Thomas Frisch

GEOLOGICAL
SURVEY
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CANADA

DEPARTMENT OF MINES
AND TECHNICAL SURVEYS

BULLETIN 141

GEOLOGY AND STRUCTURE OF THE YELLOWKNIFE GREENSTONE BELT, DISTRICT OF MACKENZIE

J. F. Henderson and I. C. Brown

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GEOLOGY AND STRUCTURE OF THE YELLOWKNIFE GREENSTONE BELT, DISTRICT OF MACKENZIE

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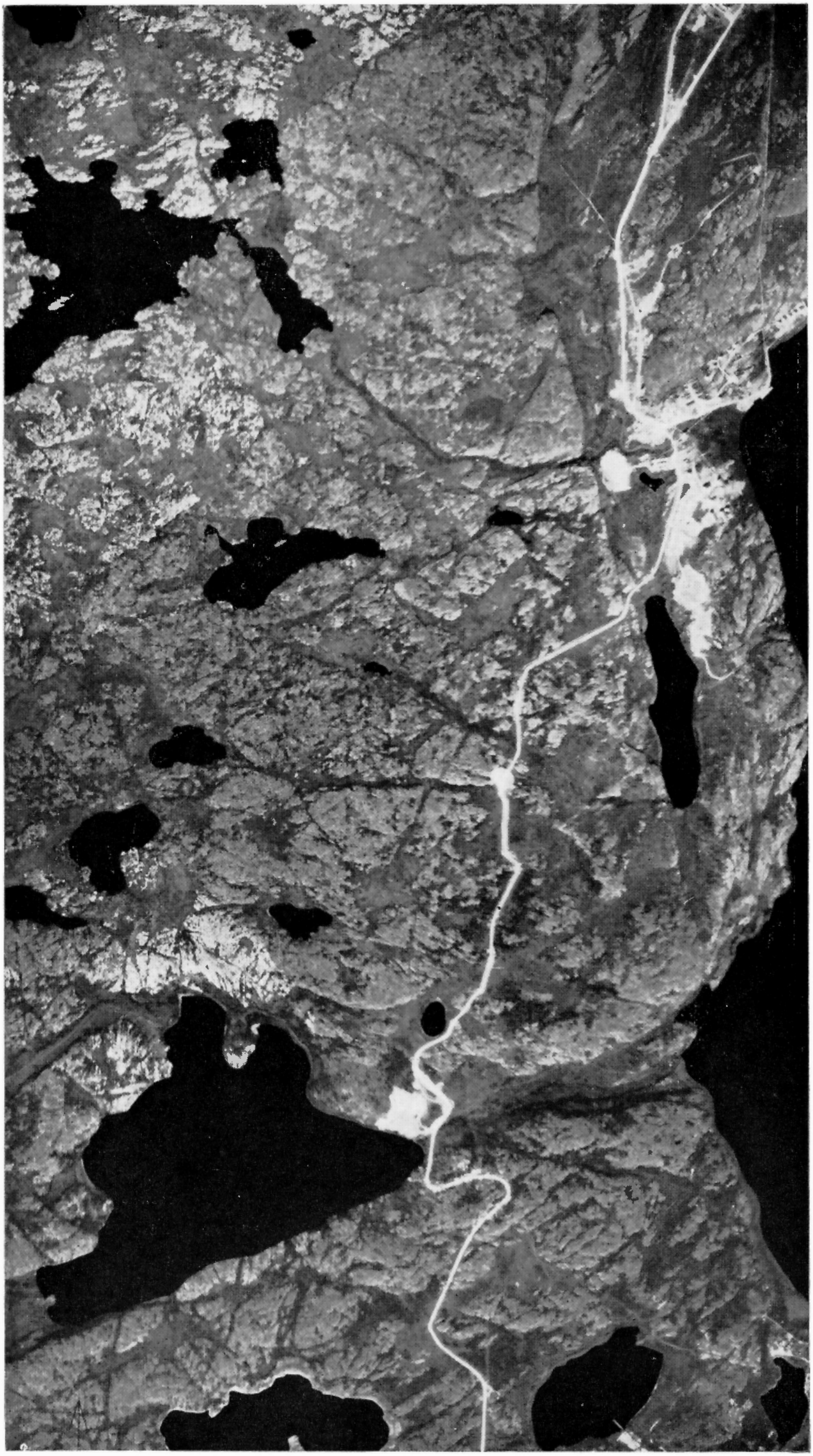

PLATE IA. Part of greenstone belt illustrating structural lineaments and other features visible on airphotos. (R.C.A.F. A12844-147)

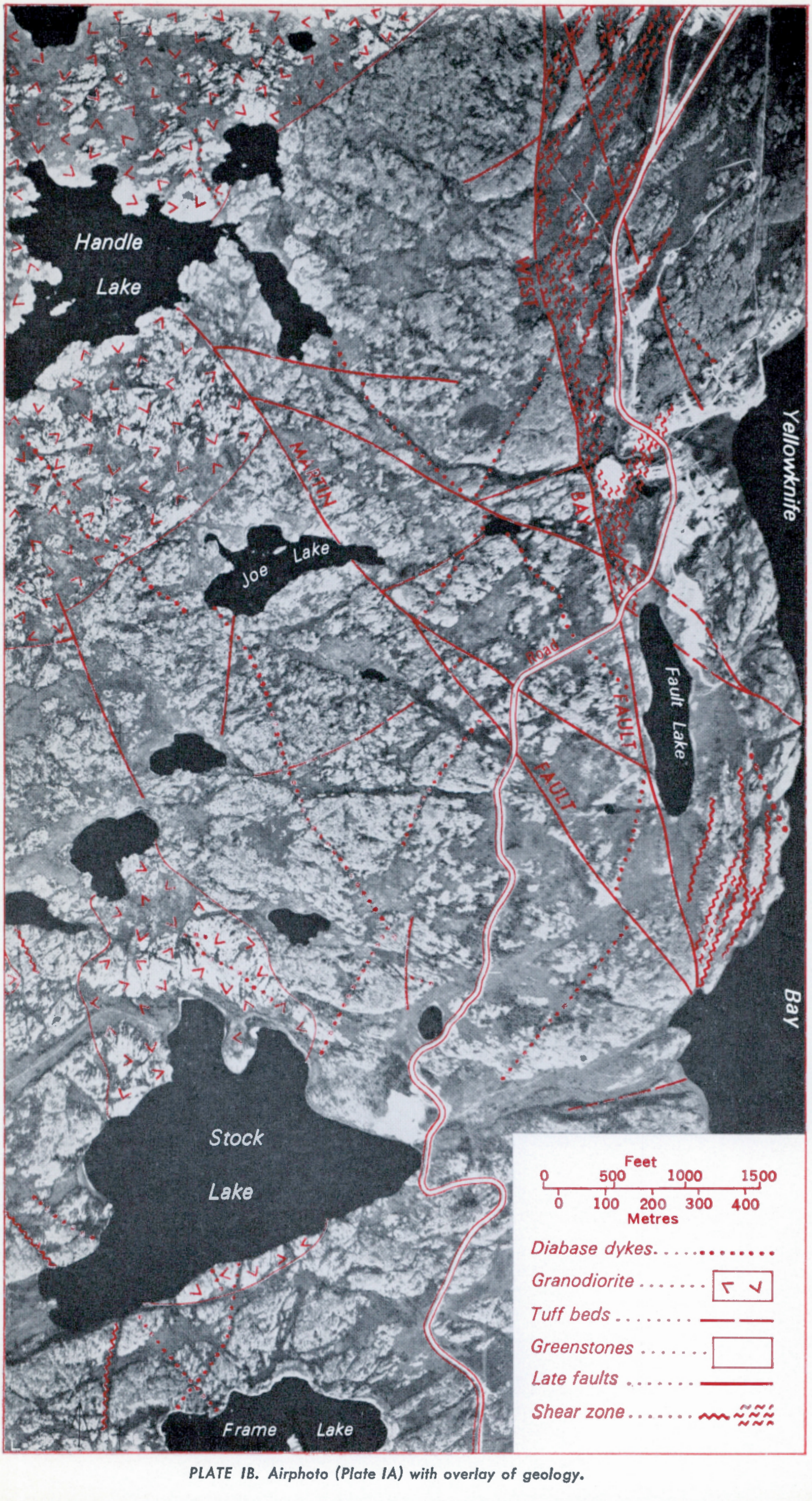

PLATE IB. *Airphoto (Plate IA) with overlay of geology.*

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By
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PREFACE

This is an account of the stratigraphy and structure of the thick succession of metamorphosed, Archaean, volcanic and sedimentary rocks that contain the important Yellowknife gold deposits. It is based on detailed studies made when outcrops were exceptionally well exposed by forest fires. The authors thus had an excellent opportunity to trace obscure contacts and observe features rarely visible.

Some new ideas are presented on the origin of pillow lavas and on the irregular diorite bodies so widely distributed through the greenstone belts of the Canadian Shield. Further light was also thrown on the nature of the spectacular faults that play so important a part in localizing and dislocating the numerous orebodies.

J. M. HARRISON,
Director, Geological Survey of Canada

OTTAWA, August 16, 1963

BULLETIN 141: Geologie und Struktur des Grünsteingürtels von Yellowknife.

Von J. F. Henderson und I. C. Brown.

Untersuchungen über die Struktur eines Komplexes von präkambrischen Gneisen und Schiefern.

БЮЛЛЕТЕНЬ 141: Геология и структура зелёнокаменной зоны Еллоунайф.

Дж. Ф. Гендерсон и И. Ч. Браун.

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GEOLOGY AND STRUCTURE OF THE YELLOWKNIFE GREENSTONE BELT

Abstract

The greenstone belt includes an almost continuously exposed section of 22,000 feet of nearly vertical Archaean meta-andesites and meta-basalts, which have been studied and mapped in detail on the scale of 1 inch to 500 feet. Pillow lavas make up about 50 per cent of the volcanic assemblage and the conclusion is reached that volcanic breccia (pillow breccia) and pillow lavas formed in much the same way, and that the key to the origin of pillow structure is to be found in the breccias. Dyke swarms and irregularly shaped bodies of meta-diorite and meta-gabbro in the volcanic assemblage, similar to those found in many greenstone belts of the Canadian Shield, have been mapped and studied in detail. The irregular bodies probably formed in place by recrystallization or dioritization of the meta-basalts and meta-andesites. The sedimentary phase of the Yellowknife Group rocks overlies the volcanic rocks apparently conformably. It comprises mainly greywackes of a flysch assemblage. The volcanic rocks are also overlain disconformably in places by a molasse assemblage of sub-greywacke and conglomerate of uncertain age.

The Giant–Campbell shear zone system has been mapped over a length of more than 12 miles and is as much as 2,000 feet wide. Made up of interlacing schist zones between horses of unsheared greenstone, it is believed to have formed along an early zone of faulting. The development of gold deposits in the schist took place after or during the late stages in the development of the shear zone system. The orebodies formed by diffusion of material from the schist to dilatant low pressure zones structurally related to noses of massive unsheared country rock within the shear zone system, or at flexures in the shear zones.

A system of late tear faults that rank with the largest dislocations in the earth's crust displaces the Yellowknife Group rocks and the early shear zone systems. The fault pattern, which is well developed, is a typical shear system formed by nearly horizontal strain or shear with lateral, rather than upward, relief. It includes two sets of almost vertical shear faults, striking at nearly right-angles to each other, and a third set developed along tension cracks at right angles to the direction of elongation or lateral relief.

Résumé

La zone de pierre verte comporte une section, à peu près toujours exposée sur une longueur de 22,000 pieds de métaandésites et de métabasaltes archéens presque à la verticale, qui a été étudiée et cartographiée en détail à l'échelle de 500 pieds au pouce. Les laves en coussins forment environ 50 p. 100 de l'assemblage volcanique, et on arrive à la conclusion que la brèche volcanique (brèche en coussins) et les laves en coussins se sont formées en grande partie de la même

façon et qu'il faut trouver l'origine des structures en coussins dans les brèches. Des essaims de dykes et des massifs irréguliers de métadiorite et métagabbro dans l'assemblage volcanique, semblables à ceux que l'on a trouvés dans les zones à pierre verte du Bouclier canadien, ont été étudiés et cartographiés en détail. Les massifs irréguliers se sont probablement formés sur place par recristallisation ou dioritisation des métabasaltes et des métaandésites. La phase sédimentaire des roches du groupe de Yellowknife recouvre les roches volcaniques apparemment en concordance. Elle comprend surtout des grauwackes d'un assemblage à flysch. Les roches volcaniques sont aussi par endroits recouvertes en discordance par un assemblage en mollasse de sous-grauwacke et de conglomérat d'un âge indéterminé.

La zone de cisaillement du réseau Giant-Campbell a été cartographiée sur une longueur de plus de 12 milles et elle atteint jusqu'à 2,000 pieds de largeur. Faite de zones à schiste enchevêtrées entre des nerfs de pierre verte non cisaillée, on croit qu'elle s'est formée le long d'une ancienne région à faille. Les gisements d'or se sont formés dans les schistes après ou durant les derniers stades d'établissement du réseau de la zone de cisaillement. Les massifs se sont formés par diffusion des matériaux provenant des schistes vers les zones dilatées à faible pression structuralement apparentées aux saillies de la roche en place non cisaillée à l'intérieur de la zone de cisaillement, ou aux flexures dans les zones de cisaillement.

Un système de plis par décrochement récents comparable aux grandes dislocations de la croûte terrestre déplace les roches du groupe de Yellowknife et les anciennes zones de cisaillement. Le réseau de failles est bien formé; c'est une zone de cisaillement typique qui a pris naissance à la suite de contrainte ou de cisaillement presque horizontal qui s'est traduit par un mouvement latéral plutôt que par un mouvement ascendant. Il comprend deux séries presque verticales de failles de cisaillement dont les directions sont presque à angle droit l'une par rapport à l'autre, et une troisième série s'est formée le long des fractures de tension à angle droit avec la direction que prend l'allongement ou le mouvement latéral.

Chapter I

INTRODUCTION

The Yellowknife greenstone belt lies along the west side of Yellowknife Bay on the north shore of Great Slave Lake. The town of Yellowknife with a population of more than 3,000 people owes its existence to the gold mines of the area. The two producing gold mines are the Con–Rycon Mine of the Consolidated Mining and Smelting Company, which came into production in 1938 and is currently (1961) milling about 500 tons a day, and the Giant Mine owned and operated by the Giant–Yellowknife Mines Limited, which came into production in 1948 and is currently milling about 1,000 tons a day. The Negus Mine produced from 1939 until 1952 when it suspended operations; in 1953 the property was acquired by the Consolidated Mining and Smelting Company and now forms part of the Con–Rycon Mine. In addition to these mines, the Akaitcho and Crestaurum Mines are potential producers, and there are several promising prospects. Detailed histories of the mines and prospects of the area are given by Lord (1951)[1].

Early geological work along the belt was done by Jolliffe (1938, 1942, 1946) who first recognized several large faults, the most significant of which is the West Bay fault, which has a separation along it of more than three miles. In 1944, large, ore-bearing shear zones were found on the Giant property on the east side of the West Bay fault. Near the south boundary of the Giant property the shear zones are cut off by the West Bay fault. This prompted Neil Campbell (1947), the district geologist of the Consolidated Mining and Smelting Company of Canada Limited, to make a detailed study of the geology in the hope of finding the continuation of these ore-bearing shear zones on the west side of the fault. In this undertaking he was successful. By careful geological mapping he matched several displaced diabase dykes on both sides of the fault, and knowing their attitudes determined the horizontal and vertical components of movement along the fault. Subsequent diamond drilling based on Campbell's work located the presumed correlatives of the Giant shear zones on the Con–Rycon and Negus properties, where they are referred to collectively as the Campbell shear zone. Most of the present production from Con–Rycon Mines comes from orebodies in the Campbell zone.

In 1946, the Geological Survey of Canada began a detailed study of the entire greenstone belt. The writers spent six field seasons in this work and carried the mapping from Kam Point, near the south end of the belt, north for more than 13

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[1] Dates, or names and dates in parentheses, refer to publications in list of *References* at end of this report. For complete bibliography of literature on area *see* Boyle, 1961, pp. 179–187.

miles to beyond the northern boundary of the property of Crestaurum Mines Limited. This bulletin and the accompanying maps describe the geology and structure of the belt. The writers did not spend any time studying the gold deposits and this bulletin does not deal with them except in so far as they are related to the structure. The geology, geochemistry, and origin of the gold deposits are treated fully in the memoir by Boyle (1961).

Geological mapping was carried out on the scale of 500 feet, mapping directly on aerial photographs enlarged from 800 to 500 feet to the inch. In some complex areas mapping was done on photographs with a scale of 100 feet to the inch, and underground workings were mapped at 40 feet to the inch. Rock exposures are plentiful over most of the belt and, at the time the mapping was done, they had been stripped of moss, lichen, and forest growth by recent forest fires leaving clear, bare outcrops. Under these favourable conditions it was possible to trace obscure contacts between rock types that would be most difficult to recognize and quite impossible to follow in most areas. Certain key members of the succession of greenstone lava flows that comprise the belt have been traced across the West Bay fault and the ore-bearing Giant–Campbell system of shear zones. The position of the extensions of these members east of the Giant–Campbell shear zone system suggests that the shear zones are related to early faults of some magnitude, and the probable extension of this fault zone system has been traced to Jackson Lake, near the northeastern limit of the map-area.

Acknowledgments

The writers are indebted to the mine operators and geologists of the area for their generous cooperation and interest in the work. Particular thanks are due to Neil Campbell of the Consolidated Mining and Smelting Company of Canada Limited, J. D. Bateman and G. Brown of Giant Yellowknife Mines Limited, C. E. Anderson of Frobisher Limited, J. D. Mason of Transcontinental Resources Limited, A. W. Johnson of Conwest Exploration Company Limited, and C. Riley of Pioneer Gold Mines of B.C. Limited, who supplied geological maps of the mining properties with which they were connected. Able assistance in the field was given by K. Hannigan in 1946, G. C. Cheriton and J. D. Hamilton in 1947, G. A. Wilson and J. S. Pickel in 1948, R. W. Boyle and R. J. Traill in 1949, T. E. Birmingham and C. H. J. Childe in 1951, and L. B. Halferdahl in 1953.

Physical Features

The topography of the belt is typical of the Canadian Shield. The country appears flat when viewed from the top of the higher hills, but in detail is rugged, with rocky hills and ridges rising abruptly from lake or muskeg to heights of 50 to 100 feet.

The area has been heavily glaciated and the ice probably retreated from the area only 10,000 to 12,000 years ago. Any decomposed or rotted rock or soil that formed in preglacial time has been ground away and everywhere the rock surfaces are fresh, scoured and polished by the ice. Striae, roches moutonnées, and the pattern of eskers in the area to the northeast of Yellowknife Bay indicate that the ice advanced from the northeast at about S60–65°W.

Surficial deposits left by the melting ice following Pleistocene glaciation include numerous erratics, outwash sand and gravel plains, and lacustrine clays. The lacustrine clays overlie the gravels and are found at elevations up to 50 feet above the present level of Great Slave Lake. Probably they were deposited soon after the retreat of the ice when the level of the lake was much higher than it is now. The sand plains east of Frame Lake and west of Stock Lake provided excellent sites for the town of Yellowknife and the airport, in the otherwise rocky, hummocky country.

The depth of permafrost seems to be a function of the depth of overburden. Bateman (1949) reported that at the Giant Yellowknife Mine permafrost is not present beneath rock outcrop, but where the thickness of overburden (clay, sand, or gravel) is 60 feet permafrost extends to a depth of 260 feet. Apparently the overburden acts as an insulating blanket that has preserved the ancient permafrost.

Structural Lineaments

Lineaments in the bedrock, plainly visible on aerial photographs and commonly recognizable on the ground, are produced by four main types of geological structures: late post-diabase faults, diabase dykes, early pre-diabase shear zones[1], and tuffaceous beds interbedded with the volcanic flows (*see* Pl. I). In addition, small granodiorite plugs in the greenstone area weather out and are marked by circular lakes or muskeg-filled areas. Locally in the granodiorite, jointing visible in outcrop has a pronounced rectangular pattern due to regular sets of joints. Elsewhere joints occur at random with no apparent regional pattern.

The most prominent topographic features are the escarpments, trenches, or fissures making the post-diabase faults. Of these, the most conspicuous is the lineament marking the West Bay fault. This escarpment extends north from Fault Lake along the west side of the valley of Baker Creek, rising 50 to 100 feet above the valley bottom as an almost continuous, vertical face (Pl. I). To the south as far as Negus Point the fault is marked by the cliff-like, nearly straight shoreline of Yellowknife Bay. The large Akaitcho fault is marked by a similar, but less pronounced, lineament. Narrow drift-filled valleys or trenches mark many of the smaller, late faults along which trees, bushes, and other vegetation have taken root. These lineaments are commonly more apparent on aerial photographs than they are to the observer on the ground. Still other late faults, particularly the east-west tension faults east of Kam Lake, are marked by open clefts or fissures that are easily recognized on the ground and in the aerial photographs (Pl. XVII).

The diabase dykes where exposed commonly show pronounced, steeply dipping joints normal to the walls which, in the larger dykes, are most apparent on

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[1] The term shear zone is so widely used in this area as a synonym for the more accurate schist zone that it has been retained in this report.

the aerial photographs. In preglacial times they weathered more rapidly than the enclosing greenstones and granodiorites, and glaciation has gouged and plucked out the rotted and fractured rock. Consequently, most of the dykes are marked by a muskeg-filled trench (Pl. I). In fact, many of them are exposed only as a plaster of diabase on the granodiorite and greenstone walls of the trenches. However, a few of the larger dykes that have not been fractured or jointed seem to have been more resistant to preglacial weathering than the granodiorite and greenstone, and these form ridges standing above the country rock. Two large diabase dykes north of Ryan Lake stand up in this way.

Both the Con and the much larger Giant–Campbell shear zone systems are made up of subparallel, interlacing, chlorite schist zones winding about and surrounding masses, or horses, of unsheared, massive country rock. In the Con system, the widths of the individual shear zones range from a few to more than 100 feet, but the average width of the system is 50 feet or less. In the Giant–Campbell system, the individual shear zones are as much as several hundred feet wide, with horses of unsheared rock up to 400 feet wide included in them; the width of the system as a whole reaches more than 1,000 feet in some sections. Much of the schist has been carbonated and, locally in and near ore zones, it is sericitized and mineralized with sulphides. In preglacial times the soft, fissile chlorite schist of the sheared zones, especially where it contained much carbonate and sulphides, weathered more deeply than the enclosing greenstones. During glaciation the rotted material was readily scoured out and the shear zones are now marked by elongated lakes and swampy, muskeg-filled valleys. Thus in the Con System the ore-bearing segment lies mostly beneath Rat Lake, and to the southeast the faulted extensions of the system lie beneath the south arm of Pud Lake and the west arm of Keg Lake.

The Giant–Campbell shear zone system between the West Bay and the Akaitcho faults is complex (north half). The system consists of wide shear zones winding around horses of massive country rock, and the whole has been offset by a series of late faults of which the Townsite is the largest. Topographically the main shear zone system is marked by one wide drift and muskeg-filled valley, and small lakes drained by Baker Creek (Pl. I). The massive horses of country rock within the shear zone system form topographic ridges or 'islands' in this otherwise low, swampy valley. North of the Akaitcho fault the extension of the Giant–Campbell shear zone system underlies Gold Lake, at least part of the drift-filled valley between Gold and Vee Lakes, the two arms of Vee Lake, and the narrow, well defined valleys extending northeast of Vee Lake.

The segment of the Giant–Campbell System on the west side of the West Bay fault (the Campbell segment) emerges from the fault beneath the waters of Yellowknife Bay at Negus Point. The emergence of the easily eroded Campbell shear zone at Negus Point causes the sudden change in strike of the shoreline from north to southwest. Southwest from Negus Point, the shore parallels the northwest boundary of the shear zone system and the northwest offsets of the shoreline reflect nicely the northwesterly offsets of the Campbell zone by the Kam, Pud, and other late faults.

Some of the tuff beds interbedded with the flows, particularly where sheared and pyritized, underlie narrow, drift-filled trenches recognizable both on the ground and in aerial photographs. Examples of such lineaments are those formed along most of the length of the Kam Point, Cemetery, and Ranney tuffs (Fig. 8).

Some of the small granodiorite stocks in the greenstone belt seem to have been particularly susceptible to deep, preglacial weathering and the removal of the weathered rock by glaciation has formed the basins for several, nearly circular lakes. The north arm of Pud Lake may have been formed in this way. The twin central part of the lake may also be underlain by a small granodiorite stock as suggested by the granodiorite–greenstone breccia outcropping along the northwestern shore. The granodiorite outcropping on the northeast shore of Pud Lake, and along the edge of the swampy area to the northwest, is heavily impregnated with pyrite. If pyrite is widely disseminated throughout the stocks it may account for their deep weathering in preglacial times.

Stock Lake (Pl. I) is also apparently largely underlain by a granodiorite stock but the reason the granodiorite weathered so deeply to form the lake basin is not clear. Where the granodiorite outcrops northwest of the lake it does not contain an abnormal amount of pyrite; in fact, the granodiorite there is a hard resistant rock that forms a group of prominent hills.

Chapter II

GENERAL GEOLOGY

All the rocks of the Yellowknife greenstone belt are of Precambrian age. The oldest comprise a succession of meta-andesite and meta-basalt flows with some intercalated meta-dacite. These in turn are overlain by greywacke, argillite, and slate, with interbedded andesite and dacite flows near the base. The sedimentary rocks, now largely altered to quartz-mica schists and hornfels, underlie the area to the east and northeast of Yellowknife for thousands of square miles. The whole assemblage of volcanic and sedimentary rocks is of Archaean age and has been named the Yellowknife Group (Henderson, 1938). In the Yellowknife area, Jolliffe (1938) divided the group into Division A, consisting predominantly of andesite flows; Division B, consisting of conglomerate, arkosic quartzite (subgreywacke), and acidic volcanic rocks which rest unconformably on the rocks of Division A; and Division C, consisting mainly of greywacke, argillite, and slate. Only the rocks of Divisions A and B occur within the area under consideration; those of Division C lie to the east.

These divisions of the Yellowknife Group have been retained, but the writers consider that, for reasons given later in this report (p. 32), much of the conglomerate and subgreywacke included in Division B by Jolliffe may be a lot younger than the Yellowknife Group. This includes the conglomerates and subgreywackes underlying the Sub Islands and the west half of Jolliffe Island, and similar conglomerates and subgreywackes that rest unconformably on the rocks of Division A northeast of the Akaitcho fault.

The volcanic and sedimentary rocks of the Yellowknife Group are intruded by several large sills and many irregular masses of meta-gabbro and meta-diorite. The volcanic flows and the basic sills and irregular intrusions, in turn, are cut by swarms of meta-diorite dykes, many of which can be traced for miles. The dyke swarms are mainly confined to the volcanic rocks of Division A but a few dykes occur in the sedimentary rocks of Division B. Porphyry dykes (porphyritic, quartz-feldspar leucodacite) cut both the volcanic flows and the basic sills and dykes. They are most abundant in the northeastern part of the area where they occur not only as dykes but as numerous, small irregular bodies. The porphyry intrusions are later than some, at least, of the early shear zone faults with which the gold bearing orebodies are associated. A few, small, dark green hornblende-biotite dykes cut the porphyry.

The Yellowknife Group rocks and the basic sills, dykes, and irregular intrusions are cut off on the west by a large granodiorite batholith. One porphyry dyke was observed to cut narrow dykes of granodiorite but, because no porphyry bodies have been found in contact with the main mass of granodiorite, their relative ages are uncertain. The youngest rocks in the area are rusty brown weathering diabase dykes of dioritic to gabbroic composition.

