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GEOLOGY OF THE ITCHEN LAKE AREA, DISTRICT OF MACKENZIE

H.H. Bostock

Energy, Mines and
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ERRATUM

Map 1473A - Geology, Itchen Lake area, District of Mackenzie to accompany GSC Memoir 391 by H.H. Bostock.

Please note that the symbols identifying the upper limit of greenschist facies and the upper limit of lower amphibolite facies were inadvertently reversed on the map legend. A corrected version of these entries is provided below for insertion in the map legend.

Mineral isograds:

Approximate upper limit of greenschist facies
(first appearence of cordierite) .... —■— —■— —■—

Approximate upper limit of lower amphibolite facies
(first appearence of sillimanite) .... —▲— —▲— —▲—

DEPARTMENT OF ENERGY, MINES AND RESOURCES
MINISTÈRE DE L'ÉNERGIE, DES MINES ET DES RESSOURCES

GEOLOGICAL SURVEY
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Preface

Interest in the mineral potential of this part of Slave Province of the Canadian Shield began with the staking of chalcopyrite showings in 1957. The discovery of gold near Contwoyto Lake led to a staking rush in 1962 but by 1966 interest had largely subsided. Interest in the area revived in 1975 with the discovery of a major base metal deposit near Itchen Lake.

The introduction in 1952 of helicopter support to the Geological Survey's reconnaissance mapping program resulted in a greatly accelerated rate of mapping. Itchen Lake area was covered during Operation Coppermine (1959) and Operation Bathurst Inlet (1962). These studies provided the first regional outline of Archean volcano-sedimentary belts and granitic areas and Aphebian supracrustal rocks.

In view of the importance of the area to understanding the complex history of this part of the Canadian Shield more detailed studies were undertaken. Dr. Bostock investigated the 4300-square mile Itchen Lake map sheet and at the same time Dr. L.P. Tremblay carried out mapping at the scale of one inch to one mile of the Contwoyto Lake region. The results of that study were published as Memoir 381.

The results presented in the present report will be of value to those concerned with the study of Precambrian geology because of the detailed manner in which the author describes the stratigraphy, structural and metamorphic history and economic geology of this interesting part of the Canadian Shield.

D.J. McLaren
Director-General
Geological Survey of Canada

Ottawa, March 1977

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GEOLOGY OF THE ITCHEN LAKE AREA, DISTRICT OF MACKENZIE

Abstract

A geological reconnaissance of 4300 sq mi of the Bear-Slave Upland was carried out in 1964–65–66.

The 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 consists of iron-formation–bearing greywacke-turbidites (Contwoyto Formation) and coarse conglomerates (Keskarrah Formation). The latest phase (Itchen Formation) consists of greywacke-turbidites alone.

With early Kenoran plutonism (minimum age 2642 m.y.), which affected rocks of the Point Lake Formation, a mylonite zone developed and minor ultramafic bodies were emplaced along the west margin of the area. Later gabbroic to granitic plutonism (minimum age 2500 m.y.) affected the greywacke-turbidites and was accompanied by metamorphism reaching the 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 area. Northwest trending dykes of the Mackenzie swarm (1200 m.y.) are concentrated in two zones some 35 mi apart along the east margin and through the central part of the area.

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

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

Résumé

Une reconnaissance géologique a été effectuée en 1964, 1965, et 1966 de 4300 milles carrés des hautes-terres de Bear-Slave.

Le sous-sol de cette région est principalement composé de roches archéennes du supergroupe de Yellowknife, que l'on peut subdiviser en trois phases qui se recouvrent l'une l'autre. La phase la plus ancienne (formation de Point Lake) consiste en roches volcaniques de caractère calco-alcalin felsique à tholéiitique mafique, et en coulées tardives locales de mugéarite. La phase intermédiaire comprend d'une part des turbidites à grauwacke qui contiennent des couches ferrifères (formation de Contwoyto), d'autre part des conglomérats grossiers (formation de Keskarrah). La phase la plus récente (formation de Itchen) est seulement composée de turbidites à grauwacke.

Avec le plutonisme ancien d'âge Kénoranien inférieur (daté à au moins 2 642 millions d'années), qui a affecté les roches de la formation de Point Lake, une zone mylonitique s'est formée, et des corps ultramafiques peu étendus se sont mis en place, le long de la marge ouest de cette région. Un plutonisme ultérieur de nature gabbroïque à granitique (daté à au moins 2 500 millions d'années) a affecté les turbidites à grauwacke, et a été accompagné d'un métamorphisme assez élevé pour créer le subfaciès à sillimanite-cordiérite-orthoclase-almandine. Les angles optiques de la cordiérite engendrée par ce métamorphisme, augmentent à mesure que le degré métamorphique s'élève.

Les argilites et quartzites d'âge aphébien supérieur déposés dans le géosynclinal Coronation se prolongent dans cette région à partir de l'ouest (groupe d'Epworth) et de l'est (groupe de Goulburn), le long de la marge nord de celle-ci. Un lambeau du groupe de Goulburn est préservé dans une portion de graben associée à la mise en place de sills de diabase.

Des dykes de diabase porphyrique d'orientation ouest nord-ouest présentent une corrélation avec des écoulements similaires préservés localement à l'intérieur du groupe d'Epworth, à l'ouest de la région étudiée. Les dykes du complexe (de dykes) du Mackenzie, d'orientation nord-ouest (âge 1 200 millions d'années) sont concentrés dans deux zones distantes d'environ 35 milles l'une de l'autre, le long de la marge est et dans la partie centrale de la région.

Les principaux gisements métallifères rencontrés sont des traces de Fe et Cu dans les roches volcaniques anciennes de caractère mafique, des traces de Fe, Zn et Cu dans les roches volcaniques felsiques, puis des formations ferrifères riches en oxydes, silicates, et sulfures, et des gisements syngénétiques locaux d'or arsenical, associés au volcanisme mafique tardif.

L'examen de la pyrrhotite dans la formation ferrifère à pyrites indique que de la pyrrhotite hexagonale (pauvre en soufre) prédomine dans le gisement de degré métamorphique le plus élevé, et qu'elle s'est probablement concentrée le long des axes de plissement aux degrés métamorphiques moins élevés.

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Introduction

Location and access

Itchen Lake map area lies between 65°00′ and 66°00′ north, and 111°00′ and 113°18′ west; the north, south and east boundaries follow lines of latitude and longitude, and the west boundary is 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 as numerous lakes of size and depth sufficient for landing such aircraft are 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 is difficult and beset by many portages. The Coppermine and Burnside rivers, which flow northward from Point and Contwoyto lakes, respectively, are navigable only by canoe. A few trees are seen locally about Point Lake but the remainder of the area is barren and 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 Inuit. Except for a manned radio beacon on an island in Contwoyto Lake immediately east of the area, there are no permanent settlements.

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, 1795). 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, 1836). "Coghead" Lake of Hearne corresponds to Contwoyto Lake (ibid.).

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 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 the season was too far advanced for them to go farther. 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. From Contwoyto Lake the party wandered southward, greatly weakened by shortage of food and fuel and losing their way in the bad September weather. Great difficulty was experienced in crossing the Coppermine River southwest 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, as Rae did between 1844 and 1855 (Rich, 1953), or via Back River to Chantrey Inlet (Back, 1836; Anderson, 1940, 1941). Various later travellers such as Warburton Pike (Pike, 1917) visited the Lac de Gras area, and some apparently reached the southeast corner of the map area during hunting expeditions with the Indians.

The first geological observations were made by C.H. Stockwell (1933), who reached Point Lake by way of Yellowknife River from Great Slave Lake and returned through 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 that he believed to overlie an older chlorite granite. These rocks were 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 diabase dykes.

The west half of the map area was mapped during Operation Coppermine 1959 (Fraser, 1960) and the east half during Operation Bathurst Inlet 1962 (Fraser, 1964). These 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 Limited in 1959. Gold was discovered in Archean metasedimentary rocks near the northwest end of Contwoyto Lake in 1961 by the Canadian Nickel Company. The large area involved in the initial staking for gold led 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 revived in 1975 when Texasgulf Inc. discovered a major base metal deposit near Itchen Lake.

Present work

Mapping in the Itchen Lake area at a scale of 4 miles to 1 inch 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. I have not investigated this subarea (south to latitude 65°30′ north, and west to longitude 111°30′ west) but have modified Tremblay's map units to be compatible with the more generalized units adopted in this report. The reconnaissance mapping 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 filming of scenes showing geological field work in the barrens, to form part of a documentary film *The Continuing Past* prepared for the Geological Survey by the National Film Board to illustrate 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 1229 feet (375 m) above sea level at Point Lake in the southwestern part of the area to somewhat over 2100 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 undulating but relief is more abrupt in the northern and northwestern parts and along the basic volcanic belts.

The principal rivers are the Coppermine and Burnside, which flow through and drain Point and Contwoyto lakes, respectively. The southern two thirds of the area drains 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 rest of the area is drained by way of Contwoyto Lake and 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 requires five portages between Point and Itchen lakes; the latter can be navigated at high water by canoe without portage as far as the first lake system.

The climate for the three summer months is typically pleasant. Time lost due to rain or fog averaged four days per season. Flies may be a nuisance from mid-July to mid-August but in some years they last only a week or two. Ice is usually suitable for ski landings by Otter or smaller aircraft 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 breakup is roughly three weeks later but varies considerably from year to year. 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 before 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 Geographical Names. Some, however, have been formally adopted. These include Concession, Fingers, Esker, Bar, Post, Wishbone, Fly and Gossan lakes, and Shallow Bay. 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 following list and in Figure 2.

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 batholith 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 (29 km) northeast of the east end of Point Lake.

Western pluton: The basic pluton 7 miles (11 km) west of Rockinghorse Lake in the northwest part of the map area.

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

Fuz pluton: The small basic pluton 8 miles (13 km) 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.

Central volcanic belt: A belt of acid and basic volcanic rocks that stretches from a point about 4 miles (6.4 km) southeast of Itchen Lake along a sinuous path to the east margin of the map area some 16 miles (25 km) south of Contwoyto Lake.

