CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

GEOLOGICAL SURVEY OF CANADA

GEOLOGY OF THE ITCHEN LAKE AREA, DISTRICT OF MACKENZIE, 76E(w/2) and part of 86H

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OPEN FILE 338

OTTAWA
1976

ABSTRACT

The report deals with geological reconnaissance of 4300 square miles of Bear-Slave Upland carried out in 1964-65-66.

The map-area is underlain primarily by Archean rocks of the Yellowknife Supergroup divisable into three overlapping phases. The oldest phase (Point Lake Formation) consists of felsic calc-alkalic to mafic tholeiitic volcanic rocks and local late mugearitic flows. A transitional phase (Contwoyto and Keskarrah Formations) consists respectively of iron-formation-bearing greywacke-turbidites and coarse conglomerates. The latest phase (Itchen Formation) consists of greywacke-turbidites alone.

Early Kenoran plutonism (min. age 2642 m.y.), which affected rocks of the Point Lake Formation, was accompanied by development of a mylonite zone and by emplacement of minor ultramafic bodies along the west margin of the area. Later gabbroic to granitic plutonism (min. age 2500 m.y.) affected the greywacke-turbidites as well, and was accompanied by metamorphism reaching sillimanite-cordierite-orthoclase-almandine subfacies. Optic axial angles of cordierite crystallized as a result of this metamorphism increase with rising metamorphic grade.

Late Aphebian argillites and quartzites of the Coronation Geosyncline extend into the area from the west (Epworth Group) and east (Goulburn Group) along its north margin. An outlier of the Goulburn Group is preserved in a half graben associated with emplacement of diabase sills.

West-northwest striking porphyritic diabase dykes are related to similar flows locally preserved within the Epworth Group west of the map-area. Northwest trending dykes of the Mackenzie swarm (1200 m.y.) are concentrated in two zones some 35 miles apart along the east margin and through the central part of the map-area.

The principal metal occurrences comprise Fe-Cu showings within early mafic volcanics, Fe-Zn-Cu showings associated with felsic volcanics, and oxide-silicate-sulfide iron-formation with local syngenetic aresenical gold deposits associated with late mafic volcanism.

Silicate iron-formation beds show variable alumina contamination resulting in variable alumina content in hornblende and crystallization of iron-rich garnet in alumina-rich beds. Alumina substitution in hornblende causes a shift in Mg-Fe distribution coefficient between coexisting hornblende and grunite toward more magnesian grunerite. Crystallization of iron-rich garnet causes a shift in both amphiboles toward more magnesian compositions.

Reconnaissance of pyrrhotite type in sulfide iron-formation suggests that hexagonal (sulfur-poor) pyrrhotite is predominant in the deposit of highest metamorphic grade and may be concentrated along fold axes at lower grades.

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LOCATION AND ACCESS

The Itchen Lake map-area lies between 65°00' and 66°00' north, and between 111°00' and 113°18' west, the north, south, and east boundaries following lines of latitude and longitude, and the west boundary being an irregular limit west of a prominent belt of basic volcanic rocks. The southern part of the area is about 200 miles (320 km) north northeast of Yellowknife and the northern part just over 100 miles (160 km) from Bathurst Inlet.

The area is most conveniently reached by bush plane from Yellowknife, numerous lakes of size and depth sufficient for landing such aircraft being distributed throughout the area. Early explorers, living largely off the land, reached the area by canoe, travelling from Great Slave Lake via the Yellowknife River, through the headwaters of Snare River to Coppermine River and thence to Point Lake. The journey however, is a difficult one beset by many portages. The Coppermine and Burnside Rivers, which flow northward from Point and Contwoyto Lakes respectively, are not navigable except by canoe. A few trees are present locally about Point Lake but the remainder of the area is barren and the whole is therefore readily accessible to landings by helicopter.

The southern part of the area forms a remote part of the hunting grounds of the Yellowknife Indians. The northeastern part is regularly visited by the Copper Esquimaux. No permanent settlement is present but there is a manned radio beacon on an island in Contwoyto Lake immediately east of the area.

HISTORY OF EXPLORATION

PREVIOUS WORK

The first white man to visit the country about Itchen Lake was likely Samuel Hearne who passed between "Point" and "Coghead" Lakes on his epic journey from Churchill, Manitoba, to the mouth of the Coppermine River in 1771 (Hearne, 1958). Although the route taken by Hearne has never been fully established, it has been reasoned that the "Point Lake" that he described was in fact the present Point Lake because Hearne noted the first appearance of trees there on his return journey (Back, 1970). "Coghead" Lake of Hearne corresponds to Contwoyto Lake (Back, 1970).

Sir John Franklin visited the area on his second expedition to the Arctic in 1820 and 1821 (Franklin, 1823). He chose the route up Yellowknife River to Coppermine River instead of taking the easier route by Great Bear Lake as he expected to be supplied during the winter and wished to establish a winter camp (Fort Enterprise) that was not too far from Great Slave Lake. The expedition reached Point Lake in September, 1820, but was deterred from going farther by the lateness of the season. Franklin again visited Point Lake on June 21st of the following year whence he travelled westward down the Lake on the ice. On the return journey the expedition crossed the Burnside River at the north end of Contwoyto Lake which Franklin named, "in consequence of Mr. Hearne having given rum to the Indians there". From Contwoyto Lake the party wandered southward, greatly weakened by shortage of food and fuel, losing their way in the bad September weather. Great difficulty was experienced in crossing the Coppermine River southeast of Point Lake, and several members died before the party reached Fort Enterprise.

Expeditions to the western arctic in search of Franklin after his disastrous third voyage of exploration passed, either to the west via Great Bear Lake to the lower Coppermine River (Rae, 1953), or via Back River to Chantrey Inlet (Back, 1970; Anderson, 1940, 1941). Various later travellers such as Warburton Pike (Pike, 1917) visited the Lac de Gras area, and some appear to have reached the southeast corner of the map-area during the hunting expeditions with the Indians.

The first geological observations in the map-area were by C.H. Stockwell (1933) who reached Point Lake via Yellowknife River from Great Slave Lake, and returned via MacKay Lake to McLeod Bay in 1932. H.S. Hicks, a member of Stockwell's party, examined the country about Hick's Lake (now Itchen Lake). Stockwell described the volcanic rocks and spectacular conglomerate near Keskarrah Bay on Point Lake which he believed to overlie an older chlorite granite. These rocks were found to be bordered by sedimentary schists, and both were shown to be intruded by younger granitic rocks. The youngest rocks within the map-area about Point Lake were found to be diabase dykes.

The west half of the map-area was mapped in the course of Operation Coppermine 1959, (Fraser, 1960); and the east half during Operation Bathurst Inlet 1962, (Fraser, 1964). These 8-mile reconnaissance surveys provided the first regional outline of Archean volcano-sedimentary belts, granitic areas, and Aphebian supracrustal rocks.

Chalcopyrite showings south of Point Lake near the west border of the map-area were staked by J. Harriman in 1957, and near the entry of Coppermine River into Point Lake by Canadian Nickel Company in 1959. Gold was discovered in Archean metasedimentary rocks near the northwest end of Contwoyto Lake in 1961 by the Canadian Nickel Company. A large area was involved in the initial staking for gold, and this lead to a staking rush in 1962. Commercial investigation spread westward from Contwoyto Lake to Itchen and Point Lakes beyond which the favourable zone apparently pinches out. By 1966 activity in the area had largely subsided. Interest in the area was revived in 1975 with the discovery of a major base metal deposit near Itchen Lake by Texasgulf Ltd.

PRESENT WORK

Four-mile mapping in the Itchen Lake area was begun in June 1964 and completed early in August, 1966. At the same time one-mile mapping was carried out in the northeast corner of the map-area by L.P. Tremblay. This sub-area (south to latitude 65°30' north, and west to longitude 111°30'west) has not been investigated by the writer but the map-units within it are modified after Tremblay so as to be compatible with the more generalized units adopted by the writer. The four-mile reconnaissance was conducted by two semi-independent, two-man traverse teams during the initial two summers, and was completed with one team in the final summer. The project included the filming of scenes showing geological field work in the barrens to form part of a documentary film, The Continuing Past, directed by the National Film Board, illustrating the work of the Geological Survey.

TOPOGRAPHY, DRAINAGE AND CLIMATE

The Itchen Lake map-area lies in the central part of the Bear-Slave Upland at the southwestern extremity of Bathurst Hills (H.S. Bostock, 1970). Elevations range from 1,229 feet (375 m) above sea level at Point Lake in the southwestern part of the area to somewhat over 2,100 feet (640 m) in the vicinity of Rockinghorse and Contwoyto Lakes. The greatest relief is somewhat over 600 feet (183 m) at Rockinghorse Lake but over much of the area local relief is 300 feet (91 m) or less. The land surface is commonly rolling but in the northern and northwestern parts, and along the basic volcanic belts, relief is more abrupt.

The principal rivers in the map-area are the Coppermine and Burnside which flow through and drain Point and Contwoyto Lakes respectively. The southern two thirds of the area drain directly into Point Lake, and a restricted region about Rockinghorse Lake drains into Takiyuak Lake to the northwest of the map-area and thence into the Coppermine. The remainder drains through Contwoyto Lake into the Burnside River. Two small rivers flow into Point Lake within the map-area, one from Itchen Lake into the north arm, and the other from the southeastern interior into the east end of the Lake. The former river requires five portages between Point and Itchen Lakes; the latter can be navigated at high water by canoe as far as the first lake system without portage.

The climate within the map-area for the three summer months is typically pleasant. Time lost due to rain or fog during the present project averaged 4 days per season. Flies may be a nuisance from middle July to middle August but in some seasons may last only a week or two. Ice suitable for ski landings by Otter or smaller aircraft is typically present in Point and Itchen Lakes until the end of the first week in June, and until later in Contwoyto Lake. In Point and Itchen lakes break-up comes roughly 3 weeks later but varies considerably from season to season. Travel on foot in the interior during this period is hindered by high water in the creeks. Fall weather, including fog, drizzle and distinctly colder temperatures, commonly sets in during the last week in August or in early September.

GEOGRAPHIC NAMES

The only major topographic features peculiar to the Itchen Lake region that had formal names prior to the present study are Contwoyto, Point, Itchen, and Yamba Lakes; Coppermine and Burnside Rivers, and Peacock and Willingham Hills. To these have been added during the present work, Keskarrah Bay and Rockinghorse Lake. Minor features within staked areas particularly near Contwoyto Lake were given informal names by exploration personnel involved in staking and subsequent evaluation of claims. Many of these names do not meet the requirements for formal nomenclature set out by the Canadian Permanent Committee on Geographic Names. Some, however have been formally adopted. These include Concession Lake, Fingers, Esker, Bar, Post, Wishbone, Fly, and Gossan Lakes, and Shallow Bay (proposed by L.P. Tremblay, 1966). Nevertheless, much of the map-area, except for the northeast corner, remains without convenient geographic reference. In the present report this is obtained by according informal names to plutons and other geographical features as set forth in the accompanying list and map, figure 2.

Table 1

List of Informal Names

Acid Batholiths

Yamba batholith: The large granitic batholith surrounding Yamba Lake in the southeast corner of the map-area.

Central belt batholith: The granitic batholith north of Yamba batholit in the east central part of the map-area.

Contwoyto batholith: The granitic batholith northwest of Contwoyto Lake in the northeast part of the map-area.

Rockinghorse batholith: The granitic batholith west of Rockinghorse Lake in the northwest part of the map-area.

Keskarrah batholith: The granitic batholith south of Keskarrah Bay in the southwest part of the map-area.

Basic Plutons

Concession pluton: The basic pluton southwest of Contwoyto Lake at Concession Lake.

Southern pluton: The basic pluton 18 miles northeast of the east end o Point Lake.

Western pluton: The basic pluton 7 miles west of Rockinghorse Lake in the northwest part of the map-area.

Eastern pluton: The small basic pluton on a peninsula on the east shor of Contwoyto Lake.

Fuz pluton: The small basic pluton 8 miles southwest of Rockinghorse Lake in the northwest part of the map-area.

Volcanic belts

Western volcanic belt: A belt of predominantly basic volcanic rocks in the west part of the map-area, extending from south to north margins, that bifurcates south of Keskarrah Bay.

Table 1 (Continued)

Central volcanic belt:	A belt of acid and basic volcanic rocks that stretches from a point about 4 miles southeast of Itchen Lake along a sinuous path to the east margin of the map-area some 16 miles south of Contwoyto Lake.

Figure 2

PLEISTOCENE GEOLOGY

The Pleistocene geology of the western part of the map-area was investigated by Craig (1960) as part of Operation Coppermine in 1959. Blake (1963) examined the eastern part of the area during Operation Bathurst Inlet in 1962.

The oldest ice flow recorded by glacial striae within the map-area appears to have been northeast or south southwest directed. Striae resulting from this flow regime were observed at three localities near Point Lake (near the west boundary of the map-area), but no other direct evidence was found. Tremblay (1967) has observed a few erratics of Goulburn rocks south of the present occurrence of the Goulburn Group and suggests that these may indicate either a net south to southwesterly ice movement, or the former occurrence of these rocks to the east or southeast of the map-area. Similar erratics were found in the hills east of Itchen Lake during the present work.

Striae, and drumlinoid hills, developed by late ice flow, trend north northwest to northwest about Contwoyto Lake. Farther to the west and southwest they show a westward fanning pattern that merges with westward directed striae evident in the Lac de Gras map-area (Folinsbee, 1949), and in the Winter Lake map-area (Fraser, 1969). More southwesterly directed striae are prominent near Point Lake where they intersect the westerly directed striae at angles up to 30 degrees or more. Drumlins within the area of intersecting striae follow either direction of striae. This feature and the local distribution of the intersecting striae suggest that they may have developed during ephemeral changes in ice flow pattern, perhaps influenced in part by the Point Lake topographic depression, that took place during the ice retreat.

Among other glacial features, eskers are prominent. These deposits which are in large part composed of sand, are the most common in the west part of the map-area. They typically follow the trend of late striae. Abandoned shore lines are well developed about 100 feet (30 m) above the present level of Contwoyto Lake (Blake, 1963). Similar shore lines were not observed about the other large lakes. Small areas of silt flat characterized by frost boils were observed locally however, particularly near the entrance to Point Lake. These lie well above the post-Pleistocene marine transgression and are likely due to deposition of glacial silt in ephemeral lakes. Rudely bedded sand, some 25 feet (7.5 m) or more thick, forms an island in the northern part of Contwoyto Lake (see Fig. 3). Although the shores of the island are badly slumped, the upper part is seen to be locally composed of up to 7 or 8 feet of roughly bedded sand and sandy organic matter containing large thin mica flakes. Underlying beds of variable sand size contain variable proportions of basalt grains. Gravel appears to have been plastered against the shores of the island by lake ice. Small amounts of peat are commonly found in the more gently sloping valleys (see Fig. 4) but in no place were exposures seen to exceed more than 4 or 5 feet (1.5 m) in thickness.

Figures 3 and 4

Drift cover within the map-area is typically thin but the area can be divided into regions of ubiquitous prominent outcrop with numerous erratics, and regions in which outcrop occurs at hill tops and in valley bottoms with gentle drift-mantled, grassy slopes predominant between. The latter terrain is extensive in the eastern part of the area southwest of Contwoyto Lake and also south of Itchen and Point Lakes, whereas the former follows an irregular belt from the southeast to northwest corners of the map-area. Eskers appear to be most numerous and extensive within and 'down-ice' from the belt of prominent outcrop perhaps indicating that ice conditions during the ice retreat permitted more efficient collection of debris by drainage within the ice over the belt of outcrop than elsewhere.

ACKNOWLEDGEMENTS

The writer was ably assisted in the field by Mr. Gerhard von Rosen (1964) and Mr. Brian Charboneau (1965) in their capacities as senior traverse assistants. Mr. Brian Mottershead and Mr. Richard Holmes (1964), Mr. Edward Reeves and Mr. Desmond Dufour (1965), and Mr. William Tuer and Mr. Stanley Hoffman (1966) provided capable assistance as junior assistants. The writer also wishes to acknowledge contributions from members of the staff of the Geological Survey of Canada; - -

Chemical analyses..............................Rapid methods staff

Spectrographic analyses.........................Spectrochemical laboratory staff

K/Ar and Rb/Sr age determinations...............R.K. Wanless and Geochronological laboratory staff

Pyrrhotite structural type......................David Fong

X-ray mineral determinations....................Robert Delabio

Floatation experiments were made by Mr. Art Page of the Mines Branch, Department of Energy, Mines and Resources. Electron probe analyses were made by George Plant, Elvira Gesparrini and G.L. Lachance.

GENERAL GEOLOGY

INTRODUCTION

The Slave Structural Province, which includes all but the Proterozoic cover in the northwest corner of the Itchen Lake map-area, constitutes an area of almost 75,000 sq. miles (194,000 sq. km) underlain predominantly by rocks of Archean age. Somewhat more than one third of this are granites of batholitic dimensions, but the greater part are sedimentary and volcanic rocks and their metamorphic equivalents. The stratified rocks are concentrated within three general areas: along the western margin of the province, as a belt extending northward through the central part of the province, and within a large less well defined more equi-dimensional area in the northeast part of the province. The granitic rocks separating these areas are mostly massive in the north and east parts of the province but in the west and south they are more widely foliated, and small areas, commonly more altered than the rest, are known for each of which some evidence indicates an age greater than that of the neighbouring stratified rocks (McGlynn and Henderson, 1970; McGlynn and Fraser, 1972). The Itchen Lake map-area lies athwart the central belt of stratified rocks in the central part of the Slave Province. It includes some granitic rocks that are younger than the stratified Archean succession and others that are older than at least a part of this succession.

The stratified Archean rocks of the Itchen Lake area consist of two partly contemporaneous volcanic and sedimentary subdivisions similar to Archean successions in other parts of the Slave Province and are thus part of the province-wide Yellowknife Supergroup as defined by Henderson (1970). The volcanic rocks of the Itchen Lake area can be further broken down into felsic calc-alkaline tuffs and flows at least in part followed by mafic, sub-alkaline flows and tuffs. The latest mafic volcanism was in places partly alkaline and was accompanied by evolution of exhalative iron and by local deposition of spectacular conglomerates. Exhalative iron was widely deposited as silicate, sulfide and magnetic oxide facies of iron-formation within the lower adjacent parts of a greywacke-turbidite succession that accumulated in basins adjacent to the volcanic rocks.

Early, Archean granitic plutonism began before deposition of at least part of the Archean volcanic succession, but very little is known of the conditions of emplacement of these early granites or of the time significance of the unconformity which separates possible basement from overlying stratified rocks. Is this basement preserved from a distinct pre-Kenoran orogenic episode, or is it essentially part of a continuously evolving Archean volcanic environment? The presence of felsic volcanic rocks as a part of the Archean volcanic sequence suggests that some early granitic plutonism occurred in conjunction with Archean volcanism in the Slave Province as it did in other parts of the Canadian Shield (Davidson, 1972). In the Itchen Lake area, where extensive, probably early calc-alkaline felsic volcanics are present, it is not clear to which alternative the basement (described by Stockwell, 1933), upon which the mafic volcanics are locally seen to rest unconformably, may belong. Some granitic rocks of early Kenoran age however were emplaced through this basement along antiformal welts within the Archean volcanic succession, and some of this granite was unroofed to provide detritus that was intercalated with the youngest mafic volcanic flows.

Evidence of early Kenoran or possibly pre-Kenoran diastrophism in the Slave Province is suggested by the occurrence of zones of mylonite-like rocks that have been partly engulfed by later Kenoran granites. One such zone is reported by Henderson, 1975 in the Hearne Lake area. Remnants of similar rocks intruded by granite occur along the west edge of a remarkably straight mafic volcanic belt at the west margin of the Itchen

Lake area, and extend south into the Winter Lake area (Fraser, 1969). Minor serpentinite bodies probably of similar age, are distributed along part of this belt perhaps providing a further reflection of early Kenoran crustal movement.

Later, Kenoran, syntectonic granitic plutonism was profound throughout extensive regions of the Slave Province producing aureoles of amphibolite facies, low pressure metamorphism where the Archean basins were invaded. Late tectonic, cross-cutting granites accompanied by pegmatites followed locally. In the Itchen Lake area metamorphic aureoles about the late Kenoran (Rb/Sr isochron age 2422 ± 95 my) syntectonic plutons reached middle to upper amphibolite facies. Along the pluton contacts upwarped margins of the adjacent Archean basins are extensively made up of the lower units of the Archean stratified succession. It therefore appears that these plutons occupy a stratigraphic position, at or near the base of the succession, where earlier plutons, which form part of the basement might be expected. Indeed, there is some reason to believe that late Kenoran syntectonic plutons throughout the Slave Province tended to be emplaced outside or along the margins of the Archean basins (McGlynn and Henderson, 1970), and that many of the plutons of the Itchen Lake area were to varying degrees compounded in this way.

Remnants of Proterozoic (Aphebian) stratified rocks of the Coronation Geosyncline (Hoffman et al., 1970) border the Slave Province on the west, northeast and southeast. Thick geosynclinal successions pass into relatively thinner strata over the margins of the Slave craton. Remnants of this cratonal cover, reflecting the various phases of geosynclinal development, are preserved within the northern part of the Itchen Lake area and provide the most nearly complete link available for correlation between northeastern and northwestern basins of the geosyncline.

Basic dykes and sills varying in age from early Aphebian to Hadrynian with a wide variety of trends have been described within the Slave Province. These reflect periods of crustal distension and in many cases were accompanied by basic volcanism, the products of which are still preserved about the margins of the province. Thus in the Itchen Lake area, where only some of these trends are expressed, early west-northwest to west trending dykes probably accompanied early flows in the Coronation geosyncline to the west. Prominent north-northwest trending dykes of the Mackenzie swarm (Fahrig and Jones, 1969) correlate with basic volcanism of Helikian age expressed in the Coppermine River flows at the northern margin of the province.

Metalliferous deposits of the Slave Province until very recently have not been prospected in any detail except in the southern regions about Yellowknife. General observations concerning the whole of the Province therefore tend to be biased by uneven distribution of data. It appears however, that iron-formation beds, extensive in the Itchen Lake area and also perhaps farther north and east, are not as well developed in the southern part of the Province. This variance in abundance of iron-formation may be sympathetic with the greater proportion of volcanics to rocks of sedimentary origin that is clearly evident in the northern part of the Province. Gold deposits associated with iron-formation in the Itchen Lake area occur on the southern margin of this northern volcanic-rich part of the Slave Province.

TABLE OF FORMATIONS

Eon	Era	Group	Formation	Lithology	Thickness metres feet	Radiometric age (m.y.)
Phanerozoic	Cenozoic			sand, gravel, peat		
				Great Unconformity		
Proterozoic	Helikian		NNW dykes	diabase and gabbro (Mackenzie dyke swarm)		1200
				Intrusive Contact		
			Sills			1555
				Intrusive Contact		
			E-W dykes	diabase and porphyritic diabase		
				Intrusive Contact		
	Aphebian	Rocks of the Coronation Geosyncline	see below	see below	see below	Between 2000 and 1750

Aphebian — Rocks of the Coronation Geosyncline:

Epworth Group Formation	Epworth Group Lithology	Goulburn Group Formation	Goulburn Group Member	Goulburn Group Lithology	Thickness 1	Thickness 2
Takiyuak	reddish brown sandstone grading locally to siltstone,	Brown Sound		(not present within the Itchen Lake map-area)	366 1200	
Cowles Lake	limestone and argillite	Kuuvik		limy and dolomitic rocks	823 2600	43 140
Recluse	argillite, sandstone siltstone, greywacke	Peacock Hills		argillite and quartzite	610 2000	49 160
Rocknest	dolomite	Burnside River		quartzite	700 2300	183± 600
Odjick	argillite quartzite	Western River	Upper Argillite	grey argillite, greywacke; some quartzite, red argillite.	640 2100	38 125±
			Quartzite	white and pink quartzites, siltstone; some gray argillite.		137 450
			Red Siltstone	concretionary red argillite, some grey and red argillite, greywacke.		148± 485
			Lower Argillite	red, grey and green argillites; some white quartzite		142 465
			Conglomerate	white quartz-pebble conglomerate		½ 2±

Eon	Era	Group	Formation	Lithology	Thickness metres feet	Radiometric age (m.y.)
				Great Unconformity		
Archean				Late Kenoran Plutons: quartz monzonite, granodiorite, granite; minor hornblende syenite		2495 K/Ar muscovite
				Intrusive Contact		
				diorite, quartz diorite, granodiorite, amphibolite.		
				Intrusive Contact		
		Yellowknife Supergroup	Itchen	metaturbidites lacking iron-formation lenses		
			Keskarrah	conglomerate; some subgreywacke, greenschist	450 1500+	
			Contwoyto	metaturbidites with interlensed iron-formation		
				Local Unconformity		
				Early Kenoran Plutons: granodiorite, quartz diorite, quartz monzonite, some quartz porphyry		2642 zircon sphene (corroborated by K/Ar muscovite 2560–2660)
				Intrusive Contact		
				serpentinite, metagabbro.		
				Intrusive Contact		
			Point Lake	f) mafic flows; some mafic tuffs; minor felsic flows.	2130± 7000	
				e) mafic tuffs, amphibolite; some pillowed flows	260 850±	
				d) banded felsic to mafic tuffs; some amphibolite, calcareous metasediments		
				c) calcareous metasediments		
				b) felsic flows with variable proportion of mafic tuffs and flows		
				a) massive felsic tuffs, some felsic flows.		
	?	?	?	Unconformity ? ?	?	
				Possible remnants of older Archean basement within hybrid and plutonic rocks especially at Keskarrah Bay.		

Notes: 1. Thickness estimates from Fraser (in Press) for the Epworth Group at the east edge of the Epworth basin.
2. Thickness estimates from Tremblay (1967) and for the Lower Argillite Member from this report.
3. Age estimate for rocks of the Coronation Geosyncline (Hoffman et al., 1970).

YELLOWKNIFE SUPERGROUP

POINT LAKE FORMATION

Introduction

The name, Point Lake Formation, is proposed for the volcanic rocks and intercalated sediments in the succession of Archean volcanic and sedimentary rocks of the Point Lake region that Stockwell (1933) described in his Point Lake - Wilson Island Group. The term, Point Lake phase, was used by Lord (1941, 1959) to refer to rocks north of the north shore of Great Slave Lake that are specifically comparable to those in the Point Lake area. Henderson (1938) applied the term, Yellowknife Group, to rocks that essentially correspond to the Point Lake phase of the Point Lake - Wilson Island Group. Subsequent authors including Brown (1950) and Wright (1951) continued this usage. The term Point Lake beds was used by Douglas (1959) for "sedimentary gneiss and schist" in the Point Lake area. In view of this varying definition of the term it might seem desirable to adopt a new name for the volcanic rocks considered in this section of the report; however, such a procedure would require the naming of a minor topographic feature to represent a formation of regional extent. In view of the good exposure of a large part of the volcanic section at and near Point Lake it seems preferable to redefine the name to apply to the primarily volcanic lower part of the Point Lake "phase" of Stockwell's Point Lake - Wilson Island Group as it occurs in the Itchen Lake area.

The Point Lake Formation is best preserved in two belts of volcanic rocks; one, the western volcanic belt, extends north-south along the west margin of the map-area and bifurcates south of Point Lake; and the second, the Central volcanic belt, extends as a complex double-pronged belt northeastward across the central part of the area toward Contwoyto Lake near which it veers southeastward. Remnants of the formation are also clearly preserved within the hybrid rocks that widely flank the Yellowknife Supergroup in the Itchen Lake area. No single type section for the formation is proposed because of the reconnaissance nature of the present study and because no single set of exposures includes all the principal lithologic types. Rather, areas illustrating each of the lithologic types will be referred to during description of each of the map subunits. The name of the formation is taken from Point Lake where it is perhaps most accessible.

The maximum thickness of the Point Lake Formation is probably in excess of 10,000 feet (3,000 m). A section of this thickness was measured in the Central volcanic belt about 21 miles (34 km) southwest of Contwoyto Lake where the basal part of the formation has been removed by faulting. Rocks in this section are in part highly schistose and there is the possibility that they have been thickened or thinned during penetrative deformation.

The Point Lake Formation within the map-area consists primarily of a series of felsic to mafic tuffs, flows and metasediments with some calcareous rocks. These rocks are in part bedded and clearly water lain, but most of them show little direct field evidence of their origin. They are however, commonly related to known volcanic rocks in composition, mineralogy and distribution, and are therefore inferred to be ultimately of pyroclastic derivation. The formation is divided into six subunits as follows:

a) Massive felsic tuffs, some felsic flows,
b) Felsic flows with variable proportions of tuffs and mafic flows,
c) Calcareous metasediments,
d) Banded felsic to mafic tuffs, some amphibolite, some calcareous metasediments,
e) Mafic tuffs, amphibolite, some pillowed flows in the central volcanic belt,
f) Mafic flows with minor tuffs and felsic flows,

Although these subunits are listed in an idealized stratigraphic sequence, the true succession is not fully known because indicators of stratigraphic tops are scarce and the rocks are extensively deformed. In addition, the calcareous metasediments ($\bar{A}$nc), which are mostly associated with banded felsic to mafic tuffs, may occur at various locations within the tuffs. Nevertheless such evidence as is available suggests that there is a progression from more felsic rock sequences in the lower part of the formation to more mafic ones in the upper part. In the western part of the map-area the felsic volcanic rocks occur mostly in the core of what appears to be a doubly plunging antiformal zone with synformal culmination in the Point Lake region, but definitive age relations between felsic and mafic volcanics were not found. In the central part of the area felsic to mafic tuffs and flows are extensively interleaved but over much of their exposure there appears to be an overall increase in the proportion of mafic rocks toward the top. In the eastern part of the map-area tuffaceous rocks are greatly predominant but again there is an increase in the proportion of mafic material and an improvement in the definition of banding in the inferred direction of stratigraphic tops. This does not however preclude the possibility that some of the basic volcanic rocks, particularly some within areas of hybrid rocks and within the thicker complexly deformed parts of the mafic volcanic belts, are older than the felsic volcanic rocks.

The base of the Point Lake Formation is unknown because felsic tuffs which comprise its lower part are granitized, faulted against, or intruded by granite rocks. The youngest strata of the formation that have been recognized were deposited synchronously with iron-formation-bearing greywackes and metaturbidites that occupy a lower part of the adjacent sedimentary basin, and lie directly beneath the Keskarrah Formation conglomerates. Mafic volcanic clasts, probably bombs, suggest that some volcanism continued during deposition of the Keskarrah Formation.

Massive Felsic Tuffs (Avat)

Felsic tuffs are most extensively preserved along the concave margin of the Central volcanic belt where they structurally underlie more mafic, banded tuffs or felsic to mafic flows. They are also evident along the east margin of the western volcanic belt near Point and Itchen Lakes. On the west margin of the latter belt somewhat similar but strongly foliated rocks, thought to be mylonites, may represent massive felsic tuffs. Similar rocks along strike in the Winter Lake area to the south, have been mapped as mylonites (Fraser, 1969).

The felsic tuffs are typically grey-white to buff weathering, grey to white or locally greenish, fine-grained rocks with a somewhat sugary texture. Where least deformed they commonly contain a few obvious grey to bluish quartz grains up to 2 or 3 mm in diameter distinctly coarser than their granular, locally sericitic, quartzo-feldspathic matrix. Porphyritic felsic flows containing plagioclase phenocrysts are present locally. Either biotite or dark green prismatic hornblende (or chlorite) may be present, typically in amounts less than a few per cent. The rock may be entirely massive in outcrop, although most commonly it has a slight whispy foliation expressed by thin lenticular concentrations of mafic minerals. Banding is rare in the lower beds but improves in higher parts of the formation which contain a greater proportion of mafic minerals. Lenticular banding, present in otherwise massive tuff at one locality along the west margin of the central belt batholith is shown in Figure 5. Rock from the vicinity of this exposure is seen in thin section to be porphyritic and the fold-like structure visible in the figure may perhaps be due to primary flow in a welded tuff (?). Where the tuff is deformed it locally forms sericitic schist, as in parts of the Central volcanic belt.

Figure 5

The lower contacts of the felsic tuffs, wherever they have been traversed, are indefinite boundaries between fine-grained massive tuffs and granitic plutonic rocks. In some areas along parts of the central volcanic belt outcrops of felsic tuff are interspersed with outcrops of medium-grained granitic rocks. At a smaller scale, as near the southeast margin of the massive felsic tuffs of the central volcanic belt, the rock may be extensively veined and dyked by granitic rocks; elsewhere, patches of medium-grained granitic rocks as small as an inch or two in diameter are locally surrounded by fine-grained tuff in the vicinity of the granite contact. South of the west arm of Itchen Lake fine-grained rocks of either tuff or flow origin appear to be gradational into medium-grained plutonic rock. On passing into the volcanic basins from granite contacts (or locally from faults), basinward dipping siliceous tuffs typically give way to more mafic and better banded tuffs, or locally directly to massive felsic or basic flows. Near the south margin of the massive felsic tuff in the Central volcanic belt this change occurs along strike as well, but there it may be due to plunge of the massive tuffs beneath the banded tuffs and flows to the west.

The felsic tuffs consist of a mosaic matrix of quartz and sodic plagioclase (albite to calcic oligoclase) in some cases accompanied by microcline. Grain size is typically 0.5 mm or less. Biotite is the most frequent mafic mineral and hornblende is less common. Locally cummingtonite is present, and in a few places, sillimanite, staurolite, cordierite and garnet. Muscovite is in some places disseminated through the rock and in others it is present as porphyroblasts or in whisps (see Fig. 7b). Accessory minerals are magnetite-ilmenite, apatite, iron sulfide, sphene, allanite, zircon and tourmaline. Clinozoisite, epidote, chlorite and carbonate are local alteration products. In places distinct equant quartz crystals up to 2 mm in diameter, which are optically continuous or recrystallized in varying degrees to a fine mosaic, are present. These may be accompanied by more or less altered phenocrysts or glomerocrysts of twinned sodic plagioclase possibly indicating that some of these rocks are recrystallized porphyritic flows.

In the mylonites that outcrop along the western edge of the Western volcanic belt, quartz and feldspar form a fine-grained, foliated, granoblastic mosaic in which quartz lenticles have also been recrystallized (see Fig. 6). In places granitic bands parallel foliation but are themselves unfoliated.

Figure 6

Felsic Flows with variable proportion of Tuffs and Mafic Flows (Ava)

The felsic flows are most extensively exposed in the middle, double-pronged part of the Central volcanic belt where they are apparently interleaved with tuffs and basic flows. The felsic tuffs of this subunit resemble those of the massive felsic tuff subunit, but grade into denser, darker coloured, more obviously porphyritic rocks thought to be felsic flows, and are in places interlayered with mafic flows like those in the mafic flow subunit.

The felsic flows are grey to white, buff, grey or greenish, typically dense tough porphyritic rocks. Whitish plagioclase phenocrysts are typically present up to 3mm in diameter with or without quartz in a fine-grained to aphanitic, siliceous, somewhat translucent matrix.

