, while epidote and calcite occur in considerable amounts in these rocks. It is obvious that the metasomatic changes which have affected the rocks in the contact zone are the introduction of silica, water and/or carbon dioxide and to a minor extent the addition of lime.

The granite itself shows reciprocal effects of contamination. As the material was emplaced, parts of the country rock were incorporated in it by assimilation and various granodioritic and dioritic hybrids have been formed. These rocks contain hornblende and oligoclase (minerals absent in the Central granite) and poorer in potash feldspar and quartz than the Central granite. The hornblende and oligoclase represent an equilibrium assemblage resulting from the reaction between the original fermic minerals (pyroxene, labradorite) and the granitic magma.

The feldspars occur as individual grains of albite, and as microcline-microperthites. Granular albite grains are abundant as narrow zones between two perthite grains. This state of occurrence may represent a sequence of processes shereby albite exsoved from an originally homogeneous potash feldspar, then migrated to the borders and margins of the grains and finally separated from the potash feldspar. Such a mechanism has been proposed by Tuttle (1952) who suggested that the granites of Group IIC were initially like the hypersolvus granites and that unmixing of plagioclase from the potash feldspar took place during cooling.

The injection of pegmatite and aplite into the consolidated mass must have completed the emplacement of the granite although the intrusion was followed by further basic dikes. After consolidation of the granite magma, parts of the granite were exposed and eroded prior to the deposition of the Conception Group rocks. Together with the volcanic rocks of the Harbour Main the granite batholith formed a stable complex which shielded younger pre-Cambrian and Paleozoic rocks from severe deformation during the Taconic and later orogenies.

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Fig. I: View of Butter Pot Hill; granite in the immediate foreground.

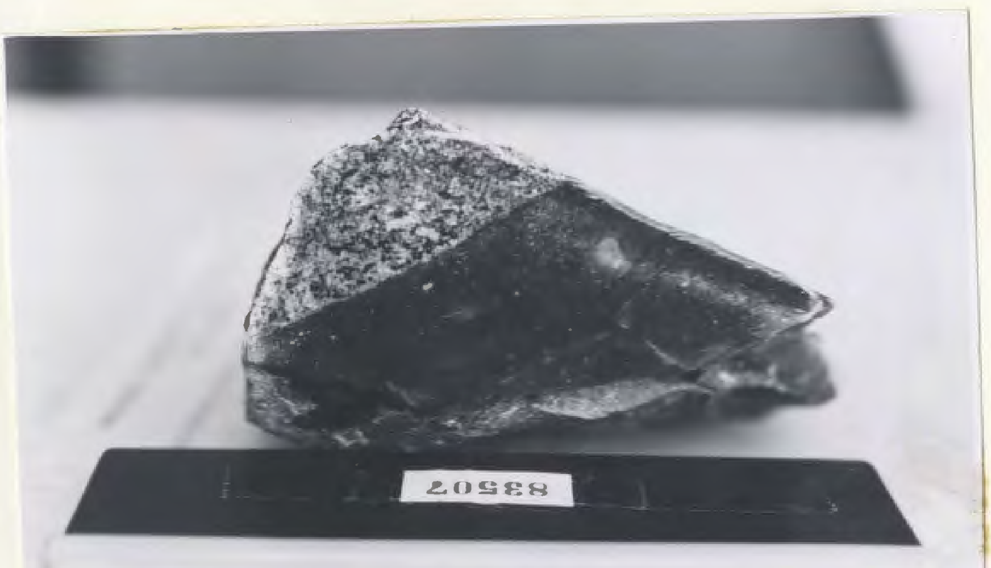


Fig. II: Granite - tuff contact.

Fig. III: Fractured albite twin lamellae; note dragging of lamellae near fracture.

Fig. IV: Chessboard albite.

Fig. V: Microcline-microperthite. Irregular films of albite (white) in microcline (grey)

Fig. VI: Allotriomorphic texture in pegmatite.