Pleistocene geology

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

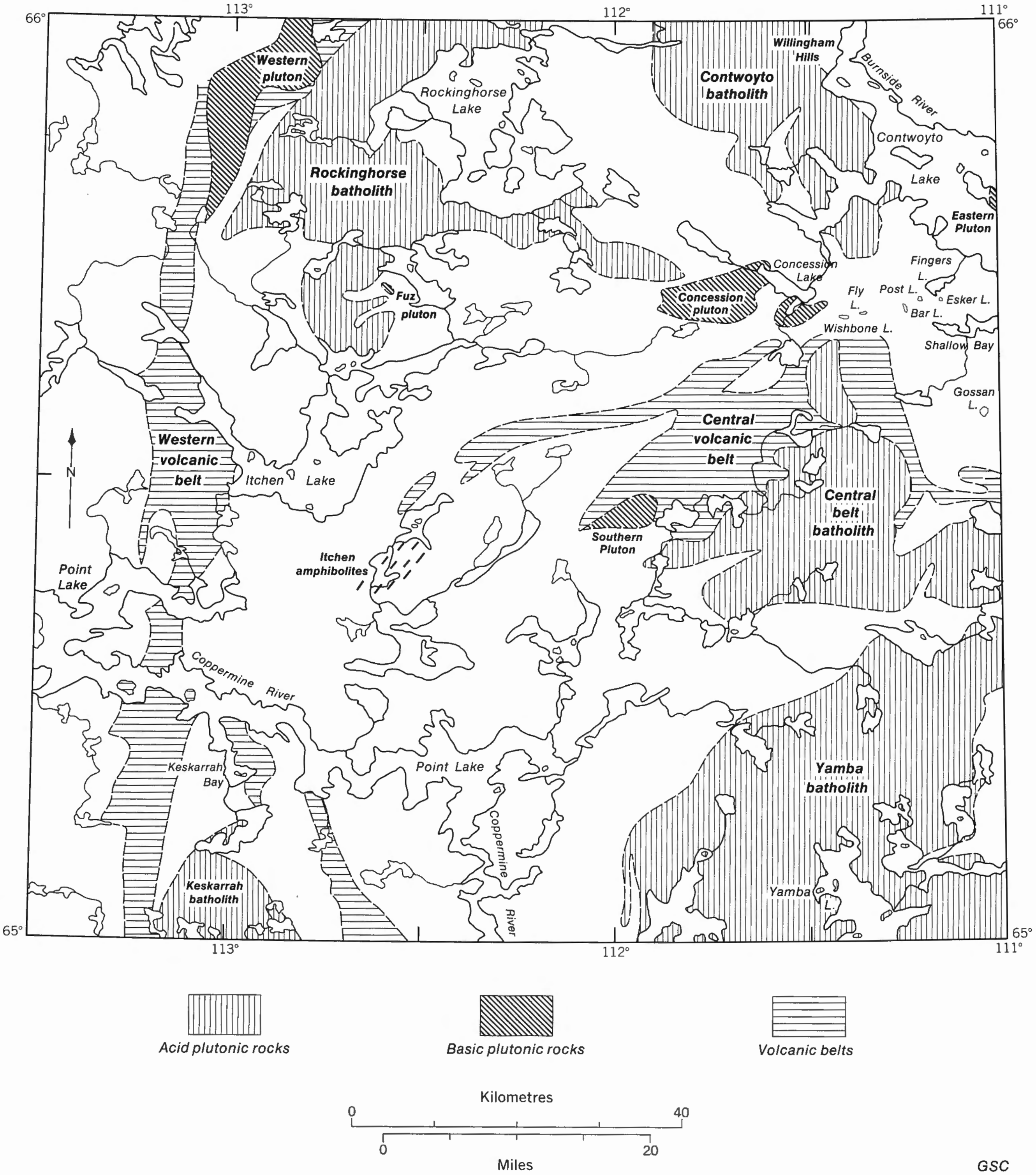

Figure 2. Location of topographic features, volcanic belts, and plutons in the Itchen Lake area.

The oldest ice flow recorded by glacial striae (Fig. 63, in pocket) 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) observed a few erratics of Goulburn rocks south of the present Goulburn Group and suggested 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 the 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 that took place during the ice retreat and that were perhaps influenced in part by the Point Lake topographic depression.

Eskers are also prominent. Composed mainly of sand, they are the most common glacial feature in the western part of the map area and typically follow the trend of late striae. Abandoned shorelines are well developed about 100 feet (30 m) above the present level of Contwoyto Lake (Blake, 1963). Similar shorelines 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 25 feet (7.5 m) or more thick forms an island in the northern part of Contwoyto Lake (Fig. 3). Although the shores of the island are badly slumped in places, the upper part is seen to be 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 (Fig. 4) but in no place were exposures more than 4 or 5 feet thick.

Drift cover 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 mainly gentle drift-mantled, grassy slopes between (Fig. 63, in pocket). 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 debris to collect by drainage more efficiently within the ice over the belt of outcrop than elsewhere.

Acknowledgments

The writer was ably assisted in the field by Gerhard von Rosen (1964) and Brian Charboneau (1965) in their capacities as senior traverse assistants. Brian Mottershead and Richard Holmes (1964), Edward Reeves and Desmond Dufour (1965), and William Tuer and Stanley Hoffman (1966) provided capable assistance as junior assistants.

Flotation experiments were made by Art Page of the Mines Branch (now Canada Centre of Mineral and Energy Technology), Department of Energy, Mines and Resources.

Figure 3 (top). Rudely bedded sand and sandy organic matter on an island near the north end of Contwoyto Lake. GSC 121079.

Figure 4 (bottom). Surficial peat deposits up to 4 or 5 feet thick occupy the floors of gently sloping valleys in rolling terrain. GSC 114528.

General geology

The Slave Structural Province, which includes all but the Proterozoic cover in the northwest corner of Itchen Lake map area, constitutes an area of almost 75 000 square miles (194 000 km^2) underlain predominantly by rocks of Archean age. Somewhat more than one third of these are granites of batholithic 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 equidimensional area in the northeastern part of the province. The granitic rocks separating these areas are mostly massive in the northern and eastern parts of the province but in the west and south they are more widely foliated, and each part has small areas, commonly more altered than the rest, in which some evidence indicates an age greater than that of the neighbouring stratified rocks (McGlynn and Henderson, 1972; McGlynn and Fraser, 1972). The Itchen Lake map area lies athwart the central belt of stratified rocks in the central part of 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 map area consist of two partly contemporaneous volcanic and sedimentary subdivisions similar to Archean successions in other parts of Slave Province and are thus part of the provincewide Yellowknife Supergroup as defined by Henderson (1970). The volcanic rocks of Itchen Lake area can be further broken down into felsic calc-alkaline tuffs and flows at least in part followed by mafic, subalkaline 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, sulphide 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.

Archean granitic plutonism began early, 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 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 and 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 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) from 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.

Kenoran syntectonic granitic plutonism later was profound throughout extensive regions of Slave Province, producing aureoles of amphibolite facies, low-pressure metamorphism, where the Archean basins were invaded. Late tectonic, crosscutting granites accompanied by pegmatites followed locally. In Itchen Lake area metamorphic aureoles about the late Kenoran (Rb/Sr isochron age 2422 ± 95 m.y.) 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 that form part of the basement might be expected. Indeed, there is some reason to believe that late Kenoran syntectonic plutons throughout Slave Province tended to be emplaced outside or along the margins of the Archean basins (McGlynn and Henderson, 1972) 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 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 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 and with a wide variety of trends, have been described within Slave Province. These reflect periods of crustal distension and in many cases were accompanied by basic volcanism, the products of which are still preserved at 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.

Until very recently metalliferous deposits of the Slave Province have not been prospected in any detail except in the southern regions around 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, extensive in the Itchen Lake area and also perhaps farther north and east, is not as well developed in the southern part of the province. This variance in abundance of iron-formation may parallel 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 Slave Province.

Yellowknife Supergroup

Point Lake Formation

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, 1951) 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. Since a large part of the volcanic section is well exposed 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: the Western volcanic belt extends north-south along the west margin of the map area and bifurcates south of Point Lake; 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 lithological types. Rather, areas illustrating each of the lithological types will be referred to during the descriptions of each of the map subunits.

The maximum thickness of the Point Lake Formation probably exceeds 10 000 feet (3000 m). A section this thick 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 partly bedded and clearly waterlain but most 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:

Massive felsic tuffs, some felsic flows
Felsic flows with variable proportions of tuffs and mafic flows
Calcareous metasediments
Banded felsic to mafic tuffs, some amphibolite, some calcareous metasediments
Mafic tuffs, amphibolite, some pillowed flows in the Central volcanic belt
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 (Anc*), which are mostly associated with banded felsic to mafic tuffs, may occur at various locations within the tuffs. Nevertheless, available evidence 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 the proportion of mafic rocks appears to increase toward the top. In the eastern part of the map area tuffaceous rocks are 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 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 that comprise its lower part are granitized, faulted against, or intruded by granitic 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.

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*Due to typesetting problems the specialized geological symbols used on Map 1473A cannot be easily reproduced in this text; whenever these symbols are essential to clarify the text the approximation using standard type is used.

Table of formations

Eon	Era	Group	Formation	Lithology				Thickness		Radiometric age
								metres (feet)		(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	Epworth Group		Goulburn Group					between 2000 and 1750†
			Formation	Lithology	Formation	Member	Lithology	*	**	
			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	793 (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 grey 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		1 ± (2 ±)	

				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	450± (1500±)	
			Keskarrah	conglomerate; some subgreywacke, greenschist		
			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 (e) mafic tuffs, amphibolite; some pillowed flows (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	2130±(7000±) 260±(850±)	
	?		?	? Unconformity ? ?		
				Possible remnants of older Archean basement within hybrid and plutonic rocks especially at Keskarrah Bay		

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* Thickness estimates from Fraser (1974) for the Epworth Group at the east edge of the Epworth basin.

** Thickness estimates from Tremblay (1967) and for the Lower Argillite member from this report.

† Age estimate for rocks of the Coronation Geosyncline (Hoffman et al., 1970).

Figure 5. Folded banding in massive felsic tuff on the west margin of the Central belt batholith. GSC 114521.

Massive felsic tuffs

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 that are distinctly coarser than their granular, locally sericitic, quartzofeldspathic 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 often it has a slight wispy foliation expressed by thin lenticular concentrations of mafic minerals. Banding is rare in the lower beds but increases in higher parts of the formation that contain a greater proportion of mafic minerals. Lenticular banding, 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 foldlike structure visible in the photograph 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.

The lower contacts of the felsic tuffs, wherever they have been traversed, are indefinite boundaries between fine-grained massive tuffs and granitic plutonic rocks. Here and there in the Central volcanic belt outcrops of felsic tuff are interspersed with outcrops of medium-grained granitic rock. 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 as small as an inch or two in diameter

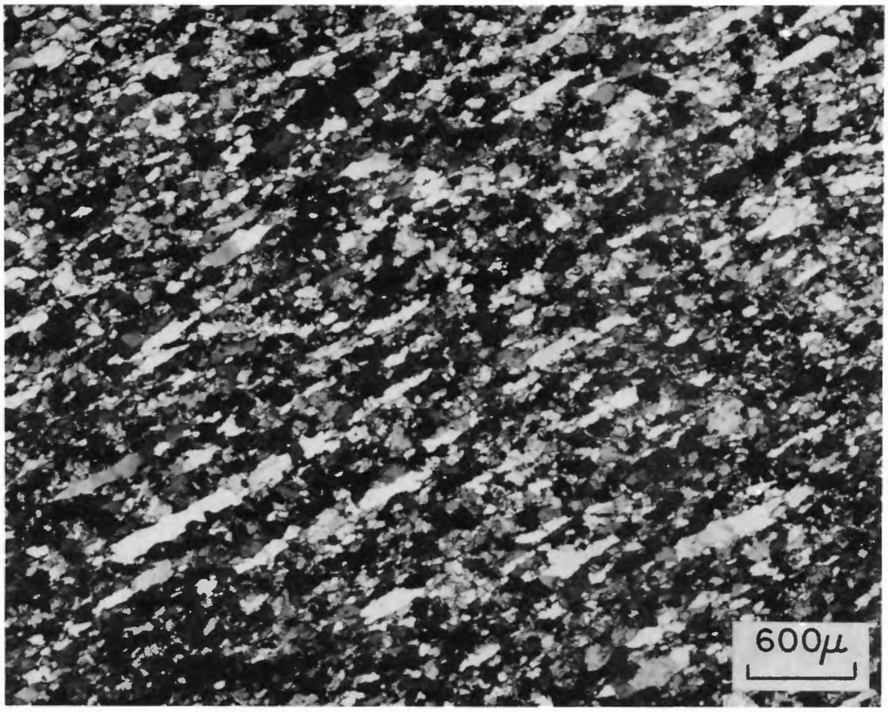


Figure 6. Quartz lenticles in mylonite possibly derived from felsic tuff along the west margin of the Western volcanic belt. GSC 202163-L.

of medium-grained rock 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 the 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 but elsewhere it is present as porphyroblasts or in wisps (Fig. 7b). Accessory minerals are magnetite-ilmenite, apatite, iron sulphide, 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 (Fig. 6). In places granitic bands parallel foliation but are themselves unfoliated.