Yellowknife Group

Within the area mapped, the Yellowknife rocks have been separated into two divisions. The lower (Division A) consists mainly of basic lava flows, some meta-dacitic flows, and many thin interbeds of tuff, breccia, and agglomerate. The upper (Division B) is dominantly sedimentary and composed of arkosic quartzite, greywacke, tuff, and conglomerate, but includes some interbedded, basic and acidic lava flows. The distinction between the two divisions is based on lithology and relative age. Where they are in contact along the shore of Yellowknife Bay, between the West Bay and Akaitcho faults, there is no evidence of an unconformity or augular discordance. However, the presence of granite–pebble-bearing conglomerate in places along and near the contact suggests an erosional interval between them.

Division A

The lava flows of Division A underlie most of the area mapped. An almost continuous section of some 22,000 feet of nearly vertical flows is exposed between Negus Point and the granodiorite to the northwest. Throughout this section, the flows and interbedded tuffs face southeast, so the assemblage is at least this thick and, as the lower part is cut off by the granodiorite, was probably originally much thicker. This succession of flows has been displaced north for more than 3 miles by the West Bay and Akaitcho faults, and is, consequently, repeated farther north on the east side of these faults. Traverses from the north edge of the map-area to the limit of greenstone mapped by Jolliffe (1946) indicate a total exposed thickness of 30,000 feet of volcanic rocks with the bottom cut off by granodiorite.

Meta-basalts and Meta-andesites

Massive and Pillowed Flows

The meta-basalts and meta-andesites near the granodiorite are fine-grained, dark green, almost black weathering, hard, brittle rocks. Away from the granodiorite the colour gradually changes to lighter green, to grey, and to buff green, and the rocks are somewhat softer and less brittle. Still farther out from the contact the rocks become brighter green and still softer, so that they tend to crush or bruise on the weathered surface when struck with a hammer, and feel soft and chalky when scratched with a pick. These changes in the physical appearance of the basic flows reflect the gradual changes in the mineralogical composition from an amphibolite facies near the granodiorite contact, through an epidote amphibolite facies which makes up the greater part of the belt, to a greenschist facies which is limited to a small area in the Giant fault block east of Bow Lake. In all these facies, including those parts of the greenschist facies that are not highly schistose, original features such as pillow structure and amygdules are well preserved. Along the shear zones a chlorite-carbonate schist facies has been superimposed on the three regional facies. These metamorphic facies and the chemical changes that have taken place to produce them were discussed by Boyle (1961, p. 8).

About 50 per cent of the flows are massive; the remainder have well-developed pillow structure. The pillowed flows or parts of flows are distinguished from the non-pillowed or massive flows on the map and Figure 8. Theoretically it should be possible to map individual flow contacts, but in practice this is extremely difficult unless the contacts are marked by a layer of flow breccia, fragmental breccia, or tuff. Where massive layers are in sharp contact with pillowed layers, with no intervening layer of pyroclastic material, a flow contact may be suspected but cannot be proved. Cooke (1931) has stated that most pillowed flows are made up of two parts, a pillowed upper part and a lower, massive, non-pillowed part of coarser grain. This does not appear to be characteristic of the pillowed flows of this belt, although a few may be of this type. Tuffs are commonly found resting directly on pillowed flows and they may fill the interstices between the uppermost pillows. This indicates that the pillows themselves may form at the top. Elsewhere, pillows lie directly on, and are flattened against, the chilled surfaces of underlying massive flows; less commonly, pillowed flows rest on tuff beds. Many pillowed layers up to 500 feet thick, for example, the Yellorex variolitic lavas, are both overlain and underlain by pyroclastic bands; in these cases the whole flow is pillowed, with no massive part. Yet again, on an island in the extreme southwest corner of the greenstone belt, a dozen or more pillowed flows, some of which are only 6 to 10 feet thick, occur interbedded with pyroclastic layers (Fig. 1). The writers found that most flows are either pillowed or massive throughout; flows that are partly pillowed and partly massive are less common but were seen, the one form grading into the other.

The massive flows are in general coarser grained than the pillowed flows, with grains as large as one-third inch or more. They may contain amygdules or ropy flow layers along their contacts, but in the main are massive and structureless. Consequently, massive flows are difficult to distinguish from the intrusive sill rocks, with which they are mineralogically identical. The coarser flows can, in fact, be differentiated from the sills only by careful study of their contacts with adjoining flows, and by recognition of original volcanic structures, such as amygdules and ropy or agglomeratic layers. If these contacts are obscured and no typical volcanic structures are recognized, it becomes virtually impossible to determine whether the rock is of extrusive or intrusive origin. In mapping such massive structureless greenstones, they were assumed to be lava flows unless direct evidence of an intrusive origin was found; that is, only those greenstones offering direct evidence of intrusive origin have been mapped as such.

Under the microscope the basic flows are seen to be composed almost entirely of secondary minerals, which consist of about 60 to 70 per cent amphibole and chlorite and 30 to 40 per cent altered plagioclase and epidote. Other minerals in lesser amounts include carbonate, white mica, biotite, apatite, zircon, magnetite, and quartz. Near the granodiorite, in the amphibolite facies, the amphibole is a green to bluish green hornblende; the plagioclase is in the andesine range and is fairly fresh and clear; and epidote, quartz, magnetite, and sphene occur only in small amounts. Farther from the granodiorite, in the epidote–amphibolite facies, the amphibole gradually changes to a fibrous, light green to almost colourless variety and the plagioclase becomes oligoclase and is intergrown with the amphibole and epidote. Quartz, magnetite, leucoxene, and small amounts of carbonate and chlorite are also present. The greenschist facies, which is developed only east of Bow Lake, contains much more chlorite in place of amphibole, and also more epidote. The plagioclase of the greenschist facies is in the albite range but it is so highly altered and filled with chlorite and carbonate minerals that the determination of its composition is difficult. Carbonate and quartz form patches or veinlets throughout, and leucoxene and sulphides are present in small amounts.

Chemical analyses of the meta-andesites and meta-basalts indicate that their major components, such as SiO_2 and CaO, differ little from those of an average basalt, although alumina is somewhat lower and total iron higher. However, their content of water, carbon dioxide, potash, and soda are markedly different from those of an average basalt, the difference probably being the result of metamorphism. The geochemistry and metamorphism of these rocks was discussed by Boyle (1961, p. 66).[1]

Pillow Structure and its Origin

Pillow lavas are widely distributed throughout the geological column, but nowhere are they more abundant than in the Archaean greenstone belts of the Canadian Shield. The problem of how and why the pillows form is a fascinating one and none of the many theories advanced seems entirely satisfactory to account for them.

The Yellowknife belt is characterized by an abundance of well preserved pillowed flows and the almost continuous, clean, glaciated rock outcrops provide an unusually good opportunity for their study. In particular, an island near the mouth of Yellowknife Bay offers an almost wholly exposed, horizontal cross-section of more than 1,000 feet of nearly vertical pillowed flows and breccias (Fig. 1). From the study of this and other sections the conclusion has been reached that breccias and pillow lavas formed in much the same way and that the key to the origin of the pillow structure is to be found in the breccias (Henderson, 1953).

In his classic paper on the origin of pillow lavas Lewis (1914) has reviewed ninety-eight descriptions of pillow and ellipsoidal structures. Of these, thirty-two suggest subaqueous origin and fifty-two imply subaerial origin. Lewis concluded

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[1] *See also* Geochemistry of the Yellowknife volcanic rocks; W. R. A. Baragar, *Canadian Journal Earth Sciences*, volume 3, 1966, pp. 9-30.

"that neither the presence or absence of water, per se, can be predicated as particularly favourable to the formation of the structure." More recently Fuller (1931) has attributed the development of pillows in the Columbia River basalts to extrusion in water, but Hoffman (1933), from observations in the same general area, reaches the opposite conclusion. Stearns (1937), from studies in Hawaii, and Noe-Nygaard (1940), in Iceland, concluded that the pillows form only by extrusion of lava in water. On the other hand, Stark (1938) described ellipsoidal structures in lavas of the Society Islands that formed subaerially.

As pointed out by McKinstry (1939), MacDonald (1953), and others, much of the disagreement on the origin of pillow structure is due to the vague usage of the term. Many geologists have applied the term 'pillow' to any ellipsoidal structure; yet several unrelated structures originating under entirely different conditions may appear ellipsoidal in certain sections. The writers follow McKinstry (1939) and Stearns (1937) in restricting the use of the term. As used in this bulletin, 'pillow lava' refers to a structure made up of spheroidal or ellipsoidal, ball-like masses of lava coated with glass or its alteration product and detached from each other by fragmental, glassy debris which also fills the interstices between the ball-like masses.

Somewhat similar, ellipsoidal structures are commonly developed in pahoehoe flows. They are, however, unrelated in form or origin to true pillow structure, although the two are commonly confused, and are formed by lava tubes which are the characteristic, internal structure of pahoehoe flows. An excellent description of how such ellipsoidal structures form and how they differ from true pillow lava is given by Gordon A. MacDonald (1953, pp. 172–174).

> Each large tube divides into smaller ones, each of which feeds a lobe of lava at the moving flow front. The entire front advances by successive protrusion of one small bulbous toe after another. Most toes advance only a few feet before they chill to immobility, after which the skin of the flow front ruptures at some other point and another toe is sent out ..... . The front is gradually built up by the accumulation of a heap of these toes, generally one to three feet in diameter, lying alongside and on top of each other. A heap of pahoehoe toes belonging to several successive flows may appear in transverse cross-section somewhat like pillow lava .... it does not, however, have the same genetical interpretation, and its misinterpretation may lead to erroneous deductions regarding the geologic history of the area. If they are well exposed, true pillow lavas can generally be distinguished without difficulty from pahoehoe toes. In general cross-section each pillow gives an impression of radial structure, whereas each toe gives an impression of concentric structure. When the toes are exposed in three dimensions it can be seen that they are more elongate than pillows. The major axis of a pillow is seldom more than three to four times as long as the short axes; a pahoehoe toe may exhibit a length along the principal axis of flowage several times greater than its cross-sectional dimensions.

There is thus an important distinction between ellipsoidal structures formed by feeder tubes such as occur in pahoehoe flows, and true pillow lava that is made up of ball-like masses of lava. The reader will recognize that by far the greater part of the ellipsoidal structure of Archaean flows is formed by true pillows. The typical Archaean pillows are not pahoehoe flows—they are not formed by a process of bulbous budding.

The pillowed flows of the Yellowknife greenstone belt are similar to those of other Archaean greenstone belts in the Canadian Shield. The pillows (Pl. II) of the pillowed flows are a few inches to 5 feet or more in length but the average is 1 foot to 2 feet. The largest seen was 28 feet long by 3 feet wide. Each pillow has a ½- to 1-inch, fine-grained, dark brown to green rim with a massive, slightly coarser grained centre. Except for a few places where this rim has ruptured, each pillow is separated from its neighbours by it and nowhere did the writers observe a connection, or neck, joining two pillows; each pillow is thus an entity. The large pillows may be bun- or mattress-shaped as compared with the nearly spherical shapes of the smaller ones. In the larger pillows, and to a lesser degree in the smaller ones the undersides conform with the smoothly rounded upper surfaces of the pillows below and the bottom of a pillow is commonly a downward pointing cusp between the curved surfaces of the underlying pillows. As first recognized by Wilson (1911), the shapes of the pillows can thus be used to determine the direction in which steeply inclined flows face or top. Amygdules are commonly developed around the rims of the pillows with a slight tendency towards a greater concentration along the upper edge.

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PLATE II. Pillowed lava. Top of flow faces towards upper left.

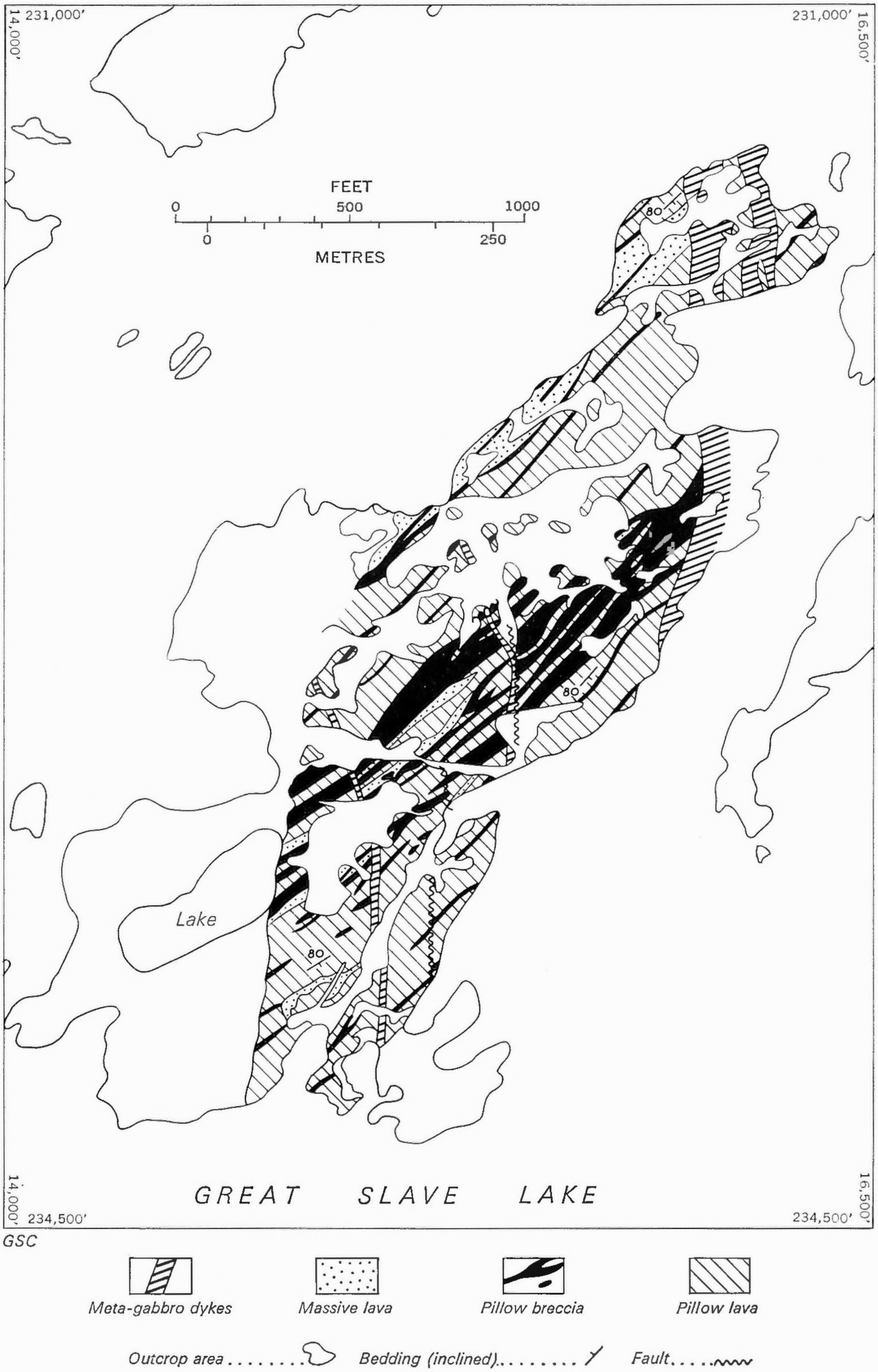

FIGURE 1. Distribution of pillow lava and breccia on island near mouth of Yellowknife Bay.

These features indicate clearly that (1) each pillow is a distinct entity which is physically unconnected with its neighbours; (2) because the bottom of each pillow conforms in shape with the top of the underlying pillow, each pillow was deposited subsequently to the pillows on which it rests; and (3) because the pillows are thus moulded on the ones below, they must have been deposited while still in a plastic condition. It seems reasonable to conclude that the pillows were deposited one on top of the other as globes of lava with tough but flexible glassy skins and still plastic interiors.

Further evidence as to the origin of the pillows is found in the breccias so commonly developed at the top and bottom of flows. A particularly fine assemblage of flows and breccias is exposed on a small island near the mouth of Yellowknife Bay (Fig. 1). On this island the breccia layers range from a foot or less to 100 feet thick. The flows and breccias strike northeast and dip and top 80°SE. The breccias (Pl. III) consist of masses of lava ranging from 1 inch to a foot or more in size, in a matrix of angular fragments from minute to pea-sized. The larger masses scattered through this fine breccia have dark, fine-grained rims and are amygdaloidal around their margins. They are in most respects identical with the pillows of a normal pillow flow; they differ only in being somewhat smaller, more elongate, and not as

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PLATE III. Typical pillow breccia.

perfectly ovoid in shape. Were they in contact with each other instead of lying in a fragmental matrix, there would be no hesitation about calling them pillows. It seems appropriate to call the breccia a pillow breccia.

The fine breccia in which the pillows are embedded is composed of unsorted, fine-grained, light green, angular to jagged fragments that range in size from minute to one-half inch or more. Under the microscope the fragments are found to be composed of a fine mat of secondary chlorite, altered feldspar, and epidote, with carbonate filling the interstices between the fragments. The fragments were probably glass originally.

The transition from pillow lava to pillow breccia takes place rather abruptly with the breccia filling the interstices between the pillows of the adjoining layer (Pl. IV) and with an occasional large pillow of the pillow layer completely surrounded by breccia (Pl. V). There is thus a transition from pillow breccia in which the pillows are surrounded by, or 'floating' in, breccia, to normal pillow lava in which the pillows are in direct contact with each other and the glassy interstitial breccia is at a minimum. Pillow breccia and pillow lava differ only in the proportion of breccia to pillows. It seems reasonable to conclude that the two have a common origin and that pillow lava is a type of breccia.

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PLATE IV. Contact of pillow breccia and overlying pillow lava.

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PLATE V. Contact of pillow breccia and underlying pillow lava, showing pillow floating in breccia.

Although the original structures are almost perfectly preserved, the rocks in the Yellowknife greenstone belt are ancient, altered flows that have been highly folded and now stand on end. Conclusions as to the original character and composition can be made with some assurance, but a certain amount of inference is necessary. Nor is there any direct evidence as to whether the flows were extruded on land or in water, although the remarkable continuity and consistent strike of thin flows and interbedded tuffs over several miles, and other indirect lines of evidence strongly suggest that they are subaqueous.

It is therefore of particular interest to find that fresh undisturbed Quaternary pillow lavas and breccias of Iceland show similar relations. Furthermore, because many of these flows are subglacial, it is possible to show that pillow structure forms only when the lava is extruded in the meltwater of the overlying glacier. Noe-Nygaard (1940), who has described the Icelandic flows, calls the pillow lavas and pillow breccias "globular basalts" and "basalt globe breccias". He considers the terms synonymous and there seems no doubt that "globular basalts" and "basalt globe breccias" are true pillow lava and pillow breccia. In these young flows as in the ancient ones at Yellowknife, there is a transition from globular basalt (pillow lava) to basalt globe breccia (pillow breccia). One such transition is described as follows (Noe-Nygaard, 1940, p. 13): "On following the globular basalt massif westwards it is found that the close packing of the globes does not continue; the farther we go from the central area, we find an even greater admixture of brownish, glassy matrix between the individual globes. The rock this forms appears as a glassy breccia in which the isolated glass covered globes seem to float." (Pl. VI).

PLATE VI

Elongated basalt globes in Quaternary basalt globe breccia, Iceland. (Photo by Noe-Nygaard, 1940, Pl. 4, Fig. 2).

Similar transitions from globular basalt to basalt globe breccia are described by Noe-Nygaard (1940, p. 58); he concluded that his investigations "have established the presence of complete transitional forms between compact globular basalt and basalt globe breccia whereby their common origin is proved." He compared the subglacial globular basalts and breccias with typical pillow structures and the subaerial flows formed in front of the ice front which entirely lack these structures, and presented convincing evidence to show that extrusion in water (in this instance meltwater from the overlying glacier) is essential for the formation of pillow lava and pillow breccia.

In summary and conclusion it is suggested that: (1) pillow lavas have a common origin with pillow breccias, into which they grade; (2) from indirect evidence in Archaean flows and from excellent direct evidence in Quaternary

Icelandic flows, extrusion in water seems essential for their development; (3) pillow breccia and pillow lava are formed by the chilling action and high heat consumption of the water. The process is akin to the granulation of slag on entering the water where an aggregate or breccia of glass fragments is formed. In nature, the subaqueous extrusion of lava is on a much more grand scale and globules of lava with glassy skins tend to form; these are the small 'floating' pillows in the breccia. A slight change in conditions leads to the development of pillows exclusively, with little or no interfilling of glass breccia; these are pillowed flows; (4) the pillows form as globules of lava with tough glassy skins and are transported as entities to their final place of deposition. In submarine eruptions, the globules (pillows) are given great mobility by the envelope of steam that surrounds them and they spread out quickly over large areas on the sea floor. Their mobility might be compared to that of globules of water that form when water is dropped on a red hot stove. Doubtless pillowed flows also form with great speed, a speed sufficient to allow the globules to be plastic and hot when they reach their final resting place and conform in shape to the underlying pillows. Pillowed flows are probably deposited with a speed comparable to that of glowing avalanche deposits observed in subaerial volcanic phenomena.

Variolitic Flows

Some of the meta-basalts and meta-andesites are variolitic and, with rare exceptions, all such variolitic lavas are pillowed. The spherules, which are most apparent on a weathered surface, are generally about the size of peas and somewhat lighter green than the enclosing rock (Pl. VII). They tend to project slightly, due to their greater hardness and resistance to erosion. They are composed of a very fine grained mixture of epidote, hornblende, and oligoclase, and the amount of feldspar in them is greater than in the rock as a whole. In some flows, the original radial structure of the spherules can be observed, particularly in the flows southwest of Negus Point near the Pud fault. Spherules of the variolitic lavas are confined to relatively few of the flows in the volcanic sequence that comprises Division A of the Yellowknife Group, and, because these flows can be traced for long distances in the otherwise nondescript assemblage of greenstones, they constitute valuable structural markers in the volcanic sequence. In all, eight separate, variolitic lava flows or series of flows have been mapped. Four of these can be traced continuously across the greenstone belt; the others occur as separate series of discontinuous lenses of variolitic lava, each of which occurs at the same stratigraphic position in the succession (Fig. 8, *in pocket*).

The most southerly of the variolitic lava flows underlies the north half of an island in Great Slave Lake, in the southwest corner of the area. On strike, to the northeast, two lenses of similar variolitic lava occur at what is probably the same stratigraphic position, one on the mainland, 3,000 feet to the northeast, and the other on an island 1,000 feet south of Kam Point. An assemblage of variolitic lavas, known as the Yellorex flows extends northeast from the south end of Keg Lake to Yellowknife Bay, south of Negus Point. From there it is displaced north

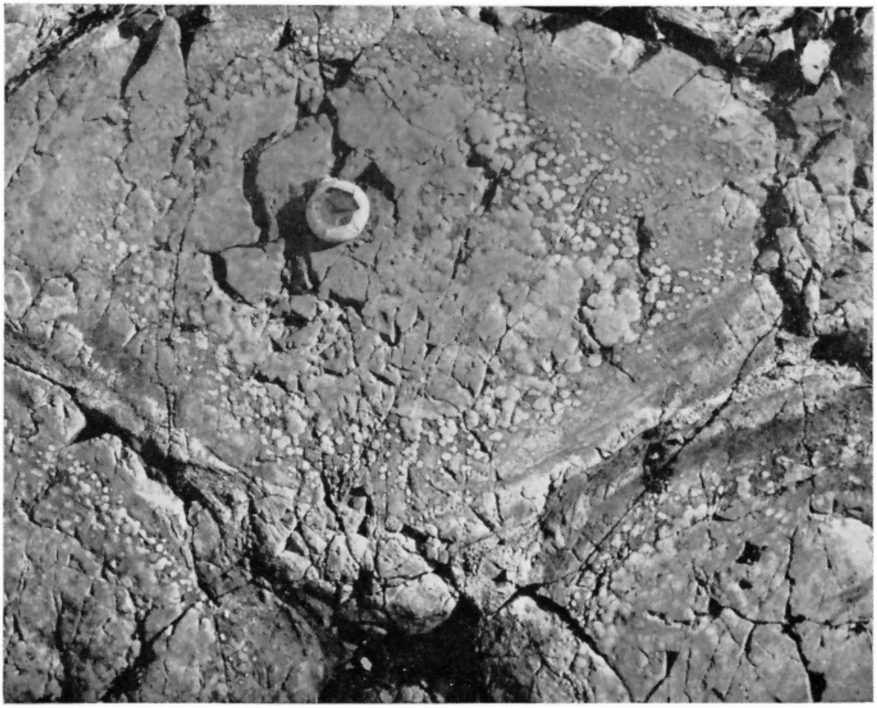

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PLATE VII. Variolitic pillowed lava, Yellorex flows, Yellorex Mines Ltd.

for more than three miles by the West Bay fault, to appear again along the shore of Yellowknife Bay east of Fault Lake. The same flows have been traced northeast from there along and near the shore of Yellowknife Bay to a point southeast of Bow Lake, where they either pinch out or are truncated by the sedimentary rocks of Division B of the Yellowknife Group.

Another assemblage of variolitic lavas, called the Negus flows, lies parallel with, and 1,000 to 1,500 feet northwest of the Yellorex flows, and extends northeast from Keg Lake to Yellowknife Bay 1,000 feet south of Mosher Island. East of the West Bay fault, these lavas outcrop 500 feet north of the A shaft of Giant Yellowknife Gold Mine, and they have been traced from there northeast through Bow Lake to the Akaitcho fault, by which they are displaced northeast more than 6,000 feet. On the northeast side of the Akaitcho fault, they extend northeast for 3,500 feet to a point where they are truncated abruptly by the overlying conglomerates and quartzites.

Several discontinuous lenses of variolitic lava lie some 2,000 feet northwest of the Negus flows. On the west side of the West Bay fault they occur at the southwest end of Pud Lake, midway between the Negus and Con mine shafts, and near the shore of Yellowknife Bay northwest of Mosher Island. On the east side of the West Bay fault, lenses of variolitic lava occur at about the same stratigraphic position 600 feet northwest of Bow Lake. Northeast of the Akaitcho fault, the variolitic lava flows south of One Arm Lake probably lie at about the same stratigraphic position.

A succession of flows, composed of variolitic lavas and known as the Fox flows, is well exposed in the northern part of the greenstone belt southeast of Trapper Lake. Northeast of the Akaitcho fault, these flows continue southwest of Vee Lake and extend northeast through its west arm to Jackson Lake. On the west side of the West Bay fault, the variolitic lavas northeast of Frame Lake lie at about the same stratigraphic position and are probably correlative with the Fox flows.

The typical Fox variolitic lavas as exposed east of Trapper Lake, at the southwest end of Vee Lake and west of Jackson Lake, comprise at least thirteen separate flows, many of which are only 10 to 15 feet thick. In most of the flows the lower part is massive and somewhat coarser grained than normal, with a narrow, fine-grained layer along the base. Near the tops, the massive lava grades upward into a pillowed, variolitic layer that may be only 3 or 4 feet thick, and this in turn is overlain by a ropy, variolitic flow top. Accessible, large, clean, glaciated outcrops of the Fox variolitic lava flows are exposed along the road east of Trapper Lake.

A thin flow of variolitic lava associated with several tuff beds lies about 1,000 feet northwest of the Fox flows. It has been traced from the southeast end of Gar Lake to Trapper Lake and northeast from there to the Akaitcho fault at the southwest end of Gold Lake. The faulted extension of this flow on the northeast side of the Akaitcho fault lies parallel with, and 100 feet south of, Rater Lake. On the west side of the West Bay fault the variolitic lava flow along the southeast side of Stock Lake may be part of the same flow.