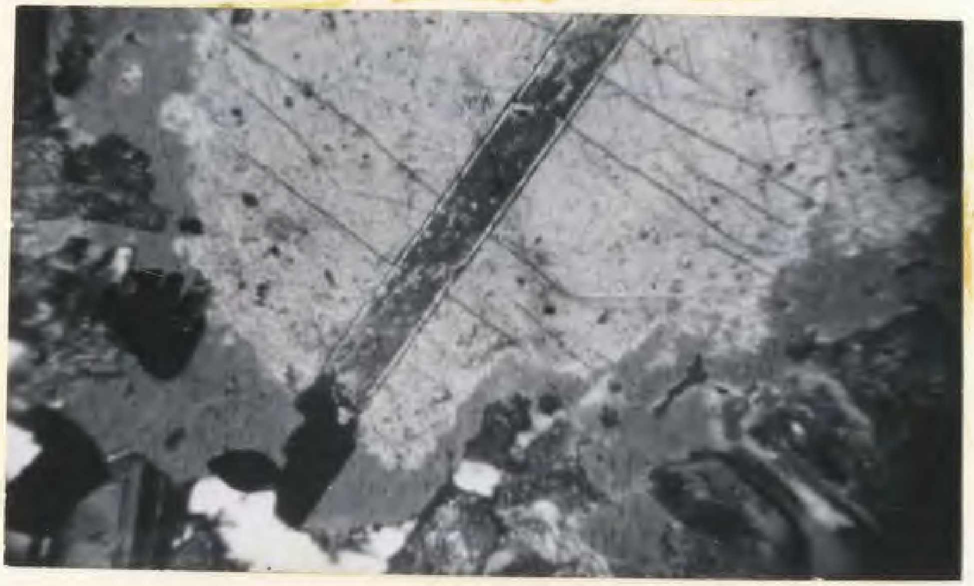


Fig. VII: Augite with a reaction rim of hornblende in hornblende diorite.

Fig. VIII: Hypidiomorphic-granular texture in olivine gabbro.

Fig. IX: Basic dike in granite. Butter Pot Hill

Fig. X: Unconformity separating granite from Lower Cambrian sediments - Duffs Coast.

Fig. XI: Quartz crystals in pegmatite - Duffs Coast.

Fig. XII: Granite-hornblende diorite contact - Butter Pot Hill.

Fig XIII: Highly fractured siltstone of the Conception Group - East Coast of Holyrood Bay.

Fig. XIV: Basic dike intruding granite - Note subangular granitic inclusions.

Fig. XV: Pink granodiorite in contact with volcanic breccia - East Coast of Holyrood Bay.