Felsic flows with variable proportion of tuffs and mafic flows

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, more obviously porphyritic rocks thought to be felsic flows, and are interlayered in places 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 up to 3 mm in diameter are typical 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 proportion of phenocrysts of quartz and albite to calcic oligoclase (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 (Fig. 7D). Some show re-entrants along their margins suggesting magmatic corrosion. In a few thin sections of felsic volcanics from 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 (Fig. 35 of felsite from hybrid rocks). Plagioclase phenocrysts are commonly slightly rounded but may be sharply euhedral (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 wispy lenses. Small amounts of epidote, chlorite and carbonate are present locally. Accessory minerals are magnetite-ilmenite, tourmaline, apatite, sphene and zircon.

Calcareous metasediments

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 (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; they are recognizable by their pitted surface and the presence of garnets or other calc-silicates.

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 sulphide. 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

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. Farther west they are interleaved with felsic to mafic flows. Similar rocks, downfolded within the Central belt batholith, have been more highly deformed and recrystal-

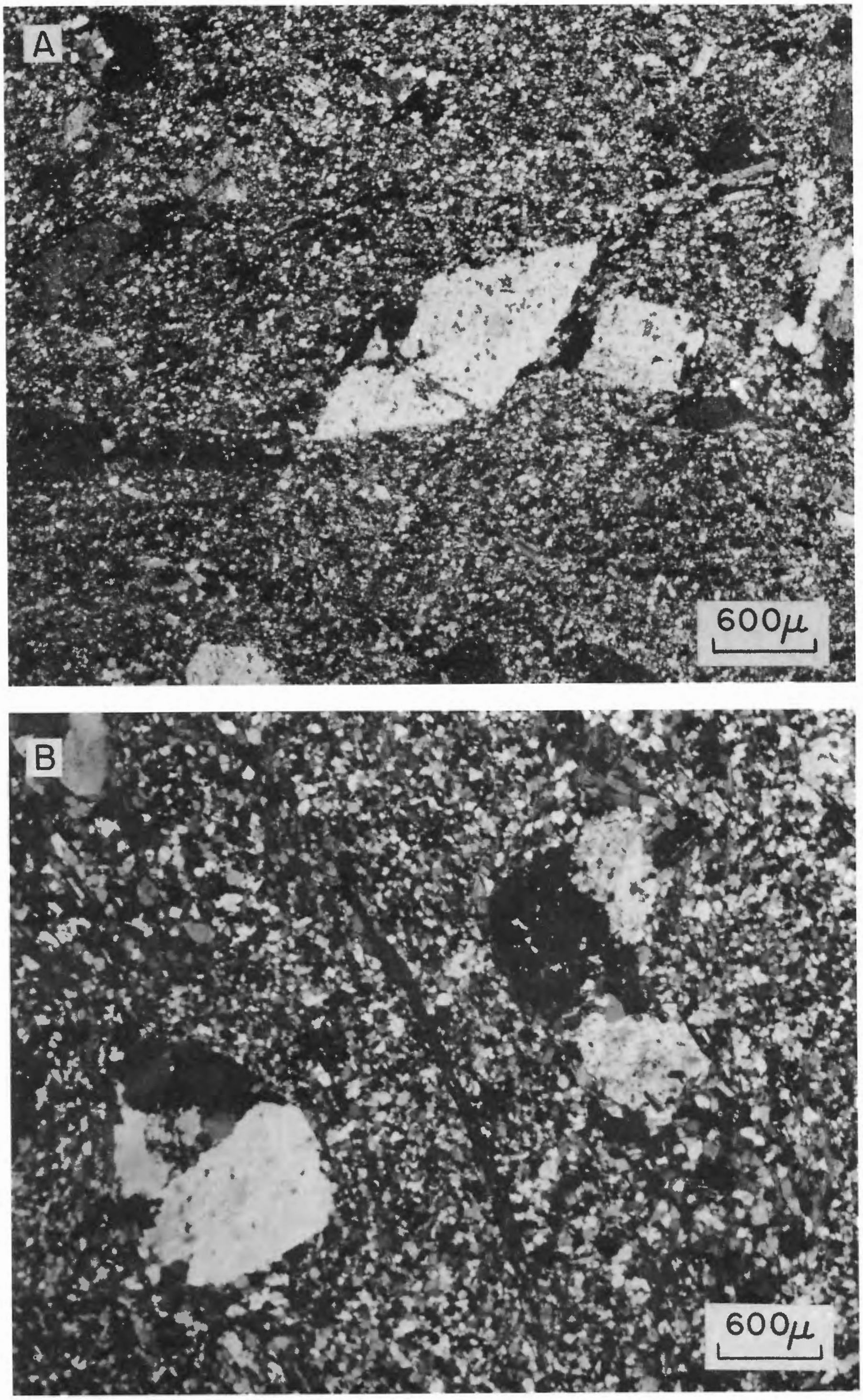
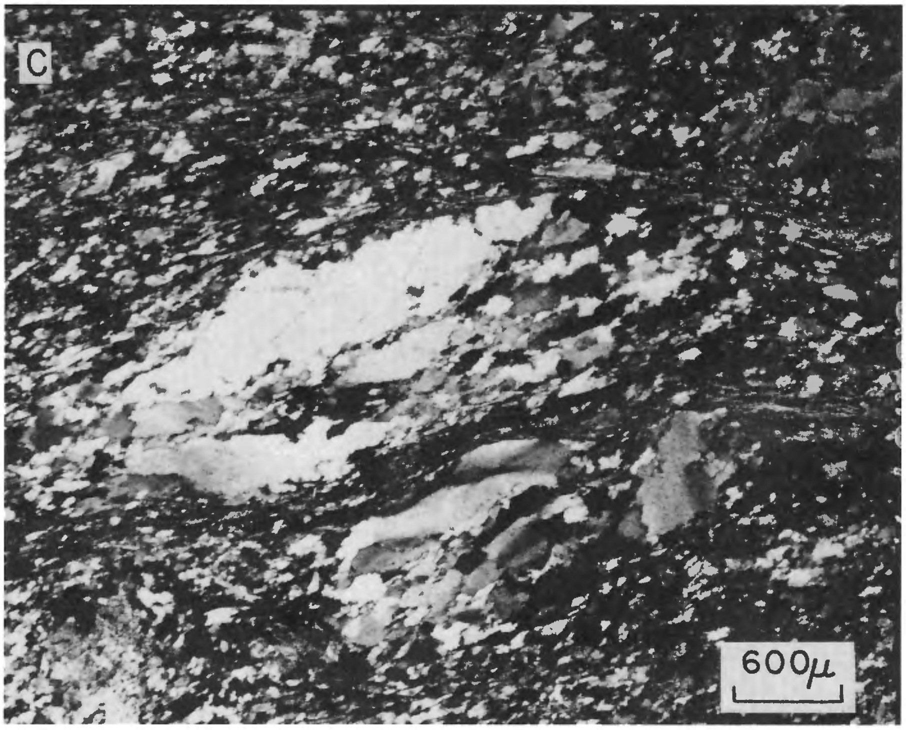
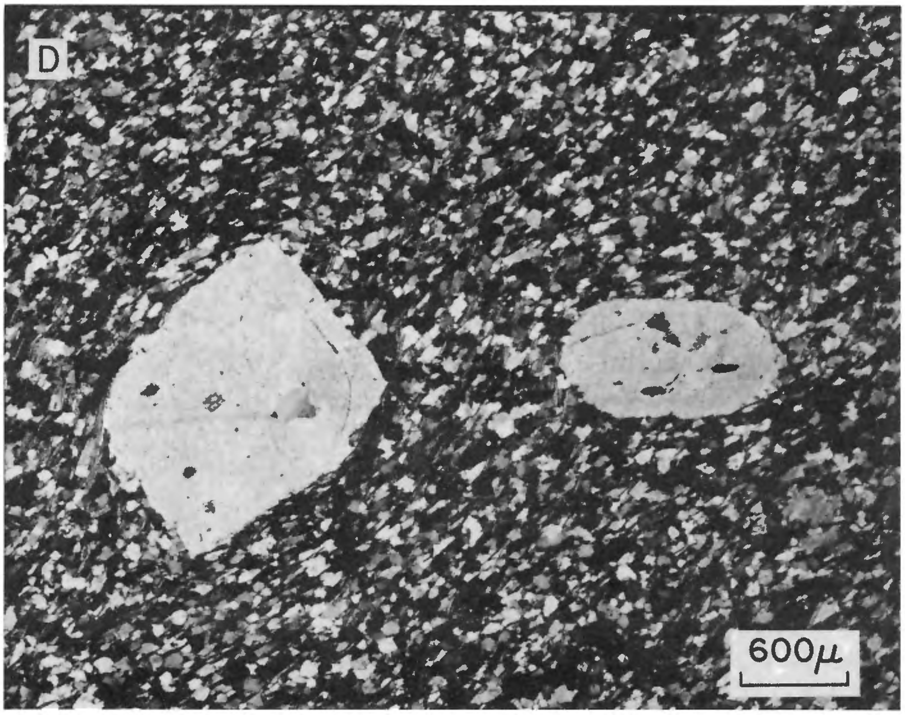


Figure 7. Phenocrysts from felsic volcanic rocks. A. Euhedral plagioclase phenocryst in felsic volcanic rock. GSC 202163-Y. B. Slightly recrystallized quartz and plagioclase phenocrysts with muscovite wisp in felsic volcanic rock. GSC 202164-C. C. Deformed quartz phenocryst in felsic volcanic rock. GSC 202164-A. D. Quartz phenocryst showing beta quartz form in felsic volcanic rock. GSC 202164-D.

lized 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 the 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, 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. Lenses of pelitic schist are rare.

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

Figure 8. Laminated siliceous marble in the north branch of the Central volcanic belt. GSC 114527.

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 centimetres 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 are 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, several millimetres in diameter and 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 ($(-)2V = 82°$) 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 sulphide. 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 ($(-)2V = 75°$) and radiating acicular anthophyllite crystals with minor quartz, magnetite, chlorite and trace apatite.