The felsic flows are composed mostly of a fine-grained matrix typically less than 0.2 mm in grain diameter, consisting of quartz, alkali feldspar and minor mafic minerals and variable proportions of phenocrysts of quartz and albite to calcic oligoclase (See Fig. 7) in places up to 3 mm in diameter. Quartz phenocrysts are commonly equant and may be sharply terminated, resembling beta quartz in form (See Fig. 7d).

Some show reentrants along their margins suggesting magmatic corrosion. In a few sections from felsic volcanics in hybrid rocks south of Rockinghorse Lake haloes of silica in the matrix surrounding quartz phenocrysts have optical orientation parallel with that of the enclosed crystal (See Fig. 35 of felsite from hybrid rocks). Plagioclase phenocrysts are commonly slightly rounded but may be sharply euhedral (See Fig. 7a). Microcline, observed in a few sections, does not form distinct phenocrysts. The chief mafic mineral, biotite, is usually present in amounts of 5 per cent or less. Hornblende was found in only one specimen. Muscovite, commonly constituting no more than 5 per cent of the rock, may be disseminated, porphyroblastic, or concentrated in whispy lenses. Small amounts of epidote, chlorite and carbonate are present locally. Accessory minerals are magnetite-ilmenite, tourmaline, apatite, sphene and zircon.

Figure 7

Calcareous Metasediments (Anc)

Thin bands and lenses of siliceous calcareous rocks are widely distributed in the banded tuffaceous parts of the Point Lake Formation. The largest of these, and the only one of mappable size, occurs near the southern fault margin of the north branch of the Central volcanic belt where a lens of siliceous marble (see Fig. 8) reaching a maximum thickness of roughly 50 to 100 feet (15 to 30 m) extends for several miles along strike.

The marble is buff-brown weathering, grey-white, fine-grained rock containing large green patches in which tremolite-actinolite is conspicuous. In places it is finely and intricately banded with siliceous material. Adjacent to the marble, and for several miles along strike beyond, calcareous lenses are present within the banded tuff, recognizable by their pitted surface and the presence of garnets or other calcsilicates.

Figure 8

The marble consists mostly of crystalline calcite with patches of tremolite-actinolite and serpentine, and scattered grains of quartz and andesine. Calc-silicate lenses along strike from the marble contain as much as 40 per cent of carbonate. Quartz, calcic plagioclase and garnet are commonly present in these lenses and may be accompanied by any one of several different minerals including microcline, diopside, hornblende, tremolite, cummingtonite, epidote and chlorite. In some lenses the plagioclase is anorthite, in others, andesine (determined by refractive index measurements). Accessory minerals are magnetite-ilmenite, apatite, sphene and iron sulfide. Similar rocks characterized by unusually basic plagioclase and locally accompanied by garnet are present in the tuffs north and south of the west arm of Itchen Lake and near the east end of the north arm of Point Lake.

Banded Felsic to Mafic Tuffs (Av)

Banded felsic to mafic tuffs are most extensively exposed in the Central volcanic belt. At the eastern extremity of the belt these rocks structurally overlie the massive felsic tuffs and comprise the upper part of the Point Lake Formation in this region. Farther west they are interleaved with felsic to mafic flows. Similar rocks, downfolded within the Central belt batholith, have been more highly deformed and recrystallized to form isolated belts and remnants of hornblende gneisses and some cordierite-anthophyllite gneiss. Banded tuffs are again prominent in the northern branch of the Central volcanic belt where the proportion of mafic tuffs and flows appears to increase both northward (upwards) across strike, and westward. About the west arm of Itchen Lake similar but more commonly chloritic banded rocks are present between massive felsic tuffs and flows to the west, and iron-formation-bearing schists of the Contwoyto Formation.

The banded felsic to mafic tuffs are chiefly fine-grained, white to grey, buff, or greenish rocks in which schistosity and fine banding or lenticular layering are widely evident. Coarser banding marked by high contrast in proportions of mafic and felsic components may be evident. Where alteration is least intense the bands are fine-grained and chloritic; where it is more intense, sericite, or biotite, or acicular hornblende, accompanied by fine, granular quartz and feldspar is characteristic of different bands. In places, particularly in the upper part of the subunit, amphibolite composed largely of prismatic hornblende is present. Elsewhere, particularly in the lower part of the subunit, calc-silicate lenses, locally bearing garnet, are evident. An outcrop consisting of stretched quartz porphyry ovoids up to a few inches in section in a green schistose hornblendic matrix was found at one locality in the central part of the Central volcanic belt, apparently associated with a massive flow within the bedded tuff. This apparently is a deformed volcanic breccia. Rarely lenses of pelitic schist are present.

Hornblendic gneisses, which form remnants of banded tuffs within the Central belt batholith, are dark green to grey, fine- to medium-grained rocks that are mostly foliated and in places preserve banding of varying thickness. Biotite-and muscovite-bearing gneisses form subordinate interlayers. Locally coarse feathery amphibole crystals are present and at one locality coarse amphibole coronas were observed about blotches of an unidentified anhedral leucocratic mineral in garnetiferous hornblende-quartz-feldspar gneiss. Grey anthophyllite-cordierite gneisses contain fibrous, radiating, pale greenish brown anthophyllite which forms interlaced sheaths that reach several centimeters in length.

Textures and mineral compositions of the banded tuffs as seen under the microscope are variable, examples resembling those of both massive felsic tuff and basic tuffs being evident. The rocks are mostly fine-grained (less than 1 mm) but some of the more felsic layers contain isolated quartz grains up to 2 or 3 mm in diameter in a fine quartz-feldspar matrix. Plagioclase megacrysts are rare but inclusions of several mm in diameter composed of several grains of quartz and plagioclase were observed in some thin sections.

The most common minerals are plagioclase (albite to labradorite), quartz, biotite, hornblende, muscovite and microcline. Cummingtonite and diopside were observed in sections from some layers. Anthophyllite ($(-)2V\simeq 82°$) was found in one section. Chlorite and epidote are present locally, particularly in rocks of low metamorphic grade. Accessory minerals are magnetite-ilmenite, apatite, sphene, and iron sulfide. Amphibolitic bands are composed of green hornblende commonly in prismatic crystals and an intermediate plagioclase. In some regions grains of poikilitic hornblende are present.

The hornblende gneisses within the Central belt batholith consist primarily of acicular pale blue-green hornblende, quartz and plagioclase, including labradorite, with traces of epidote, carbonate, muscovite, chlorite, magnetite-ilmenite and apatite. Cordierite-anthophyllite gneiss consists chiefly of cordierite ($(-)2V\simeq 75°$) and radiating acicular anthophyllite crystals with minor quartz, magnetite, chlorite and trace apatite.

<u>Mafic Tuffs (Avt)</u>

Mafic tuffs occur as bands within the banded tuff (unit 1d), but in two areas they form distinct mappable units that structurally overlie more felsic rocks. The most extensive of these lies along the west margin of the Western volcanic belt where mafic tuffs are up to 850 feet (260 m) thick. The second area comprises the northern side of the north branch of the Central volcanic belt where the mafic tuffs contain some pillowed flows particularly in the western part of the belt.

The mafic tuffs along the west margin of the Western volcanic belt are characteristically dark green, fine-grained rocks. Where least altered they are commonly laminated with darker green, more hornblendic lamellae interbanded with lighter green more feldspathic lamellae. More uniform, dark green, schistose tuffs containing a sprinkling of white feldspar grains are commonly present in the lower part of the subunit and may represent a more altered equivalent of the overlying rocks. Thin siliceous bands, in places bearing white plagioclase megacrysts are interleaved locally. Where tuffs are least altered and bedding is evident, scour and fill structure can locally be discerned (See Fig. 9). Where the subunit intersects the north shore of the south arm of Point Lake a variety of stretched altered siliceous to mafic pebbles, possibly derived from the siliceous volcanic subunits (See Fig. 10), were observed in the tuff.

Figures 9 & 10

In the northern branch of the Central volcanic belt, dark green, fine-grained, schistose amphibolites characterized by prismatic hornblende, with some interbanded siliceous tuffs, are prominent in the northern, upper part of the section. Locally elongate pillows are preserved indicating that mafic flows are present, and such flows are most numerous at the western end of the northern branch. Similar amphibolites have been observed at the eastern extremity of the Central volcanic belt southwest of Contwoyto Lake and in the southern part of the Central volcanic belt but in the latter occurrence their relationship to the surrounding tuffs and flows is not clear.

The grain size of the mafic tuffs ranges from 0.2 to 1.5 mm. Green or blue-green hornblende is abundant, and is accompanied by andesine or more rarely by calcic oligoclase or labradorite, but in some places quartz is the principal felsic mineral comprising up to 40 per cent of the rock. Locally calcareous laminae are preserved (See Fig. 11). Rarely, traces of oscillatory zoning are present in plagioclase and this zoning is typically diffuse with either normal or reversed trends. Cummingtonite or clinopyroxene are found locally in the more highly metamorphosed rocks and epidote, chlorite, carbonate, and clinozoisite are evident in rocks of lower metamorphic grade. Garnet and muscovite are less common. Accessory magnetite-ilmenite, sphene, apatite and iron sulfide are common, but zircon is rare.

Figure 11

Mafic Flows (Avt)

The mafic flows of the Point Lake Formation are most prominent in the Western volcanic belt, but are also numerous in the southern branch of the central belt, and in the western part of the northern branch. The maximum thickness of flows in unknown, but, south of Point Lake very roughly 7,000 feet (2,100 m) of mafic flows are preserved within a syncline the base of which is at least locally faulted.

Figures 12 & 13

The mafic flows are typically dark weathering, dark green to yellow-green, fine-grained rocks that may be pillowed (See Fig. 12 and 13) or massive. Lighter green and distinctive grey flows occur in the area about the south arm of Point Lake. Zones of greenish, grey, or black, fine-grained, laminated slaty or schistose, locally carbonate-bearing, locally sulfide-rich sediments are present here and there between flows.

A pillow breccia with matrix consisting in large part of oxide iron-formation occurs on the northwest shore of the second point west of Keskarrah Bay (See Fig. 14). In some places, principally in the northern part of the western belt, pinkish-grey, aphanitic or porphyritic felsic flows or sills were observed. The thickest of these forms a flat bottomed lens some 80 feet (25 m) long with a dome-like structure 30 feet (9 m) high on its eastern (upper) side.

Figure 14

Structures within the mafic flows are poorly known south of Point Lake and west of Keskarrah Bay, however pillow tops clearly indicate the presence of a tight synform the core of which is occupied by conglomerates of the Keskarrah Formation. A distinctive grey flow at or near the base of the conglomerate probably represents a late phase of Point Lake volcanism. Between the arms of Point Lake a similar grey flow occurs within a thin discontinuous belt of grey and green mafic volcanic rocks east of the conglomerate, and pillows in green flows to the west of the conglomerate face toward the conglomerate. Field relations of the grey flows suggest that the flows north of the south arm also lie on the limbs of a synform with the conglomerate at its core, and that the mafic flows pinch out eastward.

The mafic flows are mostly fine grained (grain size 0.5 mm or less), but where they are more intensely recrystallized hornblende is coarser grained. Green or blue-green hornblende is the prinicipal mineral in the darker green flows and is accompanied by calcic oligoclase or andesine. Minor quartz and variable proportions of chlorite, carbonate, epidote or clinozoisite may be present. Accessory minerals are magnetite-ilmenite, iron sulfide, sphene and apatite. In the lighter green flows, found at the core of the syncline south of Point Lake the principal mineral is epidote with prominent chlorite and smaller amounts of quartz and calcite. Sodic plagioclase was recognizeable in one flow by its low refractive index. Magnetite-ilmenite and sulfides are accessory minerals. A thin section from the grey flow north of the south arm of Point Lake shows randomly oriented, chiefly elongate, lath-shaped, sodic plagioclase crystals up to 1.4 mm in length with interstitial chlorite-carbonate, and accessory sulfide and rutile (?).

Chemical Analyses of the Volcanic Rocks

Chemical analyses, by a combination of X-ray fluorescence and chemical methods, of volcanic rocks from each of the major subunits of the Point Lake Formation are given in Table 2. The similarity in variation shown by mafic to felsic rocks containing volcanic structures or textures on the one hand, and the comparable, largely tuffaceous amphibolites, banded rocks, and massive felsic rocks on the other lends support to the conclusion that the Point Lake Formation is principally of volcanic origin. In the following diagrams analyses for each of the major lithologies are given distinctive symbols, and are plotted together to illustrate this similarity.

Figure 15

Tables 2 & 3

The chemical analyses have been classified according to the system of Irvine and Baragar (1971). The alkali-silica diagram and normative Ol'-Ne'-Q' (olivine-nepheline-quartz) projection (Figures 15-1 and 15-2) indicate that the volcanic suite characterizing the Point Lake Formation in the Itchen Lake area is subalkalic. Only one of the analyses shows consistently alkaline characteristics. This analysis (634) represents a grey mugearite flow along the east margin of the Keskarrah Formation conglomerate and presumably reflects a very late variation in the volcanism typical of the Point Lake Formation. Alumina vs. normative plagioclase and A.F.M. plots, suggested by Irvine and Baragar (1971) as a basis for division of the sub-alkaline rock series into tholeiitic and calc-alkaline subseries, divides samples from the Point Lake Formation into two groups (see Fig. 15-3 and 15-4) with felsic rocks falling in the calc-alkaline field and mafic rocks straddling the boundary but lying mainly in the tholeiitic field. The rocks of the Point Lake Formation may be further classified, using the normative colour index vs. normative plagioclase, and Ab'-Or-An cation per cent plots of Irvine and Baragar, (see Figs. 15-5 and 15-6). These plots suggest that basalt, andesite, dacite and rhyolite are present. The plots together demonstrate, as is suggested in the field by differences in mineralogy and colour, that the mafic and felsic volcanic rocks are chemically distinct. This is particularly well illustrated by the isolation of the two groups of analyses in the alkalis vs. silica and A.F.M. plots.

The mafic rocks are found to be largely normal potassium-poor basalts and andesites comparable to those found elsewhere in the Archean volcanic belts of the Canadian shield. This is born out by direct comparison of the analyses with averages published by Wilson et al. (1965) for volcanic rocks of the Superior Province, and by Baragar (1966) for rocks from the Yellowknife area.

The felsic rocks of the Point Lake Formation, in comparison to those from the Yellowknife area (see Fig. 16), appear to be silica-rich, and magnesia poor. The Point Lake felsites are comparable to soda-rich rhyolites from the Superior Province described by Wilson et al., 1965 (see Fig. 17). Rocks similar to the potassic rhyolites described by these authors are not common in the Itchen Lake area, and indeed the occurrence of such rocks within Archean volcanic belts is probably exceptional (Ridler, 1970).

Figures 16 & 17

Among the mafic volcanic rocks, sample 634 (Table 2) is clearly distinctive representing a mugearitic flow at the contact between the Point Lake and Keskarrah Formations. Samples 539 and 587 (Table 12), representing medium green basic flows from the upper part of the Point Lake Formation south of Point Lake show little chemical variation from samples taken lower in the section. The high CaO content of 539 partly reflects microscopic carbonate veins.

Six samples of felsic volcanic rocks, both tuffs and flows, are typical of the felsic volcanics thought to lie in the lower part of the Point Lake Formation. Average values for the major oxides for these samples are shown in column 7, Table 3. Sample 425, the only sample with excess potash over soda, might have been excluded on the basis that the rock is somewhat sheared. The average analysis is rather similar to that given by Viljoen and Viljoen (1969) as typical of widespread feldspar porphyries intrusive into the Komati Formation in the lower part of the early Precambrian Onverwacht Group, South Africa.

Other felsic analyses (Table 3) include two (199 and 139) of tuffs that are likely contaminated by calcareous sediment, one (124) from the mylonite zone at the base of the Western volcanic belt, one (792) penetratively deformed felsic tuff in the north arm of the Central volcanic belt, two (882 and 886) of felsic porphyries from the hybrid zone south of Rockinghorse Lake, and one (147a) from a thin felsic flow interbedded within the mafic pile at the north end of the Western volcanic belt. The latter four rocks are more potassic than the typical felsic volcanics, the first three perhaps as a result of migration of potassium during metamorphism and deformation. Sample 147a however, being from within the basic volcanic pile, is probably younger and may represent a later phase of volcanism.

Comparison of the volcanic suite at Itchen Lake with the volcanic rocks about Yellowknife described by Baragar (1966) suggests that the mafic rocks of the Point Lake Formation are similar to those at Yellowknife (see Fig. 16). An iron enrichment trend, suggested by Baragar for the Yellowknife volcanics, is not evident in the Point Lake Formation but this may be due to the small number of analyses compared. The felsic rocks from both areas tend to be calc-alkaline but those from the Point Lake Formation are more siliceous than are the majority of felsic rocks at Yellowknife.

Origin and Age Relations

The volcanic and subaqueous origin of the mafic flows of the Point Lake Formation is clearly indicated through the widespread occurrence of recognizeable pillows. Numerous subhedral plagioclase phenocrysts, with or without quartz phenocrysts, in a fine-grained quartzo-feldspathic matrix strongly suggest a volcanic origin among the more felsic rocks. Less well demonstrated is the origin of the banded felsic to mafic rocks. The association of these rocks, however, with demonstrated volcanic flows in various volcanic belts, and their similar range in chemical compositions (see discussion of chemical analyses) except perhaps for the local addition of carbonate (possibly of exhalative origin), is clear. The data suggest that the banded felsic to mafic rocks have a large volcanic component derived from the same sources as the flows. This component was widely distributed between volcanic centres being thinner in the more remote areas, and therefore probably took the form of wind blown tuffs, or perhaps of ash flows in the case of the more massive felsic rocks. Locally preserved scour and fill structures, quartz-rich bands, carbonate lenses, and rare conglomerate beds, however, indicate that these rocks have been to a greater or lesser extent reworked and modified by sedimentary processes.

The Point Lake Formation typically dips away from major granitic bodies where it is exposed in contact with them. In places, as along the west margin of the Western volcanic belt, the contact is probably mylonitized and later intruded by granitic rocks. Elsewhere, it tends to be gradational either by gradual change in character of the rocks, or by interleaving of bodies of either lithology at varying scales. The base of the Point Lake Formation is therefore 'lost' within the granitic plutons which are in part younger, but which in part may represent the basement upon which it was deposited. More detailed work will be required to establish the preservation of a sialic basement upon which the early volcanics were extruded.

The age of the Point Lake Formation relative to the Contwoyto and Keskarrah Formations is fairly clear. North of Point Lake, where iron-formation-bearing slates of the Contwoyto Formation lie against pillowed flows (the contact is not exposed) pillows in the flows indicate stratigraphic sequence from the flows up into the Contwoyto Formation. The Point Lake Formation is therefore probably mostly older than the Contwoyto Formation. On the other hand a pillow breccia near the top of the Point Lake Formation contains oxide iron-formation similar to that in the Contwoyto Formation as matrix, and mafic volcanic clasts, likely bombs, are present within the Keskarrah Formation. It thus appears that late Point Lake volcanism continued during deposition of the Contwoyto Formation and terminated, perhaps explosively, during deposition of the Keskarrah Formation conglomerates.

The relative age of felsic and mafic volcanism within the Point Lake Formation is less clear. The intervention of mafic flows immediately west of Itchen Lake between felsic volcanics to the west and the Contwoyto Formation to the east without evidence of faulting indicates that the basic volcanics here are younger than the main exposures of felsic volcanics.

Moreover, pillow tops in the basalt face eastward. Similarly in the central volcanic belt mafic volcanic rocks over extensive areas intervene between felsic volcanics and the Itchen Formation. In both areas the felsic volcanic rocks appear to lie on or be intruded by plutonic rocks and basic volcanics stratigraphically below them are not evident. The simplest senario consistent with these observations would suggest that mafic volcanism for the most part followed a period of extensive felsic volcanism and may have terminated in the Point Lake area with a few alkalic (mugearitic) flows. This may indeed have been the case.

On the other hand felsic and mafic volcanism are clearly in places overlapping and there is little evidence for any extensive unconformity between them. Furthermore the assumption of a single volcanic cycle progressing from major felsic to mafic phases is the reverse of volcanic cycles documented at Yellowknife and in other Archean volcanic belts in the shield (Baragar, 1966; Ridler, 1970; Goodwin, 1973). The observations admit the possibility that felsic and mafic volcanism were to a considerable extent concommitant and that mafic rocks older than the felsites may be preserved in some parts of the main volcanic belts and within areas of hybrid rocks. Nevertheless it seems clear that over extensive regions of the Itchen Lake area where the contact between Point Lake and younger formations is exposed, the latest volcanic unit is a mafic one.

ULTRAMAFIC AND RELATED ROCKS (Aub and Abn)

Several small bodies of serpentine and of possibly related hornblende-rich metagabbro are present along the Western volcanic belt. Similar, possibly related rocks are reported by Fraser (1969) within hybrid gneisses at the east end of Akaiyesseh Lake in the Winter Lake area to the south. One serpentine lens of unknown length and about 30 feet (9 m) thick is present near the west contact of the mafic tuffs some 6 miles (10 km) west of Itchen Lake. A second of similar width is exposed on a south facing slope within mafic tuff about one and a half miles (2.5 km) south of Point Lake, and a third body of unknown thickness is present near the east margin of the Western volcanic belt just over 4 miles (6.5 km) north of the south boundary of the map-area. Two metagabbro bodies several hundred feet thick and probably a mile or more in length occur near the base of the mafic flows along the west margin of the western volcanic belt 2 (3.2 km) and 6 (9.5 km) miles south of Point Lake. A third small body was observed in a similar position about one mile (0.4 km) farther south.

The serpentine bodies are characteristically buff brown weathering, sea-green, and very fine grained. Weathered surfaces may be finely ridged reflecting a schistosity that is less apparent on fresh surfaces. The metagabbros are dark green weathering, dark green, medium-grained, massive rocks rich in hornblende.

The serpentine bodies consist of about 75 per cent massive fine-grained serpentine. The remainder is largely chlorite, tremolite-chlorite, or anthophyllite-chlorite, and magnetite. Chlorite may exist in anastamosing masses vaguely outlining serpentine-tremolite granules about 1.5 mm in diameter, or chlorite may form in whisps producing a whispy schistosity through otherwise massive serpentine. The metagabbros are medium to coarse grained (up to 7 mm) with 60 to 70 percent of pale brown to green amphibole and lesser intermediate plagioclase (andesine or labradorite), chlorite, epidote, and opaques.

Table 4

Chemical Analyses

Chemical analyses of four serpentinites and two metagabbros from the western part of the map-area are shown in Table 4. The serpentinites are clearly ultramafic in their low silica and alumina and high magnesia contents. They are similar to many alpine ultramafics in low CaO and high water contents (high degree of serpentinization). On the other hand the Cr-Ni ratios of the ultramafics from the Itchen Lake area are unlike the alpine peridoites described by Irvine and Findlay (1972) and are comparable to Cr-Ni ratios found by these authors in layered ultramafic intrusions. The low contents of Al_2O_3 and CaO are unlike those of most ultramafic lavas (komatiites as defined by Brooks and Hart, 1974).

Age and Origin

The ultramafic rocks and hornblende-rich metagabbros lie mostly within the mafic tuffs below the mafic flows of the Point Lake Formation. Near the south boundary of the map-area there appear to be mafic flows on either side of serpentinite but the succession there may be repeated by faulting. The ultramafic rocks are therefore not older than the mafic tuffs that appear within the Point Lake Formation. Because they are deformed in contrast to Aphebian rocks (Epworth and Goulburn Groups) to the northwest and northeast, they are almost certainly of Archean age, but no other direct evidence of their age is at hand.

The distribution of the serpentinite bodies suggests that they follow the basic tuff horizon in the Point Lake Formation around major folds and are older than this folding. These rocks appear more complexly folded than the Keskarrah Formation in the core of the syncline to the east. Folding in this latter formation was accompanied by greenschist facies metamorphism that is thought to be responsible for the K/Ar muscovite ages (2660 ± 75 my, 2560 ± 75 my) obtained from granitic cobbles in metaconglomerate. On this rather tenuous evidence evolution of the ultramafic rocks is considered to be related to early Kenoran tectonic activity (about 2650 my), which accompanied deposition of the Keskarrah Formation, rather than to later Kenoran plutonism (about 2500 my), which was responsible for high grade metamorphism and granitic intrusion over much of the eastern and central parts of the map-area.

The origin of the minor ultramafic bodies along the west margin of the Itchen Lake area is obscure because they have been deformed and metamorphosed, and textures or structures which might have offered clues to their original nature have been destroyed. The distribution of these bodies is peculiar however, insofar as they appear to be present in or near a layer of basic tuffs that is overlain by a thick series of basalts and presumably rests on felsic volcanic rocks. Stratigraphic restriction of the bodies is consistent with their derivation from ultramafic lava flows, however their composition is not similar to that of komatiites which typically contain more CaO and Al_2O_3. The compositions of the Itchen ultramafic bodies thus make them more refractory than typical komatiites and less likely to have appeared at the surface in liquid form.

On the other hand the serpentinite bodies lie along the west margin of the Western volcanic belt in close proximity to remnants of a mylonite zone and the ages of both mylonitization and ultramafics are, so far as known, similar. It is therefore more likely that the ultramafic rocks were emplaced tectonically perhaps in conjunction with the development of a major early Precambrian fault zone along the west margin of the map-area.

THE CONTWOYTO FORMATION

The name, Contwoyto Formation is proposed for a unit consisting predominantly of the metamorphic equivalents of greywackes and mudstones of turbidite origin, but the definition includes the essential presence of scattered discontinuous bands and lenses of silicate, sulfide or oxide (magnetite) iron-formation. Also present are minor quartz-rich, carbonate-rich and chlorite-rich beds, and more rarely graphite-bearing lenses. The name Contwoyto is taken from Contwoyto Lake in the northeast part of the map-area, but the original derivation of the term, according to Franklin (1824), is from the Copper Indians who used the name "Contwoyto, or Rum Lake in consequence of Mr. (Samuel) Hearne having here given the Indians who accompanied him some of that liquor".

The Contwoyto Formation is bordered on the southeast by the Itchen Formation (6), an extensive unit of similar turbidites without iron-formation. Together these two formations occupy most of a great southward concave arcuate belt of basin-like form, the greywacke-turbidite basin, that extends a distance in excess of 80 miles (130 km) from the south margin of the map-area at Point Lake to the east margin at Contwoyto Lake. On the north margin of the basin the Contwoyto Formation passes into migmatites within which remnants of iron-formation are recognizeable to within a few miles of the north boundary of the map-area at Rockinghorse Lake. On the south margin of the greywacke-turbidite basin the Contwoyto Formation has not been recognized but migmatites, which occur farther south, locally contain garnetiferous amphibolites like those near the north boundary of the map-area. It is possible therefore that rocks correlative to the Contwoyto Formation are present on both margins of the greywacke-turbidite basin.

Along the east margin of the Western volcanic belt the Contwoyto Formation lies upon mafic flows or chloritic schists, or possibly locally on felsic volcanic rocks of the Point Lake Formation, but near Point Lake it was probably deposited contemporaneously with the neighbouring mafic flows. Structural evidence suggests that the Contwoyto Formation is overlain by the Keskarrah Formation. The southeastern limit of the formation is defined by the last detected iron-formation lens as no other stratigraphic markers were observed in the host beds. The symmetry of the greywacke-turbidite basin, with volcanic rocks at its periphery, suggests that the Contwoyto Formation lies beneath rocks of the Itchen Formation, but the structural complexity of these rocks is such that an intertongueing relationship is also possible.

The thickness of the Contwoyto Formation is unknown for the beds are typically isoclinally folded with folds of unknown but presumably short wavelength. Although tops of graded beds (see Fig. 19) and scour and fill structures are locally evident it has only rarely been possible to examine more than a few tens of feet of the formation without uncertainty of repetition of beds by folding. An isoclinal fold axis defined by back to back graded beds in slate along the south arm of Point Lake (see Fig. 18) would likely pass unnoticed inland where beds are concealed by lichens and outcrop is discontinuous.

Figures 18 & 19

The Contwoyto Formation is divisible into two subunits, one characterized by oxide facies iron-formation beds and lenses that occurs chiefly in the Point Lake region about the Keskarrah delta or fan, and a second more extensive subunit characterized by silicate and sulfide iron-formation beds and lenses. The best exposures of the oxide facies are along and near the north arm of Point Lake. The sulfide-silicate facies is best exposed at the main showing stripped by Canadian Nickel Company near Contwoyto Lake (see Fig. 53). The overall section of the formation is best seen northwest of Itchen Lake where exposure is most continuous. A more detailed description of the formation in the Contwoyto area is given by Tremblay (1975).

Oxide Iron-Formation Facies (Acp2 and Acs2)

The oxide iron-formation facies of the Contwoyto Formation occurs chiefly near Point Lake where the metamorphic grade of the rocks is low (greenschist facies) but minor occurrences of magnetite-rich facies also occur locally along the south margin of the Concession diorite pluton, and in the Contwoyto area (Baragar and Hornbrook, 1963). The oxide iron-formation beds consist of dull grey to blue-grey magnetite-rich beds and lenses up to a few inches thick in iron-rich bands commonly up to 10 feet (3 m) and possibly locally as much as 500 feet (152 m) thick interlayered with grey to brownish or greenish fine-grained greywacke, and blue-grey to greenish slate. Rarely rusty weathering iron carbonate-bearing beds are present. Magnetite-rich layers and lenses are commonly bordered by chlorite or amphibole-rich layers showing sharp or gradational contacts with greywacke (see Fig. 20). In places recessed weathered surfaces reflect the presence of carbonate, and elsewhere thin quartz-rich lenses, possibly derived from chert, are present.

Figure 20

The oxide facies iron-formation consists chiefly of fine-grained (grain diameter commonly up to 0.1 mm) quartz and magnetite with some amphibole, chlorite, epidote and carbonate. A little hematite (possibly derived from alteration of carbonate), a sericite-like micaceous mineral, biotite, and sulfide are present in some specimens. Where most coarsely crystalline, magnetite occurs in tiny octahedra. Scapolite was observed along a vein cutting oxide facies iron-formation near the west margin of the volcanic belt on the south shore of the north arm of Point Lake.

Silicate-Sulfide Iron-Formation Facies (Acp_1 and Acs_1)

The silicate-sulfide iron-formation facies occurs within the eastern exposures of the Contwoyto Formation about Point Lake and throughout the formation elsewhere. This facies forms layers and lenses commonly up to 10 feet (3 m) thick and in places over 100 feet (30 m) thick. Dark to medium green layers reflect variation in concentration of quartz, amphibole and opaques (see Fig. 21). Where the metamorphic grade is appropriate, grey-purple, brownish, or reddish garnets are present in irregular patches or concentrated in discrete bands that appear to be most common near the margins of the iron-rich beds (see Fig. 21). Lenses and beds of nearly pure, fine-grained quartz, likely derived through recrystallization of chert, make up a small proportion of the rock (see Fig. 22). Sulfides, commonly in bands parallel to layering but also in patches or lenses, are widely present and produce rather unspectacular reddish-brown gossans. Pyrrhotite is by far the most abundant sulfide in most regions but is widely accompanied by small amounts of chalcopyrite and pyrite. Arsenopyrite and loellingite are major components over restricted areas but are apparently absent elsewhere. Pyrite is the dominant sulfide in some iron-formation lenses in the region of low metamorphic grade near the east margin of the map-area. Gold, so far as is known, is concentrated in the arsenic-bearing regions of the silicate-sulfide iron-formation facies.

Figures 21 and 22

The silicate-sulfide iron-formation facies is composed chiefly of amphibole and quartz with opaque minerals (chiefly sulfides) being a major constituent of some layers. Two, and locally, three phases of amphibole are present in widely varying proportions. Grunerite, characterized by weak absorption, inclined extinction, an optic axial angle near 90 degrees and a sign mostly negative, high birefringence and local polysynthetic twins, is typically the most abundant amphibole phase. Grunerite is typically rimmed or intergrown with a green hornblende characterized by the pleochroic formula; x ochre, y brown, and z dark blue-green, and a much lower negative optic axial angle. In rocks of lower metamorphic grade grunerite commonly forms coarse irregular radiating aggregates with poikilitic, fine-grained opaque inclusions. Garnet if present, also tends to be poikilitic. In areas of higher metamorphic grade, the amphiboles form more nearly equant crystals, opaque minerals are coarser and to a greater extent interstitial, and garnet is cleaner. Gedrite, the aluminous anthophyllite, was identified by electron probe analyses in one specimen. Quartz is mostly disseminated but also occurs as widely spaced, fine-grained, almost pure layers and lenses with a few scattered amphibole needles and some apatite. Such quartz-rich bands likely formed from chert. Locally important constituents are epidote, diopside, plagioclase, chlorite and biotite, the latter being locally concentrated in beds with garnet. The only common accessory mineral is apatite. Iron-formation adjacent to the Fuz metagabbro pluton shows alteration of amphiboles to fine-grained talc (identified by x-ray) and magnetite. Minor pyrrhotite in bands within the iron-formation is rimmed by magnetite.

Host Sediments

Host rocks for the iron-formation lenses and layers, both oxide facies and silicate-sulfide facies, are metamorphic equivalents of the greywacke-mudstone lithologic assemblages typical of sediments of the Yellowknife Supergroup elsewhere in the Slave Province. At low metamorphic grades these rocks are chiefly fine-grained, grey to blue-grey or greenish chlorite and biotite-bearing slates, phyllites and greywackes, but throughout most of the area, metamorphic grade being above greenschist facies, grey andalusite-cordierite schist, grey to brownish sillimanite-cordierite knotted schist, or gneiss is typical. Pale to dark green chlorite schist with and without garnet, black graphitic schist and grey to brownish siltstones are present locally and are most common in the lower part of the formation near Point Lake. The host rocks for the most part closely resemble those of the Itchen Formation (6) which lies to the south and east of the Contwoyto Formation, and a more detailed account of them is given in the description of that formation.

Chemical Analyses

Chemical analyses of silicate and oxide facies iron-formation (see Table 5) were made by the rapid method which for these rocks can be considered only semiquantitative so far as iron content is concerned. The data (Table 5) suggest that the silicate facies is enriched in CaO and MgO with respect to the oxide facies. When Al_2O_3, MgO, and CaO are compared (see Fig. 23) there is a suggestion that an inverse relation exists between CaO and MgO + Al_2O_3 within the non-garnetiferous beds of silicate iron-formation. Such a relationship might reflect variable contamination of silicate iron-formation by syngenetic or diagenetic deposition of carbonate or magnesian chlorite. Although the constant ratio of about 58 parts MgO to 42 parts Al_2O_3 lies well within the chemical range shown by chlorites (see Deer, Howie and Zussman, 1962), contamination by a chlorite of this composition fails to explain the composition of the garnetiferous layer which is also part of the silicate iron-formation. Furthermore the $MgO-Al_2O_3$ variations in the amphiboles which are a prominent constituent of the silicate iron-formation beds do not support such a constant relationship (see section on mineralogy). It seems more likely that the original iron-formation beds were in varying degrees calcareous and that the apparent constancy of MgO/Al_2O_3 in the non-garnetiferous silicate iron-formation is fortuitous. Of the alkalis K_2O is the most variable and this is probably reflected in variable sericite content in the oxide facies. A single analyses of richly garnetiferous iron-formation shows high alumina content in comparison to all other iron-formation analyses, but the low Na_2O and K_2O contents are normal as in the garnet-free silicate iron-formation bands. It is further evident that potash does not increase with increase in alumina in hornblendes from the silicate facies (see section on mineralogical investigations). These compositional trends may reflect periodic settling of the finest argillaceous fraction of turbidity flows that contributed to the formation of the adjacent greywacke-turbidite, into the environment of iron-formation deposition where alkalis were in most cases removed by hydrogen ion exchange. Chemical analyses of rocks from the greywacke-turbidite succession, which form the host rocks for the iron-formation lenses, are given in Table 6 with the description of the Itchen Formation.