PLATE I

GEOLOGICAL MAP

HOLYROOD AREA

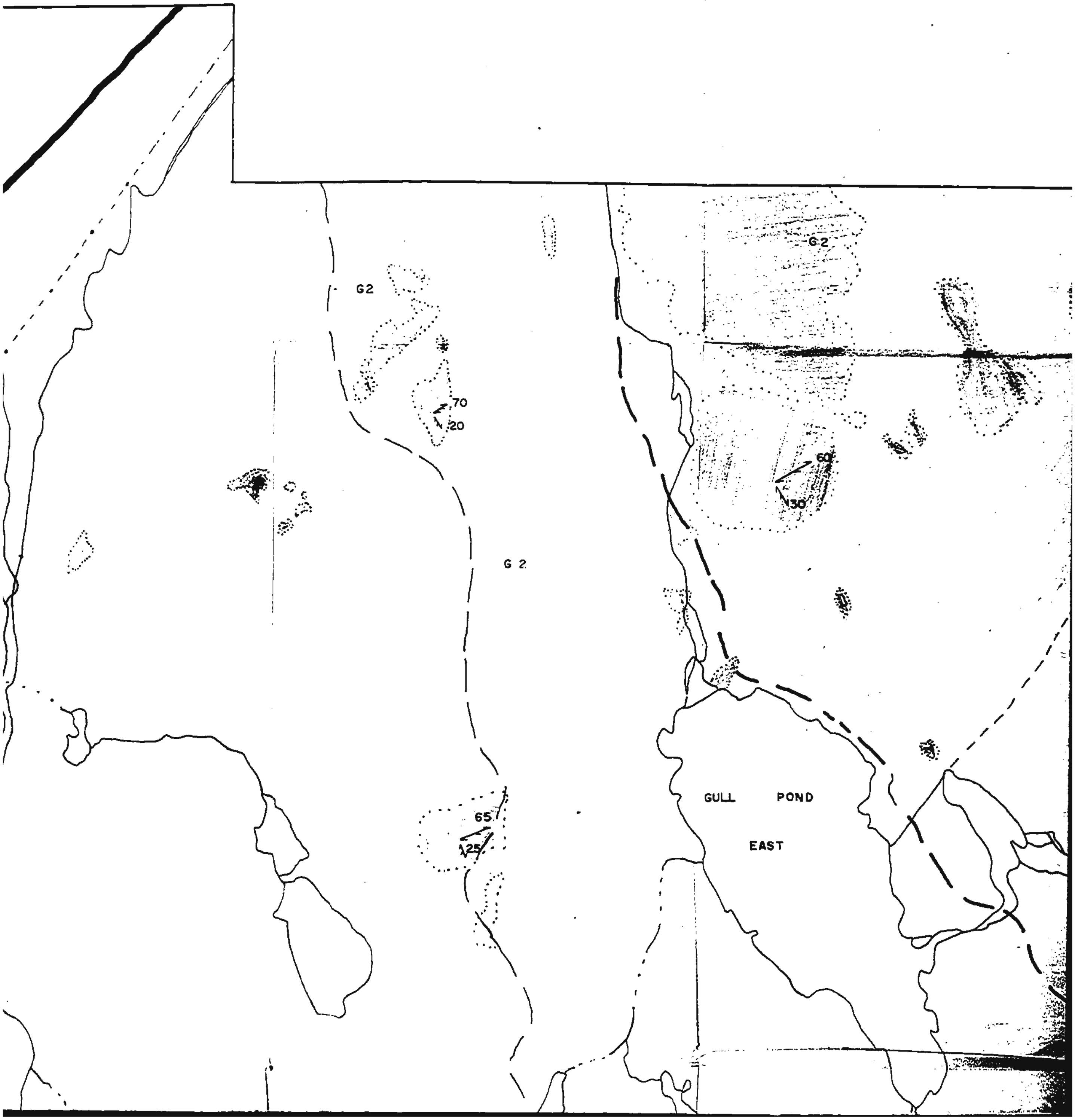