Mafic tuffs

Mafic tuffs occur as bands within the banded tuff, but in two areas they form distinct mappable units that structurally overlie more felsic rocks. The most extensive of these lies

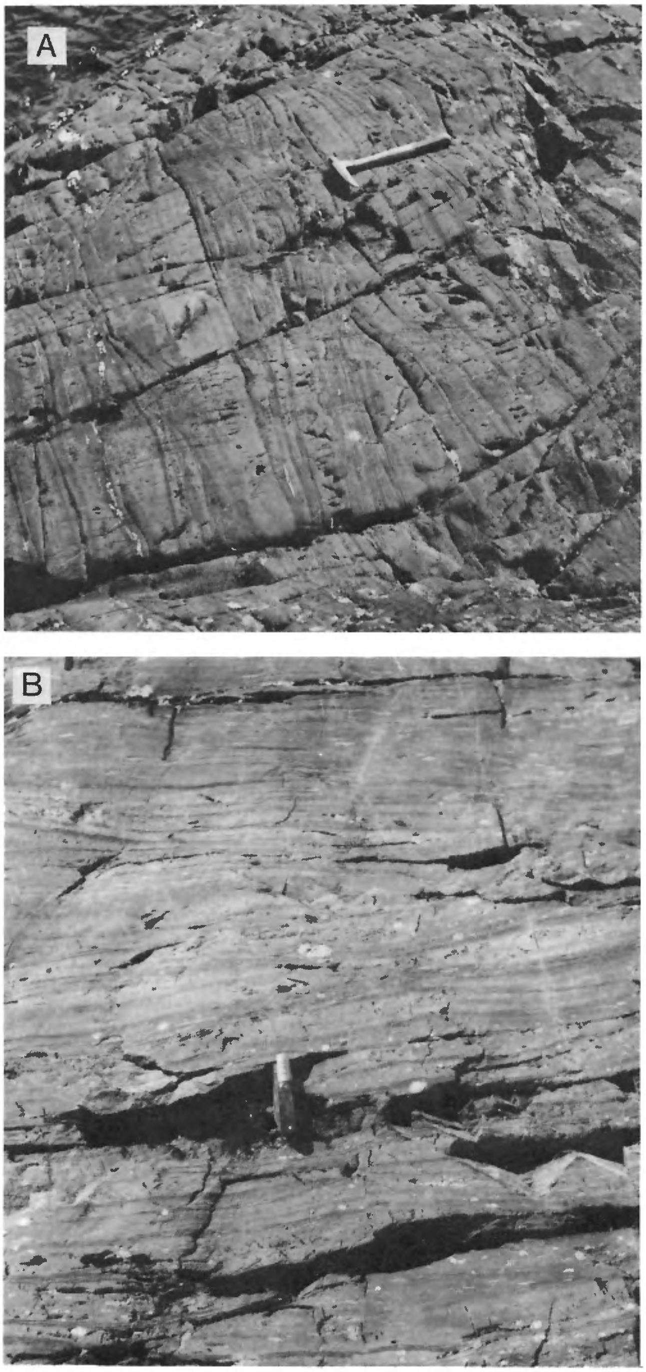


Figure 9. Scour and fill structure in laminated mafic tuff on the north shore, south arm of Point Lake. A–GSC 121143; B–GSC 121141.

Figure 10. Pebbles in laminated mafic tuff in the Western volcanic belt. GSC 121135.

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, local scour and fill structures can be discerned (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 (Fig. 10), were observed in the tuff.

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; 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 also in the southern part of the Central volcanic belt, where 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 composing up to 40 per cent of the rock. Locally calcareous laminae are preserved (Fig. 11). Traces of oscillatory zoning in plagioclase are rare and this zoning is typically diffuse with either normal or reversed trends. Cummingtonite or clinopyroxene is found locally in the more highly metamorphosed rocks and epidote,

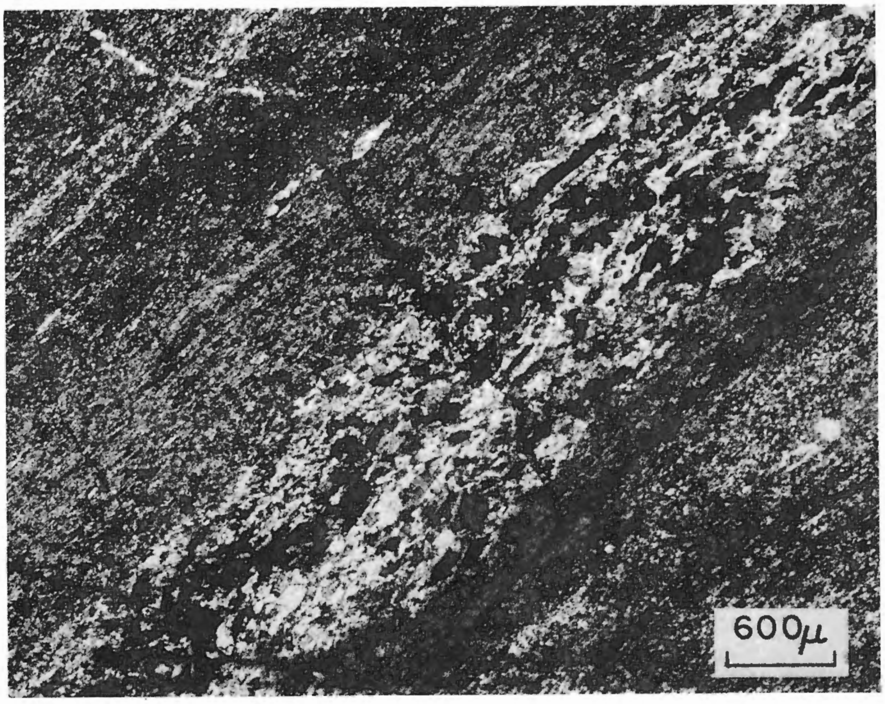


Figure 11. Banded mafic tuff showing fine-grained bands of hornblende, plagioclase and quartz with a central band composed of coarser grained hornblende, epidote and muscovite. GSC 202164-P.

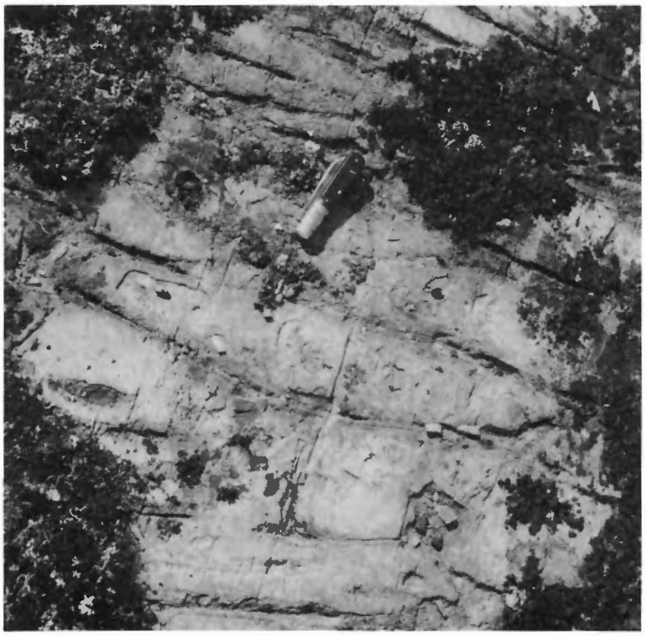


Figure 12 (top). Bulbous deformed pillows in mafic flows on the shore of Point Lake. GSC 121137.

Figure 13 (bottom). Elongate deformed pillows in a mafic flow in the Central volcanic belt. GSC 114525.

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 sulphide are common, but zircon is rare.

Mafic flows

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 is unknown but south of Point Lake roughly 7000 feet (2100 m) of mafic flows are preserved within a syncline the base of which is at least locally faulted.

Figure 14. Pillow breccia consisting of fragments of mafic volcanic rocks with magnetic iron-formation in interstices. GSC 121128.

The mafic flows are typically dark weathering, dark green to yellow-green, fine-grained rocks that may be pillowed (Figs. 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 sulphide-rich sediments are present here and there between flows. A pillow breccia with matrix consisting in large part of magnetic oxide facies iron-formation occurs on the northwest shore of the second point west of Keskarrah Bay (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 domelike structure 30 feet (9 m) high on its eastern (upper) side.

Structures within the mafic flows are poorly known south of Point Lake and west of Keskarrah Bay but pillow tops clearly indicate the presence of a tight syncline 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 syncline with the conglomerate at its core, and that the mafic flows pinch out eastward.

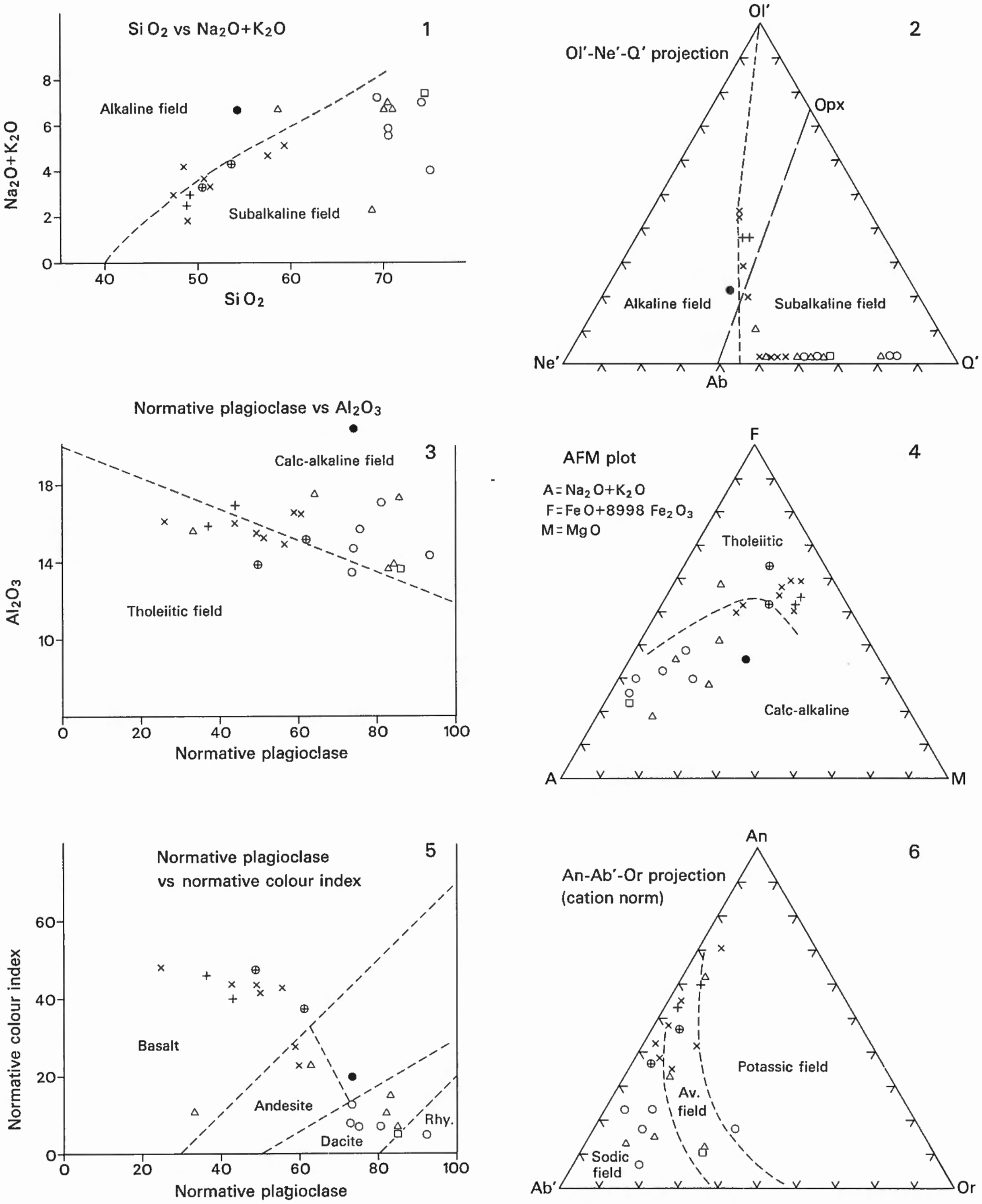


Figure 15. Classification of volcanic rocks of the Point Lake Formation by the system of Irvine and Baragar (1971).