The Stock variolitic lava flow has been traced throughout the greenstone belt, and because of its unique character forms one of the best marker flows in the belt. It extends east from the granodiorite stock on the north side of Stock Lake to the West Bay fault. There, it is displaced north more than three miles to the north tip of Gar Lake, from where it extends north to the Akaitcho fault, by which it is displaced northeast nearly 4,000 feet to a point 600 feet northwest of the south end of Rater Lake. From there, it has been traced northeast to a point 1,500 feet south of Daigle Lake.

The Stock lava flow is more schistose than most flows, and the pillows are greatly elongated (Pl. VIII). The spherules in it occur in the pillow rims as well as around the margins of the pillows. In most of the variolitic lava flows the spherules rarely exceed the size of peas, but in this unique flow they attain sizes of one inch and even two inches, and stand out prominently on weathered surfaces, as striking, whitish, chert-like nodules in the dark green chloritic pillows and pillow rims.

Several lenses of variolitic lavas occur about 2,000 feet northwest of the Stock flow. On the west side of the West Bay fault, two such lenses occur west of Fault Lake. These variolitic lavas are probably correlative with those on the east side of the West Bay fault to the north and south of David Lake, and with those on the northeast side of the Akaitcho fault, some 2,500 feet northwest of Rater Lake and 500 feet northwest of Shadow Lake.

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PLATE VIII. Stock variolitic flow, near road to Crestaurum Mines Ltd.

Porphyritic Flows

A few of the meta-basalt and meta-andesite lavas contain light weathering feldspar phenocrysts up to 1 inch in length in both their pillowed and massive parts. The porphyritic lavas are rare and are largely confined to a horizon stratigraphically above, that is, to the southeast of, the dacite flows (Townsite flows and sills).

On the west side of the West Bay fault, porphyritic lavas outcrop on the southeast shore of Frame Lake east of the Pud fault and just south of the road between Yellowknife townsite and the old townsite. They form a band up to 250 feet wide striking northeast parallel with the road. The feldspar phenocrysts occur in both pillowed and massive lavas. On the east side of the West Bay fault, similar porphyritic lavas outcrop some 200 feet west of the Akaitcho mine shaft and can be traced north-northeast for 2,000 feet to the Akaitcho fault. These flows are highly amygdaloidal, with vesicles filled with chlorite that weather chocolate brown and give the rock a spotted appearance. The feldspar phenocrysts are plentiful in places and up to 1 inch in length. On the northeast side of the Akaitcho fault, an almost identical assemblage of porphyritic amygdaloidal lavas outcrops on the point on the southeast side of Vee Lake. These lavas can be traced southwest for 2,500 feet along and near the shore of the lake. The same flows outcrop on strike to the northeast, along the shore of Walsh Lake 2,500 feet northeast of the northeast end of Vee Lake.

These unusual porphyritic lavas occur in each of the fault block segments into which the greenstone belt is divided. Because they are lithologically similar and occur at about the same stratigraphic position a few hundred feet above and to the southeast of the dacites and meta-gabbro sills, they probably represent a once continuous series of flows, and are correlative with each other.

Somewhat similar porphyritic lavas have been described and discussed by Moore (1956, p. 9) in the Courageous–Matthews Lakes area 150 miles northeast of Yellowknife.

Meta-dacites

The main assemblage of porphyritic, quartz-feldspar meta-dacite flows and associated agglomerates, breccias, and tuffs lies northwest of Yellowknife townsite and has been called the Townsite flows (Trail, 1950). These flows, in the aggregate, are about 1,200 feet thick, but have been split into two bands by a large meta-gabbro sill. An excellent section of the flows is exposed west of the old townsite near the West Bay fault.

Near the shore of Yellowknife Bay, the Townsite meta-dacites and associated meta-gabbro sills are displaced north more than 3 miles by the West Bay fault and appear again on the east side of the fault west of the Giant C shaft. Apparently they are again faulted along a north-trending drift-filled valley about 5,000 feet northeast of the place where they emerge from the West Bay fault, because they cannot be found on strike on the east side of this valley despite almost continuous rock outcrops. Similar meta-dacite flows and associated meta-gabbro sills outcrop on the northeast side of the Akaitcho fault at the south end of Vee Lake, and extend from there to Jackson Lake. These are considered to be faulted segments of the Townsite flows and sills.

The more acidic meta-dacite flows are fine-grained, white to light buff weathering rocks. They are highly porphyritic, with numerous feldspar phenocrysts up to one-eighth inch in size and less common, smaller, rounded, opalescent, grey quartz phenocrysts, all scattered through a fine-grained groundmass. On a freshly broken surface the rock is dark grey to greenish with blocky, grey to pinkish feldspar phenocrysts in a flinty, fine-grained groundmass. This rock grades into more basic, light green to buff-green weathering types that are dark greenish grey on freshly broken surfaces. Except that they contain feldspar phenocrysts and weather lighter green, these more basic meta-dacites do not differ greatly in appearance from the meta-andesites and meta-basalts.

The more acidic types are characterized by many discontinuous, lens-like bodies of breccia and agglomerate, most of which cannot be traced far along strike. These fragmental rocks are exposed in each faulted segment of the belt. In the Frame Lake segment west of Frame Lake a fragmental band about 30 feet wide parallels the contact and is separated from the contact with the underlying meta-gabbro sill by about 50 feet of massive dacite. In this band the meta-dacite fragments are from 1 inch to 18 inches in size in a rusty weathering matrix of similar composition. Several breccias and agglomerates were also observed east of

Frame Lake and west of Yellowknife Bay where they are associated with a pillowed flow. Indeed, in this area much of the light weathering more acidic meta-dacite is fragmental with shadowy fragments up to a foot or more in size distinguishable on clean weathered surfaces. One well defined, agglomeratic, tuffaceous zone has been traced for more than 2,000 feet and is up to 100 feet wide. Some of the agglomeratic material shows a rude stratification and contains interbeds of tuffaceous material. The fragments of meta-dacite range from minute to 2 feet in diameter and are enclosed in a schistose matrix of similar composition. The interbedded tuffs, up to 3 feet thick, are well bedded and some show a gradation in size of grain from bottom to top.

Many of the flows are massive and structureless, except for amygdules, flow lines, and the like which can generally be found on close examination. Pillow structure is well developed in some of the darker green, more basic meta-dacites, but has not been observed in the light weathering flows. The best exposures of pillowed flows are northeast of Frame Lake about 700 feet southwest of Yellowknife Bay. Here the base of a layer of massive meta-dacite about 200 feet wide is in contact with the large underlying meta-gabbro sill. It is overlain to the southeast by a pillowed layer about 20 feet wide and more than 100 feet long. Several of the well preserved pillows have quartz-filled amygdules around the inside of the pillow rims which themselves contain prominent feldspar phenocrysts. Pillow rims are also preserved in the meta-dacites in the Baker Creek segment between the Brock and Oly shafts. There, however, the rocks are strongly sheared and the pillow outlines much distorted.

Under the microscope the meta-dacites are seen to be composed of numerous, fairly fresh phenocrysts of plagioclase and some of quartz in a fine-grained groundmass of plagioclase, quartz, chlorite, and biotite, with minor amounts of carbonate, white mica, epidote and zoisite, apatite, magnetite, and pyrite. Though the grade of metamorphism calls for the presence of albite, the plagioclase phenocrysts in the sections examined are predominantly oligoclase, and albite is rare or absent. The plagioclase of the groundmass, although too fine to determine accurately, seems to be of about the same composition as the phenocrysts. The phenocrysts are commonly shattered and the cracks filled with chlorite or carbonate. The groundmass of the light weathering meta-dacites contains more plagioclase and correspondingly less ferromagnesian minerals than that of the dark phase. Also, whereas in the light coloured meta-dacites, biotite, partly altered to chloride, is the more plentiful ferromagnesian mineral, in the groundmass of the dark phase chlorite is abundant with only a little biotite present. Actinolite is developed at the expense of chlorite in the meta-dacites of the Frame Lake segment, near the granodiorite.

Evidently the mineralogical composition of these rocks is not the original composition, and the extent of alteration has been such as to make accurate petrographic classification impossible. Conclusions as to their original character and origin must rest largely on field evidence. The presence of fragmental layers, representing original agglomerates and breccias, bedded, presumably tuffaceous layers, and pillow structures with well preserved amygdules, indicate that the rocks are largely of extrusive origin and form part of the volcanic succession. Their mineralogical composition suggests they were originally of dacitic composition and were altered to meta-dacites at the same time as the underlying and overlying basalts and andesites were altered to meta-andesites and meta-basalts.

There is the possibility that this more siliceous, porphyritic assemblage may have formed from normal meta-basalts and meta-andesites by a later process of alteration and metasomatism involving albitization and silicification. Northeast of Vee Lake (and in a lesser degree in other areas), many porphyritic (leuco-dacite) dykes and irregularly shaped bodies appear to cut the meta-dacites, meta-andesites, and meta-basalts (p. 44). Texturally and mineralogically the porphyries are similar to the meta-dacites and it is practically impossible to distinguish the two except where their crosscutting relations can be observed. There is some evidence that these porphyries are in part, at least, of metasomatic origin and were formed in place rather than by intrusion in magmatic form. If these porphyries formed in place by replacement of the country rocks, is it possible that the rocks mapped as meta-dacites also formed by a similar process? Were the meta-dacites originally meta-andesites and meta-basalts that have undergone further alteration involving albitization, silicification, and porphyritization? Carrying this line of thought a step further, is the association of the meta-gabbro sills with the meta-dacites coincidental or is there a genetic relation between the two? Could the sills be metamorphic basic differentiates formed during the silicification and albitization processes that may have formed the meta-dacites from original meta-andesites and meta-basalts?

To these hypothetical questions the evidence, as it would be interpreted by most geologists, is negative. Nevertheless, the origin of the meta-dacites and porphyries has perplexed the writers and others who have worked in the area, and these are questions to which future workers may give much thought.

Pyroclastic Rocks

Pyroclastic rocks occur throughout the volcanic assemblage, but are most abundant in the upper part. This is apparent in the southern part of the greenstone belt, where the number and thickness of tuffaceous beds increase markedly toward the mouth of Yellowknife Bay. Near the end of the period of vulcanism great amounts of agglomerate and breccia were spewed out. These form the outer fringe of islands on the shore of Great Slave Lake west of the southern group of the Sub Islands. Similar agglomerates and breccias underlie the northern tip of Latham Island, 9 miles to the north, where they occupy almost the same stratigraphic position and are probably the faulted extension of the upper part of the same agglomeratic band.

The pyroclastic rocks may be divided into two types: (a) breccias and agglomerates, and (b) fine-grained, bedded cherty tuffs and crystal tuffs.

Breccias and Agglomerates

The breccias and agglomerates range from bands a few feet to several hundred feet in thickness but average 5 to 10 feet, sometimes grading into tuffs along strike. The bands are remarkably continuous, and although irregular in detail, maintain a constant strike. Most of them are composed of fragments of the same composition as the enclosing lavas and range from a few inches to a foot or more in size. These fragments are in general elliptical, and lie in a matrix of small, angular fragments up to the size of peas. The large ovoid fragments have darker, chilled rims and may be amygdaloidal around their margins. They resemble the pillows of the pillowed lavas except that they are smaller and instead of being in contact with each other as in the lavas, they lie in a fine fragmental matrix (*see* pp. 9–17). Flow breccias composed of lava fragments in a ropy, scoriaceous flow matrix are somewhat similar to those with fragmental matrices. One type seems to grade into the other and it is difficult to distinguish true flow breccias from the much more common agglomeratic breccias.

The agglomerates and breccias that form the outermost fringe of islands in Great Slave Lake, about 4,000 feet west of the southerly group of the Sub Islands, are a remarkable assemblage that must be more than 500 feet thick. They are at, or near, the top of Division A of the Yellowknife Group. To the southeast beneath the waters of Yellowknife Bay they are probably overlain by the sedimentary and volcanic rocks of Division B.

The agglomerates and breccias are composed of angular to subangular, green-grey, fine-grained fragments, some of which are amygdular (Pl. IX). The fragments are up to 6 inches in size but average 2 or 3 inches. In most outcrops little or no sorting is evident, although some rude stratification is present in places. For the most part the fragments are very closely packed and the matrix merely fills the spaces between the jagged fragments. The matrix is a light grey weathering, fine-grained, cherty looking material which, under the microscope, is seen to be composed of a fine-grained mixture of feldspar and quartz, epidote and zoisite with a few feldspar phenocrysts. The matrix, although lighter weathering, differs little in composition from the fragments. Similar agglomerates and breccias, underlying the northern end of Latham Island 9 miles to the north, occupy nearly the same stratigraphic position in the volcanic sequence and are probably the faulted extension of the upper part of the same band of rocks. The Latham Island agglomerate is a highly schistose, light green weathering rock that is green-grey with a chloritic-micaceous sheen on a fresh fracture. It is composed of fragments up to a foot or more in length but averaging 2 to 3 inches. The fragments may originally have been angular but have been greatly deformed and elongated to several times their initial length. Most of the fragments are grey-green, fine-grained rocks but some are of crystal tuff. From a study of the weathered surface the matrix seems to have been originally a fragmental tuffaceous material but it has been altered to a chlorite-mica schist.

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PLATE IX. Volcanic agglomerate, islands west of Sub Islands.

Tuffs

Fine-grained, cherty tuffs and coarser, crystal tuffs are closely associated and generally occur together in the same band. They are well bedded, chalky white to pinkish weathering rocks that are light to dark grey on freshly broken surfaces. The bands range in thickness from a few inches to more than 100 feet, and some of them have been traced for several miles along strike. The crystal tuffs are composed of closely packed, blocky, angular feldspar grains up to one-quarter inch in size. The individual beds, which are from a few inches to several feet thick, commonly show a gradation in grain size from coarse at the bottom to fine at the top; indeed many beds grade into cherty tuff at the top. The cherty tuffs are composed of a very fine grained mosaic of quartz with some albite, and may have been in large part a chemical precipitate. They have been observed to fill the interstices between pillows on top of pillowed flows. Many of the tuffs, particularly those north of Stock Lake, have a high content of pyrite and graphite.

The tuffs formed on the sea bottom during intervals between outpourings of the lava flows. They are probably in large part formed of detritus associated with the extrusion of the flows. Boyle (1961, p. 70) has speculated that the high content of sulphur and carbon in many of them, both of which are essential to life, was concentrated by biogenic processes.

Four bands of tuff have proved valuable as marker beds because they possess distinctive features that permit their correlation in the three major fault blocks into which the greenstone belt is divided by the West Bay and Akaitcho faults. One of these, known as the Bode tuff, lies stratigraphically above, that is, to the southeast of the Yellorex variolitic lavas. On the west side of the West Bay fault this tuff band is in two parts, separated from the Yellorex flows by 200 to 300 feet of massive and pillowed lavas. The two parts join near the shore of Yellowknife Bay south of the Pud Fault to form a single band 45 to 50 feet wide. This tuff band is unusual in that it contains, near its base, angular fragments up to 10 inches in diameter of a light weathering felsite. It is overlain to the southeast by massive, coarse-grained meta-basalt characterized by peculiar blebs of hornblende that give the rock a mottled appearance on the weathered surface. On the east side of the West Bay fault this characteristic tuff band outcrops on the shore of Yellowknife Bay east of the north end of Fault Lake, where it is again underlain by the Yellorex variolitic lava flows and overlain by the mottled meta-basalt. To the northeast it is displaced by a fault, but appears again near the shore of the bay east of the Giant A shaft, and has been traced northeast for more than 5,000 feet to where it either pinches out or is truncated by the overlying sedimentary rocks of Division B of the Yellowknife Group.

Another series of tuffaceous beds, known as the Cemetery tuffs, underlies the prominent valley between the south end of Stock Lake and Yellowknife Bay. These tuff beds are unusual in that they are associated with narrow bands of light weathering dacite or rhyolite flows. On the east side of the West Bay fault, the Cemetery tuffs and accompanying light weathering lavas outcrop northeast of Gar Lake and probably underlie the drift-filled valley that extends north from Trapper Lake to the Akaitcho fault. On the northeast side of the Akaitcho fault the faulted extension of the Cemetery tuffs underlies the long depression occupied in part by Rater Lake and extending northeasterly to the northern boundary of the mapped area.

Two unusual bands of tuff, which have been called the Ranney chert and Ranney tuff, have been traced throughout the greater part of the greenstone belt.

The Ranney chert is a fine-grained, cherty, pink to light grey weathering rock that is laminated and bedded in places but for the most part is structureless; it varies in thickness from 1 foot to 10 feet and is a characteristic and persistent band. West of the West Bay fault it extends from east of Joe Lake northeasterly to the West Bay fault about 1,000 feet northwest of Giant A shaft. East of the West Bay fault it lies some 500 feet west of David Lake and can be traced through excellent outcrops to the Akaitcho fault. It is displaced some 3,000 feet northwest by the Akaitcho and its subsidiary faults. The Ranney chert may be traced northeast of the Akaitcho fault for several thousand feet, gradually decreasing in width and probably pinching out before reaching Daigle Lake. On strike to the northeast the cherty tuff band south of Crestaurum Mines shaft is lithologically similar, appears to be in the same stratigraphic position, and is probably the continuation of the Ranney chert (*see* p. 71). Here it is disrupted by a meta-gabbro intrusion but segments and lenses of the tuff can be followed northeast to near the limits of the map-area.

The Ranney tuff lies southeast of the Ranney chert. West of the West Bay fault it is separated from the Ranney chert by about 800 feet of massive and pillowed flows of which the upper 500 feet are sparsely variolitic, with variolites in only a few of the rather scanty pillows. The Ranney tuff is overlain to the southeast by 400 feet of characteristic, light weathering pillowed flows, followed by strongly variolitic flows.

East of the West Bay fault, the Ranney tuff outcrops at the north end of David Lake where it contains gold-bearing quartz veins and lenses. From there north to the Akaitcho fault it is separated from the Ranney chert by about 1,100 feet of pillowed and massive flows. Some of the pillows in these flows contain variolites but they are so sparsely distributed that the flows are not mapped as variolitic. To the east the Ranney tuff is overlain by 300 feet of the light weathering, pillowed flows followed by strongly variolitic pillowed flows.

Northeast of the Akaitcho fault the same succession is repeated. There, the well developed variolitic flow southeast of the Ranney tuff dies out some 3,000 feet northeast of the Akaitcho fault but appears again southeast of Finger Lake. South of Crestaurum Mines and Shaft, variolitic flows southeast of the Ranney chert lie at about the same stratigraphic position and are probably correlative with the sparsely variolitic flows to the south.

Division B

The sedimentary and volcanic rocks of Division B of the Yellowknife Group probably underlie the greater part of the area covered by the waters of Yellowknife Bay. Outcrops of these rocks are limited to the southeast part of Latham Island, the east part of Jolliffe Island, some of the smaller islands in Yellowknife Bay, a narrow selvedge along the shore of the bay, south of the Akaitcho fault, and a somewhat larger area to the north of the fault along Yellowknife River. Rocks of Division B are in direct contact with those of Division A for a short distance along the shore of Yellowknife Bay, south of the Akaitcho fault. A coarse conglomerate occurs locally along this contact, but the common sedimentary rocks of this division are arkosic quartzite, greywackes, and crystal tuff. A few pillowed and massive meta-andesite lava flows and agglomerates are interbedded with the sedimentary rocks. Northeast of the Akaitcho fault, light weathering porphyritic dacites form most of the outcrops.

Lithology

The conglomerate, which is confined to a few outcrops near the shore of Yellowknife Bay south of Bow Lake, is mainly composed of fragments derived from the volcanic assemblage of Division A. Most of the fragments are meta-andesite and meta-basalt, but some contain spherules and these were probably derived from the underlying variolitic lava. There are, in addition some vein-quartz pebbles and a few large cobbles of a massive pink to grey coarse-grained granitic rock. Apart from the granite cobbles and quartz pebbles, which are well rounded, the fragments are mostly subangular. They vary in size from minute grains to fragments 20 inches or more across, and are poorly sorted, with little or no apparent bedding. The matrix is a jumble of small fragments of rocks similar to those that compose the larger fragments and of grains of quartz and feldspar up to one-quarter inch long. Resting directly on the conglomerate is a band of white weathering, coarse, arkosic quartzite composed of quartz and feldspar grains and small fragments of a cherty rock.

The crystal tuffs are best exposed on Latham and Jolliffe Islands. They are well bedded, light grey weathering rocks (grey to green on freshly broken surfaces) composed of blocky feldspar crystals, quartz grains up to one-quarter inch long, and small fragments of cherty material, in a fine-grained matrix of chlorite, quartz, and feldspar. Fine-grained, thinly laminated, slaty beds are interbedded with the crystal tuffs. On the east side of Latham and Jolliffe Islands these tuffaceous and slaty beds grade upward into fine textured greywackes and slates, which are typical of the sedimentary rocks of the Yellowknife Group that outcrop along the east side of Yellowknife Bay and for thousands of square miles to the east of the bay. A characteristic feature of most of the sedimentary beds, including the crystal tuffs, is a marked gradation in grain size in individual beds from sandy textured material at the base to fine argillaceous material at the top.

Meta-andesite flows are intercalated with the sedimentary rocks of Division B of the Yellowknife Group, along the shore of Yellowknife Bay south of Bow Lake and the east side of Latham Island. These flows are lithologically similar to the meta-andesites of Division A.

The dacite flows outcropping northeast of the Akaitcho fault consist of light pink weathering, porphyritic dacites and light grey weathering, fine-grained, non-porphyritic dacites. Phenocrysts, where present, are mainly quartz, with some feldspar, in a grey, fine-grained groundmass. Bands of fragmental and flow breccias, some showing ropy flow structures and amygdaloidal layers, indicate that these rocks are of extrusive origin. However, many large outcrops do not exhibit volcanic structures, and it is possible that an intrusive phase may also be represented.

Age Relations

Good exposures of the contact between the rocks of Divisions A and B of the Yellowknife Group are limited to the area along the shore of Yellowknife Bay, south and east of Bow Lake. Along this contact there is no clearly defined discordance between the strike of the flows and tuffs of Division A and those of Division B. Members of both divisions strike northeast, dip 75 to 80°NW, and face southeast. One thousand feet southwest of the Akaitcho fault, the variolitic lava flow that lies near the contact appears to be truncated at a small angle by the overlying sedimentary rocks, but this flow becomes progressively thinner to the northeast and may pinch out rather than be truncated. The bands of cherty and crystal tuffs interbedded with the lavas near the top of Division A are similar to the tuffs and tuffaceous sedimentary beds mapped as the lower part of Division B. Nor is there any sudden change in the character of the sedimentary facies, apart from the occurrence of the local lens of conglomerate and arkosic quartzite near the contact. However, the presence of granite pebbles in the conglomerate and the possible truncation of the variolitic flow suggest that an erosional interval of some duration may have intervened between the deposition of rocks of Division A and those of Division B.

At the north end of Latham Island, the contact between the rocks of Divisions A and B has been placed somewhat arbitrarily at the top, or southeast, of the agglomerate that underlies the north tip of this land. The contact of the agglomerate at the top of Division A and the overlying crystal tuffs with thin intercalated lava flows of Division B is not well enough exposed to determine the structural relations between them.

Sedimentary Rocks of Uncertain Age

Sedimentary rocks of uncertain age underlie the Sub Islands and the west half of Jolliffe Island, and form a narrow, northeasterly trending belt between the rocks of Divisions A and B of the Yellowknife Group north of the Akaitcho fault. These rocks, which are mostly subgreywacke (impure quartzite) and conglomerate, rest with marked angular unconformity on the rocks of Division A of the Yellowknife Group, but were not found in contact with rocks of Division B.

Lithology

On the Sub Islands, the conglomerate is composed of an assortment of closely packed pebbles and cobbles of granite, fine-grained greenstones, grey felsites and chert, argillite and ferruginous carbonate, vein quartz, and jasper (Pl. X). The conglomerate is poorly sorted, and the fragments range from an inch or less to boulders 1½ to 2 feet in diameter, but average about 2 or 3 inches. The pebbles and cobbles are well rounded. The matrix is a coarse, gritty textured subgreywacke, which also occurs as interbeds and lenses in the conglomerate. The central part of the island is a white weathering, grey, fine- to medium-grained subgreywacke, with many interbeds and lenses of pebbly conglomerate. Well developed crossbedding is common throughout. In many of the granite pebbles all the minerals, except the quartz, are altered to a brown aggregate of carbonate and sericite. Because only some of the granite pebbles are altered, the alteration must have occurred prior to their incorporation in the conglomerate, suggesting that the conglomerate was derived in part from a regolith of deeply weathered granite.

The conglomerates and subgreywackes of Jolliffe Island are similar to those in the Sub Islands except that the crossbedding is not so well developed, the

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PLATE X. Conglomerate, Sub Islands.

ferruginous carbonate and jasper pebbles are missing, and all the granite pebbles are fresh. The rock is also more schistose, and some elongation of the softer pebbles is noticeable.

The belt extending northeast from the Akaitcho fault west of Shot Lake consists of a 10- to 200-foot-thick layer of conglomerate overlain by subgreywacke. The conglomerate is a greenish brown weathering rock in which the fragments show considerable elongation. The fragments are closely packed and up to 2 or 3 feet in length but average 4 or 5 inches. The larger ones occur near the base and, although now considerably elongated, were probably originally angular; the smaller ones are well rounded. The pebbles and cobbles are predominantly fine- to medium-grained greenstones and quartz-feldspar porphyries derived from the underlying volcanic flows of Division A of the Yellowknife Group and the meta-gabbro intrusions. Many vein-quartz pebbles are present, and a few granite pebbles and cobbles occur in the upper part of the belt well above the unconformity. The matrix is a green, gritty aggregate of small pieces of the same rocks as those that form the pebbles and cobbles; it becomes more quartzitic in the upper part.

The change from conglomerate to subgreywacke takes place abruptly. Near the conglomerate the overlying subgreywacke is thinly laminated and, in weathering, breaks along the bedding to form plates a fraction of an inch thick. Farther from the conglomerate the beds are thicker, ranging from a few inches to several feet. The typical subgreywackes are fine- to medium-grained, sandy textured rocks, that are now somewhat schistose and flaggy. Isolated, well rounded pebbles of granite, greenstone, and other rocks, up to two inches in diameter, are present in many of the beds, and thin, pebbly layers are fairly common. Crossbedding is particularly well developed in the lower part of the succession but is common throughout. The order of deposition of the beds, which are nearly vertical and overturned locally, is therefore not often in doubt.

Under the microscope the subgreywackes are seen to be composed of angular to subangular, quartz grains in a fine-grained matrix of carbonate, colourless mica, quartz, and a little chlorite. Chert and feldspar grains are fairly plentiful in some beds. The detrital quartz grains make up between 35 and 45 per cent of the rock and are scattered through the fine-grained matrix that makes up the balance. The preponderance of matrix over sand detrital grains, the angularity of the grains, and the carbonate-micaceous matrix are characteristic features of subgreywackes, into which class these original sandstones fall (Pettijohn, 1957, pp. 316–321). A less specific but perhaps more descriptive field name is impure quartzite.

Age Relations

The unconformity between these sedimentary rocks and the volcanic flows of Division A of the Yellowknife Group is well exposed in many outcrops between the Akaitcho fault and Walsh and Jackson Lakes.