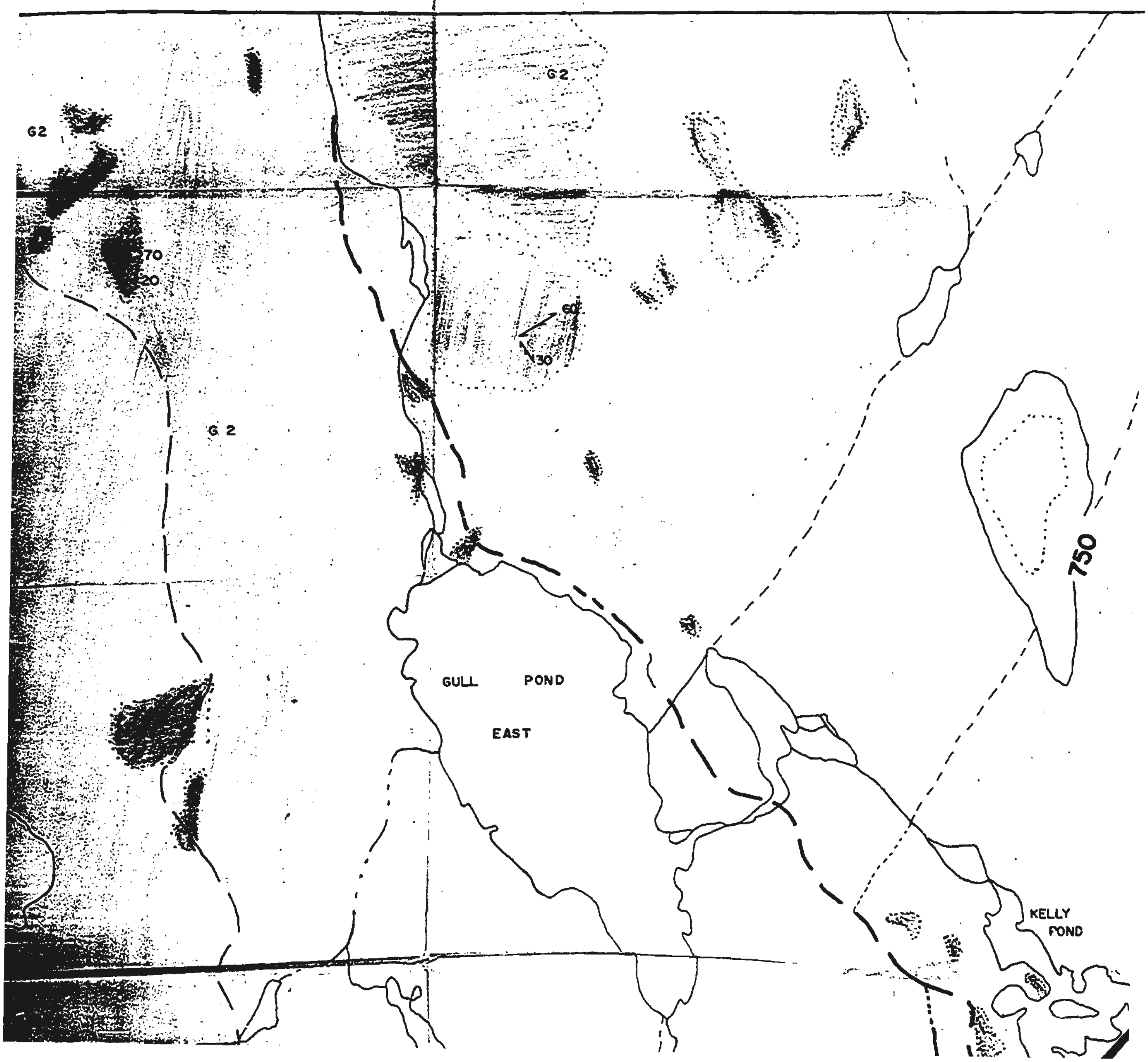
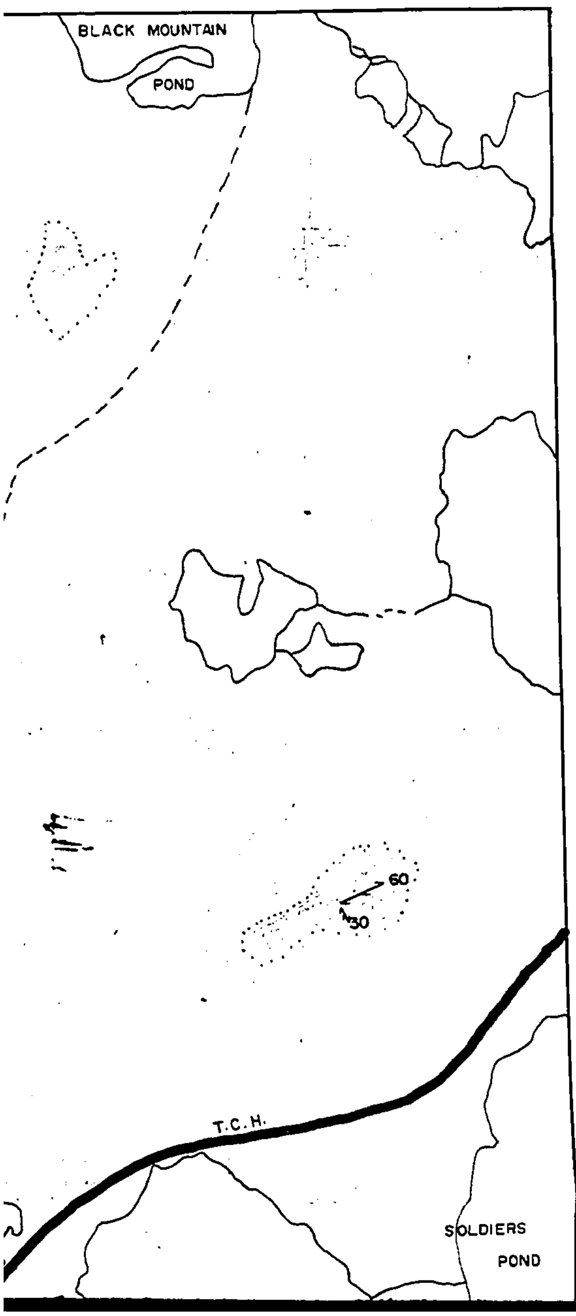