Figure 23

Table 5

Stratigraphic Relations

The stratigraphic sequence from the Point Lake Formation to the lower part of the Contwoyto Formation is fairly clear. Pillows within the Point Lake Formation along the river between Point and Itchen Lakes provide top determinations which indicate that the Contwoyto Formation overlies the Point Lake Formation at that locality. Farther south the occurrence of oxide facies iron-formation as matrix to a pillow breccia within the upper part of the Point Lake Formation suggests that late Point Lake volcanism was contemporaneous with deposition of the Contwoyto Formation. Furthermore, the presence of mafic clasts, probably bombs, within the Keskarrah Formation conglomerates (see Fig. 25) which overlie the Contwoyto Formation, suggests that this volcanism continued throughout the period of deposition of the Contwoyto Formation. Thus the Contwoyto Formation is seen as a facies equivalent of a late phase of Point Lake volcanism.

Remote from Keskarrah Bay the Point Lake Formation, or a recognizeable remnant of similar rocks, intervenes between migmatite derived from the greywacke-turbidite succession and the contacts of major plutons. To the extent that these major plutons contain remnants of the early felsic units of the Point Lake Formation, or possibly of an even older basement, this distribution tends to support the view that a younging of strata takes place toward the centre of the greywacke-turbidite basin. The Contwoyto Formation is distributed almost entirely along the west to north margin of the main greywacke-turbidite basin and this relationship suggests that it may be older than the iron-formation-free greywacke-turbidites (part of the Itchen Formation) that occupy the centre of this basin. It does not preclude the possibility however that Contwoyto and Itchen Formations to a greater or lesser degree intertongue and are therefore in part stratigraphically equivalent.

The distribution of iron-formation lenses within the greywacke-turbidite basin was probably controlled primarily by the availability of iron in solution, but in part by the rapidity of local sedimentation rates. Thus the present distribution of the Contwoyto Formation suggests that the principal source or sources of iron were along the west to north margin of the basin. The abrupt termination of the Contwoyto Formation along the margin of the greywacke-turbidite basin south of Point Lake may be due to removal of the iron-rich beds by faulting and erosion. It may also however be due to non-deposition of iron in this area due to some environmental control. Such a control might be provided by limitation of the source of iron to regions about and to the north of Point Lake, and the operation of a prevailing northerly current or drift during Contwoyto time.

The exhalative model for Archean iron-formation sedimentation developed by Goodwin (1965), Ridler (1970), Goodwin (1973) and others suggests that iron-formation facies may be used to identify the environment of deposition of iron-rich sediments and in some cases the volcanic sources of iron. Application of this model to the Itchen Lake area would imply that the region about Point Lake in the vicinity of the Keskarrah delta or fan, with its large masses of conglomerate, and with possibly contemporaneous zinc mineralization (proximal exhalite) in the uppermost part of the Point Lake Formation, is one potential source area from which iron deposited within the Contwoyto Formation may have been derived. Whether other major contributing sources existed or not is unknown, but it is perhaps possible that a prevailing current may have been responsible for spreading of the iron along the margin of the basin to the north and west, and for preventing its spread to the south.

The sequence of iron-formation facies from oxide through carbonate and silicate to sulfide facies has been established as an indication of increasing depth of iron precipitation within a depositional basin. In the Itchen Lake area this sequence, with its predominance of silicate-sulfide facies, suggests that the greater part of the Contwoyto Formation as now preserved was deposited in the deeper parts of the greywacke-turbidite basin. Isolated remnants of oxide facies on the outer margin of the basin suggest a more oxygenic depositional environment. Such an environment likely reflects proximity to the atmospheric interface and hence perhaps to the shore line. The discontinuous nature of these remnants of oxide facies suggests that the basin floor was not covered by a continuous blanket of oxide facies and hence that deposition began in an already established basin rather than in one that expanded from a minor depression during deposition. The unusually large concentration of oxide facies in the immediate vicinity of the Keskarrah delta or fan is probably in part due to local relative down warping of the oxide facies relative to silicate-sulfide facies to the east along a fault which separates the two, but it may also reflect proximity to a principal source of iron.

KESKARRAH FORMATION (Akcg and Akw)

The name, Keskarrah Formation, is proposed for conglomerate with some calcareous subgreywacke, and greenschist that occur chiefly in a three pronged body that crosses Point Lake on either side of Keskarrah Bay, but it includes a large lens of conglomerate extending southeast from the west shore of the next major bay to the east. Similar rocks are described in the Winter Lake map-area along the southward projection of the Western volcanic belt (Fraser, 1969).

The Keskarrah Formation is named after Keskarrah Bay about the mouth of which it is best exposed. The name is derived from that of the native hunter who guided Sir John Franklin from Fort Enterprise to Point Lake in September, 1820. The party reached Point Lake at Keskarrah Bay where Franklin determined the longitude and latitude clearly defining the location of the bay.

South of Point Lake the Keskarrah Formation lies upon basic flows of the Point Lake Formation, a relationship that is clearly indicated by pillows in the flows and by cross-bedded subgreywacke associated with the conglomerate. On the point that forms the west shore of Keskarrah Bay however, the conglomerate apparently lies directly on chlorite-epidote-bearing rocks (chlorite granite of Stockwell, 1933, here included with hybrid rocks(Āngv)). On the peninsula between the north and south arms of Point Lake the conglomerate is structurally underlain in large part by iron-formation-bearing slate, but lenses of mafic volcanic rocks occur at the contacts near the shore and locally possibly within the formation.

The Keskarrah Formation thickens toward Point Lake from both north and south, the widest section possibly as much as three miles (5 km) wide, being beneath the lake. The conglomerates along the lake shore are clearly repeated by folding and faulting but it appears likely that they reach approximately 1,500 feet (475 m) or more in maximum thickness.

The Keskarrah Formation consists of at least two huge lenses predominantly composed of largely structureless but deformed conglomerates with scattered lenses of vaguely bedded, calcareous greywacke and greenschist, and a large folded lens of well bedded, crossbedded subgreywacke. Some mafic flows of the Point Lake Formation are present at the lower contacts of the conglomerate and a few may be intercalated within it. The coarser conglomerates of the Keskarrah Formation weather with a grey to greenish, often pitted surface (due to carbonate in the matrix between boulders) so that the glacially rounded lichen-covered outcrops are not readily distinguished from some of the pillowed volcanic rocks from a distance or from the air. Coarse conglomerate containing abundant boulders of quartz diorite to granodiorite, commonly ranging up to two feet (0.6 m) and rarely two and one half feet (0.76 m) in diameter, and typically smaller ovoids (possibly in part volcanic bombs) of fine-grained mafic rocks closely packed in a calcareous greywacke matrix, is prominent on either side of the mouth of Keskarrah Bay and on the north shore opposite its mouth. Bands of green to olive greenschist and brownish weathering carbonate-rich greenschist up to 300 feet (91 m) thick are present locally. Small brown weathering lenses of calcareous greywacke often containing traces of crossbedding are widely scattered (see Fig. 24). In the bay and valley west of Keskarrah Bay cobbles are typically somewhat smaller and scarcer but a few cobbles as large as 2 feet (0.6 m) in diameter were observed near the south western extremity of the formation. Light buff-grey weathering, yellow-green subgreywacke with quartz grains locally 2 mm in diameter is present in a large band striking across the peninsula that forms the west shore of this bay. No pebbles or cobbles were observed in this subgreywacke but two conglomerate beds up to 30 feet (9 m) thick were seen within the mafic flows to the northeast. On the north shore of Point Lake northwest of Keskarrah Bay and inland, greenschists and calcareous greenschist are locally interleaved with the conglomerate which is typically finer grained than that to the south and east. On the south shore of the north arm of Point Lake the Formation is only a few hundred feet thick and is limited on either side by iron-formation-bearing slates. There it consists mostly of greenschists containing two layers of stretched pebbles up to two and one half inches (6.3 cm) in length. Small sulfide gossans are numerous.

Figures 24 and 25

Clasts in the Keskarrah Formation (see Fig. 25) are predominantly of meta-quartz diorite or granodiorite, the major constituents of most boulders being sodic plagioclase and quartz with lesser amounts of secondary muscovite, chlorite and epidote. The maximum grain size is 2 to 3 mm. Also forming a major constituent in the coarser conglomerates are ovoid clasts of fine- to medium-grained, green to dark green mafic rocks (see Fig. 25D). These clasts blend into the greenish gritty matrix to such an extent that it is locally difficult to tell which type of clast is the more abundant. Several mafic clasts with particularly fine-grained dark or light green borders (see Fig. 25A and B) appear to be volcanic bombs with chilled or altered margins. White vein-quartz pebbles are concentrated in the medium and fine conglomerates. Fine-grained, buff-white pebbles of siliceous material resembling non-porphyritic, massive felsic tuff are of moderate abundance locally and gneissic clasts are rare. Where the conglomerates are fine-grained, a few exposures composed of masses of chips of green to yellow-green siltstones were observed (see Fig. 26).

Figures 26 and 27

The conglomerate is typically schistose and locally, highly schistose (see Fig. 27). The more mafic clasts tend to be more distorted than are the more siliceous ones (see Fig. 25E). Ratios of maximum to minimum apparent diameter for siliceous clasts are commonly 4 to 1 and in some places greater. Conjugate shears are in many places well developed within the clasts.

The cobbles in the conglomerate may be compared with lithologies within the Keskarrah batholith, and with the hybrid rocks that surround it south of Keskarrah Bay (as originally suggested by Stockwell, 1933). Rocks similar to the meta-quartz diorite were found locally in the northeastern area of hybrid rocks. Granodiorite cobbles are comparable to granitic rocks seen in the southern core of Keskarrah batholith but are mostly more altered than the rocks in place. Fine-grained siliceous rocks of possible felsic volcanic origin are represented locally near the southern and western shores of Keskarrah Bay. Mafic volcanic rocks that are common in the northern area of hybrid rocks may find some counterparts among the mafic ovoids in the conglomerate.

Three boulders from the Keskarrah Formation examined in thin section proved to be of a meta-quartz diorite consisting chiefly of medium-grained anhedral, twinned albite and quartz with some chlorite and carbonate. Two contained muscovite and one contained biotite and magnetite. Accessory apatite and zircon were observed in one boulder each but efforts to concentrate zircon for age determination were unsuccessful due to the very small size of the zircons. Quartz grains or patches within the boulders commonly appear recrystallized locally forming a mosaic of disoriented, typically strained grains surrounding albite (see Fig. 28C). Albite is anhedral and finely sericitized with polysynthetic twinning locally bent. Chlorite occurs as irregular fine-grained patches of variable colour. Muscovite appears in larger flakes with more regular cleavage but locally has interleaved chlorite. One boulder of altered granodiorite contains about 15 per cent microcline and accessory sphene in addition to quartz, albite, chlorite, muscovite and carbonate.

Figure 28

Five finer-grained siliceous subspherical pebbles from a single locality near the northeast margin of the Keskarrah Formation were examined in thin section with a view to determining their origin and source. Two of the pebbles are weakly foliated, consisting primarily of a mosaic of anhedral quartz and albite mostly 0.1 to 0.8 mm in grain size (see Fig. 28A)

Carbonate, chlorite, muscovite and microcline are minor constituents. Some albite grains show clear rims about sericitized cores. Scattered throughout the pebbles are equant, sericitized albite crystals up to 2.5 mm in diameter with serrated margins but quartz megacrysts like those common in felsites of the Point Lake Formation were not observed. One pebble of moderately foliated siliceous rock consists of a somewhat schistose quartz-albite-potassium feldspar mosaic, with grains about 0.1 mm in diameter, containing a cluster of quartz grains possibly resulting from disruption and slight stringing out of a megacryst. A disaggregated albite grain in the same pebble is 2.5 mm in diameter and could perhaps have been a phenocryst. The remaining two pebbles are more strongly foliated. One is entirely of quartz, containing lenses of strained quartz of varying sizes and shapes with serrated margins in a quartz mosaic of 0.05 mm grain size. The second consists of equant to somewhat augen-shaped albite crystals in a quartz-feldspar-sericite matrix in which very fine-grained lenses intertwine with coarser lenses (0.5 mm grain size). The single quartz pebble is probably of sheared vein quartz as such material in less altered form is evident in some parts of the conglomerate. The remaining pebbles bear a strong textural and mineralogical resemblance to the massive felsic rocks of the Point Lake Formation, although a clearly recognizeable porphyritic texture (but see Fig. 28D) involving both quartz and albite, that would demonstrate a volcanic origin, was not found.

The matrix of the conglomerate consists of variable proportions of fragments of strained, locally recrystallized, quartz and sericitized albite in a fine-grained siliceous, commonly schistose matrix consisting of sericite, chlorite and carbonate, the latter forming up to 50 per cent of the matrix in places. Carbonate grains picked from two thin sections for identification by x-ray proved to be calcite. Secondary muscovite and/or epidote are present in some sections, and in others chips of very fine-grained siliceous rock were observed. Mafic fragments in one matrix proved to be microlitic, of a texture similar to but finer grained than that of the grey feldspathic flow (mugearite) that underlies the Keskarrah Formation north of Keskarrah Bay. Greywacke lenses within the conglomerate are similar to the matrix between cobbles and boulders except that in the lenses the proportion of small clasts to matrix may be lower and the proportion of quartz to feldspar higher. Carbonate grains picked for x-ray determination from three greywacke lenses, were all found to be dolomite (in contrast to carbonate in the conglomerate matrix). Carbonate-rich schist layers within the conglomerate consist of dolomite or ankeritic dolomite with a variable but subordinate proportion of quartz and altered plagioclase grains together with whispy lenticular patches of sericitic material.

Origin and Age Relations

The volcanic affinity of the Keskarrah Formation is indicated by the presence of an abundant volcanic detrital component within the conglomerates. This component is of two types: one composed of mafic to intermediate volcanic ovoids and subangular clasts including bomb-like clasts up to small boulder size, and a second composed of felsic pebbles resembling the extensive felsic volcanics of the Point Lake Formation. The smaller size higher degree of sphericity and lesser abundance of the latter suggests that they have been derived from erosion of pre-existing felsic rocks at some distance. On the other hand the greater abundance and size of the mafic ovoids, the bomb-like appearance of some of them, and the textural similarity between some microlitic clasts and the grey flows that occur with the Keskarrah Formation, suggest that the more mafic clasts are of younger, more proximal pyroclastic origin. Formation of the Keskarrah conglomerates may thus be related to explosive basic to intermediate volcanism of a type that also produced the youngest flows of the Point Lake Formation. Prominent admixture of still coarser plutonic detritus indicates that this volcanism was accompanied by crustal instability.

A structural unconformity separates the Keskarrah conglomerates on the northwest point of Keskarrah Bay from hybrid rocks to the south (as reported by Stockwell, 1933). Although the precise contact (subsequently described by Henderson 1973) was not seen during the present study, it is clear that granitic rocks intrusive within the hybrid rocks are not found to penetrate the conglomerate, and the conglomerate near the contact dips at 45 degrees away from the granitic rocks with tops in the same direction as shown by crossbeds within interlensed greywacke. If this unconformity were of regional extent, it should be found elsewhere between Point Lake and either Itchen or Contwoyto Formations; however no other instance of structural discordance at these contacts has been demonstrated. It seems likely therefore that the unconformity is a local one. West of Keskarrah Bay the unconformity map perhaps extend from the base of the conglomerate at its contact with the hybrid rocks southward into the upper part of the volcanic pile where a roughly defined boundary separates hornblende-rich from overlying epidote-rich metavolcanic rocks. To the north of Keskarrah Bay the unconformity may extend a short distance along the contacts of the main volcanic belts where flows, in part hornblende-rich, may be more altered than adjacent slates, greywacke and conglomerate. Nevertheless, the local distribution of structural discordance, its occurrence at the 'nose' of a regional antiform with the Keskarrah batholith at its core, and the presence of granodiorite detritus immediately above the unconformity suggest that the unconformity represents a local upheaval that accompanied emplacement of the Keskarrah batholith within a rapidly evolving tectonic welt. Such an interpretation is consistent with available radiometric data from the conglomerate and from the Keskarrah batholith. It is still possible however, (as originally implied by Stockwell, 1933) that within the hybrid rocks at Keskarrah Bay there exist remnants of an older sialic basement. In this case it seems likely that the younger local unconformity, to which development of the Keskarrah conglomerate is related, has locally been superimposed upon rocks of much greater age, and that the unconformity at the west entrance to Keskarrah Bay may fortuitously include not only most of Point Lake time but an extended earlier interval as well.

Radiometric dating of the granitic complex that intrudes hybrid rocks south of Keskarrah Bay (the Keskarrah batholith) has yielded a zircon age of 2642 ± 15 m.y. and a sphene age of 2637 ± 15 m.y. suggesting that intrusion of these rocks occurred not later than that time. Muscovite from plutonic boulders in the Keskarrah conglomerates yields K/Ar dates of 2560 ± 75 m.y. and 2660 ± 75 m.y. which are believed to represent the age of greenschist facies metamorphism because muscovite is not so common in the Keskarrah batholith. These radiometric data indicate that volcanism intrusion of the granite complex, uplift, erosion, folding, and metamorphism about Keskarrah Bay probably took place before the main period of granitic plutonism (about 2500 m.y.). They further suggest that these early events are all related as part of an early orogenic episode prominently expressed in the discontinuous belt of conglomerates known to exist along the east margin of the early granite complex from the southern part of the Winter Lake map-area northward as far as Point Lake.

The environment of deposition of the Keskarrah Formation was characterized by unstable conditions as indicated by its conglomeratic texture and variable clast size. Immaturity of the matrix and accompanying greywacke, and coarse textures suggest rapid uplift of source and rapid deposition and burial of derived sediments. Rounding of boulders, and concentration of coarse clastics in restricted areas along the contact between Point Lake and Contwoyto or Itchen Formations is consistent with stream transport and deltaic or submarine fan deposition at the west edge of a broad basin that was accumulating fine clastics. Northward decrease in size and abundance of clasts in the conglomerate, and correlation of lithologies represented in the clasts with rocks south of Point Lake suggests that the stream involved drained an area of uplift near the south west corner of the map-area.

ITCHEN FORMATION (AIp and AIs)

The name, Itchen Formation, is proposed for the metamorphic equivalents of greywackes and mudstones of the Itchen Lake area that are similar to those of the Contwoyto Formation but unlike that Formation lack the iron-formation lenses by which it is characterized. The formation is best exposed along the shores of Point Lake where the rocks are chiefly in middle amphibolite facies. It is well, but somewhat less cleanly and extensively exposed at Itchen Lake where the rocks are chiefly in lower amphibolite facies. As the name Point Lake Formation has already been accorded to the volcanic rocks at the base of the Yellowknife Supergroup it seems appropriate to select the name Itchen Formation for the rocks here concerned.

The formation extends from the south border of the map-area west of Coppermine River in a broad southeastward concave arc to the east border of the map-area south of Contwoyto Lake. To the south similar rocks project for nearly 50 miles (80 km) southward into the Winter Lake area (Fraser, 1969); and to the east they extend for some 25 miles (40 km) into the eastern part of the Contwoyto Lake area where they have been mapped on a regional scale by Fraser (1964). Hybrid gneisses probably derived from similar rocks are even more extensive.

The Itchen Formation is conformable with the Contwoyto Formation along its northwestern periphery where the contact is marked by the disappearance of iron-formation lenses which characterize the Contwoyto Formation. At its southeastern margin the Itchen Formation lies upon various subunits of the Point Lake Formation without apparent discordance, or it passes into hybrid metamorphic rocks that surround the Yamba batholith The thickness of the formation is unknown for it is in many, and presumably in most, places tightly folded; its great exposure however would suggest a thickness in excess of several thousand feet.

Figure 29

The metagreywacke-metaturbidite succession within the Itchen Formation is mostly well bedded. Beds are evident on the great majority of well washed shoreline outcrops about Point Lake but elsewhere, lichen cover and staining may render bedding obscure. Beds range from less than one inch (2.54 cm) to many feet thick but are most commonly less than 18 inches (46 cm) thick. At many outcrops 6 (15 cm) to 8 (20 cm) inch graded beds are exposed across much of the surface (see Figs. 18 and 19), and where beds have reached lower to middle amphibolite facies metamorphic grade, cordierite or late chlorite is commonly concentrated in knots or feathery patches in the upper parts of the beds to produce reverse grading (see Fig. 29). Commonly a few nearly massive greywacke beds are intercalated within more finely bedded and graded sections, but these beds may also show fine lamination due to biotite concentration. Such lamination commonly reveals load casts (see Fig. 30), and more rarely small channels are evident (see Fig. 31). In places thick argillite beds are present and these may bear chiastolite as well as cordierite megacrysts in amphibolite facies terrane. Some greywacke beds contain ovoid calcareous concretions up to 8 (20 cm) or

10 (25 cm) inches in diameter that typically follow the centre of the bed in which they occur (see Fig. 32). Concretion horizons are concentrated in the central (upper) parts of the Itchen Formation. Concretions were not observed in the Contwoyto Formation. Locally fine-grained quartz-plagioclase-rich beds of unusually low mafic content are present and at one place about one mile southeast of Itchen Lake such rocks form a light coloured strip visible on aerial photographs.

Figures 30, 31 and 32

In the greenschist facies the argillites and slates are mostly dark grey to blue-grey and the greywackes grey. At higher grade the schists are lighter grey to grey-brown and more commonly display slightly rusty weathered surface.

Greywackes, slates and argillites of the Itchen Formation, where of greenschist metamorphic grade, are seen in thin section to consist primarily of very fine-grained quartz, plagioclase feldspar and either chlorite or biotite or both. Muscovite is present in most specimens. Locally phenoclasts or more rarely, small rock fragments are evident in a finer-grained matrix. In places potash feldspar fragments are preserved. Accessory minerals are tourmaline, apatite, zircon, opaques and locally, sphene. The latter is of interest because it is restricted in these rocks to the greenschist facies.

Schists of the Itchen Formation, where of amphibolite facies, consist of fine-grained (0.01 to 0.1 mm) quartz, oligoclase (or rarely andesine) and biotite. Commonly porphyroblasts of cordierite that reach from one to several centimeters in diameter, and less commonly andalusite porphyroblasts, are present. The porphyroblasts produce the characteristic mottled appearance on fresh surfaces (see Fig. 30) and knobby or knotted character on weathered surfaces. Locally biotite or muscovite is porphyroblastic. Sillimanite appears in schists of middle amphibolite facies where it may be fibrolitic or fine grained and next to impossible to detect without the aid of a microscope. The coexistence of andalusite and sillimanite in the same thin section is common. Rarely staurolite and/or garnet are present, the former mostly as tiny inclusions in other minerals. Accessory minerals are magnetite, pyrite, tourmaline, apatite, sulfide and zircon. Tourmaline crystals, commonly zoned with blue cores and orange-brown rims, locally constitute up to about one per cent of the rocks.

Greywacke beds consist chiefly of fine-grained (mostly less than 1 mm) quartz, plagioclase (oligoclase to sodic andesine) and biotite, but may also contain muscovite. Quartz constitutes up to 85 per cent of quartz-rich layers. Cordierite, andalusite and sillimanite are present in some beds but are less prominent than in the pelitic rocks. Rarely a little green hornblende appears in slightly more calcareous beds. One concretion from a greywacke bed was found to consist of quartz, labradorite, biotite, cummingtonite, hornblende and accessory zircon and apatite. Accessory minerals in normal greywacke beds are apatite, zircon, magnetite, locally tourmaline, and rarely calcite. No rock fragments or phenoclasts were recognized in rocks of the Itchen Formation above greenschist facies but it is likely that phenoclasts such as those observed in the argillites would have been rendered indistinguishable during deformation and recrystallization.

Chemical Analyses

Chemical analyses of six samples of slate, greywacke and knotted schist from the Itchen and Contwoyto Formations were made by the rapid methods. The analyses fall in a range similar to rocks derived from other Precambrian greywacke-turbidite assemblages but one analysis of schist adjacent to silicate sulfide iron-formation between the arms of Point Lake is unique in containing 1.83 weight per cent of carbon derived from graphite

Table 6

Age Relations and Origin

The age relations between the Itchen Formation and other formation in the Itchen Lake area are not directly evident because the Itchen Formatio being composed in large part of incompetent strata, has been closely folded. As a result stratigraphic tops are useful, in an interformational sense, only where they are completely exposed within a few feet of the contact with adjacent formations. No outcrops satisfying these criteria were found. On the other hand the gross disposition of the formation with respect to the Point Lake and Contwoyto Formations, as already described with reference to the Contwoyto Formation, indicates that although the Itchen and Contwoyto Formations may intertongue the Itchen Formation likely includes the youngest of the Archean strata.

The sequence from greywacke-turbidite beds containing iron-formation to similar rocks free of iron-formation may in part reflect variation in environmental conditions under which these rocks were deposited such as have been already discussed with respect to the Contwoyto Formation. Continued deposition of greywacke-turbidites after deposition of the last iron-formation is consistent with the concept that the evolution of iron-rich solutions was associated with the terminal phase of Point Lake volcanism and may have been the last manifestation of it. More detailed work will be required to see whether sediments of the Itchen Formation in the central part of the greywacke-turbidite basin (and therefore probably the youngest beds) show a greater proportion of pelitic beds than do similar rocks within the Contwoyto Formation. These younger turbidites, insofar as they may reflect degradation of the Point Lake volcanic terrane after termination of volcanism, might be expected to include a higher proportion of the more weathered and finer-grained sedimentary detritus.

PLUTONIC AND HYBRID ROCKS

EARLY KENORAN GRANITIC ROCKS (Agd)

Early Kenoran granitic rocks are recognized at the core of the antiform south of Keskarrah Bay where they have been dated radiometrically, and within the south prong of the Central volcanic belt where a small body of quartz porphyry has textures similar to those of the surrounding volcanic rocks. Remnants of plutonic rocks of similar age may be present within the batholith west of Rockinghorse Lake, southeast of the Central volcanic belt, and possibly west of the Western volcanic belt.

These early Kenoran plutonic rocks range from granite to quartz diorite but granodiorite and quartz diorite are in most areas predominant. Many of the potash feldspar free plutonic rocks here classified as quartz diorite however, contain biotite as the major mafic mineral, and oligoclase rather than a more basic plagioclase. They are therefore not typical quartz diorites but they grade into rocks containing andesine and it seems preferable to group them with quartz diorites.

The Keskarrah Batholith

The Keskarrah batholith (Fig. 2) occupies a roughly triangular area about 11 miles (18 km) wide along the southeast border of the map-area and projects some 8 miles (13 km) northward to within 2 miles (3 km) of Keskarrah Bay. To the south of the map-area it may continue for as much as 50 miles (80 km) or more into the Winter Lake map-area.

The rock is mostly white, biotite leuco-granodiorite with a pink variant possibly richer in potash feldspar. Commonly the rock is pink stained along fractures or veins. Textures are mostly massive equigranular and medium-fine grained (1.5 to 2 mm) but in places plagioclase is slightly porphyroblastic with crystals about 4 mm in diameter. Little foliation is evident in the central parts of the intrusion but near the contacts, where granodiorite includes, and is interleaved with, volcanic rocks and some gneiss, a foliation is more commonly developed. Pegmatitic patches and dykes are present locally.

The principal minerals observed in thin section are in order of decreasing abundance, calcic oligoclase, quartz, microcline, biotite, blue-green hornblende, and epidote. Chlorite or muscovite are present locally. Accessory minerals are sphene, magnetite, apatite, zircon and allanite. Sphene locally occurs in abundant large euhedral zoned brown and colourless crystals in which either core or rim may be coloured. Plagioclase crystals locally show oscillatory normal zoning with extreme outer rims of albite. Alteration has in places partially disrupted both twins and zoning.

Age Relations and Origin

The Keskarrah granodiorite clearly intrudes a mafic volcanic phase of the Point Lake Formation within the hybrid rocks that surround it. Hybridization is thought to be mostly due to emplacement of the granodiorite which is therefore younger than the lower volcanic beds of the Point Lake Formation. Boulders of granodiorite and deformed clasts of mafic volcanic rock are present within conglomerate of the Keskarrah Formation so that it appears probable that emplacement of the granodiorite occurred before deposition of the conglomerate which took place at the end of Point Lake volcanism.

Radiometric dating of the Keskarrah granodiorite gives a zircon date of 2642 ± 15 m.y. and a sphene date of 2637 ± 15 m.y. These dates are interpreted to represent the age of emplacement of the granodiorite. Secondary muscovite within granodiorite boulders in the Keskarrah conglomerates give K/Ar dates of 2660 ± 75 m.y. and 2560 ± 75 m.y. and these presumably reflect an age of metamorphism essentially coeval with granitic plutonism. Thus it is envisaged that rapid orogenic evolution permitted intrusion of granodiorite, uplift, erosion, deposition of conglomerate and metamorphism within a time interval of a few million years. These ages probably preclude derivation of the boulders from now widespread plutonic rocks evolved during the main phase of plutonism late in the Kenoran orogeny (about 2500 m.y.). Emplacement of the Keskarrah batholith early in the Kenoran orogeny is thus indicated on both stratigraphic and radiometric grounds.

Quartz Porphyry of the Central Volcanic Belt

A small, poorly exposed body of quartz porphyry forms a lens some one mile (1.6 km) wide by 4 miles (6.4 km) long within the south prong of the Central volcanic belt. The rock is grey-white with a slightly greenish tinge, and is characterized by scattered to abundant blue-grey quartz crystals in a fine-grained to medium-fine-grained matrix of quartz, feldspar and minor chlorite and biotite. The rock resembles some of the felsic volcanic rocks of the surrounding volcanic belt particularly in the presence of quartz megacrysts but is noticeably coarser grained. To the east and southeast some scattered outcrops of finer-grained acid tuff comparable to that in the Point Lake Formation are interspersed with outcrops of granitic rocks that unlike the quartz porphyry do not display prominent bluish quartz megacrysts. Contact relations with the surrounding rocks are unknown but it is clear that the porphyry has been altered and sheared in a manner similar to that shown by the volcanic rocks elsewhere along the belt and is unlike the more massive granitic outcrops to the east.

The quartz porphyry consists of quartz megacrysts locally 4 mm but mostly 1.5 to 2 mm in diameter in a fine-grained, albite-rich albite-quartz matrix. Minor muscovite is present in most specimens and biotite, epidote, carbonate and chlorite are present locally. Accessory minerals, allanite, apatite and zircon, are scarce, very fine-grained, and anhedral. Of four samples stained none showed identifiable potash feldspar.

Age and Origin

The quartz porphyry is thought to be similar in age to the surrounding volcanic rocks because of the similarities in texture, degree of alteration and deformation. The coarser grain displayed by the quartz porphyry relative to the volcanic rocks may indicate that it is part of a hypabyssal intrusion within the Point Lake volcanic pile. The abundance of albite and the absence of potash feldspar in the quartz porphyry contrast with the more potassic compositions evident in the later Kenoran granitic intrusions.

Other Granitic Rocks of Possible Early Kenoran Age

Granitic rocks of batholitic extent (Fig. 2), which lie east of the Central volcanic belt (Central Belt batholith) and west of Rockinghorse Lake (Rockinghorse batholith), locally intrude metamorphosed rocks of the greywacke-turbidite succession and are therefore at least in part younger than these metasediments. On the other hand, because the contacts about the granitic rocks are widely characterized by rocks of, or derived from, the older Point Lake Formation, cross cutting relations do not indicate unequivocally whether the batholith is entirely or only partly late Kenoran in age. Remnants of older granitic crust may therefore exist within some of these bodies, but such batholiths will be described in more detail with the younger granitic rocks to which they are perhaps more clearly related.

The Central Belt batholith, which intrudes the greywacke-turbidite succession only at its southeastern extremity, displays in its northern regions gradational contacts with the oldest rocks of the Point Lake Formation; moreover inliers of the Point Lake Formation have apparently been locally down folded to form supracrustal remnants with moderate to steep dips within the batholith. The northern part of the pluton is thus a likely area to look for remnants of early Kenoran granitic rocks.

The Rockinghorse batholith includes rocks of the older greywacke-turbidite succession along its southern and eastern margins. Within the batholith and about its northwestern margin are rocks derived from the Point Lake Formation which do not appear to have reached the high grades of metamorphism that obtained along the contacts of Yamba Lake and Contwoyto batholiths. Such a low grade of metamorphism appears more characteristic of the early Kenoran plutonism and may suggest a search for early Kenoran granite within the Rockinghorse batholith.

LATE KENORAN PLUTONIC ROCKS

Late Kenoran (about 2500 m.y.) plutonism produced both basic and granitic plutons. In general the basic bodies show some signs of alteration and intrusion by minor granitic bodies and are therefore considered to be older. It is possible however, that some of both the basic and granitic plutons include remnants of older early Kenoran (about 2650 m.y.) rocks that have been partly recrystallized during late Kenoran plutonism.

Dioritic Plutons (Adi)

Major dioritic plutons ranging in composition from gabbro and amphibolite to granodiorite are present in the vicinity of Concession Lake (Concession pluton), southeast of the Central volcanic belt (Southern pluton) and along the northwestern continuation of the Western volcanic belt (Western pluton). Smaller bodies occur on a peninsula on the east side of Contwoyto Lake (Eastern pluton), north of Itchen Lake (Fuz pluton) and in a swarm of dyke or lense-like bodies restricted to a small area southwest of Itchen Lake (the Itchen amphibolites). The disposition of these plutons is illustrated in Figure 2. Other still smaller bodies are widely preserved within the hybrid rocks. They are perhaps less common within rocks of the Yellowknife Supergroup, and are not known to intrude the late Kenoran granitic rocks.

Concession Pluton

The Concession pluton consists of two large bodies and a number of peripheral dykes and lenses that lie mostly to the south and west of Concession Lake. The eastern body is poorly exposed and outcrop in the western body improves only locally. The pluton consists of hornblende granodiorite of variable colour index and quartz diorite. Amphibolite outcrops in a restricted zone near the northwestern margin. Quartz is present in all specimens examined under the microscope. Small amounts of disseminated pyrite are common. The rock is mostly massive but slight foliation was observed locally near the margins of the pluton. Veins and patches of granitic pegmatite are numerous within the pluton, and dioritic veins were observed to have intruded biotite gneiss at one locality near the southwest contact of the western body.