West of the south end of Walsh Lake, the unconformity is almost continuously exposed for some 2000 feet. The conglomerate fills irregularities and depressions on an old erosion surface in the pillow lavas. A well defined flow of variolitic lava (Negus flow), striking N55°E and dipping 75 to 80°SE, is truncated by the conglomerate, which strikes N10°E and dips 75°SE. Several tuff and breccia bands between the flows, also truncated by the conglomerate, show the same discordance in strike.

Other excellent exposures of the unconformity lie west of the south end of Jackson Lake, where the conglomerate, which truncates a large meta-gabbro sill, consists mainly of angular fragments of the sill. The contact between conglomerate and sill is extremely irregular in detail, with the conglomerate filling the hollows or embayments in the old erosion surface and the subgreywacke in direct contact with the basement on the spurs or higher parts. This is exemplified by the large embayment on the old erosion surface north of the sill and southwest of Jackson Lake (north half). In this depression the conglomerate is nearly 300 feet thick, whereas, just to the north and south, subgreywacke is in direct contact with the old erosion surface.

The conglomerates and subgreywackes have not been found in contact with rocks of Division B of the Yellowknife Group. Along the belt between the Akaitcho fault and Walsh Lake a drift-filled valley lies between them and the dacites of

Division B to the east. The conglomerates and subgreywackes dip and face 75 to 80°SE across the belt, and hence if no fault lies along the valley between them, they underlie the dacitic flows to the southeast. On Jolliffe Island, the conglomerates and subgreywackes are not in contact with Yellowknife strata that underlie the eastern half of the island. There, however, the nearly vertical conglomerate and subgreywacke beds face west, whereas the Yellowknife Group strata face east and the two are, presumably, separated by a fault.

From the above relations, Jolliffe (1942) concluded that the conglomerates and subgreywackes formed the basal part of Division B of the Yellowknife Group. This conclusion may be correct, but several lines of evidence suggest strongly that they are much younger, and post-Yellowknife in age:

1. Contrasting Lithology. The sedimentary rocks of Division B of the Yellowknife Group are thinly bedded, dark grey to green-grey, tuffaceous and argillaceous greywackes. They contain interbedded volcanic flows similar to those of Division A. In many beds a characteristic feature is a gradation in grain size from the relatively coarse grains at the bottom to the fine ones at the top. Crossbedding is rare or lacking.

On the other hand, the conglomerates and subgreywackes contain no volcanic flows or tuffaceous beds. The subgreywackes are light grey rocks with a predominantly carbonate-micaceous matrix, as compared with the predominantly dark green chloritic matrix of the Yellowknife Group sedimentary rocks. Crossbedding is a characteristic feature of the subgreywackes in contrast with the graded bedding so common in the Yellowknife strata.

The lithological differences indicate that the sediments that formed these rocks were deposited in entirely different environments and hence were probably deposited at different times. The greywacke assemblage of Division B of the Yellowknife Group, which with associated greenstone flows extends over thousands of square miles to the northeast of the Yellowknife area, is a typical flysch assemblage of geosynclinal sediments deposited in a tectonically active, rapidly subsiding basin and was derived from an orogenically active area. The assemblage accumulated rapidly without interruption in a deep water marine environment as waste products from a highland mass.

The subgreywackes and conglomerates are also the immature products of erosion of a highland area but, as indicated by the abundant crossbedding and conglomerate, they were deposited in relatively shallow water. Sediments of this type belong to the molasse assemblage which commonly follows the flysch greywacke assemblage as subsidence of the geosyncline decreases or sedimentation overtakes it and, as a consequence, the deep water, marine, geosynclinal environment is followed by shallow water conditions. The subgreywacke assemblage thus appears late in the orogenic cycle and, in contrast with the deep water marine greywackes, is deposited in a mixed continental and marine environment, such as a deltaic coastal plain (Pettijohn, 1957, pp. 615–622).

II. Contrasting Relations with Underlying Rocks. Where observed in contact, the rocks of Division B of Yellowknife Group are apparently conformable in strike and dip with those of Division A. No evidence of a structural discordance or unconformity has been found, although the contact may mark an erosional interval or disconformity. In contrast, the conglomerates and subgreywackes rest with marked structural discordance on the irregular surface of the rocks of Division A. It seems unlikely that sedimentary rocks of the same age, in two areas less than a mile apart, would exhibit such contrasting structural relations with a common, old erosion surface.

III. Relations to Intrusive Rocks. The Yellowknife Group rocks, including those of Division B, are intruded by many bodies of meta-gabbro and meta-diorite, for example, the meta-gabbro sills on Latham Island. The conglomerates and subgreywackes, on the other hand, rest unconformably on similar basic intrusions, such as the meta-gabbro sill between Walsh and Jackson Lakes. It is possible that the early basic intrusions are of different ages, one earlier and the other later than the conglomerate and subgreywacke, but this seems unlikely because none have been found cutting the conglomerate and subgreywacke. More probably, the early basic intrusions are older than the conglomerate and subgreywacke. In this case the conglomerate and subgreywackes (Unit 11) are post-Yellowknife in age.

Meta-Gabbro and Meta-Diorite

The early basic intrusive rocks have been divided into sills, irregularly shaped bodies, and dykes, ranging in composition from meta-gabbro to meta-diorite and are mineralogically similar. The separation of the dykes from the sills and irregularly shaped bodies is an arbitrary division based primarily on shape. The dykes cut the sills and most of the irregular intrusions and show fine-grained margins against them. However, a small meta-gabbro stock immediately southwest of Shadow Lake (north half) is younger than the dykes, with fine-grained margins against them, and in the northern part of the area northeast of Vee Lake, many dykes are irregular in outline along strike, and are inseparable from the irregularly shaped intrusions. Consequently, it appears that, despite their crosscutting relations, most of the early, basic intrusive rocks are closely related in time and origin. Possibly the irregularly shaped intrusions are the more deeply seated equivalents of the dykes, and where erosion exposes the more deeply buried rocks, irregularly shaped bodies are more abundant than dykes.

No evidence has been found to indicate that the dykes are feeders to the flows. None of the hundreds of dykes mapped have been found to merge into a flow; on the contrary, all cut across the flows with fine-grained margins against them. Further, the dykes are most numerous and largest in the southern part of the area where the upper part of the volcanic succession is exposed; the reverse condition should hold if the dykes were feeders to the flows.

Sills

On the west side of the West Bay fault are two well defined groups of sills (Fig. 8). The most southerly, or Kam group, extends southwest from Kam Point along the shore of Yellowknife Bay. The largest sill is on the mainland, but one or more, parallel, smaller sills outcrop on the islands to the south. The other group of sills lies north of Yellowknife townsite and has been called the Townsite group. These sills strike northeast through Frame Lake parallel with the volcanic flows and with the Kam sills to the south.

On the east side of the West Bay fault the probable faulted extension of the Kam sills forms part of the point west of Jolliffe Island (the location of the old Yellowknife townsite). The faulted extension of the Townsite sills outcrops 1,000 feet northwest of the Giant B shaft.

Southwest of Kam Point, the largest of the Kam sills lies along a tuffaceous band or bands, and is underlain and overlain by thin tuff layers (south half). The sill has fine-grained margins against the tuffs, and in a few places sends off small apophyses into them. Several layers of tuff lie within the sill and strike parallel with its walls. These tuff beds are cut off in places by the sill but appear again along the projected strike. Apparently they have not been moved or disturbed in any way by emplacement of the sill. This might be explained by considering the tuffs as parting screens between separate intrusions; but there is no evidence of more than one intrusion. It is remarkable that a 10- to 15-foot band of tuff would not at least be warped by the emplacement of such a large body of rock.

When examined on a clean weathered surface, the typical sill rock is seen to be composed of about 60 per cent hornblende and 40 per cent greenish white, altered feldspar. The grain size varies, but in general ranges from one-quarter to one-half inch. On freshly broken surfaces the rock is a typical greenstone, and it is difficult to recognize individual hornblende and highly altered feldspar crystals. In places the variations in grain size and texture produce a distinct banding (Pl. XI). These bands may be from 6 inches to 20 feet or more wide, and lie parallel with the walls of the sill. Some bands show large blocky hornblende crystals that give the rock a mottled appearance (Pl. XI); others contain long, feathery or fern-like ones; still others are much finer grained.

On the west side of the West Bay fault are the three Townsite sills (south half). The southernmost lies between dacite flows, and extends from the granodiorite contact on the west to within 600 feet of the West Bay fault, where it ends abruptly. This sill is a massive, coarse-grained, altered hornblende-feldspar rock similar to the Kam sills except that it shows little or no banding. The central and northern sills extend east from the granodiorite contact to the West Bay fault. A narrow layer or partition of tuff and andesitic flow rock separates the two sills. About 1,000 feet west of the West Bay fault this partition and the sills are offset 500 feet south. The central sill is porphyritic, and in this respect is unique because no other porphyritic sills have been found in the area; otherwise it resembles the southern sill. The phenocrysts are composed of white weathering, altered feldspar

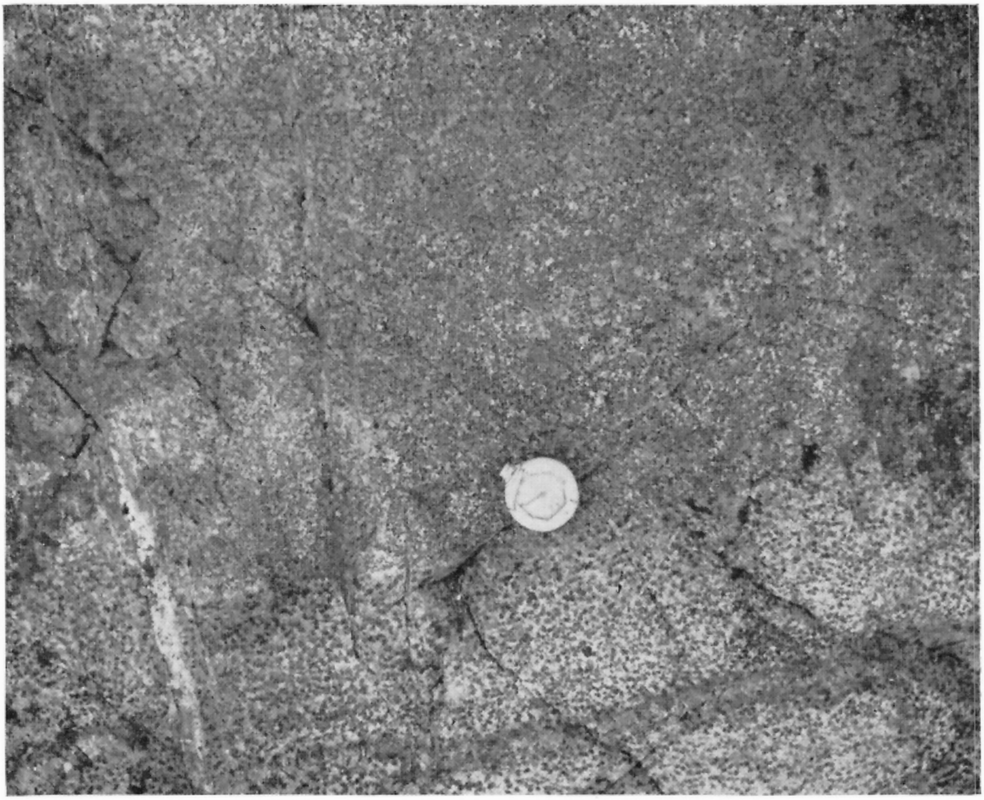

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PLATE XI. Meta-gabbro sill, Kam Point, showing feathery fern-like amphiboles (darker band) and blocky amphiboles (lighter band).

crystals or aggregates of crystals averaging one-quarter to one-half inch in size, but up to 1 inch or more. The most northerly sill is composed of a massive, structureless rock that is finer grained and weathers a more brownish green than the porphyritic sill. The faulted extensions of these sills outcrop on the east side of the West Bay fault, northwest of Giant B shaft. Lack of outcrops and much faulting in this vicinity make it difficult to outline their boundaries, but both porphyritic and non-porphyritic types are represented. North of the Akaitcho fault, a large sill (or sills) extending through Vee Lake is probably the faulted extension of these three sills.

Under the microscope, the rock of the Kam and Townsite sills is seen to be composed mainly of secondary minerals including hornblende and other amphiboles (60–65 per cent), plagioclase (15–20 per cent), epidote (15–20 per cent), with smaller amounts of chlorite, white mica, biotite, carbonate, magnetite, pyrite, zircon, apatite, and quartz. The sills are thus mineralogically similar to the meta-basalts and meta-andesites and, like them, gradually change in mineralogical composition from the amphibolite facies near the grandiorite to the epidote–amphibolite facies that makes up the greater part of the belt. The hornblende occurs as large irregular crystals and fine uralitic needles. In the epidote–amphibolite facies epidote, clinozoisite, and chlorite are more abundantly developed in place of amphibole. The plagioclase is altered to a fine-grained mass of clinozoisite, white mica, hornblende, and carbonate. In a few thin sections where it could be determined, the composition of the original plagioclase was labradorite.

Irregularly Shaped Bodies

The irregularly shaped bodies are as much as several hundred feet wide, and extremely erratic in outline. Some are sill-like, with their longer dimensions paralleling the strike of the flows in which they lie, but most of them are more dyke-like in form, cutting across the flows at all angles. They are probably equally irregular in outline at depth, as, where observations can be made, their contacts appear to range in dip from nearly horizontal to nearly vertical.

These dioritic rocks are composed of roughly 50 per cent hornblende and 50 per cent altered feldspar. They are greenstones, mineralogically and chemically similar to the meta-andesite and meta-basalt flows (Boyle, 1961, p. 66). Some are coarser grained than some of the flows, but many are no coarser than the central parts of thick flows. Contacts may be well defined, the diorite having a fine-grained margin against the flows, but in places contacts are gradational. Where exposures are poor it is difficult and in places impossible to distinguish between the diorite and the greenstone flows in which it lies.

Dioritic rocks such as these are not unique to the Yellowknife belt; they are commonly developed in Archaean andesitic and basaltic flows (greenstone belts) throughout the Canadian Shield. In the Bousquet-Joannés area, Quebec—"Even more troublesome are . . . a number of bodies of diorite. They are green to almost black rocks consisting of variable proportions of hornblende and feldspar and a few small eyes of quartz, and always much altered to secondary minerals. The main difficulty is distinguishing them from the thick basic flows." (Gunning, 1941). In the Kirkland Lake gold belt—"Bodies of altered basic intrusives are associated with the Keewatin series . . . . The rocks are characteristically massive, dark green to greenish black in colour, and of intermediate to coarse texture, but they become finer grained at their boundaries. Whenever coarse grained rocks are poorly exposed it is difficult to decide whether they are intrusive or extrusive." (Thomson, 1948, p. 15).

In the Noranda district of Quebec—"The contacts with dioritic intrusives . . . are of three types (1) sharply defined (2) transitional (3) marked by a zone of breccia. Where the contact is well defined the diorite has a fine grained edge against the rock it intrudes. The transitional contact is most strongly exemplified in the Newbec property. An andesite area, which is almost wholly enclosed in diorite, in places has the texture and mineralogical composition of diorite, yet the presence of pillow structure proves it is andesite recrystallized." (Wilson, 1941, p. 31). In the Mud Lake area of Quebec—"Small bodies of diorite are numerous throughout the Keewatin volcanics of Gaboury and Blondeau townships. They vary considerably in appearance and composition but are commonly dark green, fine to medium grained rocks. The finer grained phases are extremely difficult to distinguish from the coarse lava flows." (Henderson, 1936, p. 15).

In containing many dioritic bodies, the Yellowknife greenstone belt is no different from other belts in the Shield. However, there are few areas where the rock exposures are as numerous, bare, and clean. This has made it possible to trace obscure contacts between dioritic rocks and flows, which in most areas would be difficult to recognize and quite impossible to follow for any distance. These contacts have been mapped in great detail. The distribution of the dioritic rocks and their structural relations to the flows are remarkable, and should be of interest to those who have had to contend with mapping similar dioritic rocks in other greenstone belts in the Shield.

On the west side of the West Bay fault the irregularly shaped bodies are confined to the area between Joe Lake and the granodiorite–greenstone contact to the north and northwest (north half). On the east side of the West Bay fault they occur throughout the area northwest of Yellowknife Bay. They are cut by meta-diorite and meta-gabbro dykes. The age of these bodies in relation to the Kam, Townsite, and other sills is not known, but probably they are closely related in time and origin.

The irregularly shaped bodies in the western part of the greenstone belt, including the areas north of Joe Lake, between Island and Ryan Lakes northwest of Daigle Lake, and north and west of Milner Lake, differ somewhat in appearance and in the nature of their contacts from the irregular bodies farther east. In mineralogical composition and texture they are similar to the true sills, but are somewhat finer grained and contain more hornblende. This mineral tends to form small aggregates of crystals, one-eighth to one-quarter inch in diameter, that give the rocks a mottled appearance on the weathered surface. Some of the bodies contain scattered white weathering feldspar phenocrysts averaging one-quarter to one-half inch in size. Contacts with both pillowed and non-pillowed flows are gradational but contacts with tuff beds are sharp. Along contacts with pillowed lavas, the transition from one to the other may be gradational over 20 feet or more. Toward the contact, the pillow lava becomes coarser and its texture approaches that of the 'intrusive' rock. However, the pillow rims persist and may be traced as slightly darker, finer grained, ovoid streaks for some distance into what otherwise appears to be an intrusive rock, before they become indistinguishable. As the grain size increases, the hornblende tends to form small clots of crystals, and in some bodies feldspar phenocrysts appear.

The irregularly shaped bodies of the eastern part of the greenstone belt, east of the West Bay fault (north half), differ in appearance from those farther west in being finer grained, lower in hornblende content and, in texture and general appearance, more like the true dykes than the sills. They differ also in having, in general, much sharper contacts with the lava flows. Contacts in many cases are knife-edged, and where they cut pillowed lavas, the pillow rims may be truncated along the contact;

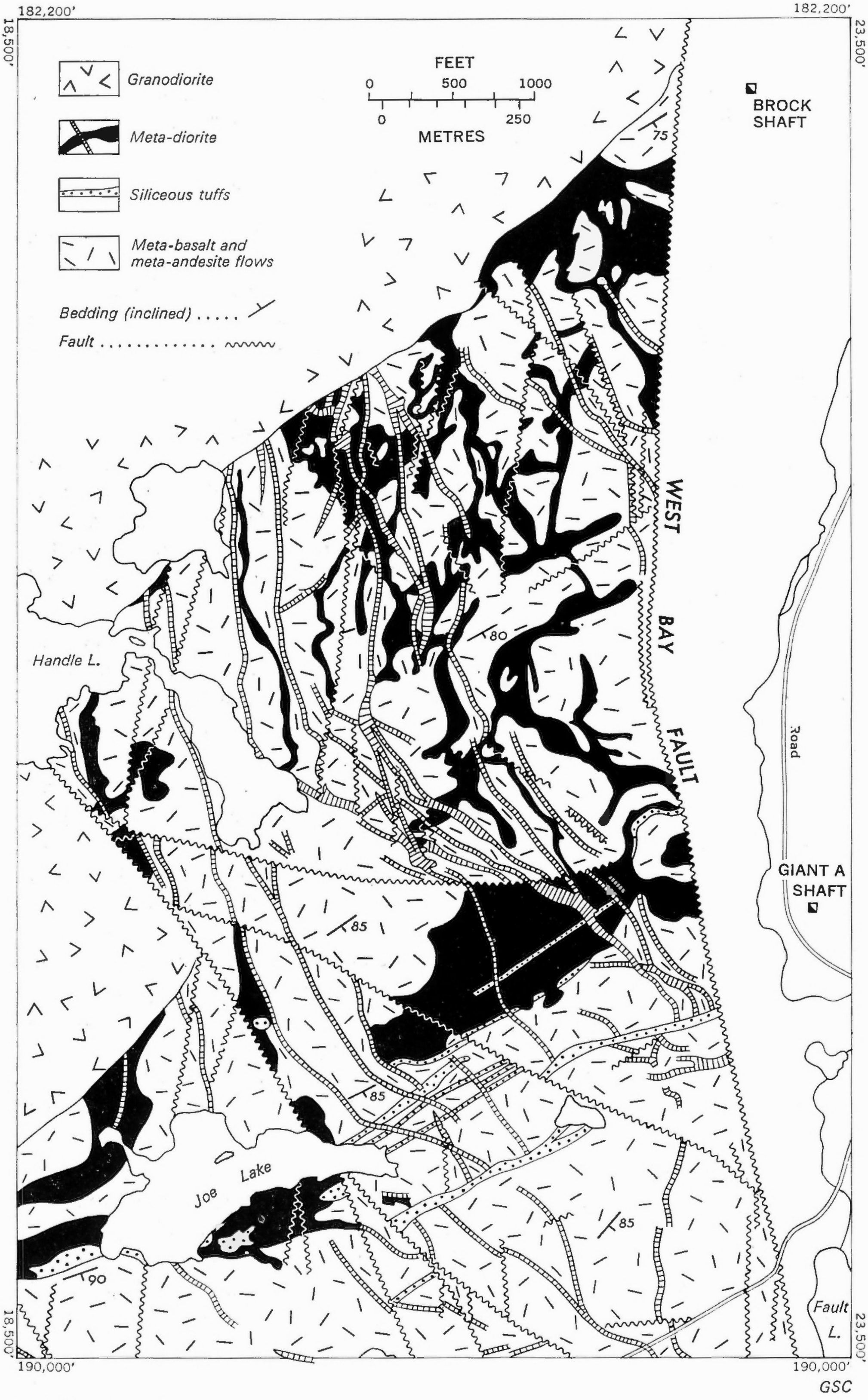

FIGURE 2. Dykes and irregular bodies of meta-diorite in meta-andesite and meta-basalt flows, northeast of Joe Lake.

some contacts, however, are gradational. Like the intrusions to the west, many of them contain widely scattered feldspar phenocrysts.

The irregularly shaped bodies of both types, whether with sharp or gradational contacts, cut across the flows at all angles, and many of them are several hundred feet wide; yet their emplacement has not disturbed the volcanic strata. Flow contacts, pillowed layers, and tuff bands that are cut by them are apparently not offset or disturbed in any way. Many of the bodies contain inclusions of lavas and of tuffaceous beds that have retained their original orientation and have not been moved or disturbed. Many examples could be cited, amongst the best of which are those northeast, and along the south shore, of Joe Lake (Fig. 2). The sill-like body northeast of Joe Lake contains fragments of a narrow tuff band which, although surrounded by and isolated in the meta-diorite, are in perfect alignment and retain the orientation they had before the meta-diorite was emplaced. Even more striking is the sill-like body along the south shore and west of Joe Lake. It contains many scattered areas or blocks of tuff up to 100 feet in diameter. These 'islands' of tuff, which are completely isolated in the two dimensions visible, have the same orientation as the tuff band of which originally they were part. Apparently they have not moved from their original position. In the area covered by Figure 2, the meta-dioritic and meta-gabbroic bodies make up 25 to 30 per cent of the rock; yet this large volume of material has been emplaced without disturbing in any way the fabric of the volcanic strata.

Between Rater and Vee Lakes the structural relation of the irregularly shaped bodies to the volcanic strata is again well illustrated (Fig. 3). Of interest is the extremely irregular outline of the meta-diorite, particularly in the northeast outcrop, and the failure of the opposite walls of the bodies to match. The relation of the tuff bands to the meta-diorite is also remarkable. Sections or fragments of tuff are entirely surrounded by meta-diorite, yet they are in perfect alignment and have not been moved from their original positions. Here the irregular bodies make up 30 to 40 per cent of the exposed rocks, yet the emplacement of this large volume of material has not disturbed the volcanic strata in any way.

The irregular meta-gabbro and meta-diorite bodies crosscut the flows; many of their contacts are well defined, others are gradational over many feet. Many of the bodies have fine-grained margins, such as would be caused by chilling of a magma during consolidation. The meta-diorites and meta-gabbros thus have many of the characteristics of intrusions, and have been so called. However, it is questionable if they are intrusions in the true meaning of that term. An intrusion is an influx of material in a state of fusion, for example, a magma, which comes from outside and therefore must make room for itself. A magma can make room by pushing aside the rock it intrudes (that is, by expansion or dilation of the country rocks) or by mechanical removal of the country rock (by a stoping process).

Forcible injection of magma with dilation of the country rock cannot have been operative here. The injection of such a large volume of material (25 to 30 per cent and in places 40 per cent of the whole) would have pushed aside the volcanic strata, displacing or at least warping them. But detailed mapping shows that the

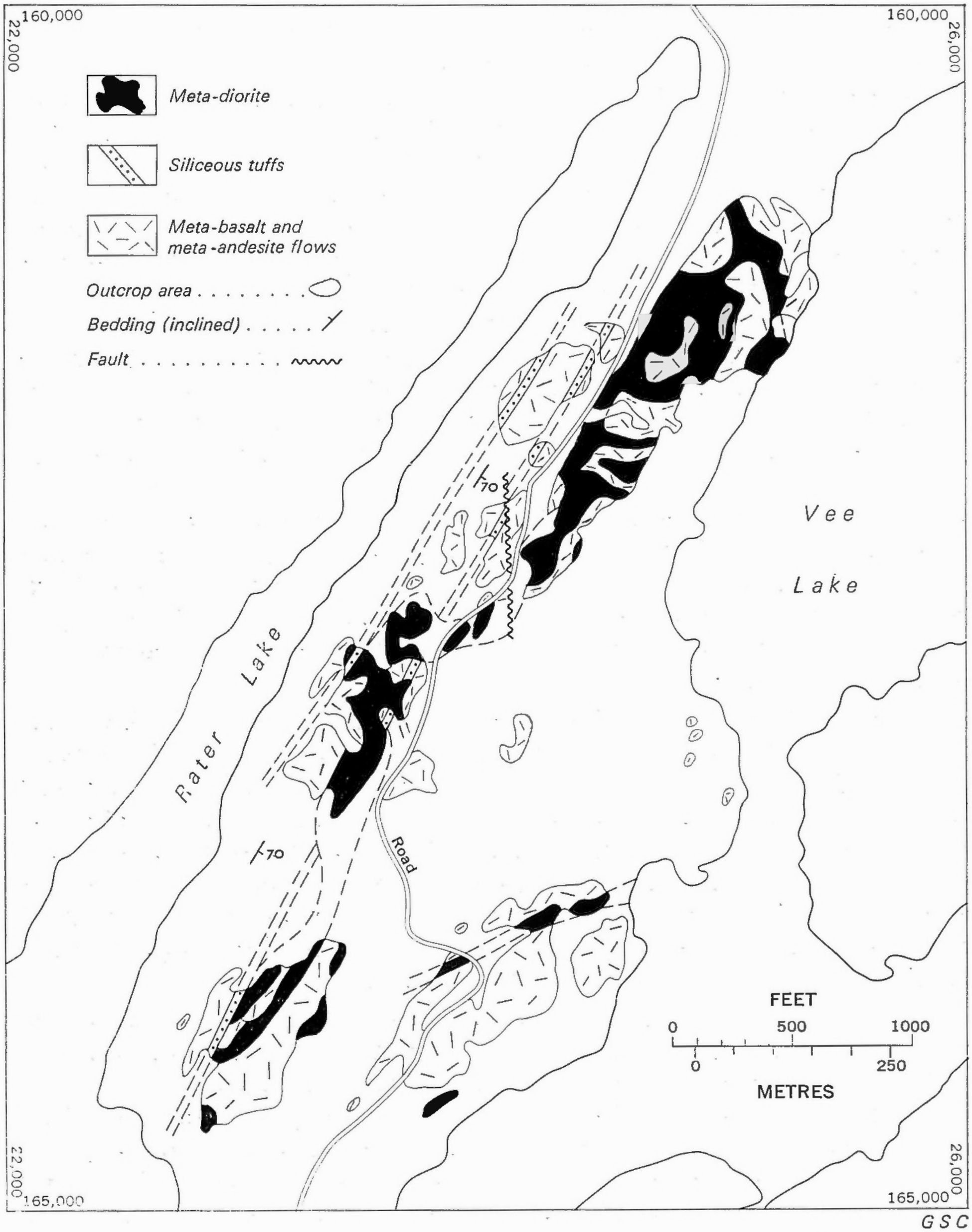

FIGURE 3. Irregular bodies of meta-diorite between Rater Lake and Vee Lake.

original fabric of the country rocks has not been disturbed at all. In weak and schistose country rocks a considerable amount of forcible intrusion may take place with relatively little apparent displacement. In such rocks, according to Noble (1952), lateral and vertical displacement may be converted in relatively short distances to a general inflation or doming. But the volcanic strata of the

Yellowknife belt are not weak and schistose rocks; they are massive flows. Forcible intrusion does not seem to have been operative here.