KEY TO PLOT SYMBOLS

Values calculated from norms after Irvine and Baragar, 1971

Nepheline + 3/5 (albite)	Ne'
Olivine + 3/4 (orthopyroxene)	Ol'
Quartz + 2/5 (albite)	Q'
Albite + 3/5 (nepheline)	Ab'

Lithologies shown on plots:

Mafic flows and dykes (Western volcanic belt)	×
Banded mafic tuffs (Western volcanic belt)	+
Amphibolites (Central volcanic belt)	⊕
Massive felsic flows and tuffs (Central and Western volcanic belts)	○
Banded felsic to mafic tuffs (Central volcanic belt)	△
Felsic flow from between mafic flows (Western volcanic belt)	□
Mugearite	●

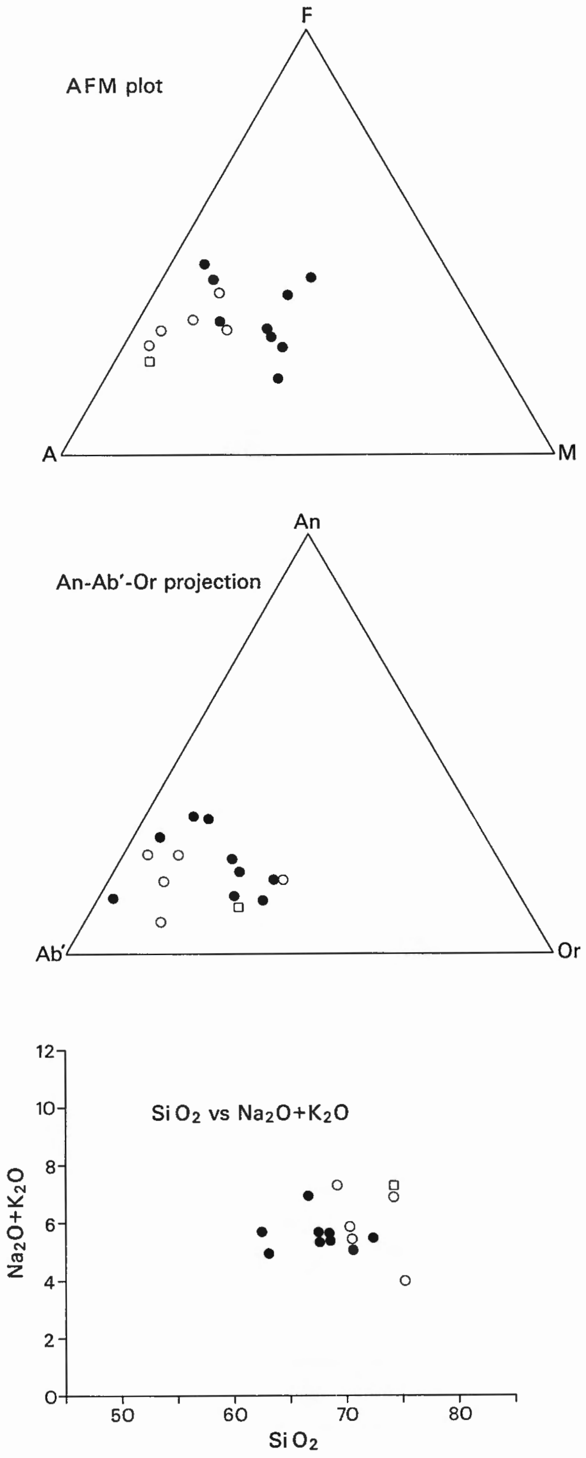
GSC

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 principal 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 sulphide, sphene and apatite. In the lighter green flows found at the core of the syncline south of Point Lake the principal mineral is epidote, chlorite is common and there are smaller amounts of quartz and calcite. Sodic plagioclase was recognizable in one flow by its low refractive index. Magnetite-ilmenite and sulphides 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 sulphide 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 Tables 1 and 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 Figure 15 analyses for each of the major lithologies are given distinctive symbols and are plotted together to illustrate this similarity.

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 (Figs. 15-1 and 15-2) indicate that the characteristic volcanic suite of 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 plotted against normative plagioclase, and AFM plots, suggested by Irvine and Baragar (1971) as a basis for division of the subalkaline rock series into tholeiitic and calc-alkaline subseries, divide samples from the Point Lake Formation into two groups (Figs. 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 (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



(Yellowknife data courtesy of W.R.A. Baragar, 1966)

Yellowknife flows . . . . ●
Massive felsic flows of the Point Lake Formation. . . . . . ○
Minor felsic flow between basalt flows in the
Western volcanic belt . . . . □

GSC

Figure 16. Comparison of alkali contents in felsic flows from Itchen Lake and Yellowknife regions.

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 AFM plots.

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

The felsic rocks of the Point Lake Formation, in comparison with those from the Yellowknife area (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) (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).

Among the mafic volcanic rocks, sample 634 (Table 1), representing a mugearitic flow at the contact between the Point Lake and Keskarrah formations, is clearly distinctive in its alkaline character. Samples 539 and 587, 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 of these samples are shown in column 7, Table 2. 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 porphyry intrusive into the Komati Formation in the lower part of the early Precambrian Onverwacht Group, South Africa.

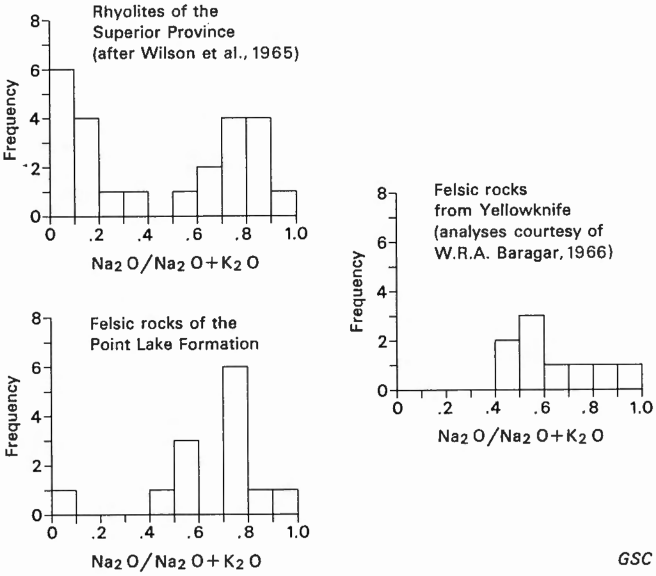


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Figure 17. Comparison of soda-potash in some Archean felsic rocks.

Other felsic analyses (Table 2) include two (199 and 139) of tuffs that are likely contaminated by calcareous sediment, one (124a) 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 described by Baragar (1966) from Yellowknife area suggests that the mafic rocks of the Point Lake Formation are similar to those at Yellowknife (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 used in this comparison. The felsic rocks from both areas tend to the 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 recognizable pillows. Numerous subhedral plagioclase phenocrysts, with or without quartz phenocrysts, in a fine-grained quartzofeldspathic 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 and is thinner in the more remote areas; it therefore probably took the form of windblown 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 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 as matrix, oxide facies iron-formation similar to that in the Contwoyto Formation and mafic volcanic clasts, likely bombs, are present within the Kaskarrah 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 occurrence 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 over extensive areas in the Central volcanic belt mafic volcanic rocks lie 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 scenario 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 clearly overlap in places 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 mafic.

Ultramafic and related rocks

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 1½ 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 long occur near the base of the mafic flows along the west margin of the Western volcanic belt 2 and 6 miles (3.2 and 9.5 km) south of Point Lake. A third small body was observed in a similar position about 1 mile (1.6 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 form anastamosing masses vaguely outlining serpentine-tremolite granules about 1.5 mm in diameter(or it may form a wispy schistosity through otherwise massive serpentine. The metagabbros are medium to coarse grained (up to 7 mm) with 60 to 70 per cent of pale brown to green amphibole and lesser intermediate plagioclase (andesine or labradorite), chlorite, epidote and opaques.

Chemical analyses

Chemical analyses of four serpentinites and two metagabbros from the western part of the map area are given in Table 3. The serpentinites are clearly ultramafic in their low silica and alumina and high magnesia contents. They are similar to many alpine ultramafics — 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 peridotites 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 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 likely to be 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 m.y., 2560 ± 75 m.y.) 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 m.y.), which accompanied deposition of the Keskarrah Formation, rather than to later Kenoran plutonism (about 2500 m.y.), which was responsible for high-grade metamorphism and granitic intrusion over much of the eastern and central parts of the map area.

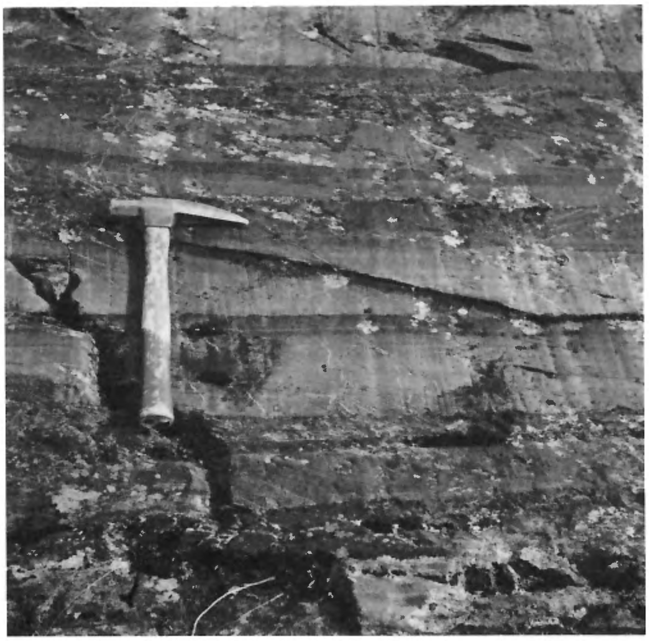


Figure 18 (top). Back-to-back graded beds in the Contwoyto Formation. GSC 121140.

Figure 19 (bottom). Greywacke-slate (metaturbidite) showing graded beds, crossed at right angles by glacial striae. GSC 121139.

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 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, but 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, sulphide or oxide (magnetite) facies 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 (1823), is from the Copper Indians who used the name "... Contwoy-to, 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, an extensive unit of similar turbidites without iron-formation. Together these two formations occupy most of a great southward-concave, arcuate belt of basinlike form, the greywacke-turbidite basin, that extends more than 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 recognizable 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 intertonguing 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 (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 the 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 (Fig. 18) would likely pass unnoticed inland where beds are concealed by lichens and outcrop is discontinuous.

The Contwoyto Formation is divisible into two subunits, one characterized by oxide facies iron-formation beds and lenses, which occurs chiefly in the Point Lake region about the Keskarrah delta or fan, and a second more extensive subunit characterized by silicate and sulphide iron-formation beds and lenses. The best exposures of the oxide facies are along and near the north arm of Point Lake. The sulphide-silicate facies is best exposed at the Main showing stripped by Canadian Nickel Company near Contwoyto Lake (Fig. 54). 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 (1976).

Oxide iron-formation facies

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 facies 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. Rusty weathering iron carbonate–bearing beds are rare. Magnetite-rich layers and lenses are commonly bordered by chlorite or amphibole-rich layers showing sharp or gradational contacts with greywacke (Fig. 20). In places recessed weathered surfaces reflect the presence of carbonate. Thin quartz-rich lenses may be derived from chert.