The western part of the pluton consists of sodic oligoclase, quartz, hornblende, and up to about 10 per cent microcline with minor epidote chlorite, biotite, muscovite and magnetite. Accessory minerals include zircon, apatite, sphene and rare allanite. Prominent subhedral plagioclase crystals 1 to 2.5 mm in length are heavily but evenly sauseritized except along crystal margins, where they are clear. Hornblende anhedra, commonly about 2 mm in diameter, contain discrete patches of epidote, or less commonly, grains of similar hornblende in a different optical orientation. Quartz and microcline form an intergranular mosaic with grains commonly 0.5 mm in diameter.

Amphibolite from near the northwestern margin of the Concession pluton consists predominantly of blue-green hornblende with minor biotite and abundant accessory apatite. Hornblende anhedra contain a few amoeboid remnants of pyroxene. Biotite locally occurs as shredded rims about amphibole. Small amounts of epidote, chlorite and sphene are also present.

The eastern part of the pluton tends to be more leucocratic and biotite forms a greater proportion of the mafic minerals. Locally there are patches of a fine-grained, hornblende-rich phase containing feldspar megacrysts. The eastern extension of the body has been mapped as biotite-bearing augen-gneiss by Tremblay (1966), and it is apparent that there is an eastward transition toward lithologies of that description.

Age Relations

The presence of dioritic dykes within the schists west of the pluton and of dioritic veins near its contacts indicates that the Concession pluton is younger than the lower part of the greywacke-turbidite succession. On the other hand textures observed in thin section indicate that the rock has been severely recrystallized without completely destroying evidence of earlier porphyritic texture. This and the abundance of small granitic and pegmatitic bodies within the intrusion suggest that its emplacement preceded major regional metamorphism associated with the emplacement of the late Kenoran granitic batholiths.

Southern Pluton

The Southern pluton lies along the southern margin of the Central volcanic belt about 20 miles (32 km) east of Itchen Lake. It also lies along the northern margin of a large area of mostly unfoliated dioritic rocks that have been abundantly and intimately intruded by quartz monzonitic and pegmatitic magma to form an agmatite complex. Similar granitic and pegmatitic bodies occur within the dioritic rocks to the north but their proportion is much reduced (probably to less than 10 per cent), and the transition from agmatite to diorite, though not well exposed, appears to be rapid.

The dioritic rocks are pink to grey-white weathering, black and light grey mottled, medium-grained rocks that are typically weakly foliated or unfoliated. They are allotriomorphic, equigranular and medium-grained (1 to 2 mm) with calcic oligoclase forming the major constituent. Quartz is present in amounts close to 10 per cent in places but is absent in others. Hornblende commonly exceeds biotite in proportion and the two comprise from roughly 10 to 20 per cent of the rock. Epidote and saussurite are alteration products. Apatite, zircon, sphene and allanite are accessory constituents. Leucocratic varieties may contain enough feldspar to be classified as granodiorite. Textures in the rock are entirely metamorphic, there being no relict phenocrysts or remnants of possibly igneous pyroxene as observed in the Concession pluton. The plagioclase is slightly antiperthitic. The hornblende locally contains abundant quartz inclusions.

Age Relations

The Southern pluton is clearly older than the late Kenoran granitic plutonism because it is intruded by granitic and pegmatitic bodies that are late Kenoran or older. Furthermore, recrystallization has completely removed all traces of primary textures. The age of the pluton relative to the greywacke-turbidite succession however is uncertain because it does not occur in exposed contact with these rocks. On the other hand hybrid rocks at the southern and eastern margins of the agmatite complex include hornblendic gneisses and some possible migmatized equivalents of the Point Lake volcanics. To the north are acid and basic volcanic rocks of the Central volcanic belt. This spatial relation with early Kenoran volcanic rocks may reflect an early Kenoran age of the Southern pluton.

Dioritic Rocks of the Western Volcanic Belt (Western Pluton)

Dioritic rocks of the Western pluton are best preserved near the north margin of the map-area some 4 to 8 miles (6 to 13 km) west of Rockinghorse Lake. Farther south similar rocks are engulfed in varying proportions by granitic rocks. The pluton is bordered on the east and west by greenstones and greenschists of the Western volcanic belt and inclusions of these rocks are common within it particularly near the margins of the pluton. Locally the coarser grained rocks of the dioritic pluton appear to pass gradationally into greenstone. In a few places bands of hornblendic gneiss are preserved. The pluton is intruded by small bodies of granitic rocks and pegmatite.

The dioritic rocks are allotriomorphic, equigranular, medium to fine grained (mostly 1 to 3 mm) and dark green, massive, or slightly foliated. The predominant constituent is plagioclase which varies in different places from calcic oligoclase to labradorite. Blue-green hornblende, locally as rims about polycrystalline patches of cummingtonite, is the second major constituent. Minor amounts of biotite, epidote and chlorite are commonly present and up to 10 per cent of quartz was observed locally. Magnetite-ilmenite, apatite, zircon, and pyrrhotite are accessory minerals.

Age Relations

The Western pluton is intimately associated with the basic volcanic rocks of the Point Lake Formation and in the absence of evidence to the contrary it is possible that it reflects subvolcanic plutonism that accompanied effusion of the surrounding basic volcanic rocks. It would then be of early Kenoran age. More detailed mapping however will be required to establish its age.

Eastern pluton

This pluton, which occurs on a peninsula in Contwoyto Lake at the east end of the map-area, was examined by Tremblay (1967) and is described as follows:

"The body trends north and locally shows transgressive intrusive relationship with the sediments and carries a few inclusions of the sediments. The rock is mainly gabbroic. It grades locally into an apparently highly altered, dark green, coarse-grained amphibolite and also into somewhat lighter dioritic and granitic rocks. The gabbroic rock is massive, reddish brown and dark green, and locally so deeply weathered that its outcrops are covered with a thick layer of black, coarse-grained sand. Hornblende in large blocky prisms, seems to be the main mineral in the amphibolite; where it is dioritic, the amount of felsic minerals is high and hornblende also seems to be the main dark mineral. The dioritic areas carry dark green amphibolitic schlieren. Granitic phases are high in biotite and quartz. In a few places where the rock is strongly gneissic it is much finer grained and resembles a mafic gneiss. Locally this gabbroic rock contains large white feldspar phenocrysts and is crudely porphyritic".

Fuz Pluton

The Fuz pluton is a small rudely lenticular gabbro body occurring some seven miles (11 km) southwest of Rockinghorse Lake. Dark green, medium-grained hornblende gabbro is exposed near the northern contact of the body. Within the body rocks appear less hornblendic and resemble gabbroic phases of the larger diabase dykes of the (post-Kenoran) Mackenzie dyke swarm. Patches of granite, pegmatite, and some quartz veins, seen within the gabbro however, indicate that it is older than the Mackenzie dykes. Near the east end of the body coarse-grained, dark green, hornblende gabbro to amphibolite, that locally disintegrates to a black sand is present. Local talcose alteration of silicate iron-formation near the east contact of the Fuz pluton appears to have resulted from emplacement of the pluton.

The Fuz pluton consists mostly of about equal parts of labradorite saussuritized plagioclase and amphibole. The latter comprises a green hornblende rimmed by colourless amphibole showing multiple twining, probably cummingtonite. A little biotite and muscovite (?), local patches of chlorite-serpentine, minor opaque minerals, and accessory apatite are present.

Age Relations

The Fuz pluton is intruded within hybrid rocks of the lower part of the greywacke-turbidite succession and is therefore not older than late Kenoran. Recrystallization of the marginal parts of the pluton suggest that it has experienced some degree of metamorphism but has not been penetratively deformed. A K/Ar whole rock age determination from the least altered part of the intrusion gives an age of 1865 ± 235 m.y. indicating that the body does not belong to the Mackenzie dyke swarm (1200 m.y., Fahrig and Jones, 1969) and is probably not correlative with the oldest diabase sills in the area (1555 ± 135 m.y.). Considering its radiometric age and degree of alteration the Fuz pluton probably belongs to the late Kenoran group of plutons.

Itchen Amphibolites

The Itchen amphibolites occur in a lenticular area about 5 miles (8 km) southeast of Itchen Lake. Individual amphibolites are irregular lenticular bodies of variable thickness that commonly form erosion resistant tops of ridges surrounded by the highly deformed knotted schists derived from the greywacke-turbidite succession. Some are banded and have associated greenschists, garnetiferous amphibolite and iron-sulfide gossans.

The rocks are typically dark greenish black and medium-fine grained (0.8 to 2.0 mm) with deformed plagioclase phenocrysts preserved in many places within a foliated matrix. Some bodies are garnetiferous, some contain acicular amphibole, and others have a massive gabbroic texture. The amphibolites are composed of about 75 per cent blue-green hornblende and 10 to 20 per cent andesine or labradorite. Up to 10 per cent quartz is present locally. One garnetiferous body proved to be free of plagioclase. Opaque minerals form up to 4 or 5 per cent of the rocks and biotite is a local minor constituent. Apatite is an ubiquitous accessory mineral whereas sphene occurs mainly where the amphibole is acicular.

Age Relations and Origin

Porphyritic textures preserved locally within the Itchen amphibolites suggest that many of them are of igneous origin but because deformation has obscured crosscutting relations with the surrounding knotted schists an intrusive origin has not been directly established. In their high content of acicular amphibole some of the amphibolites resemble volcanic amphibolites of the Central and Western volcanic belts. It seems likely therefore that many of the amphibolites are hypabyssal intrusions related in age to the late Kenoran basic plutons. Some of the amphibolites, particularly those banded bodies bearing garnets and associate with iron sulphides however, may be of sedimentary or pyroclastic origin. The absence of grunerite and the presence of plagioclase and sphene in one amphibolite of this type suggests that they are not derived from silicate iron-formation analagous to that present in the Contwoyto Formation It is possible that they may represent tuffaceous deposits in part diluted with pelite that formed perhaps in association with neighbouring hypabyssal basic intrusions.

Small basic bodies

North of Point Lake and about 10 miles (16 km) east of Keskarrah Bay a gabbro lens up to about 250 to 300 feet (76 to 91 m) wide lies parallel with foliation in the surrounding migmatite. A zone of iron sulfide gossans 2 to 3 feet (0.6 to 0.9 m) wide follows its western margin. The gabbro is medium green, foliated and fine to coarse grained. It consists mostly of blue green hornblende and normally zoned labradorite with some garnet and local remnants of clinopyroxene and cummingtonite. Minor biotite, epidote, chlorite and opaques, and accessory sphene and apatite are present.

A small medium-fine-grained metagabbro body is poorly exposed within the greywacke-turbidite succession near the contact between Itchen and Contwoyto Formations about one mile east of the river between Itchen and Point Lakes. The body is elongated at a high angle to the strike of local bedding and is probably a dyke. It is intruded by a diabase dyke of the Mackenzie swarm.

Remnants of medium-grained hornblende-rich dioritic rocks occur within the granitic batholith east of the Central volcanic belt. These are intruded by the granitic rocks and are therefore older than late Kenoran plutonism. Similar dioritic rocks occur as large inclusions about the margins of the Yamba batholith.

Late Kenoran Granitic Rocks (Aqm)

Yamba Batholith

The Yamba batholith surrounds Yamba Lake at the southeast corner of the map-area. It occupies some 500 square miles (1,295 sq km) within the map-area and projects at least 10 miles (16 km) southward into the Lac de Gras map-area. The batholith differs from others in the Itchen Lake region in being widely subporphyritic to porphyritic, particularly in its eastern regions.

Along the southwest margin of the batholith equigranular granitic rocks commonly containing biotite-rich zones are interleaved with migmatite, and there is a broad halo of upper amphibolite facies metamorphism. Farther north along the northwestern contact, where the aureole of high grade metamorphism is thinner, the transition from granitic rocks to migmatite is more abrupt and hornblende-bearing dioritic and amphibolitic migmatites are present locally. In an east-northeasterly trending zone at the contact east of Yamba Lake the granitic rocks are highly sheared.

In the western peripheral parts of the batholith the rocks are medium-grained and equigranular with biotite, and in some places, hornblende forming 5 to 10 per cent. Biotite- and hornblende-rich remnants are present locally. Within the pluton the rocks are commonly more leucocratic and vary from medium to coarse grained. In the interior and eastern parts of the batholith potash feldspar is commonly porphyritic, the phenocrysts locally reaching 5 cm in diameter.

Rocks of the Yamba batholith are medium grained and commonly contain microcline phenocrysts. The major minerals are plagioclase (albite to calcic oligoclase), quartz and microcline with up to 10 per cent mafic minerals, chiefly biotite. Chlorite and/or epidote are local constituents, and small amounts of muscovite are typically present. Accessory minerals are magnetite-ilmenite, zircon, apatite and locally allanite. Plagioclase is commonly subhedral and occurs in places as euhedral inclusions within microcline phenocrysts where it may be rimmed with albite. Quartz may show normal, serrated or rarely partial euhedral margins. Compositionally the batholith is chiefly quartz monzonite with lesser amounts of granite and some granodiorite.

Age relations and Origin

The Yamba batholith intrudes migmatites derived from the greywacke turbidite succession and is therefore not older than late Kenoran. It is intruded by diabase dykes of the Mackenzie swarm (age of intrusion, 1200 m.y.), Fahrig and Jones, 1969). Radiometric ages of the Yamba batholith are between 2525 ± 98 m.y. (λ87Rb = 1.39) and 2390 ± 98 m.y. (λ87Rb = 1.47). Coarse muscovite (5 mm in diameter) from a fresh granitic dyke intrusive into amphibolite equivalent to the Point Lake Formation farther north, has given a K/Ar age of 2495 ± 70 m.y. These dates probably reflect the same period of plutonism and suggest that intrusion of the batholith occurred about 2500 m.y. ago.

Central Belt Batholith

The Central belt batholith (see Fig. 2) underlies roughly 150 square miles (388 sq. km) on the southern concave side of a large indentation within the Central volcanic belt. At its southern limit it is separated from the Yamba batholith by a belt of hybrid rocks containing remnants of both volcanic rocks and pelitic schists. The Central belt batholith is poorly exposed relative to the other major plutons. In its northern regions medium-grained to coarse-grained granitic rocks grade into, or occur in outcrops interspersed with buff-orange to grey-white, nearly massive felsic tuffs, and these rocks in turn are structurally overlain by better banded, more mafic tuffs about the periphery of the batholith. Similar but more hornblendic tuffs appear to be downfolded into the batholith in its central region. Along the southern margin of the batholith where the granitic rocks are slightly coarser grained, felsic tuffs are not recognized, but local patches of migmatite and biotite-rich schlieren are common. Granitic rocks of the Central belt batholith are mostly pinkish-red to buff-white, medium to fine grained, biotite quartz diorite and granodiorite, but more potassic rocks are present locally.

The grain size of the granitic rocks ranges mostly from 1 to 3 mm. Plagioclase (albite or sodic oligoclase) and quartz are the major minerals. Microcline content is variable but generally constitutes less than 20 per cent. Minor minerals are biotite and magnetite, and small amounts of secondary chlorite, epidote and muscovite are usually present. Accessory minerals include zircon, apatite, sphene and locally allanite, but in some specimens zircon as unusually tiny crystals appears to be the only accessory. Textures are xenomorphic, nearly equigranular and mostly massive. Microcline in places forms patchy antiperthitic intergrowths in plagioclase and where more abundant may be inhomogeneously distributed as large anhedral poikilitic grains enclosing medium-fine-grained quartz and plagioclase.

Age Relations and Origin

The southern part of the Central belt batholith contains rocks intrusive into gneisses probably derived from the Itchen Formation and is therefore probably younger than it is. The northern part however, is gradational into rocks in the lower part of the Point Lake Formation and may therefore be partly or largely of early Kenoran age.

Contwoyto Batholith

The Contwoyto batholith underlies 120 square miles (311 sq. km) at the northwest end of Contwoyto Lake. On its eastern side it is covered by Contwoyto Lake and overlain by the basal units of the Goulburn Group (Western River Formation). To the south it is intrusive into the Contwoyto Formation and to the west it intrudes hybrid rocks derived from that formation. North of the map-area the batholith forms part of a little known plutonic complex containing large remnants of metavolcanic rocks and gneisses that extends north to Cornation Gulf.

The Contwoyto batholith, within the map-area, consists of white to buff or pink weathering, locally red stained, white to pale grey pink or green, medium-to medium-fine-grained, equigranular granodiorite to granite. The principal mafic mineral if biotite which forms from 2 to 10 per cent of the rock but mostly about 5 per cent. Rarely hornblende is prominent. Grey to colourless quartz constitutes about 20 to 30 per cent. Pyrite and magnetite are common accessory minerals widely visible in hand specimen and red stain derived from these minerals is prominent locally. Biotite-rich inclusions and schlieren are present here and there throughout the batholith, and are numerous along the margins particularly in the southern regions. Small bodies of pegmatite are widespread.

Contacts between the batholith and the Contwoyto Formation are discordant and intrusive according to Tremblay, 1966. Farther northwest hybrid rocks along the contact are permeated by granitic rocks but there is a pronounced increase in schist or gneiss layers, schlieren and inclusions in the contact zone. In the far northwest granitic rocks bearing scattered hybrid gneiss remnants pass gradationally into granitic rocks containing more numerous lenses and inclusions of gneiss.

The rock is chiefly medium grained (2 mm) commonly with some larger feldspar crystals approaching 5 mm in diameter. Major minerals are quartz, microcline and plagioclase (albite to sodic oligoclase) with the two feldspars in widely varying proportions. Biotite, muscovite and chlorite are minor constituents and apatite and zircon ubiquitous accessory constituents. Sillimanite occurs with muscovite in the granite at one locality.

Age Relations and Origin

The Contwoyto batholith is younger than the greywacke-turbidite succession which it intrudes. It must also post-date (possibly only slightly) the severe deformation of the hybrid rocks along its southwest margin because the prominent foliation found in the gneisses there is not evident within the batholith. The increasing degree of granite invasion of the gneisses northwestward along the batholith contact indicates increasing severity of plutonism in this direction.

Rockinghorse Batholith

The Rockinghorse batholith (Fig. 2) underlies about 250 square miles (647 sq. km) within the map-area near Rockinghorse Lake. It is unconformably overlain by the Rockinghorse Lake outlier of the Goulburn Group. It is bordered with indefinite contacts on the east; on the south by hybrid rocks derived partly from the lower part of the greywacke-turbidite succession; and on the west by basic volcanic rocks of the Point Lake Formation and hybrid rocks derived therefrom.

The Rockinghorse batholith comprises a particularly heterogeneous assemblage of lithologies but is mostly quartz diorite to granodiorite. Much of the central part of the pluton is composed of coarse-grained, massive, grey weathering, black and white quartz diorite consisting of large anhedral, white, finely twinned crystals of plagioclase locally up to about 3 cm in diameter in a matrix of quartz, finer plagioclase and biotite (grains 3 to 5 mm in diameter). Commonly the megacrysts are partly buff-pink stained suggesting an erroneously high content of potash feldspar, but in places some microcline is present. Mafic percentage ranges from about 10 to 20. Elsewhere, particularly near the north boundary of the map-area, pink to white, medium-to fine-grained, leucocratic chlorite granodiorite is present. In the southern part of the batholith near its contacts with biotite-rich migmatites, are fine-grained leucocratic granitic gneisses and lenses of greenschist suggesting that the batholitic rocks may perhaps have formed through recrystallization of felsic to mafic volcano-sedimentary rocks derived from the Point Lake Formation. Plutonic rocks south of Rockinghorse Lake are granitic including some diorite in which remnants of biotite schist and felsitic rocks are less abundant than in the surrounding hybrid rocks.

The coarse-grained quartz diorite phase of the Rockinghorse batholith consists chiefly of calcic oligoclase and quartz with about 7 to 15 per cent biotite and minor amounts of hornblende, epidote and chlorite. Zircon, apatite, and locally, sphene are accessory minerals. Plagioclase is vaguely normally zoned with sericitized cores. Small amounts of microcline occur locally as exsolution patches within plagioclase and as discrete grains. Medium-fine-grained granodiorite in the northern part of the batholith consists chiefly of quartz and oligoclase with about 10 per cent of microcline and minor chlorite, muscovite and magnetite-ilmenite.

Age Relations and Origin

Plutonic rocks presumably related to the Rockinghorse batholith are interleaved with hybrid rocks derived from the greywacke-turbidite succession along its southwest margin. On the other hand about much of its periphery it is in contact with rocks derived from the lower part of the Yellowknife Supergroup and locally it appears to have been derived from these rocks by recrystallization. In view of this and because the batholith apparently in part occupies the same geantiformal structure in which the early Kenoran Keskarrah batholith occurs farther south, it would be of interest to examine the age of the interior of the pluton radiometrically for evidence of earlier granitic rocks. It is clear however, that the Rockinghorse batholith is at least in part and possibly largely of late Kenoran age. A minimum age, K/Ar 2075 ± 65 m.y., has been obtained from biotite in quartz diorite along the southeast margin of the batholith.

Granitic Rocks of the Western Plutonic Zone

The western plutonic zone lies to the west of the Western volcanic belt (Fig. 2) stretching from the north to the south boundaries of the map-area along its western margin. It consists primarily of hybrid rocks in the southern part of the map-area but includes extensive irregular bodies of cleaner granitic rocks in the north. The granitic rocks engulf remnants of basic volcanics and diorite, and in the southern part of the map-area include small bodies of banded biotite gneiss which are unlike the migmatites derived from the greywacke-turbidite succession. The granitic rocks also engulf remnants of mylonite possibly derived from felsitic tuffs along the west margin of the western volcanic belt, and they further intrude the basic tuffs that overlie the mylonite.

The granitic rocks of the western plutonic zone are medium-grained massive quartz diorite to quartz monzonite. They are white to buff weathering and grey to pale pink or red on fresh surfaces, but very commonly are red stained so that the proportion of potash feldspar to plagioclase is difficult to estimate. Locally scattered feldspar megacrysts are present. Biotite, or rarely hornblende, is the principal mafic mineral but in places is partly or wholly altered to chlorite. Minor pegmatites are common and locally the granodiorite is intruded by small bodies of pink granite.

Most of the rocks of the western plutonic zone are quartz diorites consisting principally of quartz, sericitized calcic oligoclase and about 5 per cent microcline. Chlorite, biotite and epidote, together constitute 5 to 10 per cent. Accessory minerals are magnetite-ilmenite, zircon, apatite, sphene and allanite. Granodiorite and quartz monzonite differ from the quartz diorite in having a greater proportion of microcline to plagioclase, a lower proportion of mafic minerals, a more sodic plagioclase, and a little muscovite.

Age Relations and Origin

The granitic rocks of the western plutonic zone form intrusive bodies which are younger than the basic volcanic rocks of the Point Lake Formation. Furthermore they intrude rocks probably derived by mylonitization from the Point Lake Formation. Their age relative to the greywacke-turbidite succession is unknown, and it is therefore not known whether they can be related to an early or late phase of Kenoran orogeny.

Minor granitic intrusions

Minor granitic plutons that occur at widely scattered localities within the Contwoyto and Itchen Formations are clearly post early Kenoran intrusions. Other bodies such as that within the hybrid rocks northeast of the east end of Point Lake, and those about the west arm of Itchen Lake may in part be structural promontories of older recrystallized and migmatized granitic basement of early Kenoran age.

An isolated body some 4 miles wide and 8 miles long (6 by 13 km) composed mostly of granitic rocks, lies within hybrid rocks about 8 miles (13 km) northeast of the east end of Point Lake. This body is largely surrounded by dioritic agmatite and migmatized hornblende-rich gneiss which separate it on the south and west from biotite-rich migmatite. The northwestern part of the body consists of white weathering massive, medium-grained leucogranodiorite with up to about 10 per cent hornblende or biotite, locally partly altered to chlorite. At the margins of the body hornblende-rich schlieren or layers of dioritic agmatite are present within the granite. To the southeast the rock is finer-grained, more commonly gneissic, and is intruded by pink hornblende granite. Farther southeast, and probably separated from the more granitic rocks to the northwest by a layer of dioritic agmatite, are migmatized granitic gneisses with hornblende-rich layers resembling the banded mafic tuffs (Av).

The leucogranodiorite is medium grained, with grains ranging mostly from 2 to 4 mm. Major minerals are quartz and sodic oligoclase; minor minerals are biotite microcline and muscovite; trace minerals are apatite, zircon, magnetite, and in places, sphene. Hornblende is present locally, and epidote and chlorite are common alteration products. Textures are massive to foliated, allotriomorphic and equigranular.

Age relations of this body are speculative. Both the granodiorite and the surrounding hornblende-rich gneisses and agmatite have been intruded by more potassic granitic rocks. Furthermore the granodiorite is surrounded on all sides, except perhaps in the northwest, by hornblendic rocks which pass outwards to the west and south into biotite-rich migmatites. This succession might be expected around a basement dome rising within the Yellowknife Supergroup. Migmatization, insofar as it appears to be related in age to the emplacement of Yamba batholith is likely of late Kenoran age but the granodiorite is older.

Along the south shore of the west arm of Itchen Lake and south of that arm a small body of granitic rocks is surrounded on the east and south by massive felsitic tuff. Although exposure is not continuous, it appears that the massive felsitic rocks pass gradationally by increase in grain size into massive medium-grained biotite granodiorite.

The massive tuff is found to consist primarily of a fine-grained (0.5 mm), allotriomorphic mosaic of quartz and albite with minor chlorite. Scattered megacrysts are stretched out parallel to lenticular concentrations of mafic minerals. Fine-grained, more massive intermediate rocks contain 10 to 20 per cent microcline, and sodic oligoclase instead of albite. Mafic minerals, though fine-grained, occur in discrete crystals. The granodiorite is similar in composition to the intermediate rock but has a medium-grained, seriate texture.

The apparently gradational contact between tuff and granitic rock is distinct from the abrupt contacts observed about small granitic intrusions within the greywacke-turbidite succession. These contact relations could perhaps have arisen if the granodiorite were emplaced in a subvolcanic environment at the same time as the tuffs were laid down.

A poorly exposed plug of granitic rock occupies a point on the south shore of Point Lake about 10 miles (16 km) west of Coppermine River. The pluton is massive and inclusion free, and its contacts are not exposed. The rock is light pink weathering, grey-white, medium-coarse grained, equigranular quartz monzonite with about 5 per cent biotite and chlorite.

A lenticular granitic body roughly two and one half miles (4 km) long is present northeast of Keskarrah Bay and east of the peninsula between two arms of Point Lake. This body is very poorly exposed and no contacts were seen. The rock is white weathering, slightly buff stained, massive, medium-grained quartz monzonite with about 3 per cent of mafic minerals including biotite and hornblende. Minor muscovite is present in places. Pegmatite occurs locally.

A small plug of granitic rocks about one mile (1.6 km) across is intruded into knotted schists some 9 miles (14 km) north of the entrance of Coppermine River into Point Lake. The rock is white to pale pink, fine to coarse grained, massive biotite-hornblende quartz monzonite with local muscovite and garnet. Mafic-rich variants occur in places.

Five granitic plugs ranging from 2 to 5 miles (3 to 8 km) in diameter intrude the Itchen Formation about the west end of the Central volcanic belt east of Itchen Lake. These are predominantly composed of white, biotite quartz monzonite, in part medium grained and equigranular, but in part containing tabular euhedral phenocrysts of potash feldspar up to 5 cm in length. White pegmatites are present locally and are particularly abundant about the eastern part of the north plug. These latter pegmatites contain coarse graphic quartz-microcline intergrowths and abundant radiating muscovite.

Two small granitic plugs intrude the Contwoyto Formation south of Rockinghorse Lake. The easternmost of these consists of white weathering, medium-grained, massive biotite quartz monzonite. The western body is also white weathering and probably of similar composition.

Three small bodies of granitic rocks are reported (Tremblay, 1966) intrusive into the greywacke-turbidite succession east of the Central volcanic belt. The westernmost of these is a large pegmatite and the easternmost is fine grained, white to buff and biotite-bearing. The northern body is of coarse-grained, massive syenite consisting principally of pink feldspar and hornblende.

Chemical Analyses of the Plutonic Rocks

Eleven samples from the plutonic rocks were analysed (see Table 7) to illustrate the range of chemical variation. Although the analyses are too few for detailed comparisons some points of interest are evident.

Table 7

Among the basic plutonic rocks the metagabbro (Fuz pluton, sample 996) is chemically distinct from the west-northwesterly striking diabase dykes (see table 11) in its high magnesia and low alumina content. This composition, if characteristic of the gabbro plutons, would suggest that they represent a more highly differentiated magma than do the diabase dykes. The association of mafic amphibolite and granodiorite (sample 665) with some of the gabbros is further indicative of differentiation but additional analyses are clearly required to confirm it.

Among the more granitic rocks the differences between samples 33 and 163, of granitic rocks within the lit-par-lit gneisses from near the Fuz metagabbro pluton and near the Yamba batholith respectively, may represent differences in the original sediments from which they were derived, but the more basic character of the latter may also in part be due to the very high metamorphic grade attained about the Yamba batholith. It is perhaps significant that molybdenum is concentrated in these samples. Samples 423 and 160 represent the Yamba batholith and are characterized by high K/Na ratios. Sample 748 from the Keskarrah batholith and samples 304 and 182 from small granitic bodies possibly derived from older basement are granodioritic with low K/Na ratios. Comparison of K_2O-Na_2O-CaO for granodiorites and for felsic tuffs and flows from the Point Lake Formation (see Figure 33) suggests that the two have mostly similar proportions of K_2O. Two analyses (304 and 182) of granitic rocks from the leucocratic cores of dome-like structures within the Point Lake Formation or hybrid rocks derived from it, may occupy an intermediate field between the granodiorites and felsic tuffs on the one hand, and the younger granites on the other.

Figure 33

Comparison of the Plutonic Rocks

Field study of the granitic plutonic rocks of the Itchen Lake map-area has indicated that all of the major plutons are heterogeneous with variants ranging from granodiorite to granite and, particularly in the western part of the map-area, to quartz diorite. It has not, however, been possible in the present study to map areas of distinctive composition although this could probably be done by mapping at a finer scale. Nevertheless an impression is gained that the Yamba batholith and perhaps the Contwoyto batholith as well, are more widely granitic (sensu stricto) than are the Rockinghorse batholith and western plutonic zone plutons, and perhaps the Keskarrah batholith. The chemical analyses are consistent with this impression but are too few to be conclusive. Thirty two partial analyses of specimens collected by the writer from the Yamba batholith were made by the geochemistry section in connection with a study of lake sediment geochemistry. Values obtained from these analyses are suspect because of the small size of specimens provided but this disadvantage is partly offset by the large number of analyses. The data, given in Table 8, show in particular that the mean value for K_2O is high (5.1 weight per cent with a standard deviation of 1.6). Examination of lake sediment potassium anomalies within the map-area (Allen et al., 1971) may provide some further support for this suggestion, although potassium in the lake sediments is clearly affected by other considerations besides the composition of the local bedrock.

Figure 34

Table 8

Potassium anomalies (Allen et al., 1971) derived from lake sediments within the map-area are compared with the distribution of granitic rocks and with relative intensity of drift cover in Figure 34. Glacial striae are included to show likely provenance of the drift. It can be seen that high potassium anomalies lie in a belt across the southern part of the map-area with highest values in areas of good outcrop over the central and southwestern parts of the Yamba batholith. To the north a broad belt of low potassium anomalies roughly follows the direction of ice movement across the map-area and is approximately coextensive with a belt of increased drift cover which blankets the Central belt batholith, the southern part of the Contwoyto batholith and the northeast part of the Yamba batholith. Potassium anomalies are also evident along the northern margin of the map-area. This pattern clearly depends in large part on the movement of glacial drift. Absence of anomalies over exposed areas of biotite-rich schist within the belt of low anomalies suggests that biotite-rich rocks do not contribute to neighbouring potassium anomalies.

in lake sediments as effectively as microcline-rich rocks, or perhaps that micas in the low-anomaly belt have been selectively removed by winnowing of drift materials during retreat of the ice. Nevertheless, the belt of high anomalies in the southern part of the map-area is so pronounced that it merits consideration. The direction of ice movement indicated by striae suggests movement from the southeast with some ice spilling west to southwest out of the northern part of the Contwoyto Lake basin. Thus high potassium anomalies in the southern part of the map-area may reflect drift derived from the Yamba batholith and perhaps from muscovite granites in the Lac-de-Gras area (Folinsbee, 1949) to the southeast as well. The northeasternmost part of Yamba batholith is blankete by drift derived from country to the east beyond the batholith. Predominance of nongranitic drift in this cover may account for lower potassium contents in lake sediments over this part of the batholith. Absence of anomalies over the Central belt batholith may reflect a combination of non-potassic drift derived from the east and perhaps a greater proportion of older non-potassic plutonic rocks in the batholith itself. In the western part of the map-area where drift cover decreases over the Rockinghorse batholith no anomalies are evident and this may reflect the less potassic composition of the main part of the batholith. Potassium anomalies that appear along the north margin of the map-area are probably in large part due to the presence of Proterozoic shales, but may also reflect enchanced exposure of the Contwoyto batholith.

Reconnaissance mapping, and perhaps the limited chemical analyses and lake sediment geochemistry as well, suggest that the late Kenoran granitic rocks tend to be potassium-rich relative to the older granitic rocks. There is a further suggestion that the older Kenoran granitic rocks may be concentrated in the west part of the map-area whereas the younger Kenoran granites and higher grades of regional metamorphism may be concentrated in the east. Confirmation of this distribution of granitic rocks should be the object of more detailed studies.

Summary

Granitic plutonic rocks within the map-area east of the Western volcanic belt may be divided into two groups of different age and possibly of different composition as well. The oldest recognized intrusions were emplaced early during the Kenoran orogeny (about 2650 m.y.), during and toward the end of Point Lake volcanism, but before deposition of the greywacke-turbidite succession that constitutes the Contwoyto and Itchen Formations. Metamorphism associated with these early intrusions does not appear to have been particularly high grade. A second more pronounced period of intrusion followed, possibly about 150 million years later. This later plutonism is predominant in most of the eastern two thirds of the map-area, was locally accompanied by the highest grades of low pressure metamorphism, and was responsible for development of extensive areas of lit-par-lit gneiss from the greywacke-turbidite succession. Plutons of this later phase were probably more potassic than those of the earlier phase. Rocks west of the Western volcanic belt may have been affected by the two ages of plutonism.

Recognition of the age category to which given major granitic plutons belong, except for those few that are dated radiometrically or are clearly intrusive into the greywacke-turbidite succession, has been difficult because batholiths of both older and younger granites tend to occur in uplifted areas about which remnants of the lower part of the Yellowknife Supergroup are preserved. Thus for some granitic bodies it is not known whether a large part or all of the granite was emplaced early in the Kenoran Orogeny and has been subject to later regional metamorphism, or whether granite emplacement and regional metamorphism were related, late Kenoran events. Granitic plutonism has been considered to be of

Kenoran age rather than younger because the youngest pluton (Yamba batholith Rb/Sr isochron minimum age 2350 ± 105 m.y. $\lambda 87Rb = 1.39 \times 10^{-11}$) is surrounded by a regional aureol of high metamorphic grade. On the other hand K/Ar biotite ages from all the granitic bodies dated give significantly younger ages (2075 - 1815 m.y.). These very young biotite ages, although they may arise from other causes, could reflect minor post Kenoran plutonism within the older granitic batholiths.