PLATE I

GEOLOGICAL MAP

ROOD AREA





25′

LEGEND

PRE-CAMBRIAN

7 **CONCEPTION GROUP**
GREENISH GREY SILTSTONES, MINOR CONGLOMERATES.

6 **RHYOLITE PORPHYRY**

5 A. BASIC DIKED INTRUDING CONCEPTION GROUP
B. OLIVINE GABBRO

3-4 **HOLYROOD BATHOLITH**
3 PINK GRANITE.
G 1 COARSE GRAINED QUARTZ ALBITE GRANITE
G 2 MEDIUM GRAINED GRANITE
4. GRANODIORITE QUARTZ DIORITE

HORNBLENDE DIORITE

1 **HARBOUR MAIN GROUP**
TUFFS, QUARTZ LATITE

AREA OF OUTCROP

BEDDING (INCLINED)

FAULT (DEFINED APPROXIMATE, INFERRED)

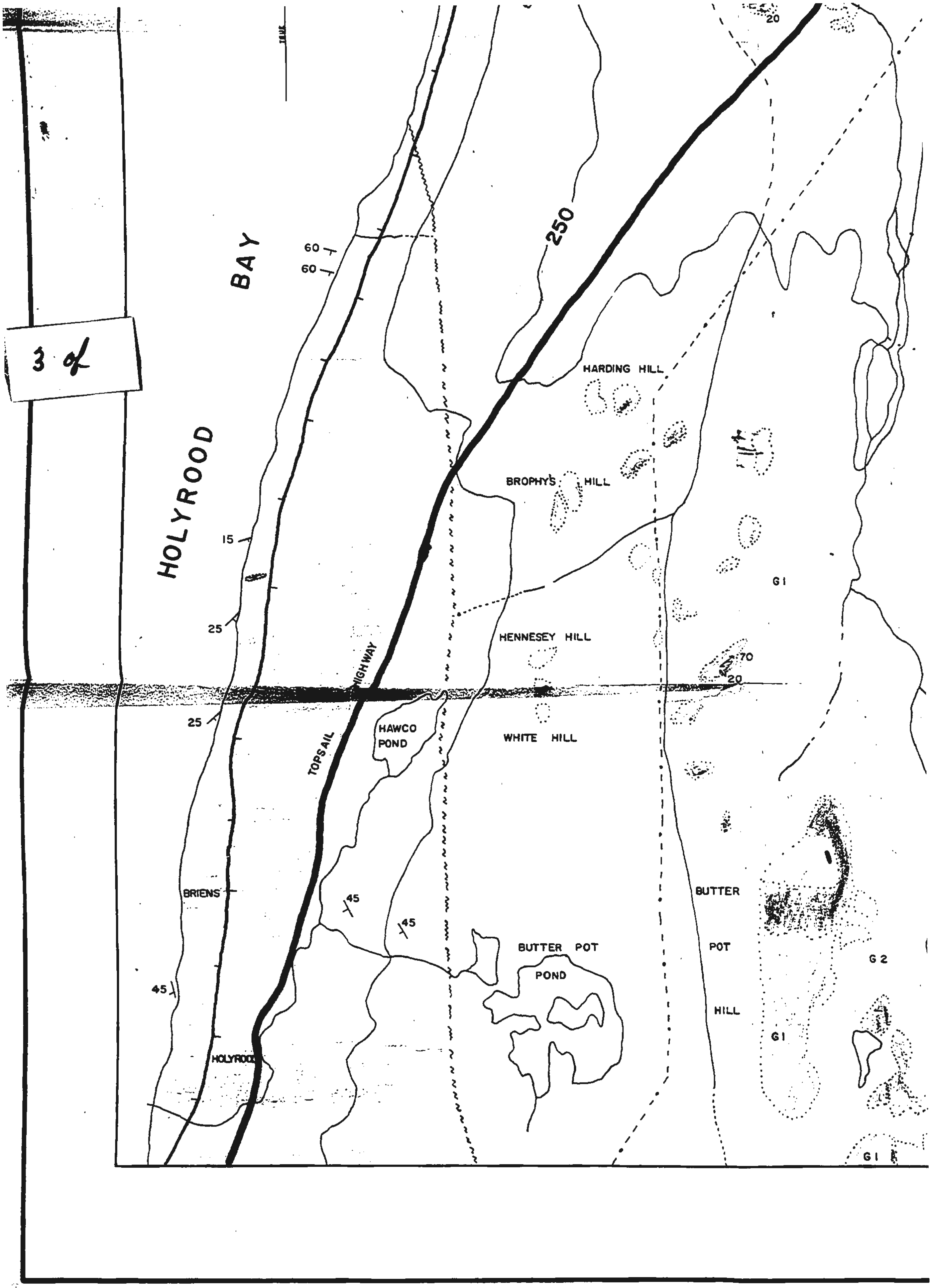
JOINTING (INCLINED)