Nor does magmatic stoping, the piecemeal assimilation of the country rock in blocks, seem a likely process of emplacement for such small, irregular bodies. Blocks of country rock, both tuffs and volcanic flow rocks, are common in the meta-diorites and meta-gabbros, but in all cases blocks have retained their original orientation and they have not moved about as they would have had to if magmatic stoping had been operative.

Because the irregular bodies of meta-diorite and meta-gabbro have not made room for themselves by dilation or forcible intrusion, or by stoping of the country rock, it seems unlikely that they were emplaced as a magma, unless much corrosion of the walls took place. Conceivably, through-flowing, superheated magma following irregular cracks might melt out irregular openings. Where the flow continued for some time the walls might be heated to coarsen their grain and create apparent gradational contacts, while in other places faster cooling might create fine-grained margins. However, it seems doubtful that any magma would have the necessary fluidity and superheat for this or, if it had, that the channel ways would create such an irregular pattern of intrusions. Possibly the irregular bodies were emplaced contemporaneously with the flows they apparently intrude, and formed from magma working its way through the hot and partly crystallized flows. Such material might become entrapped in the volcanic pile, recrystallize, and even locally remelt the adjoining still hot flows, but such an origin does not solve the space problem. More likely, the irregular bodies of meta-diorite and meta-gabbro formed in place at a later period by some process of dioritization of the greenstone flows. The process may have been one of replacement (metasomatism) or simply refusion or recrystallization. Because their chemical compositions are so similar (Boyle, 1961, p. 67), little or no chemical change would be involved in the development of one from the other.

Dykes

The dykes are most numerous and widest on the west side of the West Bay fault, where they form about 10 per cent of the rock of the greenstone belt. They strike north in the southern part of the area, swinging to northwest farther north, and dip 60°W or less, some having dips as low as 35°. The larger dykes are up to 300 feet wide, but the average width is 10 to 40 feet.

The dykes contain no inclusions of country rock and their borders are always chilled against the walls. In general, the walls match and would fit together if the dyke were removed. Where dykes cross tuff bands, the tuff may extend as a screen partly across the dyke, but the tuff itself is not disturbed or moved. In other instances, as in the tuff band 300 feet southeast of Keg Lake (south half), a dyke may either terminate at the tuff or continue on the other side as a dyke of different width. The dykes show no tendency to extend along the bedding planes of the tuff nor to branch out between volcanic flows. At the place where it peters out the dyke is wedge-shaped.

On the east side of the West Bay fault, south of the Akaitcho fault, a swarm of dykes appears northwest of Trapper Lake. North of the Akaitcho fault, the faulted extension of this dyke swarm lies north and northwest of Rater Lake. The dykes there strike north to northeast and, in contrast with those on the west side of the West Bay fault, most of them dip east at 40–60°. The difference in the strike of the dykes on either side of the West Bay fault is as remarkable as the change in dip. West of the West Bay fault the dykes transect the flows at angles of 60–90°, whereas east of the fault they strike nearly parallel with them. The reason for the markedly different attitudes of the dykes in relation to the flows in different parts of the belt is obscure. Probably it indicates that the dykes were emplaced considerably later than, and consequently were not feeders to, the flows. Perhaps it is significant that the larger, early shear zones, like the dykes, also transect the flows at a considerable angle and dip west on the west side of the West Bay fault, but on the east side of the fault they strike nearly parallel with the flows and most of them dip east.

The dykes have been divided into porphyritic and non-porphyritic types. This is an arbitrary division, for some dykes change from porphyritic to non-porphyritic along strike but most of them maintain their textural characteristics for long distances. The most common dykes weather green to buff-green and are dark green on freshly broken surfaces. Their grain size ranges from one-quarter inch or more in the larger dykes to fine in the smaller ones. Feldspar phenocrysts, where present, range in size in different dykes from one-quarter inch or less to 3 inches, but average about one-half inch (Pl. XII). They weather light green to white. Some have good crystal outlines and are single crystals; others, particularly the larger ones, are aggregates of crystals. They may be abundant, forming as much as 25 per cent of the dyke, or widely scattered. In some dykes they are evenly distributed; in others they occur only here and there in streaks or clusters. Commonly, peculiar features of a dyke, such as the size, shape, distribution of the phenocrysts, grain size, and texture, persist for long distances, and thus a dyke can be distinguished from its neighbours and traced from outcrop to outcrop for thousands of feet, some for several miles.

Under the microscope, the dykes seem mineralogically similar to the sills, irregular bodies, and the basic volcanic flows. Hornblende composes as much as 60 to 70 per cent of the rock. Plagioclase, which comprises the remainder is almost completely altered to epidote, white mica, and chlorite or amphibole. As in the other greenstone rocks of the belt, the amounts of epidote and chlorite increase in place of hornblende in the epidote–amphibolite facies, away from the granodiorite contact. The feldspar crystals are lath-shaped and tend to be enclosed by the large hornblende crystals, suggesting that the dyke rocks had an original ophitic to poikilophitic texture. Where determinations are possible, the plagioclase can be observed to range from labradorite to andesine. The feldspar phenocrysts, when present, are entirely altered to a fine mass of epidote, white mica, amphibole, and chlorite.

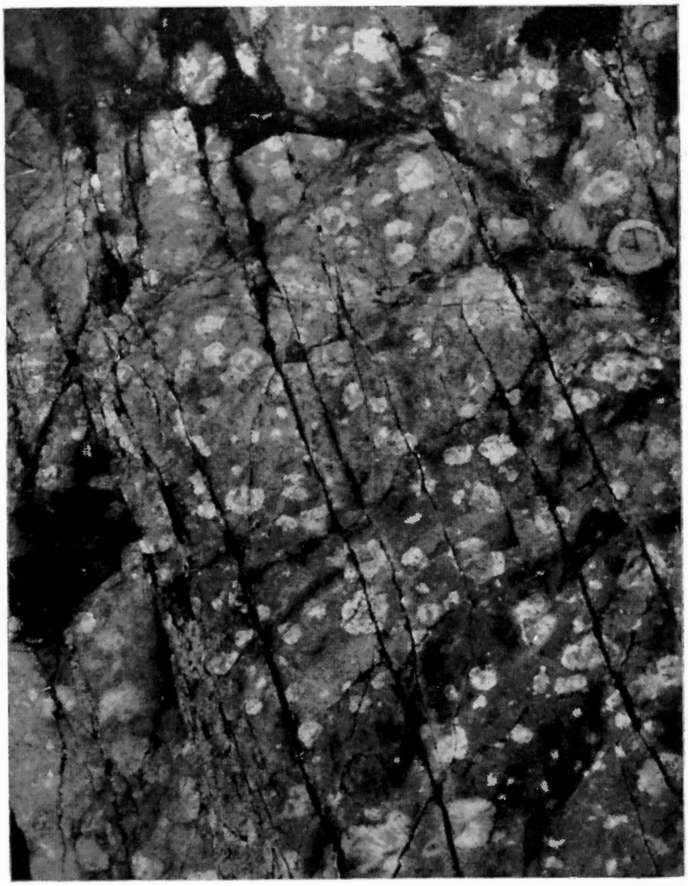

PLATE XII

Porphyritic meta-diorite dyke.

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In chemical composition, the meta-diorite and meta-gabbro dykes are essentially similar to the meta-andesites and meta-basalts they intrude, the main difference being 1 to 2 per cent less silica and about 1½ per cent more magnesia (Boyle, 1961, p. 67).

A less common type of dyke weathers pale green and is light green on freshly broken surfaces. It contains about the same proportion of hornblende to feldspar, but the hornblende is a pale green variety. These dykes are usually coarse grained and porphyritic; they make excellent structural markers because they are easily recognized and followed from outcrop to outcrop. A marker dyke of this type has been traced 4½ miles from the shore north of Kam Point to Stock Lake. Petrographically, this dyke is similar to the more common types, except that the hornblende is a more colourless variety and the plagioclase is completely replaced by epidote and white mica.

A third type of dyke, still less common, is a dark green rock that weathers chocolate-brown. Many contain phenocrysts of feldspar up to one-quarter inch long in a fine-grained groundmass. Quartz amygdules may occur along the margins. Several dykes of this type occur 1,000 to 1,500 feet west of Negus Point. Under the microscope, these dykes are seen to be composed of 45 to 50 per cent andesine, 25 to 30 per cent hornblende, and 10 to 15 per cent quartz. The feldspar of the matrix is fresh, but the phenocrysts are altered to a fine-grained mass of epidote, colourless mica, and hornblende.

Dykes of all types cut one another and have fine-grained margins. In most places the porphyritic dykes cut the non-porphyritic, but there are many exceptions. The chocolate-brown dykes generally cut the others. Many of the dykes are composite, with younger dykes injected along the centres or margins of older dykes. In these instances, and where one dyke crosses another, the younger dyke shows a fine-grained margin against the older. The large 'marker' dyke south of Keg Lake is an excellent example of a composite dyke cut by several younger dykes.

Porphyritic Leuco-Dacite (Quartz-Feldspar Porphyry)

Dykes and irregular bodies of porphyritic (quartz-feldspar) leuco-dacite are abundant from Vee Lake north to the limit of the area mapped; only a few narrow dykes are found south of this lake although several dykes and small bodies of porphyry were encountered underground in the Con–Rycon mine. Most of the porphyry bodies are dyke-like in form, with a general northwest strike, but many are most irregular in shape. The average width of the dyke-like bodies is 10 to 30 feet, but some of the irregularly shaped bodies may be as much as 300 feet wide.

The most common type is a light buff to grey rock that weathers white to light waxy yellow. It is composed of as much as 40 per cent feldspar and quartz phenocrysts averaging one-quarter inch in size in a fine-grained groundmass. Porphyries of a less common type may contain only a few quartz phenocrysts. Where the two types were observed in contact, the quartz-feldspar porphyry is cut by the quartz porphyry. Other small dyke-like bodies are fine grained and cherty in appearance. Some bodies become finer grained near their contacts with the greenstones, but others show no change near the contact, which in all cases is sharp.

Under the microscope, the feldspar phenocrysts are seen to be almost completely altered to white mica, but the quartz phenocrysts are fresh and unstrained. The groundmass is a fine mosaic of quartz and feldspar, and colourless mica or carbonate or a mixture of both, with some chlorite and chloritized biotite. The feldspar phenocrysts are commonly zoned with altered cores. They are generally andesine (An_{35}). Small amounts of magnetite, leucoxene, zircon, apatite, rutile, and epidote are also present. As shown by Boyle (1961, p. 71), the chemical composition of the porphyries is similar to that of the contact phase of the granodiorite, which has a relatively high soda to potash ratio. They differ from the granodiorite in having a much higher content of sulphur and carbon dioxide, and a relative enrichment in chromium.

The porphyries cut the meta-diorite and meta-gabbro sills and dykes. They have not been found in contact with the main body of granodiorite and some may be older, but east of the north end of Ryan Lake a porphyry dyke cuts three narrow granodiorite dykes. The age of the porphyry bodies in relation to the early shear zones is confusing. Two north-striking, quartz-feldspar porphyry dykes, 2,000 and 3,000 feet, respectively, northeast of the north arm of Vee Lake, definitely cut, and have fine-grained borders against, chlorite schist and carbonate stringers in the schist of a large sheared zone. Yet, other porphyry bodies nearby are sheared and displaced along shear zones of similar type.

Seven hundred feet north of Walsh Lake, a quartz-feldspar porphyry dyke is truncated at the unconformity between the Yellowknife Group and the unclassified sedimentary rocks. It might be reasoned from this that, because the porphyries are at least in part younger than the shear zones, the shear zones are older than the unclassified sedimentary rocks. However, the equally reasonable assumption may be that porphyries of several ages are represented. With the data at hand, this is probably the safer assumption.

The porphyries look like igneous rocks. The dyke-like form of most of the masses as well as their crosscutting relations and sharp contacts with the flows and meta-diorite and meta-gabbro bodies also suggest igneous intrusion. Other lines of evidence suggest that they may be of metasomatic replacement origin. Petrographically, the porphyries are similar to the porphyries of the Porcupine District which have been described by Whitman (1927), Evans (1944), and Holmes (1944) as metasomatic replacements and by Moore (1954) and Robinson (1923) as igneous intrusions.

Many of the criteria described and considered by Evans (1944) to indicate a metasomatic replacement origin for the Porcupine porphyries are also present in the Yellowknife porphyries. Under the microscope, most of the quartz phenocrysts are seen to be rounded, many are deeply embayed by the groundmass, and many others contain inclusions of groundmass material; still others have edges tonguing into the sheared groundmass. Most of the quartz phenocrysts are fresh and unstrained and some quartz and feldspar phenocrysts cut across the schistosity. These points suggest that the phenocrysts formed long after the groundmass, and are actually metacrysts.

Structurally, also, metasomatic replacement is suggested by the failure to match of the walls of country rock enclosing many of the porphyry bodies. Indeed many of the bodies are extremely irregular in outline with rounded and saw-toothed borders and with stringers running out into the country rock. Inclusions or 'islands' of country rock in the porphyry are rare, but where they do occur, as in the large porphyry body west of the south end of Jackson Lake, they have apparently not been moved by the emplacement of the porphyry, but retain the same orientation (indicated by flow contacts, etc.) as the 'mainland' of country rock.

Indirectly, also, the relatively high content of chromium in the porphyries, which is also high in the greenstones, suggests that they formed by replacement rather than intrusion (Boyle, 1961, p. 76).

Granodiorite

A large, granitic batholith cuts off the greenstone belt on the west. Only the eastern margin of this batholith lies within the mapped area and this part is mainly granodiorite. To the west, away from the contact with the greenstone and beyond the limits of the map-area, the high soda to potash ratio that characterizes the granodiorite of the contact zone decreases gradually and the granodiorite grades into granite with a much higher potash to soda ratio (Boyle, 1961, p. 71).

Two small stocks, which were probably emplaced about the same time as the main batholith, lie within the greenstone belt; the larger underlies Stock Lake and the smaller is to the northeast of Pud Lake. A third small body, which does not reach the surface, has been found at the 900-foot level of the Con mine about 1,000 feet west of the Negus shaft.

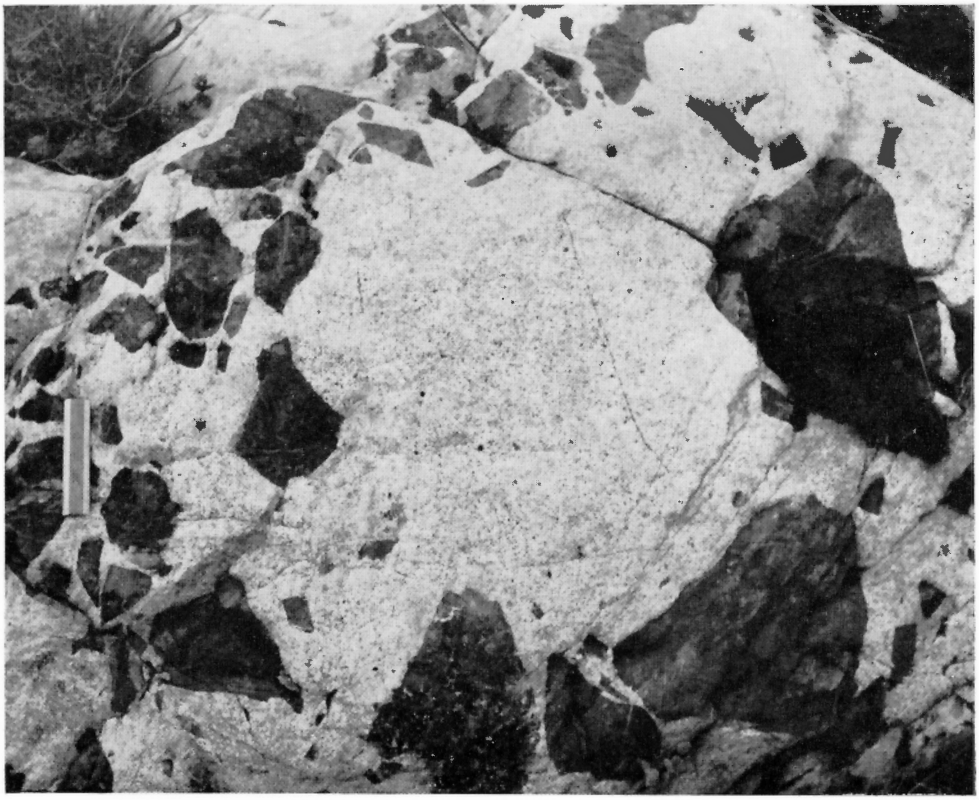
The typical granodiorite is a fresh, massive, structureless rock, light grey to reddish on freshly broken surfaces and weathering white to reddish. The grain size ranges from one-tenth to one-quarter inch and the rock is locally porphyritic, with feldspar phenocrysts up to three-eighths inch long. Microscopic examination shows the granodiorite to be composed of 20 to 25 per cent quartz, 40 to 50 per cent plagioclase, 10 to 15 per cent microcline, and 3 to 10 per cent biotite or biotite and hornblende. The composition of the plagioclase ranges from oligoclase to andesine, with most of it about An_{30}. Many of the crystals are zoned and the centres are cloudy with secondary white mica. The phenocrysts, where present, consist of plagioclase of the same composition as those of the groundmass. The potash feldspar is mainly microcline and microcline-perthite. The biotite varies from dark brown to green and much of it is altered to chlorite; some colourless mica, probably muscovite, is intimately associated with the biotite. Accessory minerals include epidote, sphene, apatite, and zircon.

Fine-grained aplite dykes and irregular masses, from a few inches to 15 feet or more wide, are fairly numerous, particularly near the greenstone contact. They cannot be traced far, nor do they appear to form a pattern of any sort. Pegmatites are rare, although the centres of some aplitic bodies are coarse grained.

The Stock Lake granodiorite is similar to the main batholith in both texture and composition. The Pud Lake granodiorite is much finer grained and less fresh in appearance. Under the microscope it is found to have almost the same composition, but the blocky oligoclase crystals and biotite are much more highly altered, the oligoclase to colourless mica and the biotite to chlorite.

Contacts between the granodioritic rocks and the greenstones are everywhere sharp, and no change in grain size or in the composition of the granodiorite is noticeable. In detail the contacts in most places are irregular, the granite sending off dykes and apophyses into the greenstones. This is particularly well illustrated southwest of Stock Lake, where a protuberance of the greenstone, into the granodiorite extending beyond the mapped area, is ribboned by dykes and small irregular bodies of granodiorite. Inclusions of greenstone (flow, dyke and sill rocks) are locally abundant in the normal granodiorite, particularly west of Frame Lake and extending to the border of the area. They range in size from fragments a few square inches to blocks hundreds of feet wide. For the most part, the inclusions are angular with knife-edged contacts with the surrounding granodiorite (Pl. XIII) and they show no evidence of assimilation by, or reaction with, the granodiorite. Many other inclusions are ribboned with granite dykes and stringers (Pl. XIV). Granodiorite, containing many greenstone inclusions, occurs also in the vicinity of the small area of greenstones northwest of David Lake, on the west side of the West Bay fault (north half).

In mapping mixtures of granodiorite and greenstones, arbitrary divisions were made. Where inclusions form less than 10 per cent of the rock it was mapped as granodiorite; where they form 10 to 50 per cent the rock was mapped as granodiorite with inclusions; and where more than 50 per cent of the rock is greenstone it was mapped as greenstone with much granodiorite. Rocks of the last type are particularly well developed in the greenstone protuberance in the granodiorite southwest of Stock Lake, in the small area of greenstone on the west side of the West Bay fault northwest of David Lake, and in the greenstones along and near the west side of the Stock Lake granodiorite. Near the western margin of



J.F.H. 4-12-47

PLATE XIII. Greenstone inclusions in granodiorite west of Kam Lake.

J.F.H. 4-15-47

PLATE XIV. Large greenstone inclusion in granodiorite, ribboned with granodioritic material, ½ mile west of granodiorite contact, Kam Lake.

the Stock Lake granodiorite the greenstones have been fractured and the granodiorite emplaced along the fractures to form a breccia of angular, dislocated blocks of greenstone, ranging from a few inches to many feet in size, with the granodiorite filling the interstices between them. Although the granodiorite is thus intimately mixed with the greenstone and makes up as much as 30 per cent of the whole rock, there is little evidence of reaction of any kind between them. Another interesting illustration of a similar phenomenon may be seen in two small areas along each of the northern shores of the two lobes of Pud Lake. There the breccia is composed of closely packed, dislocated, angular fragments of greenstone, and the interstitial material, which makes up not more than 10 per cent of the rock, is a fine-grained aplitic phase of the granodiorite. These breccias are developed near the Pud Lake granodiorite which outcrops along the northeast shore of the lake and could mark the top or border phase of two granodiorite bodies that may underlie the two lobes of Pud Lake.

In only two areas is there evidence of reaction or assimilation of the greenstone by the granodiorite. Along the southwest shore of the small lake 3,000 feet west of Frame Lake (south half), a coarse-grained, mottled rock is exposed over an area of less than 1,000 square feet. It is composed of 50 to 60 per cent feldspar, 30 to 40 per cent black hornblende in crystals up to 1 inch in length, and 5 to 10 per cent quartz. It contains numerous subangular to rounded fragments of greenstone up to 3 inches in diameter (Pl. XV). The dark greenstone fragments are enclosed by a light coloured, fine-grained envelope or corona of feldspar and hornblende, one-quarter to one-half inch thick. Many of the inclusions seemed to have been completely transformed into large hornblende crystals; others are in various stages of transformation. This isolated body of hybrid rock is cut by the normal granodiorite in which it lies and also occurs as scattered inclusions in it.

J.F.H. 4-7-47

PLATE XV. Hybrid rock formed by reaction or assimilation of greenstone (dark, subangular to rounded fragments) and granodiorite.

A somewhat similar hybrid rock outcrops south of the large bay on the east shore of Ryan Lake (north half). It is a medium-grained, green-grey to pinkish weathering rock with white weathering feldspar phenocrysts up to one-quarter inch in size scattered through it. The groundmass is composed of 50 per cent feldspar and 50 per cent dark green to black hornblende and it contains inclusions of greenstone in various stages of assimilation. However, the contact with the main greenstone belt is sharp, with dykes and apophyses of the hybrid rock cutting the greenstones with clean-cut, sharp contacts. The normal granodiorite, in turn, has well defined intrusive relations with the hybrid rock.

Boyle (1961, p. 72) has shown by chemical analyses of samples of greenstone (amphibolite), the hybrid granite (granitized amphibolite), the normal granodiorite (grey granite), and the granite 2 miles west of the greenstone belt, that in this sequence there is an increase in the content of silica and alkalis, a marked decrease in aluminum, calcium, iron, magnesium, and manganese, a constant decrease of water, and, in the final stages, a decrease of carbon dioxide and sulphur. The development of this sequence of rocks is considered by Boyle to be the result of granitization and transformation of the greenstone to granite.

Boyle (1961, p. 74) considered

> . . . that the western granite was formed principally by granitization of a great thickness of sediments that lay stratigraphically below the greenstones. As the metasomatic granite developed, the sediments were engulfed and the granitic material partly mobilized. When the lavas (greenstones) were reached the process came to a halt because of the contrasting chemical environment, and only a limited amount of granitization of the lavas took place. This explains the development of a basic phase in the granitic mass at its contact with greenstones as well as the local areas of granitization in the greenstones.

Whether or not the batholith as a whole is of ultrametamorphic (metasomatic) origin as postulated by Boyle, it seems clear that the granodiorite border phase, including the hybrid material, was once mobile and, in relation to the greenstones, behaved as a magma. That it was mobile and capable of intrusion is clearly indicated by the clean-cut contacts of the granodiorite with the greenstone, the numerous dykes and apophyses of granodiorite that cut the greenstone, and the many dislocated and isolated inclusions of greenstone in the normal granodiorite that show little or no evidence of reaction with it.

Diabase Gabbro

The late diabase dykes form two sets, one, which is by far the more numerous, striking northwest, and the other northeast; both dip at steep to vertical angles. The dykes range in width from a few inches to a maximum of 350 feet. The larger dykes, and many of the narrower ones, are remarkably persistent for long distances and, because they are displaced by the late faults, they are useful in estimating the movement along the faults (Fig. 8). Thus, two parallel northeasterly striking dykes (Dykes A and B, Fig. 8), about 1,800 feet apart, can be traced northeast from Stock Lake to the West Bay fault; picked up again on the east side of the fault some 4 miles to the north, followed north along strike across numerous small faults to the Akaitcho fault; picked up again about half a mile to the northwest on the northeast side of the Akaitcho fault, and traced from there north to Ryan Lake. A rather narrow northeasterly trending dyke outcropping on Kam Point (Dyke D, Fig. 8) is displaced northwest by the Kam and Pud faults before being displaced near Negus Point by the West Bay fault. It continues on the east side of the West Bay fault some 3 miles to the north along the shore of Yellowknife Bay south of Fault Lake. The dyke can be followed to the northeast near the shore where it is displaced by the two branches of the Townsite fault and finally is hidden by the waters of

Yellowknife Bay before reaching the Akaitcho fault. A large diabase dyke (Dyke C) has been traced from Frame Lake southeast through the Con and Rycon Mines properties to the shore of Yellowknife Bay half a mile north of Negus Point where it is displaced north more than 3 miles by the West Bay fault to emerge on the east side of the fault at the north end of Fault Lake. It was these two dykes, inclined to the West Bay fault and to each other, that Campbell (1948) used to calculate the horizontal and vertical components of movement along the West Bay fault.

The dykes are medium- to fine-grained rocks that weather a characteristic rusty brown and are mottled grey to greenish grey on freshly broken surfaces. They are composed of about equal parts of grey plagioclase and dark green pyroxene, and most of them, particularly the finer grained ones, carry lath-shaped feldspar crystals, which give the rock an ophitic texture. A few dykes contain feldspar phenocrysts that weather yellowish green. The dykes have fine-grained, chilled margins against the wall-rocks. The wall-rocks in contact with the dykes are but little altered. They may be baked to a rusty red for a few inches or feet from the contact but even the large 350-foot dyke southwest of Gar Lake has reddened the granite for less than 30 feet from its margin. Most of the dykes weather more rapidly than the intruded rock and so are marked by narrow, steep-walled, muskeg-filled trenches. A plaster of chilled dyke rock can generally be found along the walls of these trenches. In general, the late dykes can be readily distinguished from the early meta-gabbro and meta-diorite dykes by their characteristic reddish brown weathered surface and the comparatively unaltered appearance of their constituent minerals on fresh fracture. Under the microscope the late dykes are seen to be composed of plagioclase feldspar and pyroxene (augite), with minor amounts of chlorite, epidote, colourless mica, hornblende, biotite, carbonate, apatite, pyrite, and magnetite or ilmenite. The plagioclase crystals are commonly zoned, and may range in composition in a single thin section from labradorite to andesine. They are partly altered to white mica and epidote, and the pyroxene to chlorite, epidote, uralitic hornblende, and minor amounts of serpentine. A little micro-pegmatitic intergrowth of quartz and feldspar commonly fills the interstices between the larger lath-shaped plagioclase crystals.