Dioritic to granodioritic intrusions locally including some amphibolite are probably mostly late Kenoran intrusions, although nearly all are metamorphosed. Some are clearly intrusive into the greywacke-turbidite succession, but others include rocks that were originally at least in places part of the Point Lake volcanic succession, but have been recrystallized and to a greater or lesser extent intruded by granitic material.

HYBRID ROCKS

The hybrid rocks consist for the most part of supracrustal rocks probably derived from the Point Lake or Contwoyto and Itchen Formation of the Yellowknife Supergroup that have been intimately intruded by granitic rocks. Some are diorite agamatites in part derived from the dioritic intrusions; and some, specifically those along the west margin of the map-area, may be of other origin. In most areas it is possible to infer the formation of the Yellowknife Supergroup from which a particular hybrid could have been derived although it is possible that some represent pre-Yellowknife phases of volcanism or sedimentation.

The hybrid rocks are subdivided into subunits based on the character of the non-granitic phase. These subunits are listed in Table 9 with their inferred correlatives within the Yellowknife Supergroup.

Table 9

Subunits of the Hybrid Gneisses

Formation	Description	Derived Hybrid Rock
Itchen and Contwoyto	greywacke-turbidite succession	lit-par-lit gneiss
Dioritic Intrusions and Point Lake	diorite, basic flows basic tuffs	diorite agmatite, amphibolite hornblende gneiss
Point Lake	acid and basic volcanic rocks	acid and basic volcanic agmatite
Point Lake	basic and mixed tuffs	amphibolite, hornblende gneiss
Point Lake	felsic and mixed tuffs	quartz feldspar (sodic plagioclase) gneiss

Quartz-feldspar Gneiss (Anqf)

The quartz-feldspar gneiss occurs in 7 discrete bodies; four in the lit-par-lit gneisses east of Coppermine River, one in similar gneisses along the northwest margin of the Yamba batholith, one within agmatite and hornblende gneiss a few miles farther northwest, and one in a faulted window of similar rocks within the basic flows of the Western volcanic belt at the southwest corner of the map-area. Other small bodies of similar gneiss are probably present within the hybrid gneisses but are very small or have not been detected at the present scale of mapping. Mylonites along the west margin of the western volcanic belt, described with the felsic tuffs, are widely intruded by granitic rocks and might equally well have been included here.

The four quartz-feldspar gneiss bodies east of Coppermine River lie within the upper amphibolite facies metamorphic aureole about the Yamba batholith. They are the most highly recrystallized and injected by granitic material, and are more granitic than the remaining bodies. Mostly they are buff-grey or pinkish-white weathering, medium-to fine-grained gneisses with up to 5 per cent of fine- to medium-grained biotite, in which bands, whisps or lenticular bodies of biotite-rich or hornblende-rich rock are present locally, parallel with foliation. Very commonly bodies of hornblende-rich gneiss and/or amphibolite locally containing garnet, occupy contact zones with lit-par-lit gneiss. A band of calc-silicate gneiss 8 feet (2 m) wide was observed near the south shore of the large bay east of Coppermine River.

These bodies are medium grained consisting primarily of quartz, and variable proportions of oligoclase and microcline. Biotite is a minor constituent, and zircon and apatite occur in trace amounts. A massive part of the westernmost quartz-feldspar gneiss body, sampled for chemical analysis (see Table 7), proved to be intermediate in composition between the late Kenoran granitic rocks and the felsic tuffs.

Quartz-feldspar gneiss with hornblende-garnet-rich layers is interbanded with lit-par-lit gneiss near the contact of the Yamba batholith about 12 miles (19 km) northwest of Yamba Lake. The rock is mostly finely laminated but contains zones of biotite-rich layers accompanied by abundant small pegmatite bodies. Banding locally shows truncation suggestive of crossbedding which, if of primary origin, indicates tops to the northwest away from the Yamba batholith. The quartzo-feldspathic zones are fine grained (grain size 0.5 to 1 mm) dense and grey with dark green amphibole-rich layers. The biotite-rich bands are medium grained.

The quartz-feldspar gneiss is primarily composed of quartz, and plagioclase as basic as anorthite (An 91, determined by oil immersion) in some layers. One layer was found to consist of quartz-anorthite-clinopyroxene with about 10 per cent of hypersthene (identified by X-ray powder diffraction), the latter displaying an unusually low negative optic axial angle of about 40 degrees. Minor amounts of a pale brown amphibole, magnetite and trace zircon are present. A second layer is composed primarily of quartz and bytownite (An 76) with small amounts of sillimanite, cordierite, garnet and biotite, and traces of magnetite, graphite (?), apatite, zircon and tourmaline. Plagioclase-rich lamelae locally contain cordierite crystals with andalusite as larger grains about their margins and sillimanite and garnet as inclusions. Tourmaline is concentrated in biotite-rich layers where it locally reaches 1 or 2 per cent of the layer.

Quartz-feldspar gneiss also forms a poorly known body within hornblende gneiss and dioritic agmatite some 6 miles (10 km) northwest of Yamba batholith. The rock, so far as is known, consists largely of white-weathering, sugary, medium-grained granitic gneiss with hornblende-rich lenses intruded by pink granite. Locally the rock is finer-grained and more regularly layered. A single specimen was found in thin section to consist principally of quartz, andesine, some green hornblende and biotite, trace apatite, zircon and magnetite, and a little secondary muscovite and epidote.

Quartz-feldspar gneiss further occurs in a window in basic volcanic rocks of the Point Lake Formation at the southwest corner of the map-area. No similar rocks were found on traverses across the Western volcanic belt either to the north or south, but an isolated body of serpentinite occurs near the strike projection of the quartz-feldspar gneisses some 2 miles (3.2 km) to the north. Because of the strong foliation developed in rocks in this window in contrast to those farther east and west, the window is thought to result from up-faulting possibly in conjunction with emplacement of serpentinite.

The gneiss consists of grey, fine-grained, highly sheared quartz-plagioclase gneiss, quartz-muscovite schist, and foliated granitic rocks bounded on the west by pillowed flows and greenschist and on the east by foliated to massive amphibolite. In thin section the quartz-feldspar gneiss is seen to be well foliated, consisting predominantly of quartz and albite with minor biotite, muscovite and microcline. Albite augen up to 2.5 mm are surrounded by matrix grains about 0.5 mm in diameter. Quartz is concentrated in long slightly undulating lenses. Quartz-muscovite schist is intensely foliated and consists primarily of lenticular quartz 0.25 mm in diameter, muscovite and biotite. Small amounts of calcic oligoclase and microcline, and trace zircon, sphene, apatite and sulfide are also present.

Amphibolite and hornblende gneiss (Anm)

Amphibolite and hornblende gneiss intruded by granitic rocks occur locally along the eastern margins of the quartz-feldspar gneiss bodies east of Coppermine River. Similar rocks occur along the southwest contact of the granodiorite body that lies some 8 miles (13 km) northeast of the east end of Point Lake. Similar gneisses also occur within the agmatite complex to the east of the granodiorite but have not been differentiated from it in the present work.

The amphibolite and hornblende gneiss mostly occur at or near contacts between quartz-plagioclase gneiss and lit-par-lit gneiss and may be interbanded with quartz-feldspar gneiss. Some amphibole-rich layers, from several millimetres to a foot or more thick, are garnet-bearing. In places amphibole in the hornblende gneiss has a feathery texture resembling that of the mixed tuffs that occur in the downfolded remnants within the Central belt batholith. Minor gossans are locally associated with massive amphibolite.

The amphibolite and hornblende-rich gneiss consist principally of green to blue-green hornblende, oligoclase or andesine, and quartz in variable proportions with minor biotite and trace amounts of apatite, magnetite-ilmenite and sphene. Minor epidote and muscovite were observed locally.

Diorite agmatite (Ang-h)

Large bodies of agmatite composed of fragments of diorite, hornblende gneiss or basic volcanics intruded by granitic rocks lie northwest of the Yamba batholith, along the southwest margin of the Rockinghorse batholith, on the flanks of the Keskarrah batholith, and on the north shore of the north arm of Point Lake. Agmatites, comprising a more abundant granitic phase and more highly digested remnants of basic rock, occur north of Point Lake between the Western volcanic belt and the Proterozoic Epworth Group strata.

Southeastern agmatites

The northwestern part of the southeastern agmatite body, which lies a few miles northwest of the Yamba batholith, consists chiefly of angular fragments of massive grey medium-grained quartz diorite in widely varying concentrations within white weathering, medium-grained, pale buff quartz monzonite. This complex is unevenly laced by pink granitic to pegmatitic dykes. To the southeast the basic phase of the complex is mostly hornblende gneiss. Near the southwest margin of the complex finer-grained massive greenstone locally forms the basic phase. Toward the southeastern margin of the complex hornblende gneiss, hornblende biotite gneiss, and quartz diorite are present but their distribution is poorly known.

Quartz diorite and hornblende gneiss fragments are medium grained and contain slightly megacrystic plagioclase in places. Blue-green hornblende and plagioclase (calcic oligoclase to sodic labradorite) are the principal constituents. Biotite, epidote, muscovite and chlorite are minor components and sphene apatite and allanite trace minerals. Plagioclase in some localities, is slightly antiperthitic and hornblende, locally poikilitic, encloses quartz.

Medium-grained (grains 1.5 mm in diameter) granite representing the granitic phase consists primarily of microcline showing coarse grid twinning, and lesser amounts of quartz, calcic oligoclase and muscovite. Minor biotite and trace apatite and zircon are also present. Local plagioclase megacrysts, 3 mm long, consist of central cores with coarse secondary muscovite, rimmed by clear oligoclase.

Agmatite Southwest of the Rockinghorse Batholith

Agmatite southwest of the Rockinghorse batholith consists in large part of diorite and quartz diorite intruded by pink to white granitic rocks and pegmatite in widely variable proportions. In the northern part of the body however, greenschist inclusions are present. In the southern part of the body fine-grained quartz-feldspar gneiss is locally included within hornblende diorite. Some parts of the complex consist of diorite or more acidic rocks that are relatively free of inclusions.

At its western margin the agmatite complex is inferred to pass abruptly into basic volcanic rocks of the Western volcanic belt. The contact with quartz diorite of the Rockinghorse batholith is less well known and less easily defined. Granitic pegmatites within the complex appear to contain little or no tourmaline unlike pegmatites within gneisses and schists derived from the greywacke-turbidite succession.

Quartz diorite from the agmatite complex examined in thin section is medium fine grained (1 mm) and consists chiefly of normally zoned andesine or oligoclase and hornblende with about 20 per cent quartz, minor biotite, chlorite, epidote, accessory magnetite, apatite and zircon. A massive quartz-feldspar gneiss inclusion within diorite in the southern part of the complex is fine grained (diameter of grains 0.2 to 0.4 mm), consisting predominantly of quartz and sodic andesine with minor blue-green hornblende and biotite and trace amounts of epidote, apatite and sphene. A chemical analysis of this gneiss (Table 3) shows it to be somewhat more mafic and calcareous than the massive tuffs of the Point Lake Formation.

Agmatite about the Keskarrah Batholith

A hybrid complex composed chiefly of basic volcanics, hornblende gabbro, amphibolite, quartz diorite and granitic rocks but including some felsic volcanic rocks and gneiss surrounds the Keskarrah batholith. Contact between hybrid complex and the batholith are marked by a distinct increase in the proportion of mafic or gneissic inclusions. Contacts between hybrid rocks and surrounding basic volcanic rocks mark the disappearance of a prominent granitic component and are locally gradational. Large areas of basic volcanic and dioritic rock in which the granitic phase forms only a small proportion are present along the northwest margin of the complex. Basic phases of the complex consisting of massive to schistose greenstones, hornblende diorite and amphibolite are widely intruded by pink and white granitic rocks and pegmatite. Rarely, and mostly in the vicinity of Keskarrah Bay, pillows are preserved. In places greenstone dykes and hornblende gabbro bodies crosscut the granitic rocks, and some hornblende gabbro intrusive into granitic rocks is itself intruded by granitic veins. Both mafic and granitic components of the hybrid complex are therefore of more than one age.

Granitic gneisses examined in thin section are thinly layered (2 to 3 cm). They comprise chiefly quartz plagioclase (calcic oligoclase) and pale green amphibole, chlorite, epidote, and more rarely, biotite. A little microcline is present locally as patches in plagioclase. Magnetite sphene, apatite, zircon and allanite are accessory minerals. In some layers blocky subhedral to equant rounded megacrysts of oligoclase up to 5 mm in diameter are closely packed in a matrix of quartz, oligoclase and mafic minerals. Such layers are in sharp contact with even grained bands of similar mineral composition which suggests that the texture may be primary. Elsewhere oligoclase megacrysts have been deformed and recrystallized so that masses of small but compositionally similar oligoclase grains are more or less evenly distributed through the original megacryst. Other layers consist largely of calcic oligoclase and hornblende These gneisses are clearly distinct from the lit-par-lit gneiss derived from the greywacke-turbidite succession, and although their origin is not known they bear resemblance to some banded tuffs of the Point Lake Formation.

A chlorite-bearing granitic rock from southwest of Keskarrah Bay is medium-fine grained (1.5 mm), massive, and consists chiefly of quartz and albite or oligoclase with minor chlorite, epidote, and trace sphene and apatite. Plagioclase comprises blocky crystals composed of patches of sericitized albite alternating with clear oligoclase that are surrounded by a finer-grained quartz-rich mosaic. The mineral composition is that of a meta-quartz diorite.

Hornblende gabbro and amphibolite intrusive into a granitic phase of the complex are fine- to medium-grained, massive rocks consisting largely of several phases of blue-green, brown-green and nearly colourless amphibole, and plagioclase of variable composition. Variable amounts of chlorite, epidote and traces of quartz, biotite, apatite and sphene are present. Subhedral plagioclase laths showing patchy saussurite are locally surrounded by hornblende suggesting an original ophitic texture.

Northern Point Lake Agmatite

A small complex of dioritic to basic volcanic agmatite up to three and one half miles wide (5.6 km) extends for about four and one half miles (7.2 km) north from the north shore of the north arm of Point Lake. Near Point Lake this body consists of fine- to medium-grained hornblende diorite, amphibolite and a complex of pink to white weathering granitic rocks including some grey granodiorite. Farther north the basic phase consists of fine-grained massive to foliated greenstone. As with agmatites about the Keskarrah batholith age relations between the basic and granitic phases are complex in that granitic rocks intrude the greenstones and dioritic rocks and basic dykes crosscut the granitic phase. The contact between agmatite and pillowed to massive basic volcanic rocks north of the complex is gradational and is marked by a decrease in the proportion of the granitic phase. The east and west contacts between agmatite complex and layered to basic tuffs are more abrupt, granitic material being distinctly less abundant in the layered rocks particularly on the east margin. There is therefore some possibility that the eastern contact may be an unconformity.

Greenstone from the northern part of the complex is massive, and fine grained (0.6 to 1 mm) with blue-green hornblende and locally megacrystic albite or sodic oligoclase as the major constituents. Minor quartz and magnetite or iron sulfide are present in places, and small amounts of carbonate, epidote and chlorite are alteration products. Trace apatite is present.

Felsic and Basic Volcanic Agmatite (Angv)

Felsic volcanics intermixed in variable proportions with basic volcanics, and intruded by granitic rocks, are found within hybrid rocks at the south end of Keskarrah Bay. Similar felsic volcanics occur in hybrid rocks to the east near and along the south shore of Point Lake. Felsic volcanic rocks and quartz diorite intruded locally by altered basic dykes occur within hybrid remnants along the south shore of, and immediately southwest of, Rockinghorse Lake. Sheared hybrid rocks possibly derived in part from felsic rocks are present in an east-west zone along the east margin of the Yamba batholith.

The felsic volcanics are typically white to buff weathering, fine grained to aphanitic, grey to pale green and show a fine lenticular foliation which may be evident only on ice-polished surfaces. Isolated quartz grains up to 2 mm in diameter are common and in places exhibit a bluish colour. The hybrid volcanics are intruded by granitic rocks but in some places appear to grade into medium-grained granitic rocks. At one locality on Keskarrah Bay a greenschist inclusion 10 feet by 4 feet (3 by 1.2 m) in section was observed within the felsic volcanics whereas at another locality a small inclusion of felsite was observed within massive basic volcanic rock.

A thin section of felsic volcanic rocks from Keskarrah Bay consists almost entirely of fine-grained quartz and sodic oligoclase with minor chlorite and traces of sulfide. Scattered fragments and possible phenocrysts of plagioclase up to 1 mm in length are present. The matrix plagioclase contains flame-like perthitic intergrowths of potash feldspar. The surrounding granitic rock is of similar mineral composition but is medium grained.

Fine-grained felsic volcanic rocks included within granitic rocks south of Rockinghorse Lake consist of quartz porphyry, carbonatized tuff, and tuff breccia. The quartz porphyry contains bipyramidal, embayed or brecciated quartz phenocrysts up to 12 mm in diameter with local matrix-quartz haloes in a matrix consisting predominantly of fine-grained quartz and sodic plagioclase (see Fig. 35). Carbonate, muscovite and chlorite are common secondary products and trace apatite and zircon are of local occurrence. One inclusion consists of scattered patches of carbonate possibly pseudomorphous after plagioclase megacrysts, in a mosaic matrix of quartz and sodic plagioclase with minor chlorite and muscovite. Tuff consists predominantly of foliated, fine-grained quartz, and plagioclase with lesser amounts of sericite, carbonate and muscovite, and inclusions of very-fine-grained cherty rock. Locally the tuff is highly carbonatized. Massive quartz diorite inclusions primarily comprise quartz and calcic oligoclase with minor chlorite and biotite, and trace apatite and zircon.

Figure 35

An altered basic dyke intruding quartz diorite consists principall of carbonate and biotite with minor sericite, chlorite, magnetite and unusually abundant apatite and sphene. Pseudomorphs of carbonate and sericite after plagioclase phenocrysts are suggested. A semiquantitative spectrographic analysis of a sample from this dyke indicated Ba, Ti, V, Ni, Zr and Sr in the 0.1 to 1.0 per cent range; Mn, and Cr in the 0.01 to 0.1 per cent range, and Co, and Sc, less than 0.01 per cent.

Hybrid, highly sheared rocks, in part possibly of felsic volcanic or hypabyssal origin, and in part derived from migmatite are present in an east-west trending zone up to 3 miles (4.8 km) wide that projects westward for about 6 miles (9.6 km) into the map-area along the southeast contact of the Yamba batholith. These rocks are mostly light green to buff-white weathering, green, and fine-grained to cherty or schistose. Migmatites are common in the eastern part of the zone where they locally contain siliceous interbands. Banding in the migmatites can locally be seen to intersect the trend of shearing at as much as 40 degrees. The western part of the zone is predominantly composed of sheared medium-grained to subporphyritic granitic rocks.

The fine-grained greenish rocks are in part breccias composed of fragments of earlier breccia, quartz and feldspar in a very fine-grained siliceous matrix containing a little chlorite, muscovite and epidote (see Fig. 36). Early breccia fragments are very similar to those in which they are included, fragment boundaries being scarcely visible. Other more highly foliated rocks are quartz-oligoclase gneisses containing about 10 per cent combined biotite, chlorite and muscovite. Very fine-grained mafics and muscovite are strung out along discrete shear planes and coarser layered-silicate crystals surround grains of cataclastic quartz and feldspar between the shears. Patches and lenses of fine-grained muscovite are scattered through the rock.

Figure 36

A thin section from foliated granitic rock near the west end of the sheared zone consists chiefly of blocky to rounded oligoclase crystals and a few microcline crystals, both up to 2.5 mm in diameter. These are closely packed in a mosaic matrix of fine-grained quartz with a little biotite and epidote that sweeps around plagioclase crystals and is responsible for foliation (see Fig. 37). Trace amounts of apatite, epidote and allanite are also present.

Figure 37

The origin of the sheared siliceous rocks is unknown, but their composition, and locally, their textures suggest a comparison with the felsic volcanic and meta-quartz diorite found elsewhere in the map-area. Interleaving of these rocks with migmatites of the greywacke-turbidite succession may have occurred through intershearing of migmatite with felsic volcanic rocks originally lower in the stratigraphic section.

Lit-par-lit Gneiss (Ang-b)

Lit-par-lit gneisses, as used in this report, refer to foliated, biotite-bearing, pelitic gneisses within which discontinuous, generally sheet-like, minor granitic bodies lie chiefly parallel with foliation; but they are gradational to and include areas of granitic rocks containing more or less abundant inclusions of pelitic gneiss. In effect they are composed almost entirely of rocks thought to be derived from the greywacke-turbidite succession that have been raised to the higher grades of metamorphism (middle and upper amphibolite facies), and intruded by granitic rocks and pegmatite.

Lit-par-lit gneisses are widespread in the eastern and central parts of the map-area where they lie between granitic plutons or follow the margins of the greywacke-turbidite succession. In the west they are more restricted, in part because the large granitic plutons in this region may have been emplaced mostly prior to their deposition and metamorphic grades are lower, and in part because supracrustal rocks older than the greywacke-turbidite succession predominate in the western part of the area.

Of particular interest within the lit-par-lit gneisses are local remnants of silicate-sulfide iron-formation which indicate that the lit-par-lit gneiss has been derived from the Contwoyto Formation. Such remnants are clearly preserved east of the Fuz pluton and south of the Contwoyto batholith. Similar rocks, accompanied by iron sulfide gossan, occur locally within lit-par-lit gneiss south and southwest of the agmatite complex that borders the Southern pluton. Along the west margin of the Contwoyto batholith however, where the lit-par-lit gneiss is highly deformed and permeated by granitic material, iron-formation lenses appear to give way to isolated remnants of biotite-garnet-rich schist locally bearing iron sulfide.

In most places the lit-par-lit gneisses are complexly folded, brown weathering, buff and brown, lenticularly banded, fine- to medium-grained rocks within which are layers or irregular bodies of grey to white or less commonly pinkish granitic rocks and pegmatite. They nevertheless display progressive alteration from rocks of the greywacke-turbidite succession through little deformed but recrystallized pelitic rocks containing variable proportions of segregated granitic material (see Figs. 32, 38 and 39) to highly deformed and almost completely disrupted gneisses (see Figs. 40 and 41). In some places layers of granitic rocks several tens of feet or more thick are present, and where foliation is nearly horizontal such rocks tend to occupy tops of hills with schist exposed only locally along their flanks (see Fig. 42).

Figures 38, 39, 40, 41, & 42

The lit-par-lit gneisses consist primarily of quartz, calcic oligoclase and biotite. Sillimanite, cordierite, muscovite, chlorite and opaques are common minor components; microcline, garnet, andalusite and amphibole are less common. Accessory minerals are apatite, zircon, occasionally tourmaline, and rarely allanite. Tourmaline is notably less common than it is in the knotted schists.

Hybrid rocks West of the Western Volcanic Belt (An-hb and Ang-h)

A narrow belt of hybrid and granitic rocks, that forms a small part of an extensive terrane lying to the west and southwest of the map-area, was mapped during the present work. This belt consists of remnants of gneisses and relatively basic plutonic rocks, engulfed within a more granitic phase. In the north part of the belt are extensive areas underlain by nearly massive plutonic rocks that have been described with the granitic rocks. South of Point Lake however massive plutonic rocks are less extensive and are mapped with the hybrid rocks.

In the hybrid rocks of this western complex that lie north of Itchen Lake the included phase consists chiefly of massive diorite or quartz diorite more basic than the enclosing plutonic rocks. Rarely massive to schistose or banded, fine-grained, basic volcanic rocks and minor metasediments are present as well. At one locality about 4 miles (6 km) south of Cowles Lake a rubbly-weathering, medium green gneiss band a few feet thick with brown weathered surface is associated with mafic metavolcanics within the hybrid rocks. This gneiss consists of roughly equal parts of hornblende and clinopyroxene and about 5 per cent of chlorite Although the gneiss megascopically resembles some metamorphosed ultramafic rocks, chemical analysis (see Table 10) shows it to be chemically distinct from both serpentinite and associated metagabbros within the map-area. The high contents of calcium and magnesium suggest that the gneiss was originall a siliceous dolomitic metasediment.

Table 10

From Point Lake to just north of Itchen Lake the older engulfed phase of the hybrid rocks is mostly composed of foliated quartz diorite-gneiss. South of Point Lake, where the granitic phase is less abundant, the rocks are primarily banded to foliated biotite and hornblende gneisses (see Fig. 43), but in the immediate vicinity of Point Lake amphibolite, metagreywacke and migmatite are present as well. These latter rocks may represent a more highly altered part of the Point Lake Formation.

Figure 43

Several gneisses near the south shore of Point Lake were examined in thin section. Migmatite at Point Lake is medium grained (2 mm) and comprises major quartz and calcic oligoclase, and minor biotite, muscovite, and chlorite. Associated greywacke is fine grained (0.3 mm) and of similar mineral composition but contains sericitized poikilitic patches probably pseudomorphous after cordierite. Grey and dark grey layered gneiss is fine grained (up to 1 mm). Leucocratic layers are composed of quartz, oligoclase, biotite and a little microcline whereas darker layers consist of quartz, oligoclase-andesine, hornblende and a little epidote.

Accessory minerals are magnetite-ilmenite, apatite, sphene and zircon. Typical biotite quartz diorite-gneiss south of Point Lake is medium grained (2 mm) and consists primarily of quartz and sodic andesine with about 10 per cent biotite and traces of epidote, muscovite, chlorite, zircon, sphene, and apatite. These gneisses are intruded by massive, medium-grained (2 to 4 mm) granodiorite composed chiefly of quartz and albite or oligoclase with up to about 25 per cent microcline and minor epidote, chlorite and muscovite. Accessory minerals are zircon and apatite.

Pegmatites, and Pegmatitic Tourmaline

Small pegmatite bodies most of which are less than 50 feet (15 m) in width are common in the map-area where rocks have reached amphibolite facies grade. These pegmatites are white to pinkish and are composed simply of quartz, feldspar, muscovite, and biotite. Pegmatites in metamorphic rocks derived from the greywacke-turbidite succession typically contain black (schorlitic) tourmaline crystals up to 5 cm in length. Black tourmaline is present also in pegmatites intrusive into plutonic rocks that intrude the greywacke-turbidite succession, but was not found in the less abundant pegmatites emplaced within rocks of the Point Lake Formation or in plutonic rocks remote from the greywacke-turbidite succession. In some pegmatites tourmaline was observed to be concentrated at the pegmatite margins, but in others no systematic concentations were detected.

In thin section the pegmatitic tourmaline shows strong pleochroism with E colourless and O blue to olive brown. Commonly the crystals are zoned so that when viewed parallel with O a sky-blue core is surrounded by an olive rim. Zone boundaries are in places irregular with rounded projections of olive rims into a blue core, with olive rims following fractures into a blue interior, or more rarely with earlier pale olive lobes within a blue core truncated by later darker olive rims. Such textures suggest that zoning occurred during alteration rather than during growth of the tourmaline crystals. In one pegmatite blue and olive patches appeared to be randomly distributed through tourmaline crystals and in tourmaline from the large island in Contwoyto Lake zoning is complex, some crystals showing pale blue cores surrounded by darker blue-olive rims, and others showing olive cores surrounded by blue rims. Such textures may indicate an additional period of alteration. Tremblay (pers. comm., 1974) reports that schist inclusions in the Contwoyto batholith in the vicinity of this pegmatite show more evidence of alteration (digestion) by the granite than do those in the vicinity of other pegmatites sampled by him. The concentration of tourmaline in pegmatites within the knotted schists, as opposed to pegmatites intrusive into the Point Lake Formation, and the presence of tourmaline as a trace mineral in the knotted schists, suggest that boron and perhaps other elements found in the pegmatitic tourmaline were derived from the turbidites which gave rise to the enclosing schists.

Black tourmaline was collected from pegmatites in various parts of the map-area (Fig. 44) for qualitative and semiquantative spectrographic analysis. Crystals were crushed, inclusions excluded, and the residue analyzed in bulk. The results of these analyses are shown in Table 11. The writer is beholden to L.P. Tremblay for five samples from the Contwoyto Lake region of the map-area.

Table 11

Figure 44

The tourmaline analyses show some variation in major element composition but none that can be related to known variations in the geological setting. Analyses show consistent high iron content as would be expected in a black (schorlitic) tourmaline. Trace elements include Mn, Cr, Sc, Cu, V, Ni, Ag, and Be. Mn and Cu occur most frequently.

Individual trace elements show no clear relation to geological setting but there is a suggestion that the trace element population increases in complexity southwestward toward the Keskarrah Bay. Additional data will be needed to confirm this trend, but further investigations along these lines seem worthwhile, particularly if it becomes evident that the trace element complexity in these pegmatites is reflecting trace element complexity indigenous to the greywacke-turbidite succession.

PROTEROZOIC ROCKS

Proterozoic rocks consisting of quartzite, sandstone, siltstone, shale, argillite, greywacke, carbonates, conglomerate and mafic hypabyssal intrusives are extensively exposed about the north end of Contwoyto Lake, at Rockinghorse Lake, and in the northwest corner of the map-area. These rocks were originally continuous, representing thin platformal cover in the east and central parts of the map-area, and thicker shelf deposits in the west. They lie on the northern cratonic margin of the Coronation Geosyncline (Hoffman et al., 1970).

Rocks of the platformal cover in the northeast corner of the map-area are continuous with the Goulburn Group to the north and east, whereas those in the northwest are continuous with the Epworth Group to the northwest of the map-area. The Rockinghorse Lake outlier of Proterozoic sediments lies about half way between these two groups. The strata of the outlier are related closely to those of the Goulburn Group and support the contention of Hoffman et al., 1970, that a northerly trending hinge line separated this group from the Epworth Group to the west.

EPWORTH GROUP

The name 'Epworth formation', derived from port Epworth (now abandoned) on Coronation Gulf at the mouth of Tree River, was originally used by O'Neill to apply to dolomite exposed there. The term was later extended (Fraser, 1960) to include the succession of strata that lie conformably above and below the dolomite. These strata were called the Epworth Group by Douglas and Maclean (1963).

The Epworth Group in the Itchen map-area is divided by Fraser (1975) into five conformable formations. These comprise: the Odjick Formation (2,100 feet (640 m), mainly argillite and quartzite), the Rocknest Formation (2,300 feet (701 m), mainly dolomite), the Recluse Formation (2,000 feet (610 m), mainly shale, argillite and siltstone), the

Cowles Lake Formation (2,600 feet (792 m), mainly limestone and argillite), and the Takiyuak Formation (1,200 feet (366 m), mainly sandstone and siltstone) for a total at the east margin of the Epworth Group, of about 10,000 feet (3,000 m).

Mapping for the present project was carried out up to the edge of the Epworth Group which occurs in the northwest corner of the area. Description of the Group is taken from Fraser (1975).

Odjick Formation (EAo)

The name, Odjick Formation, is derived from Odjick Lake west of the Itchen Lake map-area, and is applied to the argillite-quartzite succession at the base of the Epworth Group (Fraser, 1975). The formation is about 2,100 feet (640 m) thick on the east margin of the Epworth basin where it enters the map-area but thickens westward to 7,500 feet (2,286 m) at Carousel Lake. The base of the formation is marked by an angular unconformity separating it from the underlying Archean plutonic and metamorphic rocks. The top is defined by the change from an argillite-quartzite succession to one consisting predominantly of carbonate.

The formation is composed of roughly equal amounts of pale green, buff, white, pink and purple quartzite, and greenish grey to purple argillite, with beds of dolomite, limestone and locally concretionary argillite near the base, and beds of dolomite near the top. A few quartz-pebble conglomerate lenses are present in most sections. Primary structures including crossbeds, ripple-marks, mudcracks and stromatolites suggest a fluvial to shallow marine origin with a source to the east and southeast of the Epworth basin (Fraser, 1975).

Rocknest Formation (EARN)

The name, Rocknest Formation (Fraser, 1975), is derived from Rocknest Lake on Coppermine River west of the Itchen Lake map-area, and is applied to the predominantly carbonate succession that overlies the Odjick Formation. The formation is 2,300 feet (701 m) thick along the east margin of the Epworth basin near the Itchen Lake map-area but thickens to 5,500 feet (1,676 m) farther west. The base of the formation is marked by the change from an argillite-quartzite succession to one consisting predominantly of carbonate. The top, though poorly exposed, is considered to be defined by a transition from dolomite containing interbedded argillite, to thinly bedded argillite of the Recluse Formation. The formation consists mainly of dark grey to pale grey and white dolomite with subordinate cyclically interbedded greenish grey argillite and minor limestone.

Recluse Formation (EAR)

The name, Recluse Formation, is derived from Recluse Lake, the locality of the type section (Fraser, 1975). The formation consists primarily of argillite, siltstone and greywacke with minor limestone. It is about 2,000 feet (610 m) thick in the eastern part of the Epworth basin near the Itchen Lake map-area and thickens westward to at least 6,500 feet (1,981 m). The base of the formation is marked by a poorly exposed transition from predominantly dolomitic rocks to argillite and siltstone. The top is not exposed but probably consists of interbedded limestone and argillite grading up into interlamined limestone-argillite of the Cowles Lake Formation.

The formation consists mostly of green, grey, and minor red argillites, black shales and slate, and minor calcareous argillite. Conspicuous beds of green argillite containing numerous pale grey limestone concretions characterize the lower part of the Recluse Formation along the east margin of the Epworth basin.

Cowles Lake Formation (EACL)

The type section of the Cowles Lake Formation (Fraser, 1975) is at Cowles Lake in the northwest corner of the map-area. There the formation consists of 2,600 feet (792 m) mainly of interbedded limestone and argillite. The base of the formation is covered but the transition from the underlying Recluse Formation is marked by the appearance of interlaminated limestone and argillite. The top of the formation is marked by a sharp transition from a thick-bedded red and maroon argillite containing thin lenses of limestone and limestone breccia to the basal red siltstone and sandstone of the Takiyuak Formation.

The argillite of the Cowles Lake Formation is grey, green and red, the latter colour occurring only in the upper half of the formation where it is interbedded with grey or greenish argillite. Argillite containing limestone lenses or concretions occurs near the base and top of the formation, and breccia composed of tabular fragments of limestone in an argillite matrix occurs in the upper part. Beds of greywacke with interlaminated limestone and argillite occur just below the red argillite.

Takiyuak Formation (EAT)

The name, Takiyuak Formation, is derived from Takiyuak Lake north of the Itchen Lake map-area (Fraser, 1975). The base of the formation is marked by reddish-brown siltstone in sharp contact with red argillite of the underlying Cowles Lake Formation. The top has been removed by erosion but 1,200 feet (366 m) of section are preserved.

The Takiyuak Formation consists of reddish brown sandstone locally grading into siltstone. Ripple-marks occur locally at the base of the formation and crossbeds are present in places throughout it.

GOULBURN GROUP

The name, Goulburn quartzite was first used by J.J. O'Neill (1924) as a formational name to describe "more than 4,000 feet (1,219 m)" of quartzite and conglomerate outcropping on Goulburn Peninsula on the west side of Bathurst Inlet. The name was elevated to group status by Wright (1957) who included, in addition the original quartzite, argillite, slate, dolomite and sandstone in the Western River area that lie beneath the quartzite. Fraser (1964) mapped the intervening country and included in addition slate, argillite and dolomite that conformably overlie the quartzite.