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 sericitelike micaceous mineral, biotite and sulphide are present in some specimens. Where most coarsely crystalline, magnetite forms 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-sulphide iron-formation facies

The silicate-sulphide 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 (Fig. 21). Where the

Figure 20. Lenses and fragments of magnetic iron-formation (medium grey) surrounded by silicate facies amphibolite (dark grey) with gradational contacts into greywacke (lighter grey). Contortion of magnetic iron-formation lenses is due to soft sediment deformation. GSC 121101.

Figure 21. Banded silicate iron-formation showing garnets concentrated in beds and in zones across bedding. GSC 114482.

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 (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 (Fig. 22). Sulphides, generally in bands parallel to layering but also in patches or lenses, are widespread and produce rather unspectacular reddish brown gossans. Pyrrhotite is by far the most abundant sulphide 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 sulphide 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-sulphide iron-formation facies.

The silicate-sulphide iron-formation facies is composed chiefly of amphibole and quartz with opaque minerals (chiefly sulphides) 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 (almandine) 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

Figure 22. Banded silicate iron-formation containing ovoid lenses of fine-grained quartzite probably derived from chert. GSC 114473.

a greater extent interstitial, and garnet is cleaner. Gedrite, the aluminous anthophyllite, was identified in one specimen by electron probe analyses. Chemical variations in the major amphiboles and garnet of the silicate facies are described in Bostock (1977). 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 but some traces of ilmenite are found. 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-sulphide facies, are metamorphic equivalents of the greywacke-mudstone lithological assemblages typical of sediments of the Yellowknife Supergroup elsewhere in 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 in 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 local 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 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 (Table 4) of silicate and oxide facies iron-formation were made by the rapid method, which for these rocks can be considered only semiquantitative as far as iron content is concerned. The data 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 (Fig. 23) there is a suggestion that an inverse relation exists between CaO and MgO + Al_2O_3 within the nongarnetiferous beds of silicate iron-formation. Such a relationship might indicate that silicate iron-formation was variably contaminated 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 (Deer et al., 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 (Bostock, 1977). 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 nongarnetiferous 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 analysis of richly garnetiferous iron-formation shows high alumina content in comparison with 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 (ibid.). 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 5 with the description of the Itchen Formation.

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 indicating that there the Contwoyto Formation overlies the Point Lake Formation. 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 mafic clasts, probably bombs, within the Keskarrah Formation conglomerates (Fig. 25) that overlie the Contwoyto Formation, suggest 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 recognizable remnant of similar rocks, separates migmatite derived from the greywacke-turbidite succession and the contacts of major plutons. To the extent that the 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 the age of the strata decreases 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 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 the 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

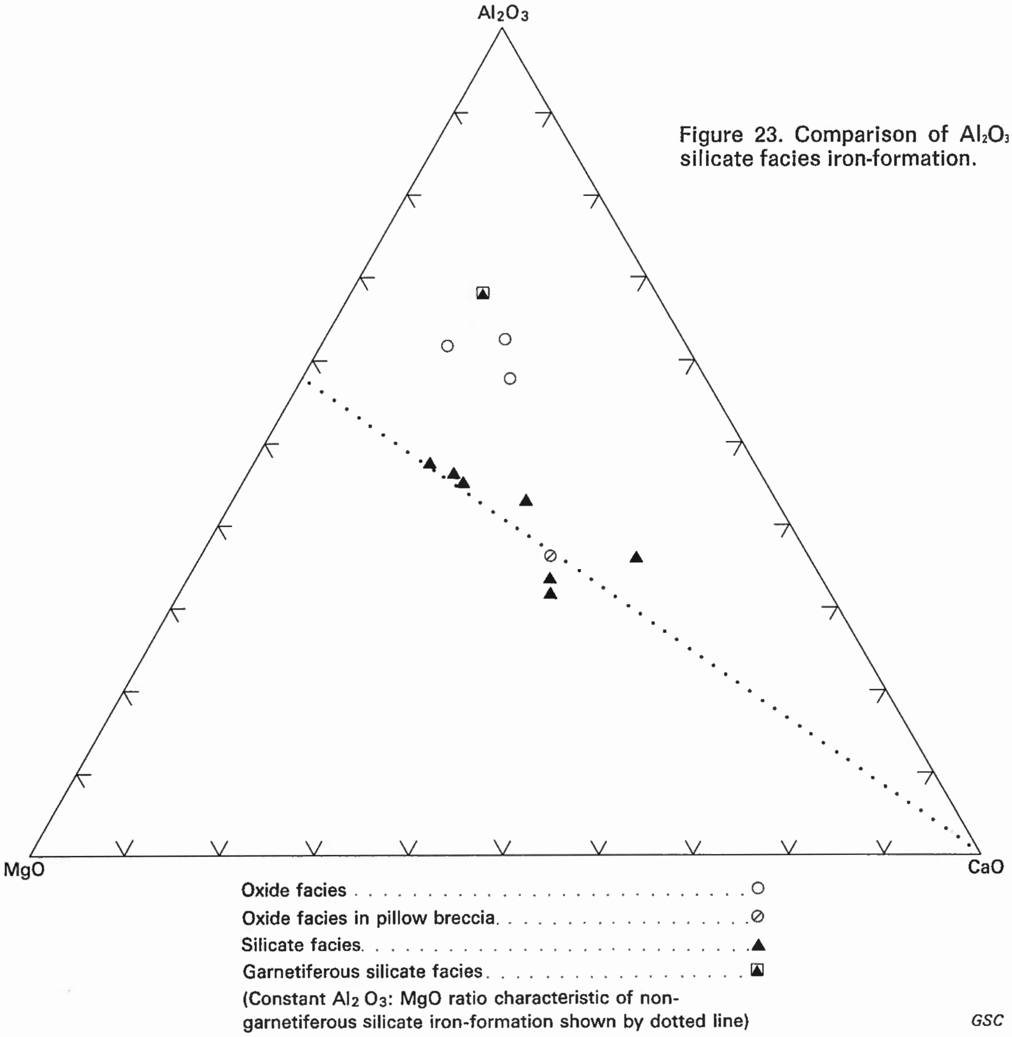


Figure 23. Comparison of Al_2O_3, MgO and CaO in oxide and silicate facies iron-formation.

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 be due to nondeposition of iron in this area due to some environmental control. Such a control might be provided by the limitation of the source of iron to regions about and to the north of Point Lake, and to 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) and the others suggest 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 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 sulphide 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-sulphide 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 shoreline. 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 downwarping of the oxide facies relative to silicate-sulphide 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

The name Keskarrah Formation is proposed for conglomerate with some calcareous subgreywacke, and greenschist, which 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 crossbedded 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 (Angv)). 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 3 miles (5 km) wide, is beneath the lake. The conglomerates along the lake shore are clearly repeated by folding and faulting but it appears likely that they reach approximately 1500 feet (457 m) or more.

The Keskarrah Formation consists of at least two huge lenses composed mainly 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 (from 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 2 feet (0.6 m) and rarely 2.5 feet (0.75 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 (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 southwestern 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 2.5 inches (6.3 cm) in length. Small sulphide gossans are numerous.


Figure 24. A calcareous subgreywacke lens in conglomerate of the Keskarrah Formation; strong foliation is nearly perpendicular to the lens. GSC 121119.

Clasts in the Keskarrah Formation (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 (Fig. 25D). These blend into the greenish gritty matrix to such an extent that it is locally

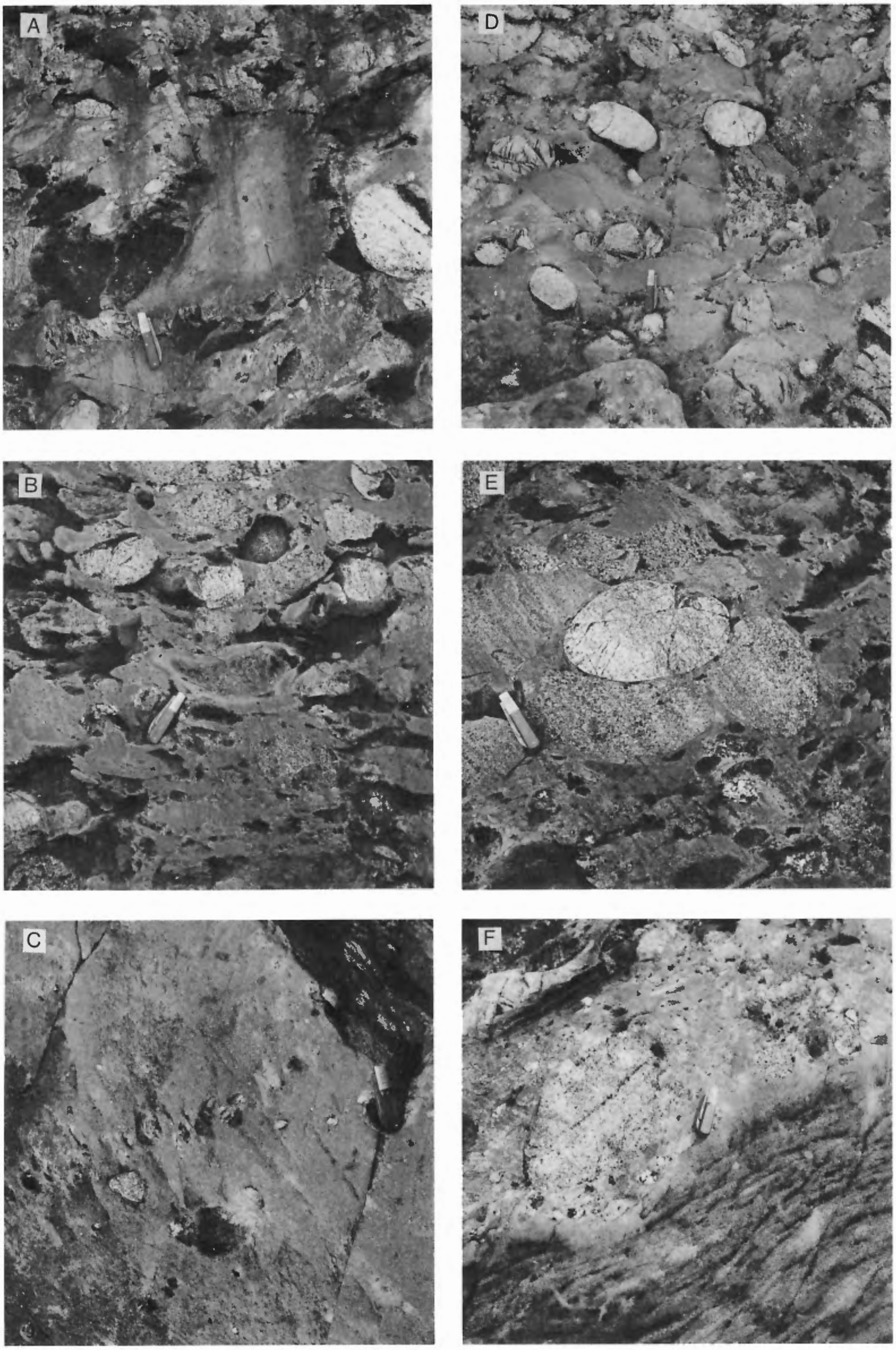


Figure 25. Phenoclasts in conglomerate of the Keskarrah Formation. A. Mafic pyroclastic fragment showing dark green chilled margin. GSC 121107. B. Mafic pyroclastic fragment showing light green margin. GSC 121114. C. Pebble bed in calcareous subgreywacke showing distortion of mafic chips parallel with foliation. GSC 121133. D. Masses of mafic volcanic fragments intermixed with granodiorite and quartz diorite cobbles. GSC 121110. E. Mafic dioritic cobbles are more severely deformed than are adjacent granodiorite cobbles. GSC 121113. F. Quartz diorite boulder projects slightly into a calcareous subgreywacke lense. GSC 121122.

difficult to tell which type of clast is the more abundant. Several mafic clasts with particularly fine grained dark or light green borders (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 nonporphyritic, 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 (Fig. 26).