Boyle (1961, p. 77) gave a chemical analysis of a composite sample of the dykes in the area, and compared it with that of an average gabbro. The analyses showed that the diabase is similar in composition to the average gabbro but has a somewhat higher water content, which Boyle suggested was derived by diffusion from the enclosing greenstones, a conclusion "substantiated by the observation that serpentinization is often more marked in diabase dykes cutting the water rich sediments and green schist facies than where they cut the water poor granites or amphibolites".

The late diabase dykes are the youngest known rocks in the greenstone belt, and because similar dykes cut late Proterozoic sandstones in areas bordering the east arm of Great Slave Lake, they are believed to be of late Proterozoic age. The dykes are not displaced by faults of the early, shear zone type, which were formed prior to their intrusion. Many examples of late dykes cutting early shear zone faults may be seen in the area. One of the best is near the shore of Yellowknife Bay half a mile northwest of Latham Island, where the more southerly of two large diabase dykes (Dyke D, Fig. 8) crosses a wide shear zone. The large dyke splits at the shear zone into dozens of dykelets from a few inches to several feet wide, each of which is chilled against the schist of the shear zone.

The diabase dykes are offset by late faults, such as the West Bay fault. So far as known, the late faults displace the diabase dykes by the same amount as they do the rocks of the Yellowknife Group, indicating little if any pre-diabase movement along these faults.

Evidence as to the age relations between northwesterly and northeasterly sets of dykes is conflicting. Where two dykes intersect, the area of intersection is generally in a muskeg-filled depression where the crosscutting relations cannot be observed. In three of the four exposed intersections seen, the northeasterly trending dykes cut those striking northwesterly, but the fourth shows the reverse relationship. Detailed petrographic studies (Wilson, 1949) of the two sets of dykes have revealed no outstanding differences between them. This, together with conflicting age relationships, suggests that they are derived from the same source and are essentially contemporaneous.[1]

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[1] Recent potassium–argon dating of the dykes indicates that the dyke sets are widely separated in age and were intruded during three periods of basaltic magmatism: 2,200, 1,500, and 1,000 million years ago. *See* Potassium–argon dates of diabase dyke systems, District of Mackenzie, N.W.T.; R. A. Burwash, H. Baadsgaard, F. A. Campbell, G. L. Cumming, and R. E. Folinsbee, Canadian Institute Mining and Metallurgy, Transactions, Volume LXVI, 1963, pp. 303–307, and Potassium–argon dates of basic intrusive rocks of District of Mackenzie, N.W.T.; Alice Payne Leech, Canadian Journal of Earth Sciences, Volume 3, 1966, pp. 389–412.

Chapter III

STRUCTURAL GEOLOGY

The lava flows and interbedded fragmental rocks of Division A of the Yellowknife Group strike northeast and dip southeast at steep to vertical angles. Locally, as in areas near and to the northwest of the Giant B shaft and southwest of Negus Point, they dip steeply at 70 to 80°NW. Many reliable determinations of the tops of flows and tuff beds indicate that the steeply inclined strata, regardless of their dip, face southeast throughout the belt with progressively younger beds from northwest to southeast.

The whole belt is much faulted. The faults may be divided into two types: (a) pre-diabase and (b) post-diabase faults. Most of the early pre-diabase faults are of the shear zone type, with chlorite schist or chlorite–sericite schist developed along them in widths ranging from a few inches in the smaller shear zones to several hundred feet in the larger (Pl. XVI). The post-diabase faults, on the other hand, are clean-cut, narrow fractures (Pl. XVII) along which the wall rocks are brecciated and a clay-like gouge may occur, but no schist has been formed. Most faults can be readily recognized as early or late on the basis of their physical character. However, the pre-diabase faults are of several ages, and some of the younger ones resemble more closely the post-diabase faults than those of the early, shear zone type. These are difficult to classify as pre- or post-diabase unless their relations to the diabase are observed. For example, the Negus fault displaces several gold-bearing shear zones and a diabase dyke and is, therefore, included with the late faults. However it in turn is displaced by several late faults of the West Bay fault system. Were its relation to the diabase not known it would be difficult to classify although its physical structure (a clean-cut fracture filled with gouge) is characteristic of the late faults.

Many small pre-diabase shear zone faults or systems of faults strike parallel with the lava flows; they commonly lie along tuff beds. Included in this group are the Ranney–Crestaurum shear zone system (Ranney tuffs), A.E.S. system (Cemetery tuffs), and the Kam Point system (Fig. 8). The larger shear zone faults or systems, on the other hand, strike north to northeast and transect the flows, in general dipping westerly at angles ranging from 60 to 45 degrees or less. Included in this group are the Con, Negus–Rycon, Giant–Campbell, Bow Lake, Stock Lake, and Handle Lake systems. In addition to the shear zones of the main systems, many narrow shear zones are localized along the borders of meta-gabbro and meta-diorite dykes, with which they conform in dip and strike.

I.C.B. 2-2-48

PLATE XVI

Early shear zone, Giant Yellowknife Mines Limited.

In general, with the possible exception of the Giant–Campbell system, the horizontal component of movement along the shear zones seems small, and surface mapping by the writers has yielded little information about the vertical component. However, Campbell (1947b) found that in several of the transecting shear zones where he was able to make determinations, the shift has been mainly vertical rather than horizontal with the west side moving up and south.

The gold deposits of the belt are developed along the early, shear zone faults. They may be divided into two closely related types: (a) well defined quartz veins introduced along narrow shear zones, such as occur along the Negus–Rycon system, and (b) large lenticular masses of highly mineralized sericite schist with vein and replacement quartz that occur along great shear zones or systems of shear zones up to several hundred feet wide. Included in the latter type are the large orebodies along the Con, Giant, and Campbell shear zone systems.

The major post-diabase faults strike between north and northwest and dip steeply west to vertically; of these, the West Bay and Akaitcho faults are the largest, the others being subsidiary to them. They are transcurrent or tear faults with a predominantly horizontal component of movement that is measurable in miles. The movement along them is 'left hand'; that is, the east side has moved north relative to the west side. Within the wedge-shaped block between the West Bay and Akaitcho faults the strike of the flows ranges from N45°E near the shore of Yellowknife Bay to a few degrees west of north, north of Trapper Lake. The change in strike was probably caused by the rotational effect on the fault block by the movement along the West Bay and Akaitcho faults.

The interpretation of the structure in such a complex area is dependent in large part on correct correlation across faults. Throughout this report repeated reference is made to particular distinctive structural markers used in such correlations. Such markers may be dykes (both early and late), distinctive flows, tuff beds, sills, and, in the case of the late faults, early shear zones. In general, the correlation of individual structural markers can be substantiated by comparison of the succession of flows, dykes, sills, etc. on either side of the fault.

PLATE XVII

Late post-diabase fault, shore of Yellowknife Bay between Negus Point and the Pud fault.

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Pre-Diabase Shear Zones

The shear zones, and the gold orebodies associated with them, have been described in detail by Boyle. The summary description that follows is taken in large part from Boyle's work (1961, pp. 12–38).

The shear zones of the greenstone belt fall into two structural categories: (1) those that parallel the volcanic flows and tuff beds and (2) those that transect them. The shear zones that parallel the flows and tuffs are narrow and discontinuous and, with a possible exception, the ones so far explored contain only small, uneconomic gold orebodies. The larger of the shear zones that cross the flows are major structures hundreds of feet wide that extend for miles. The major gold-bearing quartz bodies of the greenstone belt are developed along them.

Internal Structure of the Shear Zones

The shear zones range in physical character from those that may be described as breccia shear zones to the much more common schist zones. Gradations from one type to the other are common. Boyle (1961, p. 14) has described them as follows:

> The breccia shear zones (which are best developed in the Negus–Rycon and Con systems) are marked by a zone of rock broken into spindle-shaped fragments locally cemented by carbonate minerals. The fragments are rarely greater than six inches in any dimension, and the majority are about the size of brazil nuts which they simulate in shape.
>
> The fragments in the ideal breccia shear zones are massive to slightly schistose in character and seldom exhibit the marked schistosity or extreme alteration of the rock composing the schist zones. Where quartz lenses occur in this type of shear zone a buff-coloured, dense, dyke-like alteration zone is present in which the outlines of the original breccia fragments can be discerned upon close examination.
>
> The schist zones are marked by linear zones of highly schistose rock which cleaves along an infinite number of parallel planes owing to the extreme lineation and parallel orientation of chlorite and sericite. The zones are especially common in the ore localities of the Con and Negus–Rycon systems and are the principal feature of the Giant–Campbell shear zone system. The shear zones which parallel the volcanic flows are also predominantly of a schistose nature. In nearly all cases the dips, and in some cases the strikes of the schist planes intersect the walls of the shear zones at a small angle.
>
> Many of the transecting shear zone systems show a gradation from the breccia shear zones to schist zones. This feature is especially common in the Negus–Rycon system where the gradation can be traced with some degree of confidence. In some of these shear zones the ideal breccia zones grade imperceptibly to schist zones both along the strike and in some cases down the dip. In the transition from the breccia type zones to the schist zones the fragments of the breccia become elongated and flattened, alteration increases concomitantly, and the fractures separating the fragments are partly or completely obliterated. The end result is a well developed schist in which traces of the primary fragmentation may appear, but in general no hint of the original breccia remains. This transition from breccia to schist can be seen in many schist zones, but in others no such genetic origin for the schist zones can be evoked. The internal features of the schist zones paralleling the flows, and those of the Giant–Campbell and portions of the Con systems, suggest that extensive brecciation was not a major factor in their development.

Boyle considered that breccia shear zones are developed in shear zones transecting the flows at a large angle, e.g. the Negus–Rycon system. In such zones alteration of the breccia fragments and the transition to schist is not marked except where quartz lenses are developed. In contrast, along the Giant–Campbell system which crosses the flows at a much smaller angle, and the Ranney–Crestaurum system which parallels the flows, schist zones rather than breccia zones are developed. In these, there is no evidence that breccia ever developed along them.

The schist zones grade from highly schistose rock along their central parts to the essentially massive unsheared country rock; in mapping, an entirely arbitrary boundary must be set between the two. On the maps accompanying this report, the schist zones are shown to comprise rocks with sufficient schistosity to break along roughly parallel planes, as opposed to the more massive country rocks which have a more irregular fracture.

Shear Zones that Parallel the Flows

Many minor, early shear zones are parallel in strike and dip with the lava flows and tuff bands. In general, such shear zones are localized along tuff bands or flow contacts. Some contain small, gold-bearing quartz lenses but, with the exception of the orebodies of Crestaurum Mines Limited, none has so far proved to contain orebodies of commercial size.

There are three main systems of parallel shear zones (Fig. 8): (1) the Kam Point system, (2) the A.E.S. system, and (3) the Ranney system.

The *Kam Point shear zones* are developed in a number of tuffaceous beds interbedded with the flows along and near the base of the Kam sill. They are displaced northeast by the Kam fault and their extension along strike to the northeast is obscured by the waters of Yellowknife Bay. The schist zones are marked by dragged and contorted areas containing gold-bearing quartz lenses and veins, which seem to form where there is a slight change in the strike and dip of the zones. As yet no orebodies of economic size have been found in any of them.

The *A.E.S. shear zone* system has developed along a series of tuffaceous beds, known as the Cemetery tuffs, which underlie the prominent valley between the southeast end of Stock Lake and Yellowknife Bay. The tuff and contained shear zones have been faulted into three main segments by the West Bay and Akaitcho faults. On the east side of the West Bay fault, the shear zone outcrops northeast of Gar Lake, where it is highly schistose with contorted zones that contain small, high grade, gold-bearing quartz veins and lenses. A detailed description of this part of the structure is given by Jolliffe (1938, pp. 16–17). The tuff and associated shear zones probably underlie the drift-filled valley that extends north from Trapper Lake to the Akaitcho fault. On the northeast side of the Akaitcho fault, the faulted extension of the A.E.S. shear zone underlies the long depression occupied in part by Rater Lake and extending northeast to the northern boundary of the area.

The *Ranney shear zone* system has developed along the Ranney tuff which outcrops on the west side of the West Bay fault west of Giant A shaft. It has been displaced north by the West Bay fault to David Lake where it outcrops at the north end of the lake and contains quartz lenses with pyrite and some gold (Boyle, 1961, p. 16). North of David Lake it is displaced some 3,000 feet northwest by the Akaitcho fault and has been traced northeast from the fault to Daigle Lake.

Most of the parallel shear zones contain, in places, quartz lenses with some sulphides and gold. Most of the mineralized zones seem to be present where the schist has been highly dragged and contorted, particularly at gentle flexures in strike and dip of the tuffs and at schist zone junctions. However, in some places quartz stringers and lenses have developed in schist zones that are but little contorted; indeed they seem to have no relation to any internal structural feature of the schist zones. These lenses may have formed in dilatant zones localized by flexures in the walls of the shear zones.

The parallel shear zones clearly cut and offset early meta-gabbro and meta-diorite dykes. None are known to offset the late diabase dykes. Evidence bearing on the age relations of the parallel shear zones to the granodiorite was not observed. Some of the parallel shear zones are offset by the transecting shear zones; all are offset by the late faults. The parallel shear zones may be the result of shearing along incompetent structural features and beds during the initial folding of the greenstone belt, but more probably they formed during the development of the extensive, transecting shear zone systems.

Shear Zones that Cross the Flows

The systems of early shear zones that cross the flows are much larger and more important economically than those that parallel the flows. Included in this group (Fig. 8) are the Con and the nearly parallel Campbell systems, both of which strike about N30°E, and the Negus–Rycon "cross-over" system of narrow shear zones, which lies between the first two and strikes about N15°W. Three miles to the north on the east side of the West Bay fault, the Giant system is the faulted extension of the Campbell system; it strikes N10°E to the Akaitcho fault. The faulted extension of the Giant system on the northeast side of the Akaitcho fault is marked by the drift-filled valley extending northeast from the fault to and along the northwest arm of Vee Lake and beyond to Jackson Lake. The Giant–Campbell system is the major structure of the area to which all the other cross shear zone systems are subsidiary. It has been traced for more than 15 miles from Kam Point near the southeast boundary to Jackson Lake at the northeast boundary of the area.

The Bow Lake system has been traced from the shore of Yellowknife Bay south of Bow Lake, north through the lake, and thence north-northwest as several narrow shear zones to the point where it joins the Giant system, south of the Akaitcho fault. The Stock and Handle Lakes systems are small, north to northeasterly striking systems, lying to the northwest of Stock Lake and east of Handle Lake.

The cross shear zone systems were probably all formed at about the same time by the same diastrophic forces.

Con System

The Con shear zone system has been traced by diamond drilling and underground work throughout the length of Rat Lake and southwest to the Pud fault (south half). From there the structure has been traced southwest along the southeast end of Pud Lake and beyond to the Kam fault, where it is again displaced to the southeast some 1,000 to 1,500 feet. Surface mapping indicates that the faulted extension of the Con system lies beneath a drift-filled valley at the northeast end of Keg Lake, and that it continues to the southwest beneath the west arm of this lake. A drift-filled valley extending southwest from the southwest end of Keg Lake probably marks further extension of the zone. To the northeast of Rat Lake the main zone splits into two or more zones and is eventually cut off by the West Bay fault. Some 3 miles to the north, on the east side of the West Bay fault, the faulted extension of the Con system probably joins the Giant–Campbell system and may be represented by the most westerly of the shear zones on the Giant Property (north half).

Southwest of the Pud fault the Con system (south half) is a single shear zone dipping 65 to 75°W. No orebodies have been found in this part of the system. Northeast of the Pud fault, several minor shear zones split off to the north from the main shear zone (C-4). The minor zones (the shaft subsystem) are narrow but well defined breccia shear zones that dip at 65°W, and contain small, high grade, gold quartz lenses, mineralized with pyrite, arsenopyrite, stibinite, chalcopyrite, sphalerite, sulphosalts, galena, and gold. The ore shoots seem to have formed at flexures in, and at junctions of, intersecting zones.

At the surface southwest of Rat Lake, the shear zone system consists of 3 shear zones striking N30°E and dipping to 60 to 65 degrees northwest. Two of these zones (C_4 and C_{31}), each less than 10 feet wide, are separated by about 50 feet of massive pillowed lava. The third zone (C-34), about 40 feet wide, outcrops beneath a drift-filled draw 100 feet to the east. At about the 500-foot level of the Con Mine the three zones merge to form the main C-4 schist zone which is more than 100 feet wide. Below the 500-foot level, the zone again splits around another horse of unsheared rock and the dip flattens from 60 to 45 degrees. In plan or horizontal section the same branching of the shear zones about horses of unsheared rock is apparent (Boyle, 1961, p. 18). Some horses are nearly 200 feet wide and the shear zones are wrapped around them to give, in places, a total width of several hundred feet for the system of zones, although the average width is about 50 feet. The orebodies are quartz lenses, pods, and replacement bodies mineralized with pyrite, arsenopyrite, stibnite, chalcopyrite, sphalerite, sulphosalts, galena, and gold. They formed around the noses of large unsheared horses of country rock at the points where the schist has been highly dragged, mashed, and contorted, or at flexures in the zones.

The zones of contorted schist containing the orebodies plunge south along the noses of the horses of unsheared rock, as do the minor structural features in the schist, such as drag-folds, boudinage structures, pods, and crenulations. Some of the smaller ore shoots have formed in drag-folds and crenulated zones in the schist, which are apparently caused by flexures in strike and dip of the zones. The main orebodies are in the wide bulbous part of the shear zone system, which encloses several horses of unsheared rock and thus forms many shear zone junctions, where intense dragging and contortion of the schist has set up conditions favourable for the formation of ore.

The average strike of the system is N8°E and the average dip is 53°W. Based on 1,813 determinations the average strike of the schistosity in the Con system is N9°E and the average dip is 63°W. Thus, the schist is essentially parallel with the walls but dips 10° more steeply than the zone.

Campbell (1949) concluded that the Con system was formed by a thrust fault with the west side, or hanging-wall, moving about 1,000 feet up and a little south relative to the foot-wall. The Con system formed at the same time and is subsidiary to the much larger Giant–Campbell shear zone system.

Negus–Rycon System

The Negus–Rycon shear zone system (south half) consists of several narrow shear zones that have been traced south from near the north end of Rat Lake where they join the Con system to the Negus fault, by which they are offset more than 1,000 feet northeast. On the south side of the Negus fault the system has been traced south to the shore of Yellowknife Bay, just west of Negus Point. The shear zones of the system strike N10 to 25°W and dip 45 to 65°W. The Negus–Rycon shear zone system links the subsidiary Con system on the north with the main Giant–Campbell system on the south, and thus is a 'cross-over' system of smaller zones between the two principal ones.

The average width of the shear zones of the Negus–Rycon system is less than 5 feet, but in places some range up to 27 feet. The shear zones contain both brecciated and schistose sections. They occur along the borders of meta-gabbro and meta-diorite dykes with which they conform in strike and dip. Displacement along the shear zones is probably not great. North of the Negus shaft the N-2 and N-3 shear zones displace quartz feldspar porphyry dykes a few feet horizontally and a small amount vertically, the west side moving up a few feet relative to the east side. East of Rat Lake the N-15 and R-53 shear zones offset an early basic dyke for a strike separation of some 600 feet. The dyke appears to dip rather gently at 35 to 45°W. The net slip is not known but the main component of movement is probably vertical with the hanging-wall moving up. The Negus–Rycon shear zone system was probably formed by thrust movements generated by the same forces that produced the Giant–Campbell and Con shear zone systems.

The ore deposits in the Negus–Rycon shear zone system (Boyle, 1961, p. 19) have been mined out; most of them were between the Rycon shaft and the Negus fault. The orebodies were developed along the shear zones as well defined quartz veins and replacement lenses. The veins were discontinuous and up to 400 feet in length, with an average width of about 2½ feet and a maximum width of about 12 feet. Not all the quartz was of ore grade. The veins contained a wide variety of metallic minerals including, in addition to gold, arsenopyrite, pyrite, stibnite, chalcopyrite, various sulphosalts, sphalerite, and galena.

As in the Con shear zone system the orebodies seem to have formed at junctions of shear zones and along flexures where the contortion and mashing of the schist was most intense. The northern part of the system east of Rat Lake contains no ore shoots although some mineralized sections are present. The absence of ore may be due to the lack of shear zone junctions and flexures in this part of the system.

Giant–Campbell System

The large, ore bearing shear zones that constitute the Giant system extend from the West Bay fault at Fault Lake north and northeast for almost 4 miles, following the largely drift-filled valley marked by Baker Creek, and on to the Akaitcho fault. On the northeast side of the Akaitcho fault the faulted extension of the Giant system lies along a drift-filled valley extending northeast from the fault to and along the northwest arm of Vee Lake and beyond to the unconformity at Jackson Lake. Branches extend through Gold Lake and along the east arm of Vee Lake.

In the hope of finding the faulted extension of the Giant system on the west side of the West Bay fault, Campbell (1949) determined the horizontal and vertical components of movement or net slip along the fault. He calculated that the faulted extension of the Giant system would emerge at the surface west of the West Bay fault, beneath the waters of Yellowknife Bay at Negus Point, more than 3 miles to the south, and that its westerly dip would carry it beneath the Negus and Con mines holdings. Subsequent diamond drilling and underground development have confirmed this conclusion and an ore bearing, shear zone system several hundred feet wide has been explored underground on the two properties. The shear zones on the west side of the West Bay fault, which are believed to be the faulted extension of the Giant system, have been called the Campbell zone or system. Thus Giant and Campbell systems were once a continuous system that has been displaced into two segments by the West Bay fault. It has been called the Giant–Campbell shear zone system.

The Giant–Campbell system has been described and discussed in several publications. The ore bearing parts of the Giant section of the system have been described by Dadson and Bateman (1948), Dadson (1949), Brown and Dadson (1953), and Brown, Dadson, and Wrigglesworth (1959). Campbell (1949) has described the Campbell part of the system, and the system as a whole has been described and discussed by the writers (1952). Boyle (1954a, 1954b, 1955, 1961, p. 21) has dealt in detail with both the broad aspects of the system and the structural control and origin of the ore shoots.

Campbell System

The Campbell system reaches the land surface beneath the waters of Yellowknife Bay southeast of Negus Point. Southwest from Negus Point, it has been traced by diamond drilling for more than 2½ miles across the Pud, Kam, and other late faults to beyond Kam Point. It maintains a strike of about N25°E and probably dips 45 to 55°W; its emergence is entirely beneath the waters of the bay. Over this distance the Campbell system remains a major structure consisting apparently of several, interlacing, chlorite schist zones aggregating several hundred feet in width. The schist of these zones is locally carbonated, sericitized, silicified, and mineralized with pyrite and other sulphides. Several widely spaced diamond drill holes have intersected material of ore grade in this part of the Campbell system.

Southwest of Kam Point (south half) the rocky islands are massive greenstones; along the shores of several of these islands the greenstone is highly schistose. This suggests that the channels between the islands are underlain by schist and that the islands may be horses of massive rock within the southwestward extension of the Campbell shear zone system.

North of Negus Point, the Campbell system is cut off by the West Bay fault and does not reach the surface, but it has been explored in the underground workings of the Con and Negus mines for more than 6,000 feet along strike. The system on the Negus property, as explored in the underground workings at the 1,775-foot level, is made up of two schist zones about 400 and 100 feet in width, which are separated by 200 feet of weakly schistose rock (Boyle, 1961, p. 21). Along strike farther north on the 2,300-foot level of the Con property, the system is 600 to 1,200 feet wide and made up of several schist zones separated by horses of weakly schistose rock. As in the Negus, it is cut off to the east by the West Bay fault.

The Campbell system is thus a complex of interlacing schist zones between horses of weakly schistose rock. Although on a much larger scale, it seems in most respects similar in character to the more thoroughly explored subsidiary Con shear zone system to the west.

Underground in the Con and Negus mines, the Campbell system strikes about N3°E and dips 47°W. Based on 695 measurements, the average strike of the schistosity was found to be N6°E, and the average dip 63°W. The steeper dip and more easterly strike of the schistosity in relation to the dip and strike of the shear zone system suggests that the west side moved up and south. However, no correlation of stratigraphic units across the system has been possible to verify this.

As in the Con shear zone system the orebodies in the Campbell system seem to have formed in dragged and contorted parts of the schist zones. These in turn were formed by flexures in the walls of the schist zones and by the buttress action of the large horses of massive rock in the schist. The drag-folded, highly contorted schist zones so formed were dilatant zones in which silicification, sericitization, and mineralization took place (Boyle, 1961, p. 22). The orebodies so formed are large, lenticular sericitic zones in the chlorite schist of the schist zones. These sericitic zones are ribboned with irregular quartz lenses and stringers and mineralized with pyrite, arsenopyrite, sulphosalts, and gold. In general the mineralized zones and ore shoots parallel the hanging-wall of the Campbell system with little or no plunge.

Quartz carbonate lenses and pods in the ore shoots are roughly parallel with the strike of the schistosity but tend to dip more steeply. The plunge of the axes of small drag-folds and crenulations is nearly horizontal in most places.

Giant System

The Giant system, which is the faulted extension of the Campbell system, emerges on the east side of the West Bay fault at Fault Lake. It strikes northeast through the Giant and Akaitcho properties to the Akaitcho fault (north half). There it is faulted northwest along this fault to Gold Lake, from whence it has been traced northeast through the northwest arm of Vee Lake to Jackson Lake.

In surface plan the system forms a pattern of parallel, subparallel, and branching schist zones separated by quantities of massive to weakly schistose rock. There is a marked tendency for the schist zones along the eastern boundary of the system to branch out into the wall rocks and there weaken and die out.

The wide schist zones are relatively soft and easily weathered. Consequently their surface outcrops lie along drift-filled valleys. In contrast the massive to weakly schistose bodies of rock between the interlacing schist zones are relatively resistant and stand up to form areas of outcrop. This is particularly well shown on the Giant property where the trace of the schist zones at the surface can be projected with assurance from the underground workings and diamond-drill data of Giant Yellowknife mines.

The schist zones are greenstones composed of chlorite, chlorite–carbonate, and sericite–chlorite–carbonate minerals and are characterized by marked schistosity. The rock from these zones splits along an infinite number of parallel schist planes and, when examined in thin section, is seen to consist of chlorite, albite, carbonate, quartz, and sericite, with a strong foliation. On the other hand the greenstone country rocks and the bodies or horses of rock within the shear zone system are massive and non-schistose or only weakly schistose. In thin section they are seen to be composed of epidote, carbonate, fibrous amphibole, chlorite, and plagioclase with no pronounced foliation. Original features such as pillows, dyke contacts, tuff bands, etc., can be distinguished in the massive rocks but have been obliterated in the schist zones. Contacts between schistose zones and massive rock are gradational over many feet.

At the north end of Fault Lake (north half), the Cameron zone and South zones form one large chlorite schist zone which in plan splits around a nose of massive rock to form an eastern branch called the East zone. The western branch of the Cameron zone and the South zone continues north to join the West and Creek zones which appear to dip west. The East zone, which dips 55°W, probably joins the Creek zone at depth. All these zones contain mineralized sections and orebodies. In plan the West and Creek zones contain several, large, elongated masses or horses of unsheared rock, and the zones together have a surface width of more than 700 feet. The system is faulted northwest by the Townsite fault. On the northeast side of the Townsite fault the extension of the East zone apparently strikes into the east wall of the system and dies out. The A.S.D. zone, dipping almost vertically to steeply east, is probably the extension of the Creek zone, and the Big Giant, Ole, and W.J.T. zones, which form a single complex schist zone with a steep, westerly dipping hanging-wall, are probably the extension of the West zone. This steep, westerly dipping hanging-wall may correspond to the hanging-wall of the Campbell system on the west side of the West Bay fault, 3 miles to the south.