The Goulburn Group in the Contwoyto Lake area was divided into four formations by Tremblay (1967) which include in ascending order: the Western River Formation (1,350 feet (411 m), mainly argillite and quartzite), the Burnside River Formation (600 feet (183 m), mainly quartzite and argillite), the Peacock Hills Formation (160 feet (49 m), mainly argillite and quartzite), and the Kuuvik Formation (140 feet (43 m), mainly carbonates and argillite) for a total of about 2,250 feet (686 m). A fifth formation called the Brown Sound Formation (Tremblay, 1968) lying at the top of the Group in the Bathurst Inlet region is not preserved within the present map-area.

Within the Itchen Lake map-area the Goulburn Group is exposed at the north end of Contwoyto Lake and on either side of Rockinghorse Lake, but in the latter locality only the lowermost formation, the Western River Formation, is preserved. That part of the group northeast of Contwoyto Lake was not examined during the present study and the account of the rocks there is taken from Tremblay (1967).

Western River Formation

The name, Western River Formation, was established by Tremblay (1971) for the basal formation of the Goulburn Group in the Beechey Lake map-area where the formation was subdivided into five members: basal conglomerate, lower argillite, red siltstone, quartzite and upper argillite. The same nomenclature was applied (Tremblay, 1967) to similar rocks at the base of the Goulburn Group in the Contwoyto Lake area, and this nomenclature is extended to the rocks at Rockinghorse Lake.

Basal Conglomerate Member (G ÆW,)

The Basal Conglomerate member at Contwoyto Lake is discontinuous, the lowest beds probably being a regolith as they fill fractures in the schist below. No similar conglomerate is exposed, although a few feet may exist, in the eastern exposures at Rockinghorse Lake. West of the lake however, yellow-green conglomerate containing quartz pebbles, commonly up to 5 cm in diameter, scattered in an argillitic to coarse sandy or limy matrix up to at least several feet thick is exposed locally. The yellow-green colour of the matrix both in the basal conglomerate and in many of the argillaceous laminae in the lower part of the succeeding member is similar to that in the altered granitic plutonic rocks that lie unconformably below, but no section fully exposing the unconformity was seen. This member has been combined with the overlying unit to form a single map-unit at 1:250,000 scale.

Lower Argillite Member (G ÆW,)

The Lower Argillite member at Contwoyto Lake consists mainly of 285 feet (87 m) of interbedded red-purple, green and grey argillites with beds marked by interlamination of colours. Near the base a few thin beds of grey to white, glassy quartzite are present and these are overlain by one or two carbonate beds up to 8 feet (2.4 m) thick, or by about

6 feet (1.8 m) of red concretionary argillite. In the bluffs at the southeast corner of Rockinghorse Lake, where the most continuous section occurs, the corresponding upper contact of the Lower Argillite member is not evident. There the lower part of the section consists of 170 feet (52 m) of yellow and green argillites with two layers of white to green, brown mottled, slightly limy quartzite 40 and 45 feet (12 and 14 m) thick. The lower of these quartzite beds contains two thin beds of carbonate. Above the quartzite layers are 295 feet (90 m) of banded argillites, mostly green in the lower 70 feet (21 m) and mostly red above, with grey bands near the top. This section is overlain by a basalt sill and no carbonate concretions are evident within it. Concretions do occur however, to the southwest of a fault that crosses the southeastern extremity of Rockinghorse Lake. There, along the shore of the southeast bay, brown silty carbonate nodules are present locally within argillite. Similar nodules, locally with thin stromatolitic carbonate beds, also occur in argillite near the diabase sill in the northeastern part of the inlier where the bottom part of the Lower Argillite member is not exposed. This suggests that the basalt sill, which overlies the Proterozoic rocks east of Rockinghorse Lake, has been emplaced mostly at a level in the section below the carbonate nodules and stromatolites, but that it rises northward until the lowermost carbonate beds appear beneath it. It furthermore, appears likely that the Lower Argillite member thickens from 285 feet (87 m) at Contwoyto Lake westward to somewhat more than 465 feet (142 m) at Rockinghorse Lake.

Intervention of the diabase sill below the nodular argillite at Rockinghorse Lake has made this horizon difficult to follow. Thus, for mapping on a 1:250,000 scale the upper part of the Lower Argillite member (above the second quartzite) at Rockinghorse Lake has been combined with the overlying Red Siltstone member.

Red Siltstone Member (GAWS)

The Red Siltstone member at Contwoyto Lake is about 500 feet (152 m) thick. The lower contact is marked by the appearance of dolomitic concretions in red argillite and the upper contact by the appearance of pink quartzite. The member consists of about 400 feet (122 m) of concretionary argillite overlain by 85 feet (26 m) of massive to thinly bedded red argillite, grey argillite and locally by a few feet of distinctive red siltstone.

At Rockinghorse Lake the Red Siltstone member is not well exposed. Concretionary argillite with local thin dolomite beds, in places stromatolitic (see Fig. 45 and 46), are exposed in the northeast part of the inlier, near the west shore of the lake, on the southeast end of the prominent peninsula in the southeast part of the lake, and on the southern islands in the central part of the lake. In the west and northwest part of the inlier white quartzite layers, locally accompanied by minor carbonate beds, occupy the tops of hills and in places appear to be interbedded with argillite. These quartzite beds are reminiscent of those in the Lower Argillite member and are in places accompanied by yellow green argillite laminae similar to those found at the base of that member. It seems unlikely however that they correlate with the Lower Argillite member because they are surrounded by extensive terrane of argillite rubble with the Lower Argillite member dipping beneath them at its periphery. These hilltop quartzites have been correlated with the succeeding quartzite member although it is possible that they are interbedde within the Red Siltstone member. In either case they appear to indicate a northward facies change within the inlier.

Figure 45 & 46

Quartzite Member (G𝔸Wq)

The Quartzite member at Contwoyto Lake is about 450 feet (137 m) thick. The base is marked by the appearance of pink quartzite, and the upper contact by the appearance of grey to olive argillite and greywacke interbedded with quartzite. The pink quartzite is 300 feet (91 m) thick and is overlain by 150 feet (46 m) of white quartzite. The former is fine grained, coarsely bedded, and well jointed. In addition to pink quartzite it includes purplish-pink, orange-pink and deep purple quartzite beds, a few thin beds of grey argillite, and locally layers and lenses of quartz-pebble conglomerate less than a foot (0.3 m) thick. The overlying white quartzite is coarse grained, coarsely bedded and commonly crossbedded. There are no quartz-pebble conglomerate layers but seams of greywacke are fairly common. At Rockinghorse Lake the Quartzite member is at least 310 feet (94 m) thick and consists of purple, buff, pink, white, and greenish quartzite with local thin quartz-jasper-pebble conglomerate beds. A carbonate bed up to 12 feet (3.7 m) thick is present at or near the base of the member, and a thin carbonate bed may be present higher within the section. A few thin breccia beds composed of slaty argillite chips in quartzite matrix were observed.

The beds at Rockinghorse Lake are overlain by at least 128 feet (39 m) of buff to pink quartzite in beds most of which are about one foot (0.3 m) thick and are interlayered with grey-olive argillite, laminated quartzite, white quartzite, and greenish greywacke. Crossbedding is present locally. These beds constitute the youngest preserved part of the Rockinghorse Lake outlier. They may correlate with the upper part of the Quartzite member at Contwoyto Lake, or with the succeeding Upper Argillite member, or they may be in part stratigraphic equivalents of both these members.

Upper Argillite Member (GAWP)

The Upper Argillite member at Contwoyto Lake is about 125 feet (38 m) thick. Its lower contact is defined by the appearance of grey argillite either above the pink quartzite or interlayered with it. The contact with the overlying Burnside River Formation occurs at the first appearance of pink quartzite beds and is generally sharp. The uppermost beds of the Rockinghorse Lake outlier may correlate with this member.

Burnside River Formation (GAB)

The name, Burnside River Formation, was applied by Tremblay (1971) to a thick succession of pink quartzite and quartz-pebble conglomerates overlying the Western River Formation in the Beechey Lake map-area. The name is taken from Burnside River north of the map-area where the best section of the formation probably occurs. The formation correspond to O'Neill's original Goulburn quartzite.

The Burnside River Formation in the Contwoyto Lake area consists of up to 600 to 800 feet (183 to 244 m) of coarse- to very-fine-grained pink quartzite with minor quartz-pebble conglomerate, and minor grey argillite seams most common near the top of the formation. The lower contact is marked by pink quartzite in contact with thin bedded red argillite, and the upper by a mixture of red, grey, green, and buff argillite. The rock is coarsely bedded and commonly crossbedded. Symmetrical ripple-marks are present in a few places.

Peacock Hills Formation (GAPH)

The name, Peacock Hills Formation was suggested by Tremblay (1967) for a succession of mostly thinly interbedded quartzite and argillite 160 feet (49 m) thick, that occur about the narrow lake immediately northeast of Contwoyto Lake. The name is derived from the

Peacock Hills which surround the lake. The lower boundary of the formation is marked by pink quartzite of the Burnside River Formation and the upper contact by a 10-foot (3 m) zone of interbedded carbonate and argillite. The argillites, which form 80 per cent of the formation are thinly bedded, and predominantly black or purple to pink near the bottom, and pink to grey near the top. The quartzite is more coarsely bedded. The formation lies along the axis of a northeast trending syncline and the argillites have developed a pronounced cleavage parallel to this fold.

Kuuvik Formation (G$\mathbb{A}$K)

The name Kuuvik Formation was proposed by Tremblay (1967) for the sequence of argillite and dolomite that conformably overlies the Peacock Hills Formation. The name is derived from Kuuvik Lake to the northeast of the map-area. The lower contact of the formation is marked by a 10-foot (3 m) zone of interbedded carbonate and argillite. The upper contact is not exposed. The formation consists of at least 140 feet (43 m) of light brown weathering, argillaceous dolomitic material interbedded toward the bottom with green and red argillites, and toward the top with thin beds of buff weathering limestone.

AGE AND CORRELATION OF THE PROTEROZOIC SEDIMENTS

The Epworth and Goulburn Groups lie unconformably upon a basement of Archean metamorphic and plutonic rocks, the Proterozoic sediments being separated at least in places from the basement by conglomerate or regolith. The youngest Archean granites in the area are dated at about 2500 m.y. by the Rb/Sr whole rock isochron method using the lower ($1.39 \times 10^{-11} \times yrs.^{-1}$) decay constant for ^{87}Rb. This date therefore provides a maximum age for both groups.

Both Epworth and Goulburn Groups are overlain unconformably by younger Proterozoic strata near Coronation Gulf. The Coppermine basalts, which form a part of this younger sequence date about 1200 m.y. (K/Ar whole rock and Rb/Sr isochron, Baragar in Wanless and Loveridge, 1972). Basic sills within the Epworth and Goulburn Groups dated by the K/Ar whole rock method have ages ranging from Coppermine age up to 1,555 m.y., the oldest date having been obtained from the eastern sill at Rockinghorse Lake. Along the west margin of the Epworth basin the Epworth Group is intruded by massive to porphyritic granite, and biotite from this granite, dated by the K/Ar method, gives an Hudsonian age of 1,760 m.y. The minimum age of the Epworth Group is therefore Hudsonian and correlation of Goulburn and Epworth Groups (Fraser and Tremblay, 1968) suggests that this minimum applies to the Goulburn as well.

Hoffman et al., (1970) proposed that the Goulburn and Epworth Groups form northern remnants of an arcuate Aphebian geosyncline, the Coronation Geosyncline, that extended from the northern to the western and southern margins of the Slave Province, where it included rocks of the Snare and the Great Slave Groups. They further suggested that emplacement of Hudsonian granite along the western margin of the geosyncline occurred at about the same time as deposition of the molasse facies within the geosyncline farther east. Consideration of sedimentation rates led to the conclusion that deposition probably began in the geosyncline no more than 2,000 million years ago and hence that the geosynclinal succession as a whole is of late Aphebian age.

Goulburn and Epworth Groups further correlate approximately on a formation by formation basis. The Western River Formation at the base of the Goulburn Group is thus the stratigraphic equivalent of the Odjick Formation of the Epworth Group. These basal formations represent a heterogeneous, laterally variable, pre-orogenic, terrigenous phase of sedimentation (Hoffman et al., 1970) which, within the present map-area respectively represent cratonic and marginal geosynclinal environments. Correlation at a more detailed level is difficult because of the much greater thickness of the Epworth Group and of the lateral variability of both groups.

Interesting northwestward variations in facies occur within the Western River Formation. In the Contwoyto area (Tremblay, 1967) the thickness of quartzite beds in the lower part of the Lower Argillite member increases northwestward, and in the Rockinghorse Lake outlier these beds have become even more prominent. The quartzite beds of the Lower Argillite member are associated with yellow-green argillites that closely resemble the colour of the very fine-grained yellow-green alteration of the basement plutonic rocks and gneisses at the unconformity. It therefore seems likely that both lithologies were derived from local erosion of the weathered Archean surface during retreat of the shore line. Subsequent darker coloured argillites probably represent influx of detritus from more distant sources.

The Red Siltstone member at Contwoyto Lake is characterized throughout its lower four fifths by carbonate nodules in argillite (Tremblay, 1967). At Rockinghorse Lake these nodules commonly display lamination convex upward and in places are accompanied by thin stromatolitic beds suggesting sedimentation in less turbid waters as at the northwestern edge of a basin or trough of shale deposition. This hypothesis is supported by the appearance within the Red Siltstone member of minor yellow green locally derived argillites along with quartzite beds resembling those in the lower part of the Lower Argillite member. These quartzite beds occur along the west margin of the Rockinghorse Lake outlier and suggest proximity to exposed Archean basement during Red Siltstone time

The great difference in thickness between the Odjick Formation (2,100 feet or 640 m) in the northwest corner of the map-area, and the Western River Formation (900 feet or 274 m) some 15 or 20 miles away at Rockinghorse Lake suggests that a topographic rise or "hinge line" existed in late Aphebian time between these two areas (Hoffman et al., 1970). This "hinge line" may in part still be reflected in the abrupt rise of some 400 to 500 feet (122 to 152 m) of the present surface of Archean rocks from the Odjick contact to the hilltops west of Rockinghorse Lake.

DIABASE AND GABBRO DYKES AND SILLS

Northwest trending diabase and gabbro dykes of the Mackenzie swarm occur throughout the Itchen Lake map-area but they are clearly concentrated along a belt immediately southwest of Contwoyto Lake where they exert a dominating influence on the regional aeromagnetic anomaly pattern. Farther west a second, less marked concentration of northwest trending dykes occurs in a belt extending from the south margin of the map-area through the east end of Point Lake to the northwest corner of the map-area. In the intervening area some dykes are evident in the aeromagnetic anomaly patterns and other known dykes are not. The dykes vary in thickness up to 550 feet (168 m), the largest being reported by Tremblay (1967) near Contwoyto Lake. All appear to be steeply dipping.

A few west-northwest to west-southwest striking diabase dykes are present within the northern part of the map-area. These dykes are up to 150 feet (46 m) thick and most appear to be steeply dipping although the dip of one was observed to be only 55 degrees to the south. Some of the westerly striking dykes are porphyritic with plagioclase phenocrysts up to 2 cm in length, but others are equigranular. One dyke of this swarm was found to contain calcite amygdules.

Sills of diabase to gabbro intrude the Epworth and Goulburn Groups near Cowles Lake, at Rockinghorse Lake, and about the north end of Contwoyto Lake. The basalt sill east of Rockinghorse Lake is about 40 feet (12 m) thick at its south margin but may be thicker elsewhere.

The dykes and sills are mostly dark grey commonly grading to greenish-grey where coarser grained or altered. Porphyritic dykes are either green or dark grey. The least altered dykes, which belong mostly to the Mackenzie swarm, are composed principally of andesine and labradorite and clinopyroxene with minor magnetite-ilmenite, and trace apatite. More altered dykes, most of which strike west-northwest, contain variable amounts of chlorite and hornblende, and some contain a little biotite and interstitial intergrowths of quartz and potash feldspar. Diabasic to gabbroic textures are typical but one large dyke was found to be microlitic. A green porphyritic dyke contains oligoclase phenocrysts in a fine-grained matrix of oligoclase, blue-green hornblende, and minor biotite, epidote, quartz and carbonate. Trace sphene in euhedral crystals and magnetite are also present.

Chemical analyses

Chemical analyses were made of three west-northwest striking diabase dykes (see Table 12). Analyses of five (northwest striking) Mackenzie dykes from within and near the map-area were obtained from W.F. Fahrig (pers. com., 1975). The latter are mostly mean compositions derived from analyses of different specimens of the same dyke.

Table 12

The analyses suggest that the west-northwest striking dykes are olivine-normative whereas the Mackenzie dykes are quartz-normative. There is a further suggestion that the west-northwest striking dykes are of more variable composition, although this may be partly due to averaging of analyses of Mackenzie dykes. Further analyses are required to substantiate these trends.

Age Relations

Three ages of diabase intrusion appear likely within the Itchen Lake map-area. The oldest of these probably comprises the westerly strikin porphyritic dykes and possibly the westerly striking equigranular dykes. This inference is based on the occurrence of porphyritic andesite flows, of similar lithology to the porphyritic dykes, that are reported by Fraser (1975) within the Rocknest Formation to the west of the map-area. A whole rock K/Ar date determined for one of these flows is 1740 ± 200 m.y. (Fraser in Wanless et al., 1966), and two dates obtained from porphyritic dykes are 1570 ± 115 m.y. and 1240 ± 80 m.y. Although these dates do not represent the age of intrusion of the respective dykes, they support the previous suggestion that the porphyritic dykes are older than the Mackenzie diabase (about 1200 m.y., Fahrig and Jones, 1969). The age of intrusion of the porphyritic dykes thus probably corresponds to the age of the Rocknest Formation, between 1750 and 2000 m.y.

Equigranular diabase to gabbro sills have intruded the Goulburn and Epworth Groups. These sills are crosscut by the Mackenzie dykes but contact relations with the more nearly east-west striking porphyritic dykes are not known. None of the latter group of dykes are known to intrude the Goulburn Group in the vicinity of the sills, although they appear within the Archean rocks a few miles to the south. This suggests that emplacement of these dykes and the sills were not related events. The sill at Contwoyto Lake intrudes the Burnside River Formation (Tremblay, 1967) and similar sills farther northeast intrude the upper part of the Goulburn Group (Fraser, 1964) suggesting that the sills are younger than the Rocknest Formation. The porphyritic dykes are therefore, by correlation with the porphyritic flows in the Rocknest Formation, older than the diabase sills. A K/Ar whole rock date, 1555 ± 135 m.y. obtained from the sill east of Rockinghorse Lake provides a possible age of emplacement that is consistent with the geological succession.

Northwest striking diabase dykes within the map-area are part of the Mackenzie dyke swarms exhaustively dated by the K/Ar whole rock and biotite methods. The results of these studies yield an approximate age of intrusion of 1200 m.y. (Fahrig and Jones, 1969).

Concentrations of Mackenzie dykes in two northwesterly trending zones near Contwoyto Lake and through the east end of Point Lake have already been pointed out. In the western zone the dykes are most densely concentrated at the margin of the high grade gneiss next to the Yamba batholith. They decrease in number where they cut across the greywacke-turbidite basin and the Rockinghorse batholith. In the eastern zone dykes are also most abundant in the sediments, where they follow the margins of the Central belt and Contwoyto batholiths but decrease in number where the zone cuts deeply into the Contwoyto batholith. Dyke intrusion thus perhaps favours zones that follow the main pluton margins whether these are exposed at the surface as is probably the case near the Central belt batholith or whether they are present at depth as is likely near the margin of the hybrid gneisses at Point Lake (see map section A-A1).

METAMORPHISM

INTRODUCTION

Archean supracrustal rocks within the map-area show wide variations in metamorphic grade that are characterized throughout by the absence of mineralogical indicators of high pressure. Thus in pelitic rocks biotite appears low in the greenschist facies. At higher grades garnet is not common except in iron-rich rocks and kyanite is absent, its place being taken by andalusite. At highest grades andalusite-cordierite-microcline assemblages appear locally and hypersthene is present in some calcareous rocks, suggesting conditions approaching those of contact metamorphism (Winkler, 1967). Metamorphic rocks of the Itchen Lake map-area therefore resemble those of the Abukuma facies series of Miyashiro (1961). Conditions of this facies series, characterized by low water vapor pressure, provide a favourable environment for the rapid changes in regional metamorphic grade that are typical of the map-area, and indeed of the Slave Province.

In the present study the metamorphic classification of Winkler, (1967) has been followed. In areas underlain by pelitic rocks isograds have been drawn at the first appearance of cordierite, at the first appearance of sillimanite, and at the first appearance of microcline with sillimanite. Thus the greater part of the map-area is divided into metamorphic zones corresponding to the greenschist facies and three subfacies of the cordierite-amphibolite facies. The latter in order of increasing metamorphic grade are: 1) the andalusite-cordierite-muscovite subfacies, 2) the sillimanite-cordierite-muscovite-almandine subfacies, and 3) the sillimanite-cordierite-orthoclase-almandine subfacies. In the following text these will be referred to as the lower, middle and upper amphibolite facies.

In areas underlain by volcanic rocks of the Point Lake Formation changes in mineralogy due to metamorphism are less obvious. Locally it has been possible to recognize the disappearance of abundant disseminated epidote marked by a change from light to dark green colours in greenstone. This change probably begins below the upper limit of the greenschist facies as increasing amounts of calcium are taken up to form more basic plagioclase. Evidence of amphibolite facies conditions can be recognized elsewhere in the volcanic succession where lenses of calcareous metasediments contain diopside. At slightly higher grade but still within the lower amphibolite facies the first appearance of cummingtonite occurs (Heywood and Davidson, 1969). In the Itchen Lake area cummingtonite is rare in the metamorphosed basic flows but is present in places in the tuffs and amphibolites of the central volcanic belt. It also occurs in nodular calcareous greywacke beds at a few localities within the Itchen Formation. Its occurrence is too sporadic to permit a cummingtonite isograd to be drawn. At the highest metamorphic grade hypersthene has been observed in a lens of calcareous metasediment. Thus the volcanic rocks are only broadly subdivided into areas corresponding approximately to greenschist facies and amphibolite facies metamorphic grade.

THE GREENSCHIST FACIES METAMORPHIC ZONE

Two belts and one outlier of greenschist facies metamorphism are present within the Itchen Lake map-area. The most westerly belt lies along the eastern side of the Western volcanic belt from Itchen Lake south to a point at least 12 miles (19 km) south of Point Lake. The second belt extends discontinuously from a point some 7 miles (11 km) north of Point Lake to the region northeast of Contwoyto Lake. The northeastern section of this belt near Contwoyto Lake is not covered in this report and the reader is referred to Tremblay (1975). An isolated region of hybrid rocks characterized by greenschist facies metamorphism lies along the south shore of Rockinghorse Lake.

The westernmost belt of greenschist facies metamorphism encompasses mostly rocks of the Point Lake, Contwoyto, and Keskarrah Formations in which lithologies range from acid to basic volcanics, and from coarse clastics to pelitic sediments and iron-formation. The rocks of lowest metamorphic grade include the Keskarrah conglomerates, adjacent flows, and part of the Contwoyto Formation. Light green mafic flows that lie beneath the conglomerates south of Point Lake are characterized by fine-grained albite and epidote. Greywacke lenses within the conglomerate contain quartz-albite-muscovite-chlorite assemblages indicative of lower greenschist facies metamorphism (Winkler, 1967). Mafic flows and tuffs remote from the greenschist facies belt are darker green. These rocks contain well crystallized oligoclase or andesine and blue-green hornblende with little epidote, suggesting amphibolite facies metamorphism. Transitional between light and dark green greenstones are intermediate rocks which render mapping of the precise upper limit of the greenschist facies in the volcanic terrane difficult. These rocks contain insufficient disseminated fine-grained epidote to markedly effect their colour and are dominated by pale green to bluish green actinolitic amphibole. Variable proportions of oligoclase are also present. Such rocks probably belong to the quartz-andalusite-plagioclase-chlorite subfacies or upper greenschist facies of metamorphism (Winkler, 1967). North of Point Lake disseminated epidote is nowhere as abundant in the mafic volcanic rocks as it is to the south. Mafic tuffs and flows along the west margin of the Western volcanic belt probably attained amphibolite facies grade because diopside occurs in a lens of calcareous metasediments and anthophyllite in meta-ultramafic rocks within this succession between Point and Itchen Lakes. To the east very fine-grained, equigranular greywackes within the volcanic belt contain the assemblage quartz-sodic plagioclase-chlorite-sericite-carbonate indicating that they are within the greenschist facies zone. The eastern limit of this zone is marked by the appearance of cordierite in the schists of the Contwoyto Formation, but it is of interest that siliceous iron-formation lenses within the slaty phyllites of this formation, apparently west of the cordierite isograd, contain radiating, highly poikilitic grunerite. Near Itchen Lake the western boundary of the greenschist facies zone probably occurs within the felsic volcanic rocks although diagnostic assemblages were not observed. To the north of that lake the boundary swings to the northeast where greenschist facies metamorphism is indicated by fine-grained tuffaceous phyllite bearing the assemblage quartz-sodic plagioclase-chlorite-epidote. The belt is terminated some seven miles northeast of the west arm of the lake where the structure swings abruptly to the northwest. Pelitic schists immediately to the north bear sillimanite-cordierite-muscovite assemblages indicating a rapid rise to middle amphibolite facies.

Rocks of the eastern belt of greenschist facies metamorphism consist primarily of greywacke, slate and phyllite of the Itchen Formation. These lithologies are characterized by the presence of metamorphic biotite and/or chlorite. Neither cordierite nor andalusite were recognized within the belt. Near the Central volcanic belt the rocks become phyllitic and where the two belts intersect the volcanic rocks appear to have attained higher metamorphic grades. Banded tuffs along the north margin of the volcanic belt contain cummingtonite and calcareous tuffs contain plagioclase which varies from albite to anorthite. Locally, there are indications of retrogression to greenschist facies, as for example where acicular actinolite crosses foliation in cummingtonite tuff, or where quartz-albite-actinolite-chlorite-muscovite assemblages occupy shear zones.

South of Rockinghorse Lake hybrid volcanic rocks and associated tuffaceous metasediments are abundantly intruded by granitic rocks. Both supracrustal rocks and some of the granitic rocks are commonly thoroughly altered, the typical mineral assemblages being quartz-chlorite-carbonate with or without biotite, muscovite, actinolite and albite or oligoclase. Pervasive alteration is therefore of greenschist facies grade.

THE LOWER AMPHIBOLITE FACIES METAMORPHIC ZONE

Belts of lower amphibolite facies metamorphic grade exist on either side of the greenschist facies metamorphic belts. The most prominent of these lower amphibolite facies belts lies along the east side of the Western volcanic belt at Point Lake and from there extends north and east to Concession Lake beyond which it splits, the northern part continuing to Contwoyto Lake and the southern extending southeast to the east border of the map-area. Narrower belts of lower amphibolite facies grade lie on either side of the eastern greenschist facies belt, and an isolated area of lower amphibolite facies metamorphism is present on either side of Point Lake at the entrance of Coppermine River.

Within the pelitic rocks of the Contwoyto and Itchen Formations rocks of the lower amphibolite facies zone commonly contain quartz-cordierite-andalusite-biotite-oligoclase assemblages. The lower boundary of the zone is marked by the first appearance of cordierite and its upper boundary by the first appearance of sillimanite. In places small grains of staurolite with yellow pleochroism are included in cordierite. Garnet appears in some schists within the Contwoyto Formation, and is present in some bands in most silicate-sulfide iron-formation lenses, where it is accompanied by blue-green hornblende, grunerite and quartz.

Page 131 intentionally omitted.

In the volcanic rocks lower amphibolite facies metamorphism is recognized with less certainty but is probably reflected in well crystallized hornblende-calcic oligoclase assemblages without appreciable epidote that are present in the northern and extreme southern parts of the Western volcanic belt. In the northeast arm of the Central volcanic belt the presence of cummingtonite and basic plagioclase indicate that at least lower amphibolite facies conditions were reached. In the southern arm cummingtonite was only observed where the arms merge, and where similar volcanic rocks are infolded within the Central belt batholith. Elsewhere in the southern arm chlorite-epidote-albite-oligoclase ± hornblende assemblages are common, but it is not clear whether lower amphibolite facies conditions were widely reached, and the characteristic mineral assemblage is a product of retrogression or whether only greenschist facies conditions were attained.

THE MIDDLE AMPHIBOLITE FACIES METAMORPHIC ZONE

Rocks of middle amphibolite facies and above are found only in those parts of the map-area to the east of the Western volcanic belt. In the north they form the outermost part of the greywacke-turbidite basin. In the central part of the map-area they underlie a region east of Itchen Lake that surrounds a group of minor granitic intrusions, and in the southeast they form a broad belt northeast of the Yamba batholith that is in most places separated from the batholith by a belt of upper amphibolite facies metamorphism. One isolated region of middle amphibolite facies metamorphism northwest of Itchen Lake is associated with hybrid pelitic schists that may be structurally separated from the rest of the basin.

Pelitic rocks of this zone are characterized by sillimanite-cordierite-muscovite-bearing assemblages. The lower limit of the zone has been placed at the first appearance of sillimanite as fibrolite. At slightly higher grades within the zone sillimanite is coarser grained, and eventually the schists become lit-par-lit gneisses. Andalusite accompanying sillimanite is not rare and may occur at any point in this progression. In the volcanic rocks, particularly the intermediate tuffs of this zone, cummingtonite is locally present but its first appearance occurs in the lower amphibolite facies zone and cannot be used to determine the isograd separating the two facies.

THE UPPER AMPHIBOLITE FACIES METAMORPHIC ZONE

Rocks of upper amphibolite facies metamorphic grade form a northeast tapering wedge along the northwest contact of the Yamba batholith. They also appear as inclusions within the batholith along its east margin.

The lower limit of the upper amphibolite facies is marked by the break-down of muscovite to form potash feldspar and sillimanite. Because of the low pressure at which the rocks have recrystallized, andalusite was apparently in many cases stable at the temperature of break-down of muscovite. Thus sillimanite-microcline-cordierite and andalusite-microcline-cordierite assemblages are interspersed, and both sillimanite and andalusite coexist at some localities. Employing the data of Winkler (1967) these assemblages indicate that upper amphibolite facies metamorphism northwest of the Yamba batholith occurred for the most part at pressures close to 2.5 kilobars and at temperatures close to 650°C. The fact that hypersthene is present locally, close to the contact of the batholith, in a quartz-hypersthene-diopside-hornblende-anorthite assemblage may suggest that still higher temperatures were attained. This assemblage appears in a calcareous band within a migmatite succession in which andalusite is present and would suggest that lower pressures as well as slightly higher temperatures obtained.

In the more basic rocks, hornblende gneiss and amphibolite, the upper amphibolite facies zone is characterized by hornblende-oligoclase/andesine in which hornblende is commonly green and plagioclase diffusely, reversely zoned. Quartz, biotite and microcline are present locally, but clinopyroxene is rare.

MINERALOGICAL INVESTIGATIONS

COEXISTING AMPHIBOLE PAIRS ± GARNET

Two coexisting amphiboles, a calcareous aluminous hornblende, and a grunerite, form the principal mafic phases in most of the silicate bands in silicate-sulfide facies iron-formation lenses in the Contwoyto Formation. Garnet is common along the margins of the iron-formation lenses and in beds and patches within. Except for magnetite or iron sulfide, found only in certain layers, quartz is the only other major constituent. Similar amphibole pairs, in which a calcareous aluminous hornblende coexists with cummingtonite, are present in the banded tuffs of the Point Lake Formation and in calcareous concretions within the Itchen Formation. Electron probe analyses of a selection of amphibole pairs, and some hornblende-grunerite-garnet triplets, were made to determine whether variation in composition of amphibole pairs could be clearly related to metamorphic grade attained as deduced from mineral assemblages in the neighbouring pelitic rocks. The investigation shows however, that the crystallization of a garnet richer in iron than either of the accompanying amphiboles exerts the predominant influence over the iron-magnesium composition of amphiboles in these rocks.

Electron probe analyses of grunerite-horblende pairs and grunerite-hornblende-garnet triplets are reported in Tables 13, 14 and 15, with the sample locations shown in Fig. 47. The analyses were obtained using a Materials Analysis Company electron microprobe equipped with a Keve energy dispersive spectrometer and automated to produce simultaneous multi-element analyses and data reduction (Plant and Lachance, 1973). Operating conditions were as follows: 20 kv. accelerating voltage, specimen current of 10 nanoamperes measured on a standard kaersutite, and a counting time of 100 seconds. The minerals were analysed for 10 elements, viz. Si, Ti, Al, Cr, Fe, Mn, Mg, Ca, Na, and K, and no other elements were detected in the energy dispersive spectra. Standards used were as follows: kaersutite (Na, Mg, Al, Si, K, Ca, Ti), chromite (Cr), biotite (Mn) and a grunerite (Fe). Except as noted below, there was no evidence of inhomogeneity within individual mineral grains, and the compositions reported in Tables 13, 14 and 15 are the average of 3 to 8 spot analyses. With the exception of sodium, the determinations have a relative accuracy of ± 1-2 per cent for major elements and up to 5 per cent for minor elements. For sodium, the relative accuracy is ± 10 per cent. Iron is reported as Fe^{2+} in the analyses and in the calculation of cation values. The latter were calculated on the basis of 23 oxygens for the amphiboles and 24 oxygens for the garnets.

Figure 47

Tables 13, 14 & 15

Two hornblendes, samples 211 and 648 are inhomogeneous. Compositional variations in these hornblendes appear to involve mainly substitution of Al_2O_3, Na_2O and K_2O for SiO_2. In one iron-formation bed, sample 1300C, suitable grains of garnet, grunerite and hornblende in close proximity were not present so that separate grunerites, one in contact with hornblende and the other in contact with garnet, were analysed.

Inspection of the data in tables 13, 14 and 15 shows that among the minor elements calcium, sodium, potassium and titanium are concentrated in hornblende. Manganese shows progressive increase from hornblende through grunerite-cummingtonite to garnet. Chromium shows no clear preferred concentration in any of these three minerals. None of these elements show clear trends in abundance in either amphibole with increasing metamorphic grade.

The principal substitutions involved in compositional variations in the amphiboles under consideration are those of magnesium, iron, aluminum, and silicon. Of these the first three enter the octahedral sites, and the latter two the tetrahedral sites of amphibole. Detailed consideration of these substitutions requires among other factors a knowledge of the ferrous-ferric iron composition which must be based on assumptions for data derived from electron probe analyses. Nevertheless the fractionation of any two of these elements between coexisting amphiboles can be expressed as a distribution coefficient. The distribution coefficient expressing the fractionation of magnesium and iron may be written as:

$$D = \frac{\text{Mg (hornblende)} \cdot \text{Fe (grunerite)}}{\text{Fe (hornblende)} \cdot \text{Mg (grunerite)}}$$

and this coefficient can be represented as the slope of the line obtained by plotting Mg(hornblende)/Fe(hornblende) against Mg(grunerite)/Fe(grunerite). In principle D will vary with the pressure and temperature of crystallization of the amphiboles. Moreover, to the extent that substitution is a non-ideal process, it may be affected by substitution of other ions such as that of aluminum. Because the two amphiboles are of similar structure, and mineral assemblages in the associated schists suggest that pressures under which the amphiboles crystallized were confined to the low pressure facies series, it may be assumed that the affect of pressure on the magnesium-iron fractionation was minimal.