The conglomerate is typically schistose and locally highly schistose (Fig. 27). The more mafic clasts tend to be more highly distorted than the more siliceous ones (Fig. 25E). Ratios of maximum to minimum apparent diameter for siliceous clasts are commonly 4 to 1 and greater in some places. 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, as originally suggested by Stockwell (1933), with the hybrid rocks that surround it south of Keskarrah Bay. 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 generally 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 are comparable to some lithologies found among the mafic ovoids in the conglomerate.

Three boulders from the Keskarrah Formation examined in thin section proved to be 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 because the crystals are so small. Quartz grains or patches within the boulders commonly appear recrystallized and locally form a mosaic of disoriented, typically strained grains surrounding albite (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.

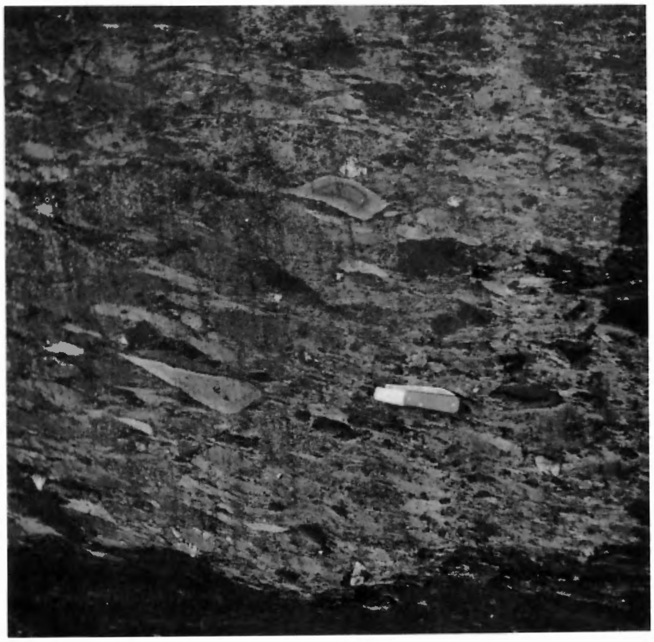


Figure 26. Yellow-green siltstone chips within conglomerate of the Keskarrah Formation. GSC 121134.

Figure 27. Severely deformed conglomerate of the Keskarrah Formation. GSC 121117.

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 (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 recognizable porphyritic texture (but see Fig. 28D) involving both quartz and albite, which would demonstrate a volcanic origin, was not found.

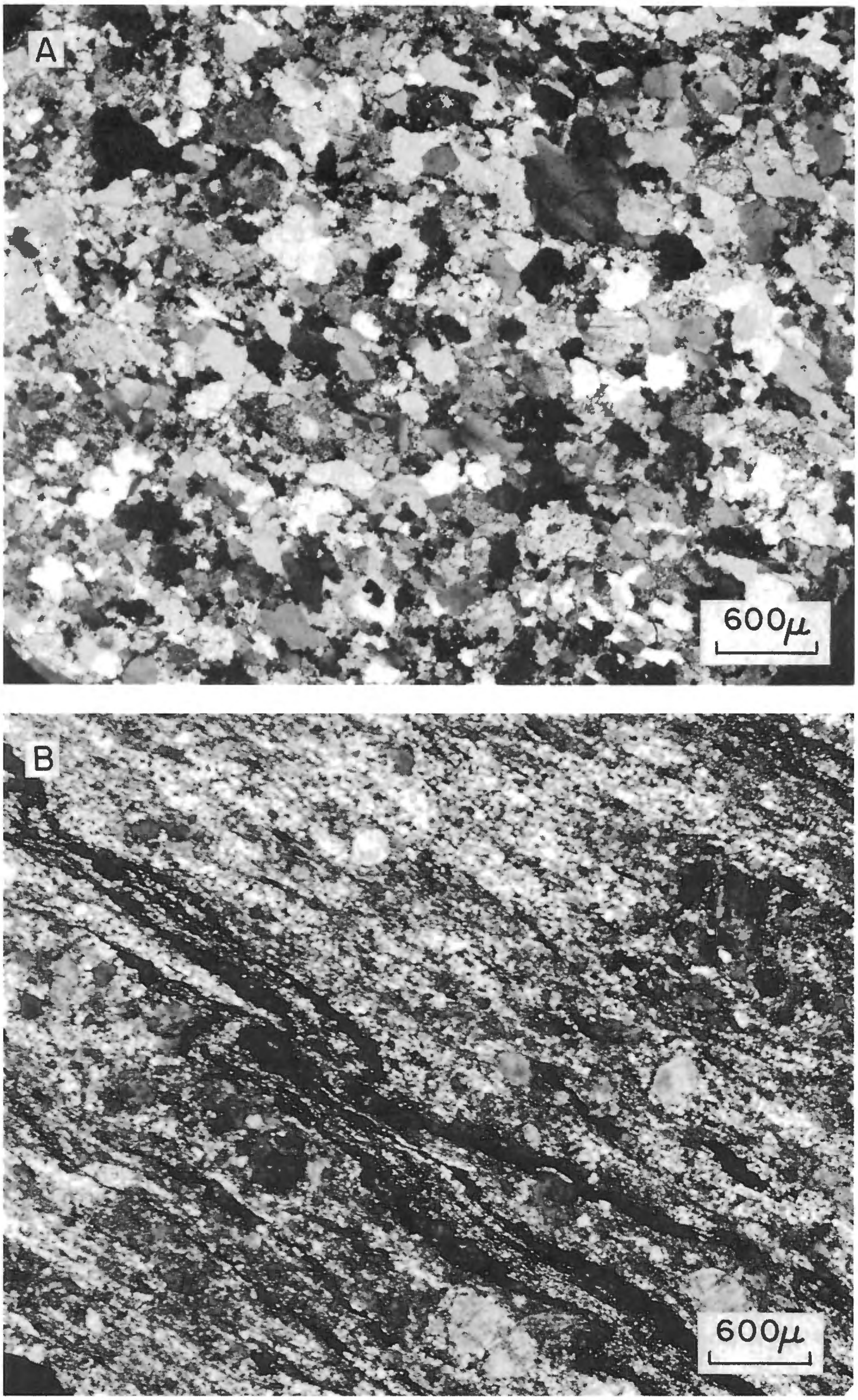
The matrix of the conglomerate consists of variable proportions of fragments of strained, locally recrystallized, quartz and sericitized albite in a fine-grained siliceous, commonly schistose matrix consisting of sericite, chlorite and carbonate, the latter forming up to 50 per cent of the matrix in places. Carbonate grains picked from two thin sections for identification by X-ray proved to be calcite. Secondary muscovite 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 wispy lenticular patches of sericitic material.

Origin and age relations

The volcanic affinity of the Keskarrah Formation is indicated by 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 bomblike clasts up to small boulder size, and a second composed of felsic pebbles resembling the extensive felsic volcanics of the Point Lake Formation. The felsic pebbles are smaller, more spherical and less abundant than the mafic ovoids. This suggests that they have been derived from erosion of felsic rocks that outcropped some distance away. On the other hand the mafic ovoids are bigger and more abundant and some of them are bomblike. This 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.

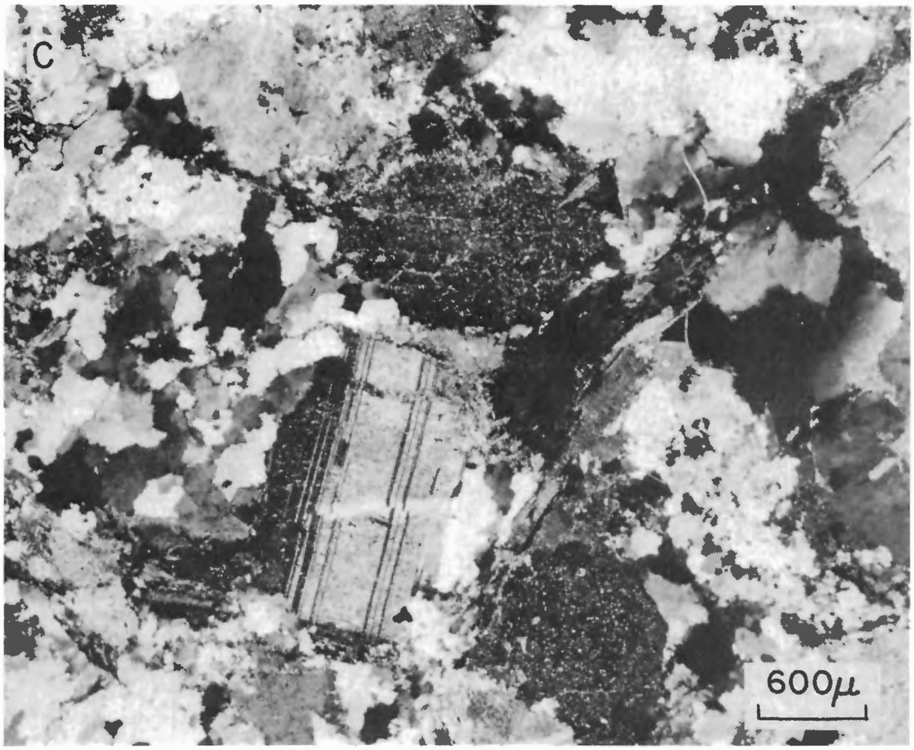
A structural unconformity separates the Keskarrah conglomerates on the northwest point of Keskarrah Bay from hybrid rocks to the south (as reported by Stockwell, 1933). Although the precise contact (subsequently described by Henderson, 1975) was not seen during the present study, it is clear that granitic 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 the Itchen Formation or the Contwoyto; however no other instance of structural discordance at these contacts has been demonstrated. It seems likely, therefore, that the unconformity is local. West of Keskarrah Bay the unconformity may 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. However, it is still possible (as originally implied by Stockwell, 1933) that within the hybrid rocks at Keskarrah Bay there exist remnants of an older sialic basement. If so 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 these rocks were intruded 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 greenshist facies metamorphism because muscovite is not as 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 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