South of Giant B shaft the nearly vertical to easterly dipping A.S.D. zone is joined, just below the surface, by a flat, westerly dipping schist zone known as the H.G. zone. This crosses over from the west-dipping, western schist zones there called the Ole and W.J.T. zones. The west-dipping H.G. zone and the near vertical A.S.D. zone intersect north of Giant B shaft over a nose of massive rock that plunges 20°NE. Both the A.S.D. and the H.G. zones contain orebodies near this intersection, which plunge northeast following the nose of massive rock, and, in cross-section, have a saddle-like shape (Boyle, 1961, p. 24). The A.S.D. zone also contains orebodies west of C shaft.

The H.G. and A.S.D. zones are thrown northwest by the 312 fault but although they have been picked up in the underground levels of the Giant mine their surface projection is difficult to predict. The Muir zone is gently east-dipping and seems to merge with the north Giant schist zone to the west. It may be the extension of the H.G. and A.S.D. zones and the north Giant may be the extension of the W.J.T. and Ole zones. The Muir zone to the northeast seems to disappear beneath massive rock. It probably splits into several branches which swing to the north and join the Bow Lake shear zone system. The dip of the hanging-wall of the north Giant zone is not known, but the schistosity dips 65 to 75°W, suggesting that the zone also dips west. Measurements of the strike and dip of the schist in all exposed workings of Giant mines were made in 1953 by I. C. Brown. Because of their relatively small number as compared with the size of the system, averages for selected groups, rather than an overall average, are given below. Few workings or drill-holes extend to the westerly limit of the system and their vertical extent is relatively small. The data are therefore only a small sample from a large and complex system.

Shaft area	Zone	Zone		Schist		No. of readings
		Strike	Dip	Strike	Dip	
A	All	N17°E	59°W	N10°E	75°W	202
B	ASD	N17°E	87°W	N19°E	64°W	228
B	West	N26°E	48°W	N21°E	75°W	683
C	ASD	N28°E	82°W	N30°E	79°W	315

A chlorite schist zone with local sericitic bands continues north from the north Giant along a pronounced valley through Moose Lake and beyond to the Akaitcho fault. Northeast of Moose Lake, Akaitcho Yellowknife mines have developed a series of gold-bearing quartz lenses in a brecciated schistose zone that dips east. This east-dipping zone probably merges with the main schist zone of the Giant system updip to the west.

At the Akaitcho fault the Giant system is displaced northwest to reappear at Gold Lake. The main zone, which dips steeply west, lies along the drift-filled valley extending from the west end of Gold Lake to Vee Lake. The gently east-dipping Lynx zone outcrops at the northeast end of Gold Lake. Both schist zones have been locally carbonated and mineralized and small shoots of ore grade have been found in them. The gently east-dipping Lynx schist zone may be correlative with the east-dipping Akaitcho zone south of the Akaitcho fault.

The Giant shear zone system continues northeast beneath the west arm of Vee Lake to Jackson Lake as a number of interlacing schist zones. Mineralization occurs in places along them but no orebodies have been found.

Orebodies

The orebodies in the Giant shear zone system are lenticular and range in width from 3 to 50 feet or more with an average width of 20 to 30 feet. They may occupy 10 to 90 per cent of the width of a schist zone. They are generally enclosed in an envelope of sericite and chlorite schist which in turn grades into the predominantly chlorite schist of the schist zone. The orebodies are composed of quartz, sericite–carbonate schist, and abundant metallic minerals including pyrite, arsenopyrite, stibnite, sulphosalts, sphalerite, chalcopyrite, and gold. The quartz occurs as lenses, pods, stringers, and irregular masses intermixed with patches of dragged and contorted sericite–carbonate schist. Typical ore contains at least 30 per cent quartz and up to 15 per cent sulphide minerals. In places vein-like bodies of well mineralized quartz cut across the strike and dip of the schistosity, but most of it occurs as *en échelon* lenses and pods that roughly parallel the schistosity or cut across it at a small angle.

As in the Con and Campbell systems the loci of orebodies seem related to shear zone junctions and flexures (Boyle, 1961, p. 25). Thus in the Cameron, South, and East zones the mineralized zones and ore shoots are developed along and around a nose of massive greenstone that plunges southwest. The massive rock, surrounded by schist, apparently acted as a buttress during repeated movements, buckling and contorting the schist and providing dilatant zones in which the orebodies formed. Similarly the ore shoots and mineralized parts of the West and Creek zones developed where two schist zones meet about a nose of massive greenstone. Again the ore shoots at the junction of H.G. and A.S.D. schist zones are saddle-like about a nose of massive greenstone that, like the saddle-shaped orebodies, plunges north at 20 degrees. There also, the schist at the junction and down the limbs of the two schist zones has been highly buckled and contorted and it is in these contorted, dilatant zones that the orebodies developed. The ore shoots in the south and central, nearly vertical A.S.D. zone formed in highly dragged parts of the schist zones that were probably formed by flexures in the walls of the shear zone.

The geochemistry and origin of the gold orebodies of the Yellowknife belt have been investigated and fully discussed by Boyle (1961, pp. 131–167). He has shown that the quartz of the gold quartz lenses, which is the principal epigenetic mineral in all the deposits, was formed from silica released during mineral alterations and chemical changes that occurred in the country rock during the formation of the schist zones. The sulphides in the shear zones originated partly by a redistribution of sulphophile elements during regional metamorphism of the greenstone and partly as the result of the chemical changes that took place during the development of the schist zones. The elements present in the orebodies thus came from the country rocks and were concentrated by the interaction of metamorphic processes and the dilatancy of the structures in which they now occur. Local dilatant zones in the schist zones have low pressure and low chemical potential for certain elements.

> To restore equilibrium such zones will be filled with the elements which are mobile within the rocks. During metamorphism the most mobile compounds and elements will be water, carbon dioxide, sulphur, arsenic, antimony, copper, lead, zinc, gold, silver and, in some cases silica. These elements and compounds probably migrate into dilatant structures by ionic diffusion through a nearly static flux of water vapour. Their route is mainly along crystal boundaries and minute cracks and fissures in the rock. (Boyle, 1961, p. 175)

Origin of Giant–Campbell Shear Zone System

The Giant–Campbell shear zone system is extremely complex. As exploration proceeded, various interpretations were advanced to explain the complexity of the pattern of schist zones. It has been suggested that the member shear zones are: (a) individual but related zones; (b) parts of one major zone that has been folded into, or has the form of, a series of anticlinal and synclinal folds since truncated by the present erosion surface and thus separated from each other; and (c) a system of interlacing shear zones between large horses of unsheared rock and is thus similar to the much smaller, and less complicated, subsidiary Con system.

In a recent paper Brown, Dadson, and Wrigglesworth (1959) offer two contrasting interpretations of the origin of the schist zones that contain the orebodies. They stress that the internal structure of the schist zones, and particularly the ore-bearing sericite–quartz zones that lie in the schist, provide much evidence of folding. Their first interpretation "attempts to account for the zone structure by simple folding of a horizon or group of horizons into the anticlinal and synclinal forms actually found. Longitudinal shear stress, caused by sliding parallel to the folded horizon as it was bent into the fold pattern, would be adequate to account for the internal structure of the zone". According to this interpretation, in the vicinity of B shaft, the W.J.T., H.G., and A.S.D. schist zones and contained orebodies developed along a single folded incompetent flow or flows and this accounts for the anticlinal-like form of the schist zone structure. They believed this interpretation likely to be valid, although recognizing that "the cross-cutting nature of the zone, its relation with certain ill-defined marker horizons, and the fact that this explanation will not fit the other mines of the district, makes it appear that this solution is inapplicable".

Their second interpretation of the structure attributes the development of the schist zones to shearing rather than folding and recognizes that the schist zones transect the regional strike of the flows at a small angle, and their regional dip at a large angle—a fact that their first interpretation fails to explain. According to their second interpretation "the obvious features of the internal structure such as drag folding, are ascribed to a shearing force which crosses the flows at an acute angle. The zone was therefore oriented by the direction of the shearing stress, which accounts for its crosscutting nature. The marker horizons fit naturally into this picture and the explanation fits other mines of the Belt".

The writers consider that the schist zones of the Giant system developed along a true shear zone or system of shear zones which originally joined, and formed part of, the Campbell shear zone system. This once continuous, shear zone system was displaced more than 3 miles along the West Bay fault. This great shear zone system is an imbricate system of shear zones, made up of many zones that split and join about large unsheared masses of country rock. Where these schist zones join or wind around large horses of unsheared country rock they may appear in plan or cross-section to be anticlinal or synclinal in shape; however this is not the result of folding but of the interlacing of the schist zones. In the Giant segment, the system cuts across the strike of the flows at a small angle; on the west side of the West Bay fault, where it is called the Campbell zone, it cuts across the flows at a larger angle.

The development of the ore deposits took place probably during the last stages of the development of the main shear zone system. The orebodies formed in dilatant low pressure zones which were created in the shear zones by subsequent but related movements to those that formed the shear zone system itself. The loci of these low pressure zones where the orebodies formed are structurally related to noses of massive unsheared country rock within the braided shear zone system, or to flexures in the shear zones.

The Giant–Campbell shear zone system (with its related and subsidiary Con, Negus–Rycon, and Bow Lake systems) is a major structure that has been traced for more than 10 miles from the south to north end of the mapped area. Was it formed by a dislocation or fault? If so, the position of key members of the Yellowknife Group cut by the structure should be offset and perhaps give some information as to the direction and amount of movement along it. Several characteristic lava flows and tuff beds have been traced across the greenstone belt, and their faulted extensions have been recognized across the West Bay and Akaitcho faults, and across the Giant shear zone system. The more important members are shown on Figure 4.

The Negus variolitic lavas have been traced northeast from Keg Lake to the shore of Yellowknife Bay east of the Negus shaft, where they are cut off by the West Bay fault. They outcrop on the east side of the fault near the Giant A shaft but not between the fault and the Giant shear zones. On the west side of the West Bay fault, the Negus flows are separated from the Townsite flows and sills by some 8,000 feet of nearly vertical lava flows. On the east side of the fault, the same marker members are less than 3,000 feet apart but the Giant shear zone system lies

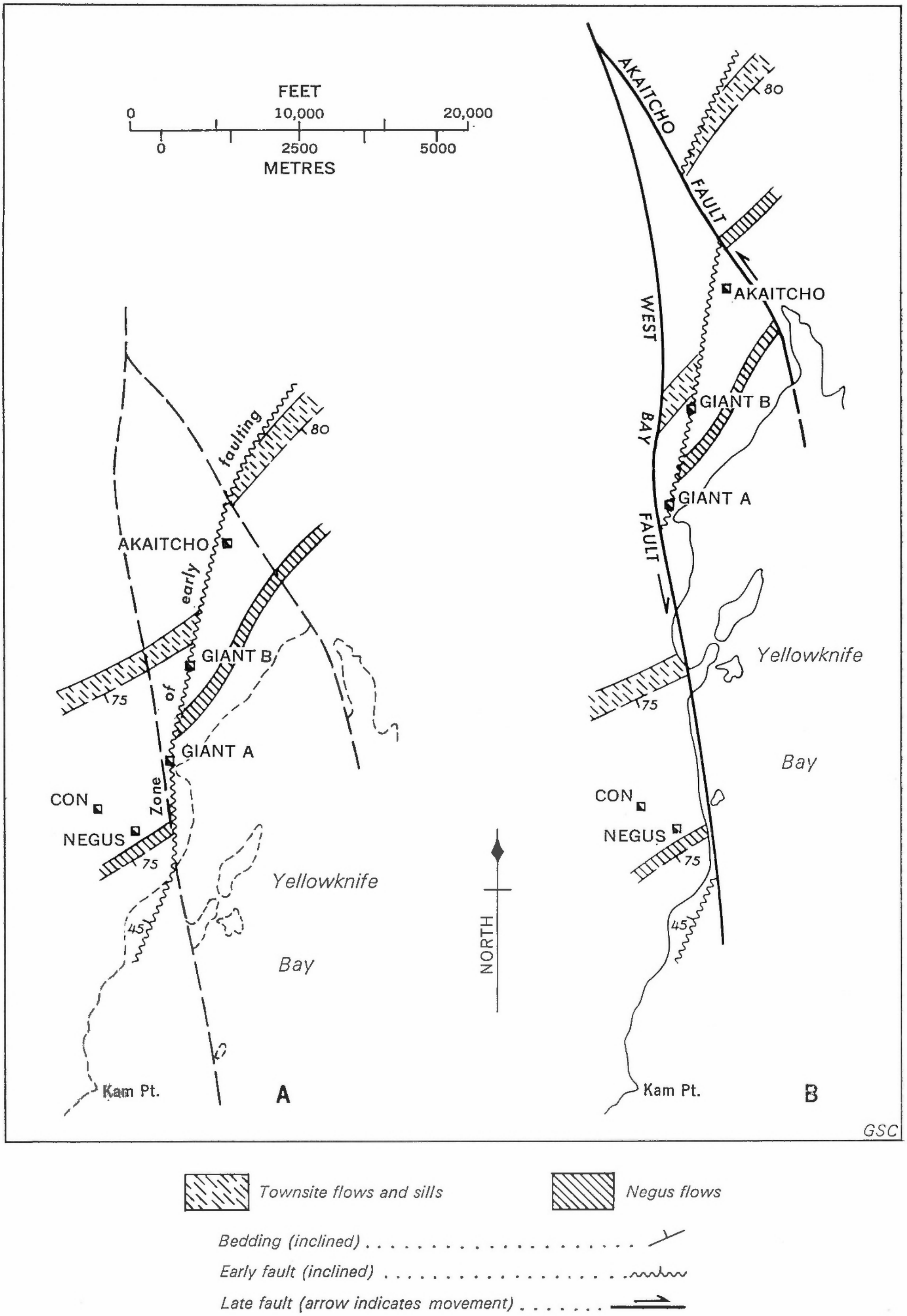

FIGURE 4. Diagrammatic illustration of position of key members of Yellowknife Group. A, hypothetical position before movement on late faults; B, present position.

between them. It seems apparent that this system must lie along, or near, an early fault or fault zone of sufficient magnitude to cut out some 3,000 to 4,000 feet of strata and thus bring the two marker volcanic members within 3,000 feet of each other. The conclusion that the shear zone system is related to this fault seems justified.

Confirmation of the existence of this early fault is found in the behaviour of the Townsite flows and sills. These are cut off by the West Bay fault north of Yellowknife townsite and reappear on the east side of the fault, west of the Giant B shaft. From there they can be traced northeast for about 5,000 feet to the drift-filled valley along which the Giant shear zone system lies. The Townsite flows and sills do not cross this valley, because outcrops are abundant on the east side, and these flows and sills would be exposed if present. They must, therefore, either pinch out abruptly, or be cut by a displacement along the valley. Their reappearance on the northeast side of the Akaitcho fault indicates that the latter alternative is more probably correct and that the valley marks a fault of some magnitude.

Probably an early fault of such magnitude would continue on the north side of the Akaitcho fault. Few reliable data on the vertical component of the Akaitcho fault have been obtained and this component is important in determining the faulted extension of the structure. However, a northeasterly trending, drift-filled valley lies northeast of the Akaitcho fault to the northwest of the Townsite flows and sills. It extends to and forms the west arm of Vee Lake. Diamond drilling indicates that much of this valley and the west arm of Vee Lake is underlain by schist, and on strike northeast of Vee Lake a system of shear zones is well exposed. This lineament marks an early fault, as shown by the displacement of the Fox flows several thousand feet northeast along it, and by the termination of the Townsite flows against it. This fault or shear zone system is believed to be the faulted extension of the Giant shear zone system.

It will be seen from examination of Figure 4 that not enough data are at hand to determine quantitatively the direction of movement or net slip along the early fault. To do this, the dip of the fault must be known and two structural markers inclined to the fault and to each other are also required. Although two markers inclined to the fault are known, they are parallel and so give only the strike separation. Nor is the dip of the zone of faulting known. The Campbell system seems to have a fairly uniform dip of 45 to 55°W and the subsidiary Con and Negus–Rycon systems also dip west. From this the assumption might be made that the fault zone to which these shear zones are believed to be related also dips west at about the same angle. On the other hand, the Giant system is much more complex. In it, the west hanging-wall schist zones including the West, Big Giant, W.J.T., North Giant, and western part of the Lynx zone dip west; the A.S.D. zones dip nearly vertical to east; and the Muir, Akaitcho, and East Lynx zones dip east. Any generalization as to the dip of the system as a whole is perhaps unwarranted with the evidence at hand. However, the west boundary of the system (hanging-wall) is well defined by large, strong, west-dipping schist zones whereas the east boundary is irregular and marked by several schist zones that branch out from the main zones into the walls where, in plan, they weaken and die out. Also, in the large, west-dipping, hanging-wall schist zones that mark the west boundary of the system, the schistosity dips more steeply than the zones themselves indicating that thrusting from the west was responsible for their development. This suggests that the principal locus of faulting has been along or near the west-dipping, west boundary schist zones and that this faulting was caused by thrusting from the west.

In any case, the evidence for displacement of some magnitude along the Giant–Campbell shear zone system seems fairly good. Whatever the attitude of the system as a whole and whatever the direction of displacement along it, assumption of a direct relation between movement and development of the shear zone system seems warranted.

Bow Lake System

The Bow Lake system (north half) lies to the east of, and is subsidiary to, the Giant system. South of Bow Lake, it lies along a drift-filled valley and is exposed only near the shore of Yellowknife Bay as a zone of strongly foliated chlorite schist about 20 feet wide. North of Bow Lake, it splits into several schist zones and breccia shear zones which, near the Akaitcho fault, appear to merge into the Akaitcho schist zone of the Giant system. The Bow Lake system is also linked with the Giant system by the Muir zone which apparently joins it northeast of Bow Lake; in fact, the northern branches of the Bow system may be the ends of A.S.D., H.G., and Muir zones of the Giant system.

Underground exploration by Giant Yellowknife Mines Limited has shown that the main Bow Lake shear zone south of Bow Lake dips at 30–40°W and joins the nearly vertical to steeply easterly dipping A.S.D. shear zone at depth. Several important orebodies have been found underground in this part of the Bow Lake shear zone system.

Stock Lake and Handle Lake Systems

The Stock and Handle Lake systems are minor but their relation to the granodiorite and to aplite dykes is interesting. The Stock system northeast of Stock Lake (north half) is a group of four breccia shear zones that are 2–5 feet wide, strike north to northeast, and dip steeply west to vertical. The shear zones cut amphibolitic greenstones, a few irregular granitic masses, and aplite and granitic dykes. They consist of foliated chlorite fragments in the areas where they cut greenstones and of poorly foliated sericite schist in the areas where they cut granite and aplite. Small quartz lenses and veins containing some gold are developed in places along them but no orebodies of mineable size have been found.

The Handle system east of Handle Lake (north half) is made up of several, narrow, parallel and cross-over shear zones striking north to northeast and with nearly vertical dips. Some contain aplite and granite dykes that show little or no evidence of shearing, but others contain similar appearing dykes that have been sheared and that contain lenses and stringers of gold-bearing quartz. One shear zone crosses the granodiorite–greenstone contact.

In the Stock and Handle Lake systems, an early period of shearing apparently provided a site for emplacement of granitic bodies, some of which were later sheared. Quartz sulphides and gold were deposited in the schist zones so formed. Thus, development of the shear zone systems seems to have been initiated at nearly the same time as the emplacement of the granodiorite but continued long after its consolidation.

Crestaurum System

The Crestaurum system (north half) lies to the northwest of Daigle Lake. The main shear zone strikes northeast and dips 50°SE; it lies along a narrow, drift-filled valley that extends from the southwest bay of Milner Lake southeast for 2,500 feet, where it joins the Daigle Lake lineament and probably continues along the lineament through Island Lake. Several small gold ore shoots have been outlined by diamond drilling along the shear zone between the Daigle Lake lineament and the Crestaurum mines shaft. North of the shaft several shear zones branch to the northwest and southeast from the main zone. No evidence of the magnitude of the movement along the shear zones of the Crestaurum system has been obtained.

Daigle Lake Lineament

The Daigle Lake lineament (north half) has been traced from Island Lake northeast to Daigle Lake and beyond to the limit of the map-area. The lineament probably marks a shear zone related to the Crestaurum system. Movement along it is not great because dykes and stratigraphic units on either side of the lineament do not seem to be much offset. However, correlation of the stratigraphic units (Ranney chert, Ranney tuff, and the variolitic flows) on either side of the lineament is not certain. The writers' correlation of units across the lineament, which should be regarded as tentative, follows.

Along the lineament immediately southwest of Daigle Lake, along which the road to Crestaurum mines lies, rock outcrops are almost continuous. Four characteristic, early meta-diorite dykes, of which two are porphyritic and two non-porphyritic, match across the draw or lineament and are not offset. At the northeast end of Daigle Lake several quartz porphyry feldspar dykes are apparently not displaced by the fault; neither is the late diabase dyke that crosses the northeast end of the lake, nor two strong north-south shear zones, one crossing the northeast end of Daigle Lake, and the other the lineament 1,000 feet to the northeast of the lake. It may be concluded that, if the Daigle Lake lineament marks a fault, the displacement along it is small.

The Ranney chert throughout the greenstone belt is characterized by sudden changes in thickness and by discontinuity. It can be traced with assurance from the Akaitcho fault northeast to within 3,500 feet of the Daigle Lake lineament. There it apparently pinches out entirely as, although outcrops are abundant, it has not been observed on strike for 1,200 feet. However, 600 feet east of the north end of Island Lake, a thin cherty tuff on strike with the Ranney chert probably marks its extension. There it is in line or on strike with the Crestaurum gold-bearing shear zone. The Crestaurum chert emerges from this shear zone southwest of the Crestaurum mine buildings. The Crestaurum chert is lithologically similar to the Ranney chert outcropping just north of the Akaitcho fault, and, because they appear to lie at the same stratigraphic position, the Ranney and Crestaurum cherts are probably correlatives.

North of the Daigle Lake lineament and east of the Crestaurum shear zone, the strike of the Crestaurum (Ranney) chert swings east and has been traced along, and north of, the northeast shore of Daigle Lake and beyond to the limit of the map-area. Since the Crestaurum (Ranney) chert swings to the east, the parallel Ranney tuff probably also swings to the east at Daigle Lake and follows along the lake and the lineament to the northeast. That the extension of the Ranney tuff lies along this lineament is further suggested by an outcrop of tuff on the south side of the lineament, 2,000 feet northeast of Daigle Lake. The thickness of the flows between the Crestaurum (Ranney) chert and the Ranney tuff northeast of Daigle Lake is only 600 feet as compared with 800 feet northeast of the Akaitcho fault and 1,500 feet still farther south, west of David Lake. But the thinning of the flows along strike to the northeast seems general throughout the belt. Thus 4,500 feet of flows lie between the Cemetery and Ranney tuffs west of the West Bay fault, 2,500 feet between the West Bay and Akaitcho faults, and only 1,000 feet southeast of Daigle Lake. Likewise, the flow sequence between the Negus flows and Townsite flows and sills decreases from 8,000 feet on the west side of the West Bay fault to 4,000 northeast of the Akaitcho fault.

That the Ranney and Crestaurum cherts are correlatives is also suggested by the development of variolites in the flows stratigraphically above or southeast of both cherts. Thus, flows with variolites lie above or southeast of the Ranney chert west of the West Bay fault, in the segment between the West Bay and Akaitcho faults, and northeast of the Akaitcho fault, but the variolites are not well enough developed to designate the flows as variolitic on the map. That the variolites are again well developed in the flows above the Crestaurum chert northwest of Daigle Lake suggests that these are the same flows and, if so, that the Crestaurum chert is the correlative of the Ranney chert.

Post-Diabase Faults

The major, post-diabase or late faults of Yellowknife Bay (Brown, 1955) rank with the largest dislocations in the earth's crust. They strike north to N25°W and dip nearly vertically. Movement along them has been mainly horizontal and 'left hand', the west side having moved south relative to the east side. Near Yellowknife, across a width of 10 miles, the total horizontal offset produced by these faults is about 11 miles. They extend 130 miles northwest to the Indin Lake greenstone–sedimentary belt where a similar set of nearly vertical 'left hand' faults has been recognized (Fig. 5). Between the Yellowknife and Indin Lake greenstone belts the fault system cuts massive granitic rocks and is expressed as a single fracture striking nearly north. Where it passes into the volcanic and sedimentary rocks at Indin Lake and Yellowknife, the single fault branches into several smaller, but still

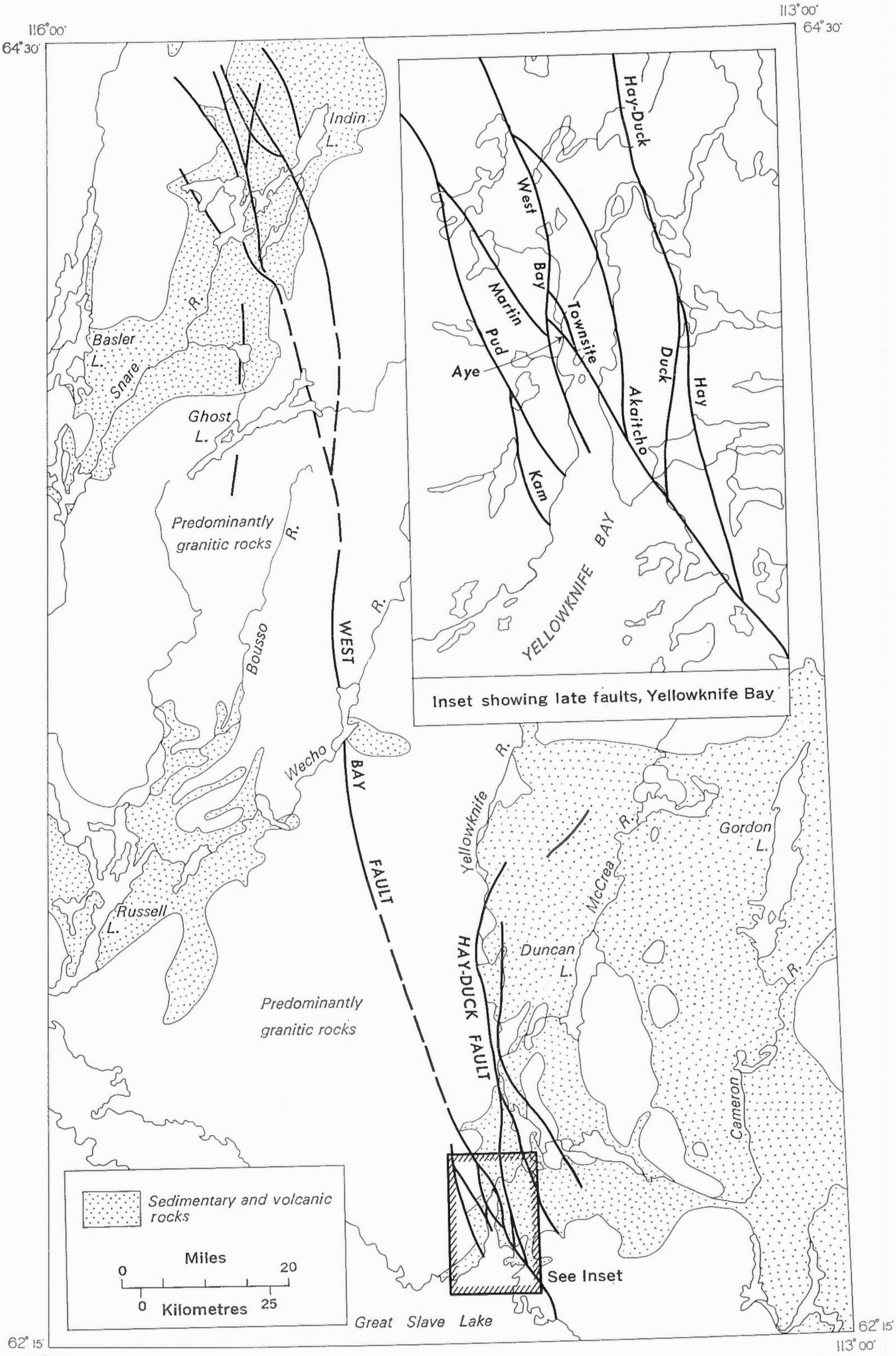

FIGURE 5. West Bay–Indin Lake fault system.

major faults with subsidiary 'cross-over' faults between them, to form a fault zone system. At the same time the strike changes from nearly north to north-northwest. The change in strike and attendant branching of the single fault to a system of faults is probably caused by the differing competency and the layered nature of the volcanic and sedimentary rocks, as compared with the massive granitic rocks.