Figures 48 & 49

In figures 48 and 49 Mg/Fe(hornblende) is plotted against Mg/Fe(grunerite-cummingtonite), and the points obtained are coded according to the metamorphic grade reached. At the same time the number of Al cations per unit cell in the hornblende is given beside each point. The data show little tendency to fall into metamorphic groupings but there is evidence that grunerites and cummingtonites are more magnesian than coexisting hornblende where the hornblendes are aluminous.

Figure 50

In figure 50 the magnesium-iron distribution coefficient, D, for each of the amphibole pairs in tables 13, 14 and 15 are plotted against the alumina content of the respective hornblende. Amphibole pairs that reached only greenschist facies metamorphism show a wide range of both alumina content and D, and those that reached higher grades show only slightly lesser ranges. The data indicate that temperature of crystallization has not been an important factor influencing the magnesium-iron distribution between these two minerals. On the other hand there is a clear trend toward inverse variation between D and the alumina content of hornblende suggesting that alumina substitution in hornblende has affected the magnesium-iron distribution.

Amphibole pairs accompanied by garnet (solid symbols) plot at the alumina-rich end of Figure 50 as would be expected from the aluminous composition of garnet. They are accompanied by at least one and possibly two D values (samples 309 and 358) representing amphibole pairs with alumina-rich hornblendes for which the metamorphic grade was probably too low to permit formation of garnet.

Figure 51

The data are consistent with the hypothesis that as alumina contamination of the host beds increases the alumina content of hornblende rises causing a shift in magnesium-iron distribution between hornblende and grunerite (or cummingtonite). Eventually, if the metamorphic grade is sufficient, garnet more iron-rich than either of the coexisting amphiboles will form (see Fig. 51B). The iron-rich nature of this garnet is probably responsible for the decidedly more magnesian compositions of both hornblende and grunerite coexisting with it (compare Fig. 51A and 51B) Although the overall composition of the host beds is not known it seems unlikely that coupled Al-Mg contamination, possible if the contaminent were predominantly a magnesian-aluminous clay mineral, is responsible for the more magnesian composition of the amphiboles because the amphibole pairs from the greenschist facies which contain aluminous hornblende but no garnet (samples 309 and 358) should then have been more magnesian.

The magnesian content of both amphiboles of one amphibole pair (sample 15, see Fig. 51A) with which no garnet was associated is high and comparable to that of amphibole pairs containing garnet. The hornblende of this pair however, has an intermediate alumina content somewhat below that of the least aluminous hornblende for which garnet coexists. This reflects the fact that some iron-formation beds were significantly more magnesian than others without at the same time being enriched in alumina.

The iron-formation beds of the Contwoyto Formation are considered to have been deposited within the greywacke-turbidite sequence during periods of reduced turbidite deposition. Distal turbidity flows presumably account for the contamination of some iron-formation beds by variable proportions of aluminous material. By comparison with the surrounding biotite schists this material was probably in large part potassium-rich clay. Possibly the cations normally absorbed to the settling clay particles were released through hydrogen ion exchange under abnormal pH conditions prevailing in the environment of silicate-sulfide facies iron-formation deposition.

CORDIERITE

Each of the subfacies of the amphibolite facies in the low pressure facies series is expressed in the Itchen Lake area, and unaltered cordierite is extensively preserved in the pelitic rocks of each of these subfacies. The Itchen Lake area therefore provides an unusually good opportunity for the investigation of variation in properties of cordierite with changes in regional metamorphic grade in rocks of this facies series. In the present study a survey of variation in optic axial angle (2V alpha) in cordierite has been undertaken to see what variations might exist and whether they could be related to known variations in the geological environment. In addition a suite of 10 cordierites was selected for partial chemical analysis by electron probe to represent localities with normal and abnormal optics from each of the metamorphic subfacies.

Optical Measurements

Values of 2V alpha determined for cordierite on the universal stage are given in Table 16, and the localities represented are shown in Figure 47. No corrections were applied to the data because of the similarity of refractive index between cordierite and the intermediate hemispheres, and because extreme rotations were not used. Individual measurements are believed accurate within ± 2 degrees.

Figure 52

Table 16

The range of 2V alpha obtained for cordierite is illustrated in histograms (Fig. 52). Sharp decreases in frequency of 2V alpha values occur at 66 degrees and 89 degrees (from composite histogram) for the Itchen Lake crystals. The lower inflection corresponds closely to the lower limiting value for common cordierite (65 degrees) given by Deer, Howie and Zussman (1962). The upper inflection however, is somewhat higher than the corresponding figure given by these authors. As will be seen this is probably due to extensive development of rocks of upper amphibolite facies, low pressure metamorphism, within the Itchen Lake map-area.

Chemical Data

Partial analyses of 10 cordierites from the same suite of rock specimens for which optic angles were determined, were made with the electron probe by G.R. Lachance (see Table 17). The method used is not as sensitive as that employed in amphibole analyses, but is believed accurate to within 2 to 10 per cent of the value given depending upon the element concerned and the amount present.

Table 17

Discussion

Myashiro (1957) has shown that optical properties of cordierite including 2V alpha depend in part upon the structural state which is related to the thermal history of cordierite. Iiamya (1958) showed that natural cordierite, converted to high-temperature cordierite by heating at various pressures, lost water and underwent an increase in optic angle. Increased pressure was found to increase the temperature at which this conversion began and ended. Folinsbee (1941) suggested that there may be an inverse relationship between the combined alkali content of cordierites and the value of 2V alpha. Data collected by Deer, Howie and Zussman (1962) however, are less convincing in this regard.

Chemically analyzed cordierites from pelitic rocks of the Itchen Lake area may show a tendency to be iron-rich at high metamorphic grade. Correlation of the two variables is not close however, and the tendency may be coincidental as it is not reported for other areas. Sodium on the other hand is highest in cordierites from lower amphibolite facies pelites and decreases in cordierite from middle amphibolite facies rocks. In schists from the upper amphibolite metamorphic facies it remains low. This trend is the inverse of that shown by 2V alpha except that the latter continues to increase in size into the upper amphibolite facies. The data are consistent with the view that increasing metamorphic grade tends to promote expulsion of alkalis (and water) from the cordierite structure and disordering of Al-Sl distribution, all of which operate to increase the size of 2V alpha. It may therefore be anticipated that within the Itchen Lake map-area the size of 2V alpha of cordierite from pelitic rocks will be primarily a function of metamorphic grade, but that pressure variations insofar as they may restrict expulsion of alkalis and water, or disordering of Al-Si, may modify the common trend locally.

The regional variation of 2V alpha of cordierite from pelitic schists within the Itchen Lake area is illustrated in Figure 53. This variation is clearly prominently affected by regional metamorphism about the Yamba batholith where unusually low pressure, high temperature metamorphic conditions are indicated by the andalusite-cordierite-microcline assemblage in nodular schists and by the local presence of hypersthene in some calcareous rocks. Highest values of 2V alpha however appear to exist in cordierite somewhat removed from the batholith contacts, and cordierite close to the contacts, which may have re-equilibrated to lower temperature conditions, has below average optic axial angles for this (upper amphibolite facies) metamorphic zone.

Figure 53

Comparison of cordierite from middle amphibolite facies rocks about the Contwoyto and Rockinghorse batholiths with that from rocks of similar facies about the Yamba batholith would be of interest but insufficient suitable material for this purpose was collected. The persistence of sillimanite-muscovite assemblages up to the batholitic contacts, and possibly to the incongruent melting point of arsenopyrite (702 ± 3 degrees, Clark, 1960 see economic geology section) may indicate metamorphism at somewhat higher pressures. If so the very low values of 2V alpha obtained from a middle amphibolite facies schist north of Itchen Lake may result from a combination of better retention of water, and equilibration to lower temperature, better ordered, states due to relatively higher pressure during metamorphism across the northern part of the map-area. A similar argument may apply along the east margin of the Yamba batholith where the upper amphibolite facies zone is also absent at the contact, and lower than normal values of 2V alpha were obtained from cordierite specimen 37 to the north of this region of the contact.

Within the nodular schists of the lower amphibolite facies low optic angles in cordierite are prominent in the northern part of the map-area consistent with relatively higher pressures during metamorphism. Two anomalously high values of 2V alpha were obtained from schists to the south of an inferred fault in the central part of the map-area. These may perhaps reflect uplift of rocks south of the fault during metamorphism. South of Point Lake 2V alpha values in this metamorphic zone are intermediate, perhaps also reflecting relatively greater depths of burial at the time of metamorphism.

SUMMARY AND INTERPRETATION OF RADIOMETRIC AGES

Radiometric dates determined for rocks in the Itchen Lake area are summarized in Table 18. The zircon and sphene dates in the table are based on U decay constants as follows: $\lambda^{238}U = 1.55126 \times 10^{-10} Yrs^{-1}$; $\lambda^{235}U = 9.8485 \times 10^{-10} Yrs^{-1}$. The Rb/Sr isochron dates given in the table are based on the smaller decay constant ($1.39 \times 10^{-11} Yrs^{-1}$) for

87 Rb because this appears to fit in better with other dates obtained from the Itchen Lake area.

Zircon and sphene concentrates from the Keskarrah batholith south of Point Lake yielded discordant U/Pb results but have minimum 207Pb/206Pb dates of 2642 ± 15 and 2637 ± m.y. respectively (R.K. Wanless, pers. com., 1975). These dates are considered to represent the minimum age of intrusion of this body and similar or older dates will likely be found in the quartz dioritic rocks of the Rockinghorse and Central belt batholiths. Conglomerate of the Keskarrah Formation to the north of the Keskarrah batholith contains clasts of granodiorite and other volcanic lithologies found to the south of Point Lake. Furthermore clast size decreases northward suggesting transport from the south. Boulders within the conglomerate contain muscovite that gives K/Ar dates of 2660 ± 75 m.y. and 2560 ± 75 m.y. Because fine-grained metamorphic muscovite is common in the matrix about these boulders, the K/Ar muscovite age is believed to reflect the age of metamorphism. Thus intrusion, uplift, and unroofing of the Keskarrah granodiorite, and deposition, foldin and metamorphism of the Keskarrah conglomerate probably occurred within an interval of 150 m.y. and were part of the same orogenic phase. Deposition of the greywacke-turbidite succession, which probably mainly followed deposition of the Keskarrah conglomerate presumably reflects the erosion of positive areas created by this early orogenic phase.

Table 18

The Yamba batholith, which intrudes the greywacke-turbidite succession, gives an Rb/Sr isochron date of 2422 ± 98 m.y. (λ^{87}Rb = 1.47 x 10^{-11} Yrs^{-1}) or 2562 m.y. (λ^{87}Rb = 1.39 x 10^{-11} Yrs^{-1}). Coarse muscovite from an unfoliated quartz monzonite dyke intrusive into rocks of the Point Lake Formation north of the Yamba batholith, presumably at the same time as the batholith itself was emplaced, yields a K/Ar date of 2495 ± 70 m.y. The best estimate of the age of intrusion of the Yamba batholith is thus about 2500 m.y. This indicates that deposition of the greywacke-turbidite succession in the Itchen Lake map-area was completed prior to 2500 m.y. ago.

Rb/Sr determinations for rocks derived from the lower volcanic part of the Yellowknife Supergroup give a scatter of Points providing a best fit isochron date about 2350 ± 105 m.y. ($\lambda\,^{87}Rb = 1.47 \times 10^{-11} \times Yrs^{-1}$) or 2485 m.y. ($^{87}Rb = 1.39 \times 10^{-11} \times Yrs^{-1}$). This date is clearly too young to represent the volcanic origin of these rocks and presumably reflects high grade metamorphism that was associated with emplacement of the younger granitic plutons. Biotite and muscovite K/Ar dates from rocks derived from the greywacke-turbidite succession range from 2125 to 2350 m.y. These dates probably reflect a combination of the effect of degassing of the Archean sediments during late Archean plutonism, and uplift responsible for development of the pre-Epworth, pre-Goulburn unconformity. Still younger K/Ar biotite dates ranging from 1815 to 2075 m.y. were obtained from the granitic plutons regardless of whether they belonged to the younger or older group of intrusions.

Eight K/Ar whole rock dates were obtained from the basic igneous rocks within the map-area. The oldest of these is from the Fuz pluton, a particularly fresh metagabbro southwest of Rockinghorse Lake. The date, 1865 ± 235 m.y. corresponds to the minimum dates obtained from biotites in the Archean plutonic rocks and indicates that the gabbro is probably not related to the younger diabase intrusions. Dates of 1570 ± 115 m.y. and 1240 ± 80 m.y. were obtained from westerly striking porphyritic dykes, and suggest that the dykes predate the Mackenzie swarm. They are likely related to porphyritic flows within the Rocknest Formation of the Epworth Group. Two dates 1555 ± 135 m.y. and 965 ± 58 m.y. were obtained from the diabase sill east of Rockinghorse Lake. The younger date probably represents a part of the sill altered during emplacement of Mackenzie dykes. The older date is the oldest obtained for sills intrusive into the Goulburn Group and may represent the approximate age of emplacement of this sill. A single date, 902 ± 106 m.y., is from a westerly trending diabase dyke containing a few quartz-feldspar stringers. The date may reflect post emplacement alteration of the dyke. Dates of 1200 ± 135 and 1335 ± 185 m.y., from dykes of the Mackenzie swarm, approximate the age of intrusion of Mackenzie dykes given by Fahrig (Wanless et al., 1965 and 1970).

STRUCTURAL GEOLOGY

MINOR STRUCTURES

BEDS AND INDICATORS OF STRATIGRAPHIC SEQUENCE

Beds, most commonly less than 18 inches thick, are well defined in most parts of the Contwoyto and Itchen Formations, although they may be difficult to discern except where scraped clean by lake or river ice. Minor structures indicating stratigraphic tops mainly comprise graded beds (see Figs. 18 and 19), but locally include scour and fill structures (see Fig. 31), and load casts (see Fig. 30), and more rarely, crossbedding. The chief indicators of tops in volcanic rocks are pillow shapes, but scour and fill structure have been observed locally in bedded tuffs (see Fig. 9).

FOLIATION

In most parts of the map-area planar distribution of metamorphic minerals has produced a foliation that is commonly parallel or nearly parallel with bedding. In some areas, particularly in the southern and central parts of the greywacke-turbidite basin, foliation intersects bedding at angles up to 90 degrees. This foliation defines an eastward concave arc that is less acute than that formed by the basin itself, and maintains its trend regardless of the facing direction indicated by graded beds, showing that it is not an axial plane cleavage related to the main phase of folding. In many places foliation is defined by elongate sections of cordierite porphyroblasts suggesting that it may have developed near a metamorphic maximum, about the time the late Kenoran granitic plutons were emplaced.

LINEAR FEATURES AND MINOR FOLDS

Mineral lineations are not abundant within the map-area but are evident locally as parallel elongate cordierite porphyroblasts and as aligned biotite in the pelitic rocks, or as aligned hornblende crystals in the volcanic rocks. Cobbles in the Keskarrah Formation conglomerate on the south shore of Point Lake are stretched with major axes defining a steep plunge within the plane of schistosity. Similar elongation of ovoids was observed in an isolated exposure of agglomerate within the Central volcanic belt.

Minor folds are fairly common in the basic tuffs along the northwestern part of the Western volcanic belt but appear to be less abundant elsewhere. Although these and other linear features are mostly steeply plunging the number of observations made is insufficient to establish a regional pattern.

MAJOR STRUCTURES

ARCHEAN ROCKS

Within the Itchen Lake map-area three major granitic bodies, the Keskarrah, Central belt, and Rockinghorse batholiths, appear to contain remnants of early Archean rocks. About the margins of these batholiths are distributed the thicker accumulations of Archean volcanic rocks (Point Lake Formation), and between them lies a great arcuate, eastward concave geosynform containing the greater part of the greywacke-turbidite succession (Contwoyto and Itchen Formations). This geosynform occupies the site of an originally more extensive basin in which the greywacke-turbidite succession was deposited. Metamorphic grades about these batholiths are commonly though not everywhere moderate.

In the northeast and southeast corners of the map-area are two major late Kenoran granitic bodies, the Contwoyto and Yamba batholiths. The emplacement of these bodies occurred in areas away from the major accumulations of early Kenoran volcanic rocks and peripheral metamorphism was of high grade. Foliation in metamorphic rocks in the vicinity of both groups of batholiths crudely parallels their contacts and dips steeply, mostly away from the granite bodies.

The basic flows of the Eastern and Western volcanic belts are of greater structural competency than are the schists of the adjacent greywacke-turbidite basins. Deformation along the volcanic belts has therefore involved more obvious faulting and more open folding than has occurred in the schist terranes.

The Western volcanic belt, made up chiefly of rocks of the Point Lake Formation, and its complex, coextensive fold belt, are flanked on the west by remnants of a steeply dipping mylonite zone. The fold belt is divided into two parts by a doubly plunging antiformal structure that reaches a complexly faulted, saddle-like culmination between the two arms of Point Lake. North of Point Lake both arms of the fold belt are progressively more extensively engulfed by plutonic rocks along the core of the antiform, but remnants of volcanic rocks, possibly still on the flanks of this structure, appear near the north margin of the map-area. South of Point Lake the western arm pinches out within 25 miles (40 km), but the eastern arm continues for some 60 miles (97 km) south of the map-area.

The central volcanic belt consists of two arms separated by down-faulted blocks of the greywacke-turbite succession. The northern arm consists of a narrow band of marble and calc-silicate gneiss succeeded to the north by banded tuffs, and by mafic tuffs and flows. The eastern end of this arm of the belt comprises predominantly felsic flows and tuffs whereas toward the western end the upper mafic member thickens and contains an increased proportion of pillowed mafic flows. Two possible pillow tops near the northwest margin of the belt suggest that it youngs toward the northwest, and the lack of obvious repetition of the three members suggests that it is not folded. These data support the interpretation that a felsic volcanic centre at the northeast end of the belt, with associated carbonate (exhalite?), overlain by banded felsic to mafic tuffs, is overlapped from the west by basic volcanics. On the other hand this picture can only be tentative because rocks in the central and western part of the arm have a penetrative foliation parallel with layering indicative of severe deformation.

The southern arm of the central volcanic belt is irregular in plan. Along the southeast contact of the arm volcanic rocks project at intervals into the Central belt batholith, and inliers within the batholi follow trends parallel both to the regional contact trend, and to the projections. It seems likely therefore that this part of the Central volcanic belt has been cross folded. The northwest arm of the belt appears to be faulted along at least part of its extent against down-dropped rocks of the greywacke-turbidite succession.

South of Concession Lake the mafic flows of the Central volcanic belt pinch out eastward and the banded tuffs become thin. They apparently thicken again slightly near the east margin of the map-area in the region southeast of Gossan Lake where amphibolite and few pillowed flows are present. The appearance of banded tuffs within the greywacke-turbidite succession at the east margin of the map-area suggests the presence in this region of a northwest plunging antiform.

The greywacke-turbidite succession, which includes the Contwoyto and Itchen Formations and hybrid gneisses derived therefrom, overlies volcanic rocks on the western and southern margins of the major westward convex arcuate structure which these pelitic rocks occupy. On the southeast this structure is joined by a subsidiary belt of high grade pelitic migmatites along the margins of which a similar lithologic symmetry is suggested. Thus a large region of agmatite at least partly derived from mafic volcanic rocks separates the northwestern part of the belt from the Central belt batholith and lenses of tuff and calc-silicate gneiss comparable to similar lenses in the Point Lake Formation are present locally near the southern contact with the Yamba batholith. This regional symmetry combined with a few pillow top determinations provides the main evidence for believing that the greywacke-turbidite succession is younger than the Point Lake volcanics, and that the major structures within which it lies are geosynformal.

Folds within the greywacke-turbidite succession are tight to isoclinal and of short wavelength relative to those in the more competent Point Lake volcanics. Fold noses and axial planes are difficult to follow so that only in a few places, as at Contwoyto Lake (L.P. Tremblay, 1967) and near the east end of Point Lake, where top determinations are most abundant, has it been possible to interpret individual folds. Along the western part of Point Lake, about Itchen Lake, and along the northern margin of the greywacke-turbidite basin scattered top determinations suggest that a disproportionate number of beds are overturned toward the west or outer margin of the basin. This suggests that folds in this region are also overturned toward the outher convex margin of the basin, and that the upright limbs have been preferentially removed by faulting.

PROTEROZOIC ROCKS

Structures within the Epworth Group are described by Fraser (1975), and those within the Goulburn Group at Contwoyto Lake by Tremblay (1975). The present report deals only with structures in the Goulburn Group at Rockinghorse Lake.

Beds in the Gouldburn Group at Rockinghorse Lake are mostly flat lying to gently dipping, dips of 5 to 10 degrees being most common. Along the northwest margin of the outlier however beds dip steeply southeastward apparently along a fault. Dips generally incline toward a focus in the central part of Rockinghorse Lake just to the west of the thickest and most extensive diabase sill. Exposures of the Goulburn Group in the central, eastern and western part of the outlier suggest that the upper surface of Archean basement reaches some 470 feet below lake level. This relief is indicated by flexing and minor faulting in strata of the Western River Formation along a northwest striking zone on the west side of the lake and by a single roughly parallel fault on the east side. The Goulburn outlier at Rockinghorse Lake thus likely occupies a half graben structure with greatest depression adjacent to the largest diabase sill within the inlier. This coincidence suggests that faulting occurred soon after emplacement of the sill and may be related to withdrawal of diabase magma from a chamber below the lake.

FAULTS

Two prominent zones of faulting are evident within Archean rocks of the map-area and are probably of Archean age. These trend north and east to northeast. Isolated east to northeast trending faults may be of the same age. Northeasterly trending strike slip faults in the northwest part of the map-area are of Proterozoic age.

A zone of northerly striking faults follows the western volcanic belt and remnants of a mylonite zone are preserved along its western margin. The appearance of small serpentinite bodies in this zone may also be related to the faulting. Apparent movement on some of the faults has been east side upward and to the north. If the ultramafic bodies are related to this movement the faults may be of early Kenoran age. Intrusion of the mylonite zone by granitic rocks indicates that it is of pre-late Kenoran age.

The most prominent zone of faulting within the map-area extends in a northeasterly direction from the east end of the north arm of Point Lake to Contwoyto Lake. Evidence for faults in this zone includes prominent lineaments where exposure is good abrupt truncation of lithologic units, and discontinuity of stratigraphic sequences. Part of the movement involved in the northeast section of the zone appears to have been thrusting of older rocks southeast over younger rocks. Emplacement of a minor granitic body across one of these faults indicates that the zone is of Archean age, but the preservation of down-dropped low grade metamorphic rocks along the zone suggests that all movement probably did not precede high grade metamorphism.

Northeasterly striking faults are prominent in the northwest corner of the map-area where they produce dextral offset of the Western volcanic belt. All formations of the Epworth Group are offset in the same manner by these faults but they do not offset dykes of the Mackenzie swarm. The faults are therefore probably of Hudsonian age.

TECTONO-STRATIGRAPHIC SUMMARY

The oldest known rocks in the Itchen Lake map-area are the lowermost volcanic rocks of the Point Lake Formation. These are separated mostly by a mylonite zone or by zones of hybrid rock from the early Kenoran quartz dioritic to granodioritic plutons. Preliminary Rb/Sr isochron dating of gneiss of similar composition from the Grenville Lake region near the west border of the Slave Province (southwest of the Itchen Lake map-area) has given a date of 3002 m.y. ($\lambda^{87}Rb=1.39x10^{-11}yrs^{-1}$) or 2838 m.y. ($\lambda^{87}Rb=1.47x10^{-11}yrs^{-1}$) Frith et al., 1974).

These rocks are described by Frith as "essentially quartz diorite" but in most places show "potash metasomatism by later pegmatitic phases". It is perhaps possible therefore that in the Itchen Lake area pre-Yellowknife basement of this age is preserved within the less potassic parts of the early Kenoran plutons among the hybrid rocks, and within the plutonic rocks to the west of the Western volcanic belt.

Yellowknife volcanism in the Itchen Lake area apparently followed a variable course from place to place, being concentrated in some centres and belts and apparently absent, or represented only by a thin layer of tuffaceous sediments in others. One of these belts, the Western volcanic belt, is of particular significance because it extends from 60 miles south of the map-area perhaps as far north as the arctic coast, a distance of some 240 miles. This belt is bordered on the west by a mylonite zone and includes small bodies of basic to ultrabasic intrusive rocks that occupy a zone near the base of the volcanic succession. Although the precise timing of formation of these rocks with respect to development of the volcanic belt as a whole is not established it is clear that the mylonite zone is of pre-late Kenoran age and the ultramafic rocks are likely of the same age. Felsic volcanic rocks evolved during the development of the belt are of limited extent. Some small rhyolitic flows occur interbedded with the mafic volcanics, but more extensive quartz porphyry flows here included within the hybrid rocks, are possibly of early Kenoran age. The latest volcanism in this belt was partly alkalic and was accompanied by deposition of a local spectacular volcanic conglomerate fan at the margin of an extensive greywacke-turbidite basin developing to the east. Deposition of the conglomerate was accompanied by uplift of an anitform along the core of the volcanic belt which exposed early Kenoran granitic rocks. Elsewhere along the northwest margin of the greywacke-turbidite basin oxide, silicate and sulphide facies iron-formation were deposited in beds possibly nearly coeval with the conglomerate. Stratiform arsenic-gold deposits were formed locally in conjunction with sulphide facies iron-formation. This belt merits further examination on the basis that it may constitute an Archean counterpart of a "plate margin" such as developed in Aphebian and later eras.

In the central part of the map-area a second more irregular belt of felsic and mafic volcanic rock developed. In part felsic and mafic volcanism were coeval but over extensive areas the latest volcanism appears to have been mafic. Remote from the main areas of volcanism much thinned layers of tuff and tuffaceous sediment are evident. No extensive iron-formation was formed but a zone of marble and calc-silicate rocks interbedded with the tuffs may represent exhalitive deposits. Terminal Point Lake volcanism was followed by, or was partly contemporaneous with, deposition of greywacke-turbidites of the Itchen Formation.

Deposition of the greywacke-turbidite succession terminated with a period of profound late Kenoran plutonism during which the greywacke-turbidite basin was intruded first by mafic plutons, and later by granitic plutons probably more potassic than the early Kenoran granitic rocks. Extensive regions about these plutons were raised to middle and upper amphibolite facies metamorphic grade characterized by pressures typical of the low pressure metamorphic facies series. No volcanic rocks or sediments directly related to emplacement of these late Kenoran plutons have been recognized within the map-area. The only known strata which may have been deposited at this time are those of the Wilson Island Group within the basin of Great Slave Lake at the south margin of the Slave Province (Stockwell, 1933). This group consists of felsic volcanics and conglomerates near the base and quartzites with minor dolomite, schists and phyllite above (Reinhardt, 1969). The group is older than the upper

Aphebian Slave Super group and is thought to be of lower Aphebian age (Fraser et. al., 1972).

The early Aphebian Era was marked within the map-area by erosion and development of the pre-Epworth, pre-Goulburn unconformity. Formation of the Coronation Geosyncline (Hoffman et al., 1970) along the margin of the Slave craton to the west was accompanied within the map-area by deposition of craton-derived early Epworth and Goulburn strata consisting primarily of orthoquartzite, shale, siltstone and carbonate. Later beds, including shale, siltstone, greywacke and sandstone were derived from the orogenic zone of the geosyncline to the west.

A succession of basic dykes and sills has intruded the Aphebian sediments. The earliest dykes were in part coarsely porphyritic, and were probably emplaced during the early development of the geosyncline producing a number of basic flows now present only in the section west of the map-area. Diabase sills (here dated at 1555 ± 135 m.y., K/Ar whole rock), emplaced within the sedimentary succession at some time during the Helikian Era, were intruded by northwest trending diabase dykes of the Mackenzie swarm about 1200 m.y. ago (Fahrig and Jones, 1969).

ECONOMIC GEOLOGY

INTRODUCTION

The earliest activity of economic significance within the map-area was the staking of copper showings by J. Harriman and associates in 1957 within the Western volcanic belt south of Point Lake. Copper showings near the entrance of Coppermine River into Point Lake were staked by Canadian Nickel Co. in 1959 and 1960. Gold-bearing amphibolites (silicate-sulfide facies iron-formation at Contwoyto Lake) were staked by the same company in 1961,and this activity sparked a flurry of prospecting which continued into 1964. The principal new discoveries were those of Canadian Nickel Co. north of Itchen Lake in 1962, and those of Giant Yellowknife Mines Limited between the arms of Point Lake in 1963. Nickel mineralization was discovered by Roberts Mining Company near the northwest shore of Itchen Lake in 1963. Except for parts of the original claim holdings of Canadian Nickel Co. in the Contwoyto and Point Lake regions, Giant Yellowknife Mines in the Point Lake region, Canadian Nidkel near Coppermine River, and a few recent claims staked between 1966 and 1974, all these early claims have since lapsed. The distribution of claims staked prior to 1974 is shown in Fig. 54, and the locations of showings examined during the current work are given in Table 19. Interest in the area has been renewed with the discovery by Texasgulf Ltd. of zinc-copper-lead-silver mineralization immediately northwest of Itchen Lake in 1975.

Table 19

Figure 54

Metal occurrences of potential economic significance within the Itchen Lake map-area include disseminated chalcopyrite-pyrrhotite in sediments within the western volcanic belt, in gneiss, and in plutonic rocks; pyrite-sphalerite-chalcopyrite in a siliceous zone in mixed conglomerate and volcanic rocks; sphalerite-chalcopyrite-pyrite-pyrrhotite in quartzo-feldspathic gneiss discovered since field work for this report; gold-arsenopyrite-loellingite deposits associated with sulfide-silicate iron-formation facies; and niccolite-pyrrhotite at the contact of a small metagabbro body with silicate-sulfide facies iron-formation. With the possible exception of disseminated chalcopyrite-pyrrhotite at the southwest margin of the Contwoyto batholith and the niccolite-pyrrhotite mineralization, all of these occurrences may be associated with changes in the volcanic stratigraphy. Chalcopyrite in the southwestern part of the western volcanic belt occurs mostly near the contact between basic tuffs and overlying flows and is therefore spatially associated with small ultramafic bodies thought to have been emplaced early in the period of basic volcanism. Chalcopyrite east of Coppermine River and that accompanied by base metal mineralization appear to be associated with felsic volcanic centres or felsic horizons within the Point Lake Formation that preceded or accompanied the main basic volcanism. Chalcopyrite at the southwest margin of the Contwoyto batholith occurs along a gradational contact between the plutonic rocks and migmatite representing the basal part of the greywacke-turbidite succession so that, although this mineralization may be related to processes involved in emplacement of the plutonic rocks, it may also have been deposited in association with volcanism before deposition of most of the greywacke-turbidite succession.

The widespread deposition of iron-formation appears to have been associated with a late phase of basic volcanism near Point Lake because a pillow breccia at that locality contains oxide facies iron-formation as a matrix like that in the adjacent Contwoyto Formation. This breccia occurs between exposures of the Keskarrah Formation and thus the timing of iron-formation deposition, late basic volcanism and evolution of the Keskarrah conglomerates appears similar. Comparable lithologic associations are found in other parts of the Shield (Ridler, 1970; Goodwin, 1965) where regional iron-formation is thought to form the distal facies of exhalitive base metal sulfide deposits. In the Itchen Lake area however, such stratigraphic information as is available suggests that the base metal occurrences are mainly associated with felsic volcanic rocks believed to have been erupted at least somewhat before the end of Point Lake volcanism. Conversely the iron-formation appears most closely related to the Keskarrah conglomerates and final basic volcanism including perhaps local alkalic (mugearitic) flows.

Gold-loellingite-arsenopyrite mineralization, which is concentrated locally with the sulfide facies iron-formation, is thought to have been deposited syngenetically with the iron-formation, gold-bearing, arsenic-rich solutions having been derived from local hot springs. Some of the arsenic-rich iron-formation is known to be nickel-bearing, and remobilization of nickel during late Kenoran emplacement of a small gabbro body is thought to account for an occurrence of niccolite-pyrrhotite mineralization.

In short the deposition of ore minerals within Archean rocks of the Itchen Lake area was principally related to Archean volcanism. The further possibility arises that this mineralization occurred in three episodes: 1) chalcopyrite occurrences related to early basic volcanism and perhaps to emplacement of minor ultramafic rocks, 2) base metal occurrences related to felsic volcanism, and 3) sulfide iron-formation related to late basic volcanism, which provided a favourable host environment for syngenetic gold-arsenic and minor nickel deposition. Further study of the Archean stratigraphy, particularly of the Point Lake Formation, would clearly lead to better definition of base and precious metal targets in the Itchen Lake area.

1) CHALCOPYRITE-PYRRHOTITE RELATED TO EARLY BASIC VOLCANISM

Minor chalcopyrite is present with pyrrhotite in dark slate and greenschist exposed in shallow trenches along the west margin of the Western volcanic belt six miles south of Point Lake. The host rocks trend east-northeast and have a steep easterly dipping foliation. Pillowed basic volcanic rocks to the east overlie the mineralized zone and dip steeply to the southeast. Pyrrhotite is thinly disseminated through the schist and slate but small amounts of chalcopyrite are concentrated in minor cross fractures.

Minor chalcopyrite and pyrrhotite are exposed in a trench in similar rocks on the western margin of the Western volcanic belt two miles south of Point Lake. There the cleavage in the slates is contorted but banded greenstone to the north (apparently less deformed) trends east-northeast and dips 65 degrees to the north. Pyrrhotite and minor chalcopyrite are disseminated along cleavage planes and coarser grained chalcopyrite and pyrrhotite in about equal amounts are concentrated along a few minor fractures. Further description of this occurrence is given by McGlynn (1973).

Minor chalcopyrite and pyrrhotite are present in a patchy gossan zone 0.3 m. wide in grey slaty greywacke on the south shore of Point Lake at the west margin of the Western volcanic belt. Bedding in the country rocks strikes northerly and dips steeply.

Minor chalcopyrite, pyrrhotite and pyrite are present in a zone 0.9 m. wide in banded amphibolite on the south shore of the north arm of Point Lake near the west margin of the Western volcanic belt. Banding strikes northeast and dips 85 degrees east.

Chalcopyrite occurrences near the west margin of the Western volcanic belt are all found near the contact between the basic tuffs and overlying basic pillowed volcanic rocks of the Point Lake Formation.

Furthermore gossans were found, at approcimately this horizon, northwest of Itchen Lake, but no copper mineralization was detected. Although none of the occurrences examined appear to show either extensive or concentrated mineralization, further prospecting of this horizon along the belt might prove rewarding.