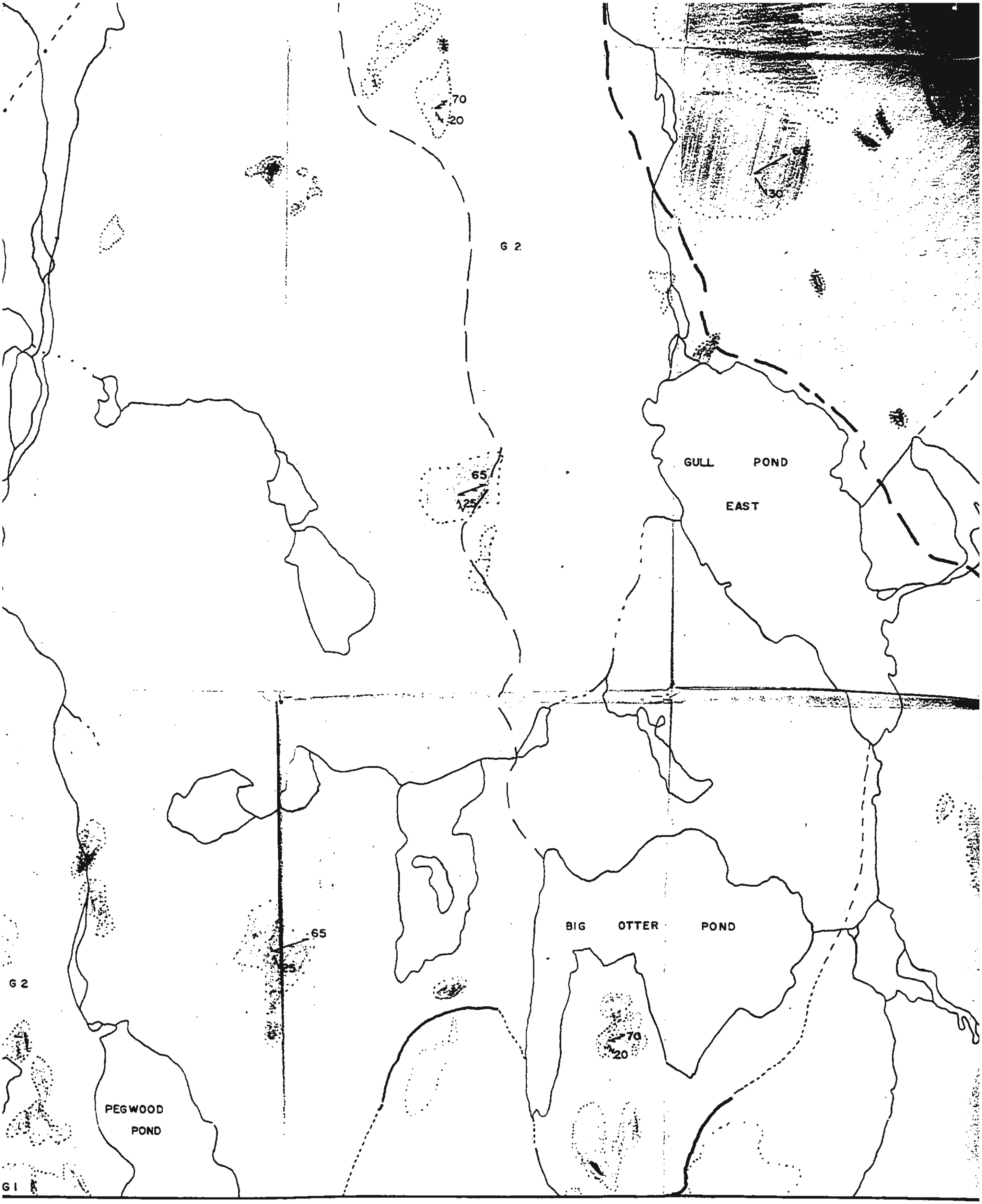
BOUNDARY (DEFINED, APPROXIMATE, INFERRED)

POWER LINE

GEOLOGY BY KWASI BARNING.

3 of


HOLYROOD BAY
250
HARDING HILL
BROPHYS HILL
HENNESEY HILL
TOPSAIL HIGHWAY
HAWCO POND
WHITE HILL
BRIENS
BUTTER POT POND
BUTTER POT HILL
HOLYROOD
G1
G2



SCALE 1: 12,500

c.1