The late faults of the Yellowknife system may be classified as major faults and smaller 'cross-over' faults. The faults of both classes are identical in structure and appearance, and probably developed at essentially the same time. The major faults have been called the West Bay, Kam–Pud, and Hay–Duck; the cross-over faults include the Akaitcho, Martin, Townsite, and Aye (Fig. 5). Hundreds of smaller, unnamed faults occur between the larger ones.

The late fault system is thus a series of major faults linked by cross-over ones, which together form a system of interlacing faults separated by segments or 'horses' of country rock. In essence, the pattern is similar to the much earlier and unrelated, ore-bearing shear zone system. However, failure in the early system has been by development of schist zones up to hundreds of feet wide, accompanied by chemical changes and the formation of new minerals of differing chemical and physical character. In contrast, failure in the late faults has been largely by mechanical grinding and brecciation of the rock along narrow planar zones of failure accompanied by only minor changes in the chemistry or mineralogy of the rock. The contrasting character of the early and late fault systems suggests that they developed under completely different conditions. Formation of the schist zone faults involving recrystallization and rock flowage probably occurred at a great depth under conditions of high pressure and elevated temperature; the late faults developed much nearer the surface where the rocks failed by fracture rather than by recrystallization and flow.

In contrast with the chlorite schist developed along the faults of the early schist zone type, the late faults are characterized by the development of rock breccia or gouge rather than schist. Even in major faults with displacements measurable in miles, the fault zone may be only a few inches wide and is commonly less than 4 feet. Within this zone the rock is brecciated, and a clay-like gouge may have formed. Locally, the finely brecciated rock may split into plates that at first glance resemble schist, but on closer inspection are found to be composed of randomly oriented rock fragments. The change from fault breccia to massive wall rock is generally sharp, and the breccia may be scaled off the massive walls. However, in places along some faults, the wall-rock may be minutely fractured for many feet from the fault and the fractures filled with hematite and ferruginous carbonate. This is particularly common where two or more faults join, as for example along the Kam fault northwest of Meg Lake (south half), where rusty hematitic alteration is so pronounced that the original nature of the greenstone flows is obscured.

The brecciated rock and gouge weather rapidly, and the typical expression of the late faults at the surface is a fissure, ranging from a few inches to several feet wide and up to several feet deep, or a drift-filled trench (Pl. XVII). These features are represented on aerial photographs as strong lineaments (Pl. I).

Quartz veins and lenses are found in places along the late faults. Some of them contain ferruginous carbonate and a little pyrite and chalcopyrite but the gold content of the veins found so far is negligible. A large 'giant' quartz vein, more than 100 feet wide, formed along the West Bay fault near its junction with the Akaitcho fault (north half). A similar but smaller vein occurs along the late fault extending west from Landing Lake. The granodiorite forming the west wall of the quartz vein along the West Bay fault is brecciated across a width of more than 400 feet. The brecciated zone is composed of a stockwork of fragments of granodiorite from a few inches to several feet in diameter, cemented by quartz and hematite veinlets. As the fault is approached, the percentage of quartz increases, the fragments of granodiorite become more and more silicified, and the stock-work grades into a massive, milky white quartz vein, 150 to 200 feet wide, that is cut by innumerable hematite veinlets. Most of the displacement along the fault seems to have taken place east of the vein near the greenstone wall of the fault, along a zone only a few inches or feet wide. Apparently the quartz vein developed within, and at the expense of, the granodiorite rather than the greenstone. This suggests that giant quartz veins are less likely to develop where both walls of a fault are greenstone.

The Fault Pattern

That part of the greenstone belt bounded on the west by the Kam fault and on the east by the Akaitcho (Fig. 6) may be considered as a fault block that has been stressed by a couple developed by the movement of the west side south relative to the east side. The resulting fault pattern is that of a typical shear system, formed in this instance by nearly horizontal strain or shear with lateral rather than upward relief. Two sets of nearly vertical shear faults developed. The first, along which most of the movement has taken place, strikes north to north-northwest and includes the West Bay, Akaitcho, and other major faults of the area. Movement along them has been left hand with the west side moving south relative to the east side and wih displacements measurable in miles. The second complementary set, striking east-northeast and nearly at right angles to the first, is best developed between the Kam and Pud faults. The movement along even the largest faults of this set is measurable in feet rather than miles. Displacement is right hand with the northwest side moving northeast relative to the southeast side. Many but by no means all have developed along, or are parallel with, planes of stratification of the lava flows. A third set of vertical faults strikes east-southeast. These faults formed along tension cracks that developed at right angles to the direction of elongation or lateral relief and have right hand movement consistent with the regional stress system. They are best developed in the fault segment between the Kam and Pud faults.

Major North-Northwest Shear Plane Faults

This set includes the major faults of the area. Movement along them has been left hand, with a block to the west of each fault moving south relative to the block to the east. This set of faults, along which most of the movement has taken place,

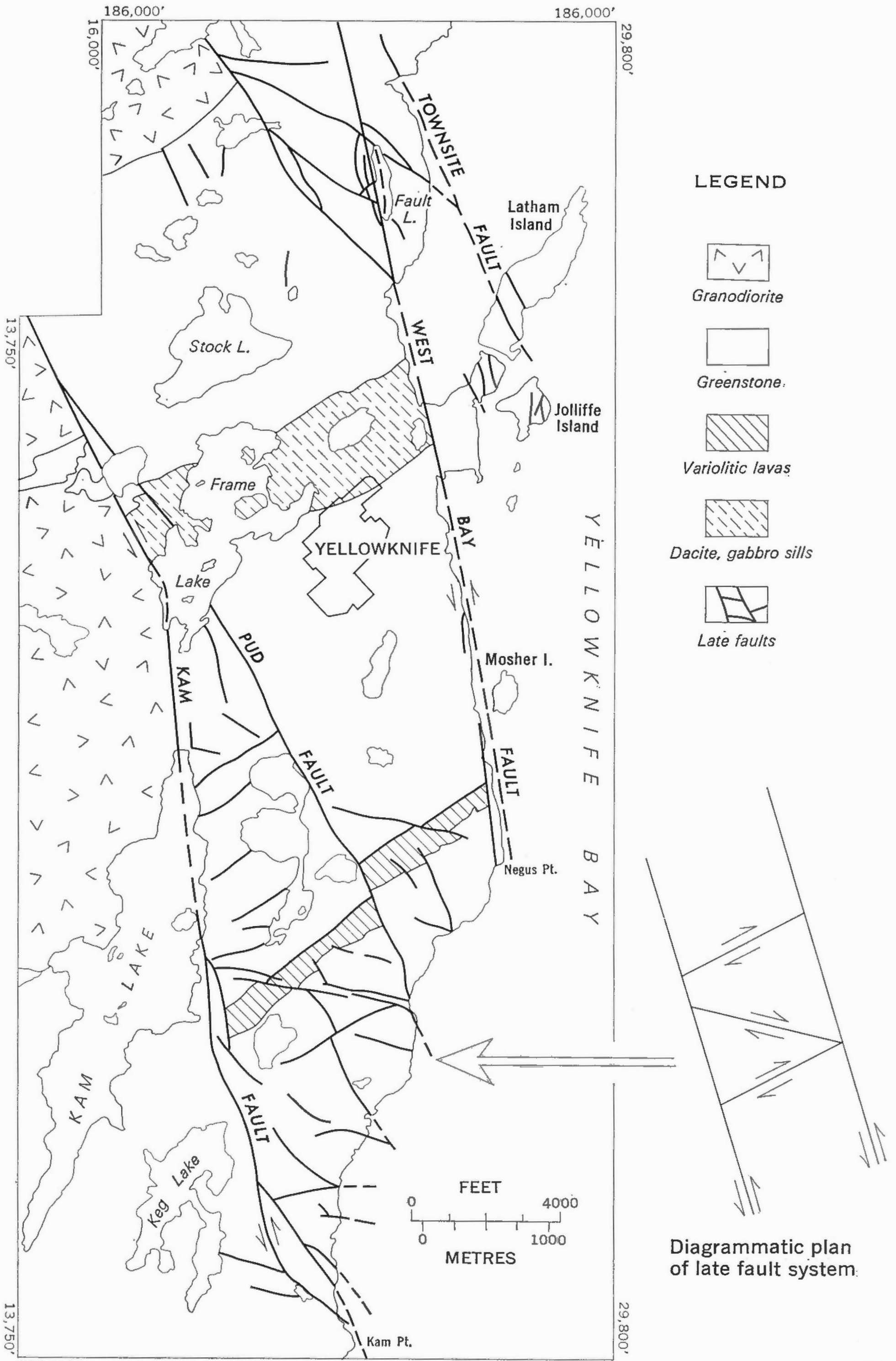

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FIGURE 6. *Actual and diagrammatic illustrations of late fault system showing the major north-northwest trending, left lateral faults (West Bay, Kam faults), along which most of the displacement has taken place; the complementary minor east-northeast trending, right lateral faults; and the east-southeast trending tension faults.*

developed nearly parallel with the greatest applied pressure or shearing force. The main faults are the West Bay, Kam, Pud, and Hay–Duck; the Townsite, Martin, Pud, and Aye are 'cross-over' faults formed between the main faults or between main and other large 'cross-over' faults (Fig. 5). Thus, the Townsite fault crosses from the Akaitcho to the West Bay fault, the Aye, from the Townsite to the West Bay, and the Martin and Pud, from the West Bay to the Kam.

The West Bay Fault

The West Bay is the principal or trunk fault of the set and system. It has been traced by diamond drilling north from Negus Point, following the shore of Yellowknife Bay, to south of Fault Lake. North from there, it is mostly well exposed, and along and for more than a mile to the north of Fault Lake the west wall of the fault forms a prominent 50- to 100-foot scarp. The dip of the fault varies but is always within 10 degrees of vertical.

The movement along the West Bay fault changes along its length, increasing to the north where it is joined by the Akaitcho and Townsite faults, which have the same left-hand movement. Based on the displacement of diabase dykes whose dips were known from diamond drilling, Campbell (1948) calculated the movement along the fault between Negus Point and Fault Lake. From an average of several calculations, he estimated that the west side moved 16,140 feet south and 1,570 feet down, relative to the east side. Using as markers a large northwesterly striking diabase dyke that lies just north of the Con and Negus shafts, and the Cemetery tuff which outcrops in the valley east of the south end of Stock Lake, Brown (1955) calculated the movement on the West Bay fault as west side 16,100 feet south and 1,500 feet down relative to the east side. The markers used by Campbell lie about 4 miles apart along the fault whereas those used by Brown are 6 miles apart. The agreement of the figures is remarkably good, particularly as the dip of the Cemetery tuffs used by Brown in his calculations is known only from surface mapping.

For the greater part of its length the trace of the West Bay fault is straight or only slightly sinuous, but 3,000 feet north of Fault Lake it bends sharply 15°E. The fault is not exposed at the bend but diamond drilling indicates that the change in strike takes place within 200 feet and that the width of the fault zone, which is only about 2 feet in this vicinity, does not increase at the bend.

The remarkable 15-degree eastward bend, and consequent easterly bulge in the fault to the north of the bend, is probably caused by the passage of the fault from layered volcanic to massive granitic rocks. This may have been of significance also in the development of the Akaitcho fault and in the change in strike in the flows in the wedge-shaped segment between the West Bay and Akaitcho faults.

The eastward bulge in the fault to the north of the bend has a granodiorite core. This core and the greenstones immediately to the south at the 15-degree bend are all massive rocks with few fractures and no sign of brecciation or mashing of any kind, such as would be expected if these rocks had moved around the bend in the fault. On the east side of the bend is the wedge-shaped segment between the

West Bay and Akaitcho faults where, in contrast, the rocks are intensely deformed, with the early Giant–Campbell shear zone system measuring hundreds of feet in width along the centre of the segment. The necessary adjustments involved in displacement of the rocks around the bend in the fault were probably taken up, in large degree, in the incompetent schist zones on this side of the fault. This suggests that the bulge cored by granodiorite on the west side of the fault moved as a unit and that, as movements occurred, the necessary adjustments due to the bulge were made entirely within the greenstones on the east side, in the wedge-shaped segment between the Akaitcho and West Bay faults. When the fault first developed and before much movement had taken place along it, the bulge, relative to the east side, was 3 miles north of its present position. This is not far from the point where the Akaitcho fault now joins the West Bay. In subsequent movement along the fault, the bulge, acting as a competent unit, would apply pressure to the rocks in front of it on the east side. They might fail by development of a subsidiary fault virtually on strike with the main fault to the north of the bulge. The Akaitcho fault may have been initiated in this way.

Further southward movement of the bulge, relative to the east side, would tend to shove aside the wedge of rocks between the West Bay and Akaitcho faults, deforming or mashing them. This wedge of rocks, caught between the southward moving block west of the West Bay fault and the relatively northward moving block northeast of the Akaitcho fault, would tend to be rotated counterclockwise. This may account for the change in the strike of the flows from normal northeast to almost north at the north edge of the wedge.

The situation is similar along the Kam fault where, at the west end of Frame Lake, a pronounced bend of 20 to 25 degrees to the west in the trace of the fault forms a bulge, which, like the bulge in the West Bay fault, has a core of massive granodiorite. There also a subsidiary fault, the Pud, formed at the northwest end of the bulge. In this case, however, because the rocks in the wedge-shaped segment between the Pud and Kam faults are massive greenstones, they failed by fracturing rather than folding and flowage. The result is a particularly fine development of three sets of fractures (Fig. 6). There a north-northwesterly trending set of left-hand faults and an east-northeasterly trending set of right-hand faults formed along the two directions of maximum shear, and a third set striking south-southeast formed along tension openings at right angles to the direction of maximum (lateral) relief.

The Akaitcho Fault

The Akaitcho fault joins the West Bay just beyond the northwest boundary of the mapped area. It has been traced southeast across Yellowknife Bay where it is joined by the Townsite and Hay–Duck faults (Fig. 5). The Akaitcho is thus a large cross-over fault between the West Bay and the Hay–Duck.

The Akaitcho fault from Yellowknife Bay northwest to Rater Lake (north half) is a single, almost vertical, narrow fissure or fracture zone not more than a foot wide. Between Rater Lake and its junction with the West Bay fault, the Akaitcho splits into five branches with many smaller subsidiary fractures. The movement along the Akaitcho fault apparently decreases to the northwest as it approaches the West Bay fault. Thus the strike separation of the Negus flows by the fault is more than 6,000 feet, whereas farther northwest the strike separation of the Stock flows and Cemetery tuffs is less than 4,000 feet. This may be due in part to the rotation of the fault segment between the West Bay and Akaitcho faults. If one imagines the north-striking flows north of Gar Lake to be rotated back again to a northeast strike, the decrease in strike separation along the north part of the Akaitcho fault is almost eliminated.

Several stratigraphic units can be correlated across the fault but their dips are known only from surface exposures. The only marker not parallel with the flows is the unconformity which, from surface outcrops, dips about 80°NW. Using as markers the unconformity, the base of the Negus variolitic flows, and the Cemetery tuffs, the calculated movement along the fault has been northeast side north about 6,200 feet. The vertical component of movement is less certain because the markers all dip nearly vertically and intersect at acute angles; a small error in the dip consequently results in an error of hundreds of feet in calculating the vertical component. However, from surface observations the Negus flows seem to dip steeply southeast, whereas the unconformity between the Yellowknife Group and the overlying subgreywacke and conglomerate dips steeply northwest; thus they dip toward each other. On the southwest side of the fault, the top of the Negus flows and the unconformity are about 1,500 feet apart, whereas on the northeast side they are some 2,000 feet apart. This indicates that the block or segment south of the Akaitcho fault moved up relative to the north side. Thus the fault segment or block between the Akaitcho and West Bay faults is a horst that moved up relative to the rocks on either side.

The Townsite Fault

The Townsite fault strikes north-northwest across the south end of Latham Island, lies just off the northeast end of Jolliffe Island, and is exposed again on the east side of Yellowknife Bay, where it joins the Akaitcho fault about a mile inland. To the northwest on the west side of Yellowknife Bay, the Townsite fault is exposed 500 feet northeast of Giant A shaft and from there swings to the north across Baker Creek and joins the West Bay fault. Thus it is a nearly vertical cross-over fault between the West Bay and Akaitcho faults.

On Latham Island on the north side of the Townsite fault, there outcrops a unique sequence of normal gabbroic sill, succeeded to the southeast by a fine-grained, dark to black phase of the sill, followed by more of the coarse normal type sill, followed by cherty tuffs grading into bedded tuffs and crystal tuffs. A gabbro sill 8 to 10 feet wide cuts the tuffs 30 feet southeast of the sill–tuff contact. On the east side of Jolliffe Island on the south side of the fault the same sequence outcrops. There is little doubt that these two sequences were once continuous and have been displaced (strike separation) about 2,000 feet by the Townsite fault.

Between the west shore of Yellowknife Bay and Latham Island the Aye fault branches northwest from the Townsite to join the West Bay north of Fault Lake (Fig. 8). The strike separation of diabase dyke D and of the Yellorex flows by the

Aye Fault is 900 to 1,000 feet. Farther northwest, east of Giant A shaft, the strike separation by the Townsite fault of diabase dyke D and the Yellorex flows is 1,400 to 1,500 feet. Thus, the sum of the strike separations of the Townsite (1,400 to 1,500 feet) and Aye (900 feet) faults is greater than that of the Townsite fault alone at Latham and Jolliffe Islands.

The Kam, Pud, and Martin Faults

The Kam fault (Fig. 8) has been traced from the shore of Yellowknife Bay north of Kam point, northwest and north to Kam Lake, and thence north along the east shore of Kam Lake to Frame Lake, where it swings northwest again to join the Martin fault at Martin Lake, beyond the limits of the map-area. This fault like all the others of this set dips steeply to vertically. The left hand strike separation of the Yellorex and Negus flows by the fault is about 1,500 feet and of diabase dyke D about 1,400 feet. The fault is joined by the Pud fault north of Frame Lake.

The Pud fault has been traced from the shore of Yellowknife Bay 4,500 feet south of Negus Point, north-northwest to and along the northeast shore of Pud Lake, and beyond to Frame Lake. North of Frame Lake it joins the Kam fault, and to the south it probably joins the West Bay fault beneath the waters of Yellowknife Bay. It is thus a cross-over fault between the Kam and West Bay faults. The left-hand strike separation of the base of the Negus flows by the fault is about 1,500 feet, and of diabase dyke D about 1,400 feet. Like the other faults of this set its dip is vertical or nearly so.

The Martin fault has been traced from Handle Lake southeast to the shore of Yellowknife Bay 2,000 feet south of Fault Lake. It is joined between Joe and Handle Lakes by three subsidiary branches, each of which adds to the displacement along it. North of Handle Lake the Martin fault continues beyond the mapped area to Martin Lake where it is joined by the Kam–Pud fault. The strike separation of the granodiorite–greenstone contact by the Martin fault is about 1,800 feet.

Complementary Minor East-Northeasterly Shear Plane Faults

This set is best developed in the fault segment between the Kam and West Bay faults, particularly between the Kam and Pud, but is also present east of the West Bay in the northern part of the area, west and northwest of Rater Lake (Fig. 6). The faults between the Kam and West Bay are parallel with the flows, striking N60° to 70°E and dipping 80°S to vertically. In the northern part of the area where the strike of the flows is more north-northeast the faults cut across the flows.

This minor set of faults is complementary to, and approximately at right angles to, the main set of north to north-northwesterly, left-hand faults along which most of the movement has taken place. Movement along the minor set has been right hand with the northwest side moving northeast relative to the southeast side. Displacement along them is small. They tend to be best developed near and to the east of the large north-northwest striking faults such as the Kam and West Bay and to die out along strike away from them. This is illustrated by several northeasterly trending faults exposed for almost their entire length on a large clean outcrop west of Pud Lake (Fig. 7). On the west side of the outcrop the strike separation is about 100 feet and the fault is a breccia zone about 6 inches wide. Along the fault to the northeast, within less than 700 feet the strike separation decreases to zero and the breccia zone narrows to a crack, which cannot be traced through the massive lava to the east. The Kam fault lies immediately to the west of this outcrop along the east shore of Kam Lake with movement of some 5,000 feet along it.

Other faults of this set are well developed east and south of Meg Lake.

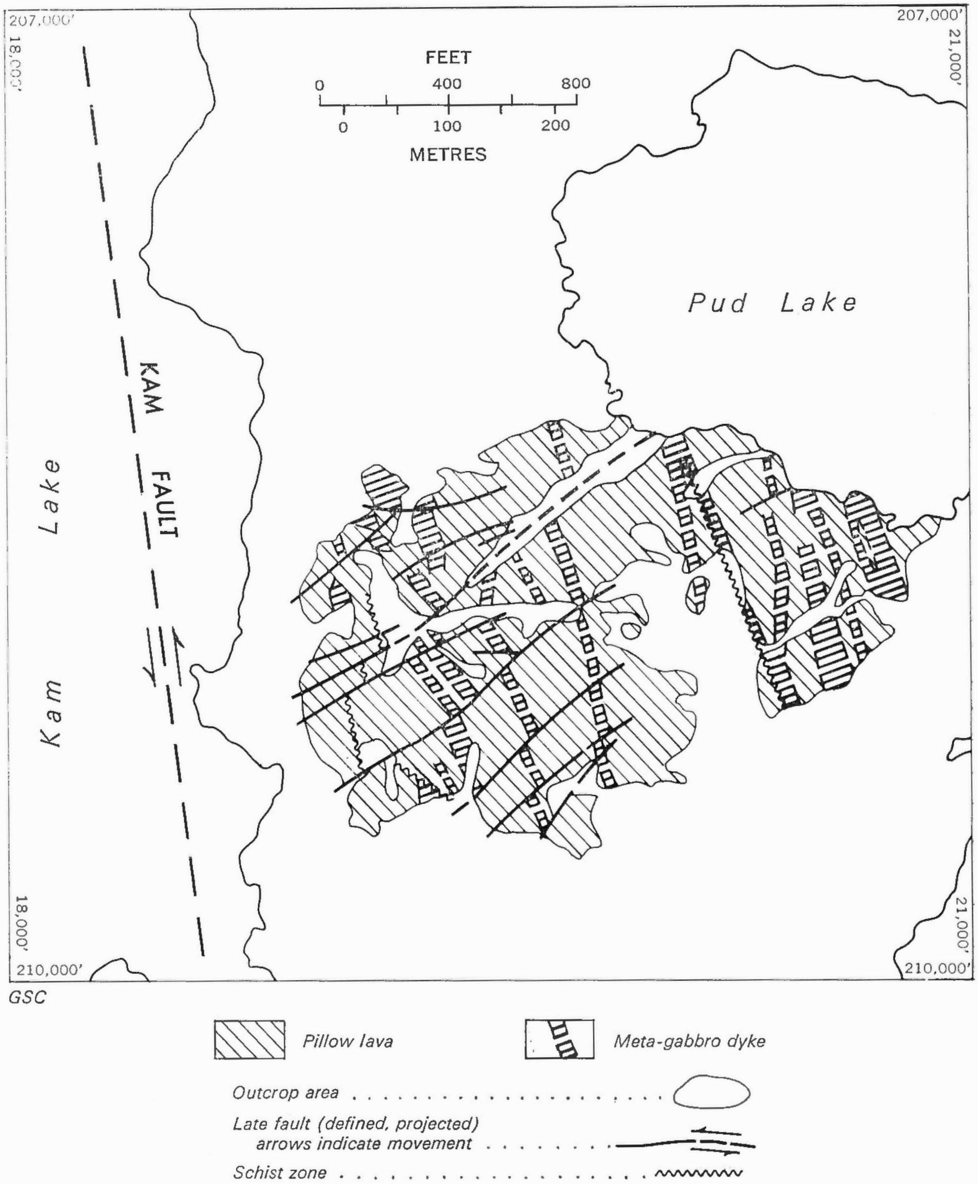

FIGURE 7. Change in strike separation along minor east-northeast trending faults related to the Kam fault.

East-Southeast Tension Faults

This set is best developed in the same places as the minor shear plane faults just described, that is, in the southern part of the area between the Kam and West Bay faults and in the northern part of the area, west and northwest of Rater Lake. In the southern part of the area they strike N70° to 80°W, in the northern part as much as N55° to 60°W. All dip at nearly vertical angles. The strike separation along them is small and measurable in tens or, at most, hundreds of feet; the displacement is commonly right hand with the north side moving east relative to the south side. Theoretically, in nearly horizontal shearing movement along parallel or vertical planes such as formed the West Bay fault system, the tensional faults should develop at about right angles to the direction of elongation. Likewise, these faults should be inclined about 45 degrees to the direction of shearing movement, here represented by the Kam, Pud, and West Bay faults. In any particular segment of the system the tensional faults are not far from the theoretical angle (Fig. 6).

The tensional faults tend to be more open than the shear plane faults; the breccia zone is generally wider, not as well cemented, and commonly weathers to give an open fissure 1 foot to 2 feet wide and as much as 10 feet deep. Some characteristic and easily accessible faults of this set are well exposed along the shore of Yellowknife Bay half-way between Negus Point and the Pud fault (Pl. XVII). Another group of faults of the tensional set are well exposed northeast of Meg Lake.

The Negus Fault

Although most of the late faults seem to fit into one or other of the three sets described above, some do not fit any obvious pattern. The most important of these is the Negus fault. It extends from the shore of Yellowknife Bay east of the Negus shaft to the Pud fault, by which it is displaced 1,000 feet south to continue southwest beneath the drift-filled valley to south of Pud Lake. The Negus fault strikes northeast or parallel with the flows and dips nearly vertically. In this respect it would seem to belong to the minor northeasterly shear plane set, but the displacement along it is left hand with the northwest side moving southeast relative to the southeast side, or the reverse of that along the northeasterly, shear plane faults.

The Negus fault is a narrow fracture filled with breccia and gouge and similar to the other late faults. It offsets the Negus orebodies and two small diabase dykes but is in turn offset by the West Bay and Pud faults. It apparently formed after the diabase dykes were emplaced but before the West Bay fault system developed.

Using as markers the hanging-wall of the Campbell shear zone, which has a uniform 45 degree westerly dip, and a steeply dipping diabase dyke, both of which have been mapped underground on several levels, movement along the Negus fault has been calculated as south side 660 feet east and up 100 feet relative to the north side.

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