2) BASE METALS ASSOCIATED WITH FELSIC VOLCANISM

SPHALERITE-CHALCOPYRITE-PYRITE NEAR ITCHEN LAKE

An important discovery of zinc-copper-lead-silver mineralization about 2 miles northwest of Itchen Lake (approximately 65°39'N, 112°49'W) was made by Texasgulf Ltd. in the summer of 1975 (P.L. Money, pers. comm., 1975). The deposit does not outcrop but occurs beneath a small lake known to Texasgulf as "Izok" Lake. Its presence was suggested by mineralized float and discovery was made by drilling from the ice. Over 7 million tons of indicated ore within the central zone of the deposit extend over a strike length of 1400 feet open to the east. Two other zones have been found but not delineated. The average grade is 14.8 per cent zinc, 3.15 per cent copper, 1.20 per cent lead, and 1.85 oz. per ton silver. The host rocks are quartzo-feldspathic gneisses of probable volcanic origin that have undergone polyphase deformation. A typical section of the central zone (provided by Texasgulf Ltd.) is shown in Fig. 55.

Figure 55

The following description of the central zone is quoted from Money and Heslop, 1976:

"The (central) zone occurs in a fairly open syncline generally plunging towards grid east. It is partly eroded towards grid west where it subcrops under the lake. There are enormous variations in thickness along and across strike. These variations are considered to be mainly primary features although they probably are partly due to deformation.

"The host rocks of the deposit, with the exception of late tourmaline pegmatite and granite, are highly metamorphosed, deformed, and recrystallized so that original textural features are generally not discernible. Locally there are indistinct probable fragments in quartzo-feldspathic rocks that are interpreted as meta-agglomerate. Most of the remaining host rocks are essentially quartz-feldspar-muscovite-biotite gneisses that have been logged as meta-rhyolite, meta-dacite, or meta-felsic tuffs depending on the relative proportions of biotite and other minerals and on their degree of unformity. More mafic rocks, with abundant chlorite or hornblende and lacking quartz, are scarce. These have been included in meta-andesite where uniform, a unit recognized only in drill holes and in units of mafic tuffs and a mixed unit considered to be made up of alternate layers of mafic and felsic tuffs. One additional metamorphic unit is CBC rock. CBC stands for chlorite-biotite-cordierite, the main constituents of this unit. The CBC rock is considered to represent a magnesium-enrichment alteration zone. It occurs in close association with and mainly beneath the massive sulphides on lines 26E, 27E, and 28E and is virtually absent elsewhere. These lines are at or adjacent to the area where the sulphide body is comparatively thin and our current interpretation is that the thin area represents a topographic high during sulphide deposition and that metal-bearing solutions were emitted from this high, probably a volcanic cone or ridge, into basins on either side. The Mg-enriched CBC rocks indicate the approximate position of the plumbing that these metal-bearing solutions rose through. It appears that this feature may have been in the order of 200 feet high and had walls with slopes of the order of 35 to 60^{o}, assuming that subsequent deformation has not greatly affected the original geometry of the system. We consider this a reasonable assumption although the longitudinal section suggests some "necking" or boudinage during deformation. Support for the idea that the thinning of the sulphides in an original feature is provided by a consideration of metal ratios on either side of the proposed volcanic cone or ridge. A plot of atomic ratios of Zn, Cu, and Pb for average drill intersections within each section shows that every section from L28 to line 30E falls in a cluster of comparatively low Zn to Cu ratios and every section from L27 to L20E, except L24E, falls in a cluster of high Zn to Cu ratios, suggesting that they were deposited from different solutions in separate basins. Although section L24E plots with the eastern group the Zn content is actually characteristic of the west group and this plot simply indicates a Cu concentration in the deepest or thickest part of the west basin.

"A considerable amount of time has been spent in trying to define and correlate originally horizontal or sub-horizontal zones in this deposit. Zoning is erratic and has no clearly defined pattern in the eastern basin. However, in the western basin there is a basal Cu-rich zone in all drill holes that intersected the sulphides where they were probably more than about 150 feet thick when deposited. This zone reaches a maximum thickness of about 70 feet. The top may have sloped up at a gentle angle towards grid north at time of deposition as it does not seem to be parallel to the top of the sulphide body.

"The basal zone is overlain by a predominantly Zn-rich zone up to 180 or 190 feet thick. Sub-zones can be defined in some sections but cannot be correlated between sections. For example, on section 26E there are five sub-zones, upper Pb-Zn, upper silicate, lower Pb-Zn, lower silicate, and Zn. Two hundred feet away, on line 24E, none of these sub-zones are recognizable, and the hole with the thickest sulphide intersection has a 32' Cu-rich sub-zone, averaging about 16% Cu and 6% Zn, within the upper Zn-zone. This Cu-rich zone has not yet been correlated with any zone in any other hole.

"An interpretation of zoning is complicated by the fact that there is evidence for the re-mobilization of both galena and chalcopyrite during metamorphism and/or deformation. These minerals are commonly found together as isolated blotches or stringers well outside of and in some cases stratigraphically above the massive sulphides. A clear-cut example of Pb re-mobilization occurs in one drill hole in which a late pegmatite assays 0.68% Pb over 42' whereas adjacent massive sulphides above and below assay 0.26% Pb over the nearest 36' and 0.37% Pb over the nearest 41' respectively. In this case, however, there is no apparent Cu-re-mobilation.

"The major sulphide minerals comprising the Izok Lake Central Zone are sphalerite, chalcopyrite, pyrite,and pyrrhotite. Minor to trace sulphides and sulphosalts include galena, and tetrahedrite. Other minerals of interest associated with these sulphides are minor magnetite and local minor gahnite, the zinc spinel. Sphalerite occurs in varieties ranging in colour from pale amber to black. The paler varieties usually occur where the sphalerite is adjacent to silicates and the dark varieties are commonly associated with pyrite. The colour presumably reflects the availability of iron during metamorphism. Gahnite, where present, is associated with sphalerite-silicate contacts. It is, of course, a characteristic mineral in metamorphosed zinc-bearing mineral deposits. Magnetite occurs associated with pyrite throughout the sulphides. We currently interpret it as a metamorphic breakdown product of pyrite.

"Small scale sulphide layering, generally of alternately pyrite-rich and sphalerite-rich layers, has been noted locally within the massive sulphides. However, such layering is neither abundant nor prominent and most of the sulphides occur as an essentially uniform aggregate over considerable thicknesses. The most readily apparent textural feature is the presence of pyrite porphyroblasts. These are particularly striking in sphalerite-rich ore. The porphyroblasts may reach two inches in diameter and quite commony are ¼" or more"

SPHALERITE-CHALCOPYRITE-PYRITE AT POINT LAKE

On the south shore of Point Lake a little over one mile northwest of Keskarrah Bay, disseminated sphalerite occurs with pyrite in a leached siliceous zone about 0.6 m. wide within a succession of greenschist, pillowed basic flows, and conglomerate of the Keskarrah Formation. The host rocks strike north-northwest and are approximately vertical. The sphalerite-bearing rock consists mostly of fine-grained silica (0.01 mm.) and small amounts of disseminated magnetite, carbonate, and chlorite. Fine-grained, dark brown sphalerite, which makes up about 5 per cent of the specimen collected, occurs with pyrite in semi-connected patches that form a crude foliation. This immediate area was examined in more detail by Henderson (1975) who discovered and reported several trace occurrences of sphalerite and one layer, one metre thick by at least 40 metres long, which contains massive sulfides (pyrite, sphalerite, and chalcopyrite) and chert. Nine representative grab samples reported on by Henderson (1975) averaged 9.62 per cent zinc, 1.10 per cent copper, 0.36 per cent lead, 1.21 oz. per ton silver, and trace (less than 0.010 oz. per ton) gold.

As a result of Henderson's (1975) report Noranda Mines Ltd. conducted a geophysical survey of the area and drilled three holes in the area of most favourable response. Two of the holes intersected narrow sulfide bands containing non-economic sulfide mineralization. The third hole drilled directly under the showing intersected 0.9 m (core length) of sulfides assaying 4.83 per cent zinc, 1.59 per cent copper, 0.2 per cent lead, 0.02 ounces per ton gold, and 1.05 ounces per ton silver (Precambrian Mining Services, pers. com. 1975).

CHALCOPYRITE EAST OF COPPERMINE RIVER

Chalcopyrite and pyrrhotite occur on the Point claims owned by Canadian Nickel Company on the east shore of Point Lake near the mouth of Coppermine River. The deposit is described by Baragar (1961) as follows:

"The claims are underlain largely by well-foliated, quartz-feldspar-biotite gneisses. Commonly the biotite content is about 20 per cent or less but some layers contain 50 to 60 per cent. Garnet is a common accessory mineral but is rarely abundant. The general strike of the foliation is from N 5° to 25°E and the dip is about 50°E, but in detail it is commonly ptygmatically folded. Several mineralized zones, marked by conspicuous gossans, occur within the gneisses -- chiefly on Point claims 3 and 5. The zones are roughly parallel with the foliation in the host rock. The mineralization is mainly finely disseminated pyrrhotite and chalcopyrite.

"The principal mineralized zone is on Point claim 5 about 1,500 (457 m.) to 2,500 (762 m.) feet south of the shore of Point Lake. It strikes about N 15° E and presumably dips 50°E in conformity with the foliation. The zone ranges in width from 20 (6 m.) to 60 (18 m.) feet and can be traced intermittently for 850 feet (259 m.) along its strike. At the south end the zone passes beneath overburden, but an outcrop 200 feet (61 m.) directly south of this point contains a weakly mineralized zone 6 (1.8 m.) to 8 (2.4 m.) feet wide that may represent its extension. Farther south only scattered mineralized lenses could be found along the strike of the zone. At its north end the zone disappears beneath a bog. Three hundred feet (91 m.) farther north in the direction of its projected strike, an outcrop of gneiss contains a mineralized belt with a similar trend. The belt is composed of patches of weakly mineralized rock up to 30 feet (9.1 m.)

wide and 30 (9.1 m.) or 40 (12.2 m.) feet long; these occur in succession for at least a few hundred feet northward. A parallel and similarly patchy zone of mineralized lenses is found about 300 feet (91 m.) to the west. Both of the latter zones are on Point claim 3.

"The main zone contains from 1 to 10 per cent sulphide minerals, finely disseminated in gneiss. The copper content ranges up to an estimated maximum of 3 per cent, and considerable parts of the zone will probably carry from 1 to 2 per cent. In the parts of the northern zones examined, the grade appears to be lower.

"A grab sample taken from the main zone about 730 feet (222 m.) from its south end gave the following assay:[1] gold, 0.005 ounce per ton; copper, 1.45 per cent."

The mineralized zone on the point claims lies near the contact between quartz-feldspar gneiss and lit-par-lit gneiss, a stratigraphic level that probably corresponds to the contact between Point Lake Formation and the greywacke-turbidite succession in less metamorphosed terranes. The quartz-feldspar gneiss is comparable to the massive and banded tuff units of the Point Lake Formation and contains at least one calc-silicate layer like calcareous rocks found in association with those units. Thus the complexly folded and migmatized inliers of quartz-feldspar gneiss near the east end of Point Lake, one of which includes he Point claims, likely represent antiformal culminations, basement promontories, or regions where the tuffs were thicker in the vicinity of felsic volcanic centres.

CHALCOPYRITE SOUTHWEST OF CONTWOYTO BATHOLITH

Disseminated pyrrhotite and pyrite with minor chalcopyrite occur in rocks of quartz monzonite to granodiorite composition at the southwest margin of the Contwoyto batholith where the contact with peripheral lit-par-lit gneiss and migmatite is gradational. These

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[1] W.R. Inman, Chief Chemist, Mines Branch, Ottawa.

plutonic rocks are red-stained over an area probably in excess of one square mile, but in most instances the rock is so weathered that the minerals responsible for the stain cannot be easily identified. Fine-grained, thinly disseminated pyrite and pyrrhotite were identified in several samples, and chalcopyrite in one. About five miles farther southwest, chalcopyrite with carbonate was found in a small vein cutting a minor body of greenstone exposed as felsenmeer within migmatite.

The classification of these chalcopyrite occurrences within the scheme used in this study is obscure, however their occurrence in highly deformed rocks of high metamorphic grade which occur at or near the base of the greywacke-turbidite succession suggests that the copper could have been remobilized from more deeply buried felsic volcanics like those east of Coppermine River. On the other hand, these traces of copper mineralization may be related to remnants of sulfide iron-formation which occur in the hybrid rocks, or to hydrothermal activity which accompanied emplacement of the Contwoyto batholith.

3) MINERALIZATION RELATED TO IRON-FORMATION AND LATE BASIC VOLCANISM

GOLD-SILVER-ARSENOPYRITE-LOELLINGITE

Studies of Archean iron-formation in other parts of the Canadian Shield have shown that gold is commonly concentrated in iron-formation, particularly in the sulfide facies (Goodwin, 1965; Ridler, 1970). This association is evident in the distribution of prospecting and development done in the Itchen Lake area which tends to follow outcrop of the Contwoyto Formation (see Fig. 54). In the present reconnaissance grab samples were selected for gold and silver analysis from each of the Archean lithologies exclusive of sulfide iron-formation (for distribution see Fig. 56) to see what distribution of these elements might obtain in rocks of this age in the Itchen Lake area. The analyses (see Table 20) were done by atomic absorption and those for gold occur mostly at the detection limit for this method. For this reason, and because of the very small amounts of gold involved, individual analyses are suspect, however comparison of groups of analyses representing the different rock units suggests that gold content is very low in the plutonic rocks but may be slightly higher in the supracrustal rocks, especially those of the Contwoyto Formation. Significant gold concentrations are shown to be present in smaples 100 and 309a representing respectively a graphite-bearing schist lens at the margin of an iron-formation band and a silicate iron-formation lens. There is also some suggestion that a low level of gold concentration exists in silicate and oxide facies iron-formation with respect to other lithologies within the map-area.

To the extent that gold appears to be concentrated in the Contwoyto Formation it is likely that even higher concentrations of this element are present in the sulfide iron-formation facies because gold, if present in the environment, commonly concentrates in sulfides, especially pyrite (Jones and Fleischer, 1969).

Figure 56

Table 20

Silicate-sulfide iron-formation lenses, in which gold is likely concentrated, occur within the lower part of the greywacke-turbidite succession along the convex margin of the greywacke-turbidite basin (see description of the Contwoyto and Itchen Formations). In the Contwoyto area Baragar and Hornbrook (1963), and Tremblay (1966) have suggested that gold is further concentrated where arsenic-bearing minerals are present within the sulfide facies iron-formation, and examination of trenches and drill sites elsewhere within the Contwoyto Formation suggests this association obtains generally throughout the map-area. It is difficult to test on a regional basis however because of the difficulty of obtaining unweathered samples during geological reconnaissance. For the same reason the distribution of arsenic minerals within the Contwoyto Formation is poorly known, but it is apparent that these minerals, and hence likely gold, are concentrated in sulfide facies iron-formation at widely scattered localities within the Contwoyto Formation.

Description of the Principal Gold-Arsenopyrite-Loellingite Occurrences

The Tree claims (see Fig. 54) of Giant Yellowknife Mines are located in rolling drift covered country between the arms of Point Lake. A few frost-heaved exposures of banded silicate-sulfide iron-formation are present within the knotted schists. Beds and foliation in the area strike northerly and dip 65 to 75 degrees to the east. Diamond drilling over a strike-length of about 1500 feet (450 m) indicates the presence of at least two silicate-sulfide iron-formation zones up to 0.3 m or more thick which contain arsenopyrite-loellingite-pyrrhotite mineralization. Surrounding pelitic schists contain cordierite and andalusite without sillimanite and therefore are of lower amphibolite facies metamorphic grade.

The Fuz claims (see Fig. 54) of Canadian Nickel Company are located in more rocky terrane about 7 miles southwest of Rockinghorse Lake immediately to the east of the Fuz metagabbro. One or more bands of silicate-sulfide iron-formation about 3 m thick outcrop intermittently on these claims over a strike-length of at least 800 feet (245 m) arsenopyrite-loellingite-pyrrhotite mineralization is exposed in three small trenches cross cutting the iron-formation. The country rocks are complexly folded lit-par-lit gneisses containing large masses of granodiorite. Mineral assemblages include sillimanite-muscovite indicating that the rocks reached middle amphibolite facies metamorphic grade. Further description of the deposit is given by Schiller and Hornbrook (1964).

The Main showing (see Fig. 54) of Canadian Nickel Company lies in drift covered, gently rolling country near the west shore of Contwoyto Lake, some 4 miles northwest of Fingers Lake. It consists of a stripped and cleaned area some 450 feet (140 m) long and about 100 feet (30 m) wide that follows the western limb of what appears to be a northward-plunging synform (see Fig. 57). The east limb of this structure which meets the west limb near the southern end of the cleared area, is exposed for about 200 feet (60 m) in a northeasterly direction.

Figure 57

The Main showing consists of a principal silicate-sulfide iron-formation layer containing arsenopyrite-loellingite-rich beds that ranges from 15 to 30 m thick (Baragar and Hornbrook, 1963). It occurs within a sequence of slates, greywackes and some lesser iron-formation layers of the Contwoyto Formation within the greenschist facies metamorphic zone but close to the amphibolite facies isograd which according to Tremblay (1966) lies a short distance to the north. Two isolated outcrops of sulfide-bearing iron-formation lies some 800 feet (245 m) to the south of the Main showing.

DESCRIPTION OF THE ORE MINERALS

Arsenic-bearing minerals, where present, are restricted to some layers or zones within the iron-formation. Within these layers or zones they are either finely disseminated or, more commonly, concentrated in patches up to 13 mm in length (see Fig. 58). More rarely they appear in patches independent of bedding or in cross cutting veins. Arsenical patches may be diamond shaped or anhedral and are mostly intergrowths of arsenic minerals with pyrrhotite. Patches are commonly elongate more or less parallel with layering in the host rocks, including some that occur in gash-like lenses, but discordant masses are known.

Figure 58

In detail, arsenic-rich patches consist of an intergrowth of pyrrhotite with arsenopyrite-loellingite. Arsenopyrite-loellingite consists of clusters of more or less euhedral arsenopyrite crystals containing corroded anhedral cores or remnant patches of loellingite distributed in symmetrical or asymmetrical arrays (see Fig. 58, 59 and 60). In pyrite-rich iron-formation from the Box claims the selvedge of arsenopyrite separating loellingite and pyrite is commonly only a few microns thick but in pyrrhotite-rich iron-formation most of the arsenopyrite rims about loellingite are thicker. Some apparent inclusions of pyrrhotite or silicate within loellingite, however, have only partial rims of arsenopyrite. Chalcopyrite, which is a minor constituent of all sulfide iron-formation lenses, appears to be slightly more abundant within patches than elsewhere. Grain size of pyrrhotite-arsenopyrite-loellingite within arsenical patches is somewhat greater than that of pyrrhotite in the surrounding sulfide-rich iron-formation (see Fig. 58).

Figures 58 and 60

Pyrrhotite both within and remote from arsenopyrite-loellingite patches commonly shows some evidence of late incipient alteration to pyrite. In some samples botryoidal pyrite has formed along fractures and grain boundaries which are outlined by pitted haloes in pyrrhotite (see Fig. 61); in still other samples no late pyrite is evident but short tiny cracks of subequal length penetrate surrounding pyrrhotite at right angles from grain boundraries and fractures.

Figure 61

Microscopic gold grains were observed in all but one of the samples of arsenopyrite-loellingite studied. Counts indicate that about 70 per cent of all observed gold grains are present at the boundaries between arsenopyrite and loellingite (see Fig. 62). As the grains at these boundaries are typically larger than those elsewhere, much more than 70 per cent of total visible gold is characterized by this distribution. Gold grains within loellingite (about 10 per cent of visible gold grains) generally resemble those at the grain boundaries but are usually smaller, and in some cases lie in fractures that terminate at the arsenopyrite-loellingite boundary. Gold grains in arsenopyrite (20 per cent of visible gold grains) are typically much smaller than those at arsenopyrite-loellingite boundaries (commonly 0.0002 mm^2 or less in section). In contrast to gold elsewhere the margins of gold grains in arsenopyrite commonly appear ragged. The very few gold grains observed at arsenopyrite-pyrrhotite boundaries were associated with small bodies of pyrrhotite apparently included in arsenopyrite. No gold was observed at other sulfide boundaries. Gold at intersilicate boundaries is prominent in one sample from the Fuz claims.

Figure 62

CHEMICAL INVESTIGATION OF METALLIC MINERALS

Trace elements

Attempts were made to obtain ground separates of the metallic minerals of the sulfide iron-formation in order to determine the partition of trace elements; gold, silver, nickel and cobalt. Pyrrhotite was found to be readily extractable by magnetic means. Loellingite and arsenopyrite however, are not sufficiently different either in specific gravity or in magnetic properties to permit a good separation. Flotation experiments to separate these two minerals were carried out by Mr. Art Page of the Metallic Minerals Research Laboratory of the Mines Branch. After scrubbing to remove the oxidized surface of grains previously subjected to attempts at gravity separation a partial separation was achieved. Under optimum conditions from a feed of 19.6 grams of 59 per cent arsenopyrite, a float of 3.8 grams of 78 per cent arsenopyrite and a non-float of 7.9 grams of 50 per cent arsenopyrite were obtained (Page, 1968). Spectrographic analyses gave the results shown in Table 21. The analyses are consistent with microscopic observations that gold and silver are concentrated in arsenopyrite with respect to loellingite (although the greater part of these elements are at the arsenopyrite-loellingite grain boundaries). They further suggest that nickel, and at lower levels cobalt, may be concentrated in loellingite with respect to arsenopyrite in some samples.

Table 21

Electron probe analyses of one sample each from the Fuz claims, from the Main showing, and from the Tree claims were made for nickel (see table 22). Although the sensitivity of the method of analysis is low it is evident that nickel is concentrated in loellingite in these samples. The analyses further suggest that additional samples might be examined to determine whether high nickel values characterize the Fuz claims. Cobalt concentrations are too low (less than 1000 ppm) for detection by the electron probe.

Table 22

Electron probe analyses for gold and silver were made on microscopic gold from each of three samples from the Fuz claims and from the main showing (see Table 23). Grains were analysed by making a line scan at one micron per second across individual grains with averages calculated at ten second intervals. Standard deviation for gold measurements on individual grains was found to be 1.2 per cent for gold and 0.8 per cent for silver. No evidence of zoning within gold grains was found, and significant between-grain variation within single samples was not detected although only the largest grains were examined. The results fail to demonstrate any difference in gold-silver ratio in gold grains between deposits but suggest that significant within-deposit variations may exist. The mean percentage of silver in gold from the Itchen Lake area calculated from these data is 14.

Table 23

Sulfur in Arsenopyrite and Pyrrhotite

The principal mineral of sulfide iron-formation in the Itchen Lake area is pyrrhotite but in places where metamorphic grade is low (Box claims) pyrite is predominant. This suggests that much or all of the sulfide facies may have been originally pyrite-rich but has lost sulfur during metamorphism. It is thus of interest to examine the relative sulfur contents of pyrrhotite at progressively higher metamorphic grades to see whether there is evidence of continued sulfur loss. To this end the proportions of monoclinic (Fe_7S_8) and of hexagonal (Fe_9S_{10}) pyrrhotite were estimated in 37 samples representative of the three main deposits by the x-ray method of Arnold (1967). The data are shown in Table 24 and are illustrated in Figure 63. At the same time relative sulfur contents of 17 arsenopyrites were estimated from d spacings using the method of Morimoto and Clark (1961), (see Table 25).

Figure 63

Tables 24 & 25

Pyrrhotite is clearly predominantly hexagonal in the Fuz claims and therefore sulfur poor. In the Main showing the pyrrhotite type distribution appears to be bimodal with the hexagonal (sulfur poor) type predominant in samples from near the nose of a fold structure, (see Figures 63 and 64), and the monoclinic type predominant on the limbs. The Tree claims show a pyrrhotite type distribution similar to that on the limbs of the fold structure at the Main showing if two samples rich in hexagonal pyrrhotite, both from the southern extremity of the deposit, are excluded. Too little is known of the detailed geology of the Tree claims to suggest a structural or metamorphic basis for setting aside the latter two samples.

Figure 64

The distribution of sulfur in arsenopyrite shows a pattern that resembles that of sulfur in pyrrhotite but is less well defined possibly because fewer samples were examined. Arsenopyrite from the Main showing appears to be relatively higher in sulfur than that from the Fuz claims. Sulfur content of arsenopyrite from the Tree claims is not distinctive if the low sulfur sample from the southern extremity is excluded (analogous to the sulfur-low pyrrhotite samples from the same location). Arsenopyrite from the nose of the fold structure at the Main showing may be sulfur-low relative to that on the limbs but more samples would be needed to confirm this.

The foregoing data indicate that, although the pyrrhotite in the Fuz claims characterized by high metamorphic grade has the lowest sulfur content, the loss of sulfur is probably reflecting more than the increase in metamorphic grade alone. The apparent deficiency of sulfur in pyrrhotite from the fold nose at the Main showing may reflect a greater structural dilatancy and hence a greater facility for sulfur loss during metamorphism in rocks in the vicinity of the nose. A similar argument can be applied to the Fuz claims where the rocks are highly deformed, and to the Tree claims which, though of intermediate metamorphic grade, are not so highly deformed and have a high proportion of sulfur-rich pyrrhotite.

Arsenopyrite/loellingite ratios

Arsenopyrite/Loellingite ratios were determined in conjunction with investigation of gold distribution by point count on polished sections etched with ferric chloride to accentuate arsenopyrite-loellingite grain boundaries. The data (Table 26) in a general way match the sulfur distribution in pyrrhotite and arsenopyrite. High proportions of loellingite were found in samples from the Fuz claims where metamorphic grade is high, deformation is severe, and sulfur is depleted in pyrrhotite and possibly in arsenopyrite as well (see Fig. 59). High proportions of arsenopyrite relative to loellingite (see Fig. 60) occur most commonly where sulfur in pyrrhotite and arsenopyrite tends to be high and metamorphic grade is low. Anomalous high concentrations of loellingite with respect to arsenopyrite were found locally near the crest of the fold structure at the Main showing, and in the sample from the Box claims. The latter sample is from the central part of the greenschist facies zone where iron-formation is pyritic (pyrite has not been altered to pyrrhotite). The loellingite there occurs as scattered crystal aggregates with thin arsenopyrite haloes within pyrite-rich beds.

The ubiquitous haloes of arsenopyrite about loellingite suggest that arsenopyrite formed as a result of reaction between loellingite and sulfur mobilized from pyrite and pyrrhotite during metamorphism. The distribution of arsenopyrite-loellingite ratios, like that of pyrrhotite types, probably reflects a combination of metamorphism necessary to mobilize sulfur and deformation necessary to disrupt the armouring effect of early formed arsenopyrite haloes about loellingite.

Table 26

DISCUSSION

The stratigraphic relations of oxide, silicate and sulfide facies iron-formation lenses in the Itchen Lake area relates these lenses to the terminal phase of Point Lake volcanism, possibly to volcanic activity associated with the Keskarrah Formation conglomerates. This scenario is very similar to that described by Goodwin (1973) based mainly on volcanic associations in the Superior Province. There also gold has been concentrated primarily in the sulfide facies of iron-formation deposited in the deeper parts of sedimentary basins that were receiving coarse volcanic conglomerates near their margins. Unlike the auriferous iron-formations of the Superior Province, those in the Itchen Lake area were accompanied by deposition of abnormally high concentrations of arsenic minerals.

Arsenic minerals within the Itchen Lake map-area, so far as is known, are present only within and associated with lenses of silicate-sulfide iron-formation. In this association they apparently occur in restricted areas at widely scattered localities stretching from Point Lake around the periphery of the greywacke-turbidite basin to the east margin of the map-area. This distribution suggests two possibilities; either the envir ent of sulfide facies iron-formation deposition was favourable ecipitation of arsenic minerals, or the already deposited fo formation beds provided a favourable host for replacement by arsenic erals. These alternatives differ significantly in that syngenetic ecipitation of arsenic could have occurred near the upper interface of he sulfide depositing environment thus allowing arsenic minerals to settle into the sediment in concentrated, perhaps flocculated, rather than in dispersed form. Epigenetic replacement by arsenic-bearing minerals on the other hand would have to have taken place in intimate contact with the finely disseminated iron sulfide-rich host.

Figure 65

Study of the Fe-As-S system (Clark, 1960) has shown that pyrite-loellingite-bearing mineral assemblages do not form under equilibrium conditions in the laboratory, the stability field of these minerals being separated by those of arsenopyrite and/or pyrrhotite (for example see Fig. 65). Moreover, the rarity of coexistence of this pair in natural ores further suggests that special conditions are required to achieve their association. On the Box claims at Contwoyto Lake, the presence of loellingite patches scattered through iron-formation beds consisting of abundant finely divided pyrite in a silicate host is therefore of particular interest. In this occurrence loellingite patches are everywhere surrounded by very thin arsenopyrite rims, but pyrite is not armoured in a similar way. The activity of mobile arsenic in the vicinity of pyrite grains was therefore at no time, even during greenschist facies metamorphism, great enough to produce arsenopyrite haloes. This suggests that loellingite was not deposited after pyrite as an epigenetic phase. Because pyrite is part of the sulfide iron-formation facies it therefore seems likely that the loellingite was also syngenetic.

Metamorphism of sulfide facies iron-formation took place under conditions of low pressure, probably not more than 5 kb. Pressures during metamorphism in the southern part of the map-area were probably less than this as indicated by formation of hypersthene and andalusite-microcline-cordierite-bearing assemblages; however in the northern part of the map-area the predominance of sillimanite-muscovite in the highest grade pelitic rocks may indicate relatively higher pressures or somewhat lower temperatures. Metamorphism under conditions of relatively low confining pressure suggests enhanced structural dilatancy and ability of volatile phases to migrate toward the surface. Thus, except in some rocks of low metamorphic grade, sulfur evolved from sulfides in iron-formation during metamorphism was in part able to leave the system, and pyrite, which may originally have been the predominant sulfide, was converted to pyrrhotite. Investigation of the frequency of pyrrhotite types has suggested that the proportion of the sulfur-low hexagonal type tends to be high in those metamorphic rocks in which dilatancy due to deformation is enhanced. Preservation of this distribution suggests that reinversion during retrogression was not possible because of the loss of earlier evolved sulfur. Retention of some mobile sulfur through the metamorphic maximum and into the period of retrogression is perhaps suggested by local replacement of pyrrhotite by pyrite along grain boundaries, and fractures within, pyrrhotite.

The data of Clark (1960) indicate that the invariant point ($702 \pm 3^\circ$ C) at which arsenopyrite breaks down to form pyrrhotite, loellingite and liquid may be reached at highest metamorphic grade. This temperature is consistent with development of sillimanite-muscovite-bearing lit-par-lit gneiss at pressures of about 5 kb (Winkler, 1967). Thus low arsenopyrite to loellingite ratios observed at the Fuz claims may reflect breakdown of arsenopyrite at its invariant point. Other explanations however must be found for apparently anomalous low ratios that occur locally in the nose of the fold structure on the main showing.

Gold occurs at low concentrations in the Contwoyto Formation and is probably further concentrated in the sulfide iron-formation lenses which it contains. Unusually high gold concentrations appear to be confined to those iron-formation lenses in which arsenic is also concentrate Because high concentrations of gold appear to be related to the presence of arsenic minerals it is perhaps possible that these acted as a sink for gold during metamorphism. High gold concentrations with similar gold-silver ratios (see table 22) occur however, in rocks of widely differing metamorphic grades. To the extent that metamorphic migration of precious metals would have to have taken place in a medium in which sulfur fugacity varied with metamorphic grade, and because the chalcophile tendencies of gold and silver differ, it seems unlikely that this process would have produced similar gold-silver ratios. In view of the probable syngenetic origin of other elements in the deposits of the Itchen Lake map-area a syngenetic origin of gold as well seems most likely.

On the basis of the above discussion the writer favours the view that gold and arsenic in the Itchen Lake map-area were concentrated syngenetically and locally as a result of superposition of a distinctive local environment upon regions of the greywacke-turbidite basin that were already favourable to sulfide facies iron-formation deposition. These distinctive conditions probably involved local introduction of gold-bearing, arsenic-rich solutions rather than concentration from sea water because the deposits represent exceptionally high concentrations of arsenic in comparison to some other metamorphosed Archean sulfide facies iron-formation where arsenic-rich minerals like loellingite are rare. Such solutions may have come from local hot springs.

Precipitation of arsenic is considered to have occurred from waters above the sedimentary interface so that iron-arsenic-rich centres, possibly the result of flocculation, were introduced into the sulfide-rich iron-formation sediment. During metamorphism these centres were converted to loellingite patches that reacted externally with sulfur-bearing vapor derived from the breakdown of pyrite and inversion of pyrrhotite to form arsenopyrite. Such arsenopyrite haloes tended to protect loellingite from further alteration. Where metamorphism was accompanied by deformation penetrative disruption of patches likely enhanced the formation of arsenopyrite haloes about loellingite. Where structural dilation occurred escape of sulfur-bearing vapor from the system was facilitated thus retarding the alteration of loellingite to arsenopyrite. Gold entrapped in the initial arsenic-rich precipitate was expelled to the arsenopyrite-loellingite boundaries. At the highest metamorphic grade attained by these deposits temperatures may have reached the invariant point (702 ± 3° C, Clark, 1960) at which arsenopyrite breaks down to form pyrrhotite, loellingite and liquid. The appearance of gold grains at intersilicate boundaries within some samples from the most severely metamorphosed deposit (Fuz claims) may indicate that break down of arsenopyrite resulted in enhanced mobility and loss of gold from arsenopyrite, and perhaps from the system as a whole.

MAGNETITE

Oxide facies iron-formation is most abundant within the Contwoyto Formation between Itchen Lake and Point Lake. In places iron-formation consisting largely of magnetite-rich laminae but including a variable proportion of quartz-rich and amphibole-rich interlayers, reaches some 500 feet (150 m) in width having presumably been repeated by folding. Semi-quantitative determination of iron (as Fe_2O_3 total) indicates that the magnetite-rich bands commonly attain roughly 45 per cent Fe_2O_3 by weight.

NICCOLITE-PYRRHOTITE

Trace amounts of nickel are present locally in loellingite in sulfide iron-formation lenses within the Contwoyto Formation (see Table 21) but nickel is not sufficiently abundant to be economically significant. Nickel is concentrated in niccolite (NiAs) along the contact of a gabbro body about 110 feet (33 m) across northeast of Itchen Lake. The contact zone, which is sheared, is exposed in four trenches along the southwest side of the gabbro. Foliation in the adjacent greywacke strikes northeast and dips from 75 degrees southeast to vertical. Niccolite, pyrrhotite, and minor chalcopyrite, found along the contact and as films and fracture fillings, extend a metre or so into the surrounding greywacke. Silicate-sulfide facies iron-formation is exposed about 300 feet (90 m) south of the gabbro and similar rocks may well occur along the contacts of the gabbro at depth. These rocks, known to contain arsenic and nickel elsewhere, provide a likely source from which these elements may have been remobilized.

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