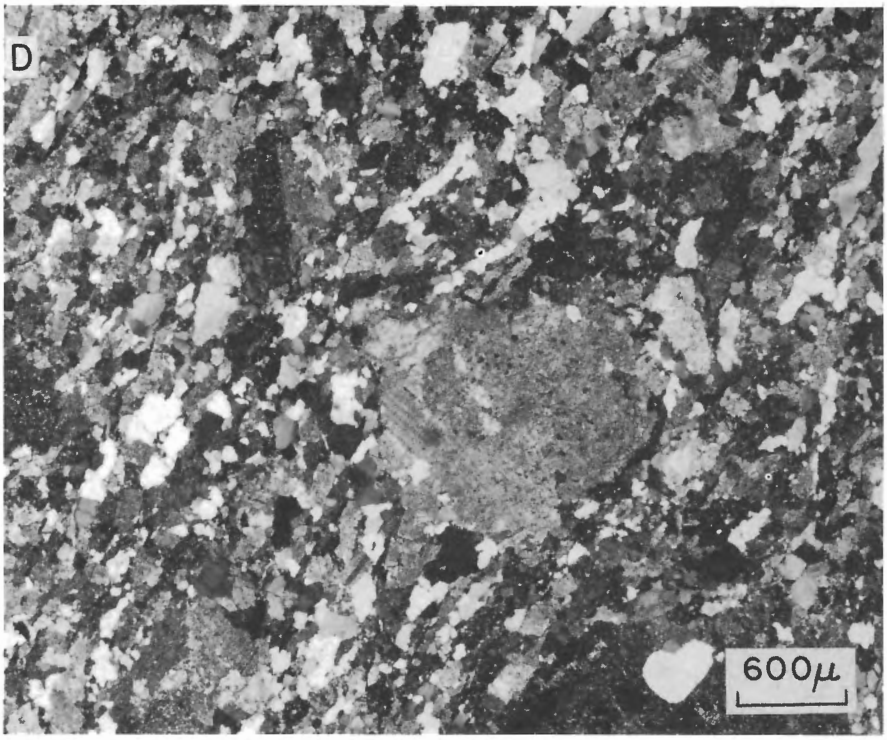


Figure 28. Phenoclasts from the Keskarrah Formation in thin section. A. A pebble showing typical felsic volcanic texture but without phenocrysts. GSC 202231-C. B. A felsic volcanic pebble showing banding and deformation possibly due to primary flow? GSC 202231-F. C. A boulder of muscovite-bearing meta–quartz diorite showing plagioclase and recrystallized quartz. GSC 202231-I. D. Pebble showing possible rounded phenocryst resembling some seen in the felsic volcanic rocks. GSC 202231-E.

in restricted areas along the contact between the Point Lake and Contwoyto or Itchen formations are consistent with stream transport and deltaic or submarine fan deposition at the west edge of a broad basin in which fine clastics were accumulating. 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 suggest that the stream drained an area of uplift near the southwest corner of the map area.

Itchen Formation

The name Itchen Formation is proposed for the metamorphic equivalents of greywackes and mudstones of the Itchen Lake area, which are similar to those of the

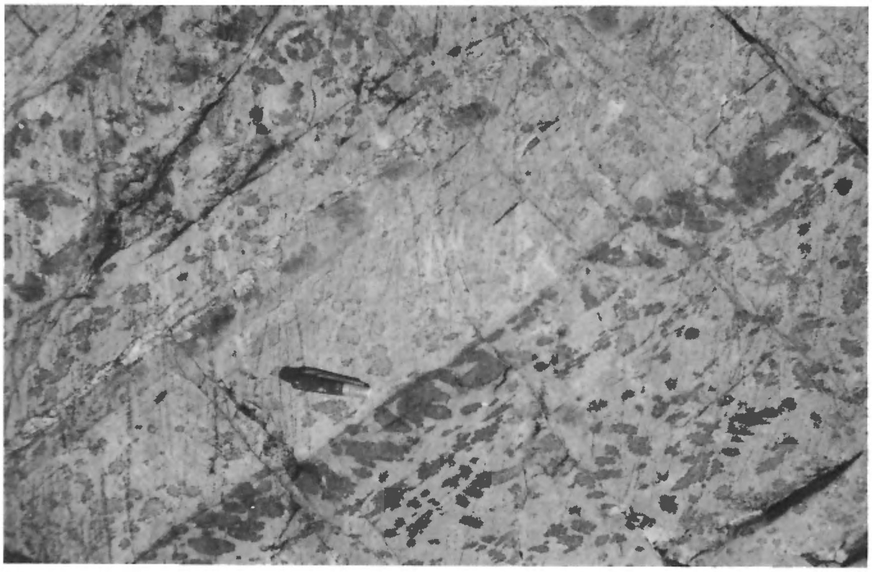


Figure 29. Reversed graded beds showing coarse feathery chlorite patches (probably pseudomorphous after cordierite) clustered at the upper margin of a bed in the Itchen Formation. GSC 114472.

Figure 30. Cordierite-andalusite–bearing bed overlain by a thin laminated greywacke bed with load casts at the contact within the Itchen Formation. GSC 114440.

Contwoyto Formation but lack the iron-formation lenses which characterize it. It is best exposed along the shores of Point Lake where the rocks are chiefly in middle amphibolite facies and is well exposed, but somewhat less cleanly and extensively, at Itchen Lake where the rocks are chiefly in lower amphibolite facies.

In a broad, southeastward-concave arc the formation extends from the south border of the map area west of Coppermine River 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); to the east they extend for some 25 miles (40 km) into the eastern part of 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 the iron-formation lenses that 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 tightly folded in many, and presumably in most, places; however, its great exposure would suggest a thickness in excess of several thousand feet.

The metagreywacke-metaturbidite succession within the Itchen Formation is mostly well bedded. Beds are evident on most well washed shoreline outcrops about Point Lake but elsewhere lichen cover and staining may render bedding obscure. Beds range in thickness from less than 1 inch (2.54 cm) to many feet but are usually less than 18 inches (46 cm) thick. At many outcrops 6-inch (15 cm) to 8-inch (20 cm) graded beds are exposed across

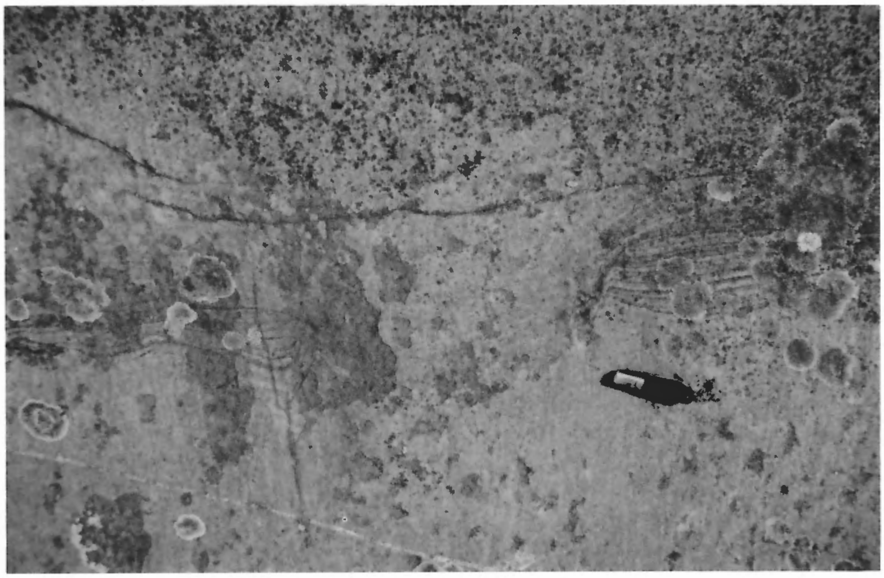


Figure 31. A small channel within massive greywacke of the Itchen Formation. GSC 114469.

Figure 32. Calcareous lenses or concretions within greywacke beds within hybrid rocks equivalent to the Itchen Formation. GSC 114451.

much of the surface (Figs. 18, 19), and where beds have reached lower to middle amphibolite facies metamorphic grade, cordierite or late chlorite is generally concentrated in knots or feathery patches in the upper parts of the beds to produce reverse grading (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 often reveals load casts (Fig. 30) and, more rarely, small channels (Fig. 31). Thick argillite beds in some places may bear chiastolite as well as cordierite megacrysts in amphibolite facies terrane. Some greywacke beds contain ovoid calcareous concretions up to 8 or 10 inches (20 to 25 cm) in diameter that typically follow the centre of the bed in which they occur (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 1 mile southeast of Itchen Lake such rocks form a light strip visible on aerial photographs.

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. Most specimens contain muscovite. 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 sphene 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. Porphyroblasts of cordierite that reach from one to several centimetres in diameter are common and andalusite porphyroblasts are less common. The porphyroblasts produce the characteristic mottled appearance on fresh surfaces (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. Andalusite and sillimanite commonly coexist in the same thin section. Staurolite or garnet are rare, the former mostly as tiny inclusions in other minerals. Accessory minerals are magnetite, pyrite, tourmaline, apatite, iron sulphide and zircon. Tourmaline crystals, often zoned with blue cores and orange-brown rims, locally constitute up to about 1 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 (chemical composition of hornblende and cummingtonite given in Bostock, 1977). 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

Seven samples of slate, greywacke and knotted schist from the Itchen and Contwoyto formations were analyzed by the rapid method chemical analysis technique (Table 5). The analyses fall in a range similar to rocks derived from other Precambrian greywacke-turbidite assemblages but one analysis of schist adjacent to silicate sulphide iron-formation between the arms of Point Lake is unique in containing 1.83 weight per cent of carbon derived from graphite.

Age relations and origin

The age relations between the Itchen Formation and other formations in the Itchen Lake area are not directly evident because the Itchen Formation, 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 regional exposure 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 that are free of iron-formation may partly reflect variation in environmental conditions under which these rocks were deposited, variations that have already been 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

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 predominate in most areas. However, many of the potash feldspar-free plutonic rocks here classified as quartz diorite 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. 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 leucogranodiorite with a pink variant possibly richer in potash feldspar. Commonly the rock is stained pink along fractures or veins.

Textures are mostly massive equigranular and medium to 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 local.

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 is 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.

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 the granodiorite was emplaced before conglomerate deposition, 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 as 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 1 mile (1.6 km) wide by 4 miles (6.4 km) long within the south prong of the Central volcanic belt. The grey-white rock has 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 the porphyry has clearly 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.

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 batholithic 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, crosscutting 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 intrudes the greywacke-turbidite succession only at its southeastern extremity, and 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 downfolded within the batholith to form supracrustal remnants with moderate to steep dips. 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 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

Major dioritic plutons ranging in composition from gabbro and amphibolite to granodiorite are present near 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 dykelike or lenticular 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 exposure 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 thin sections examined. 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 sausurritized 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.

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 texture observed in thin section indicates 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 outcrops 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, and medium grained (1 to 2 mm), and typically are weakly foliated or unfoliated. They are allotriomorphic, equigranular with calcic oligoclase forming the major constituent. Quartz is present in amounts close to 10 per cent in some 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 potash 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.

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. However, the age of the pluton relative to the greywacke-turbidite succession 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 for 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 forming 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.

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 will be required to establish its age.

Eastern pluton

This pluton, on a peninsula in Contwoyto Lake at the east end of the map area, was examined by Tremblay (1967) and 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 some 7 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. However, patches of granite, pegmatite, and some quartz veins, seen within the gabbro indicate that it is older than the Mackenzie dykes. Near the east end of the body is coarse-grained, dark green, hornblende gabbro to amphibolite, which locally disintegrates to a black sand. 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 amphibole comprises a green hornblende rimmed by colourless amphibole showing multiple twinning, probably cummingtonite. A little biotite and muscovite(?), local patches of chlorite-serpentine, minor opaque minerals, and accessory apatite are present.

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 suggests 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 frequently 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-sulphide gossans.

The rocks are typically dark greenish black and medium fine grained (0.8 to 2 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 a ubiquitous accessory mineral whereas sphene occurs mainly where the amphibole is acicular.

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 that many are hypabyssal intrusions related in age to the late Kenoran basic plutons. However, some of the amphibolites, particularly those banded bodies bearing garnets and associated with iron sulphides 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 analogous to that in the Contwoyto Formation. 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 sulphide 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 found.

A small medium- to fine-grained metagabbro body is poorly exposed within the greywacke-turbidite succession near the contact between the Itchen and Contwoyto formations about 1 mile (1.6 km) 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 appear as large inclusions about the margins of the Yamba batholith.

Late Kenoran granitic rocks (Agm)

Yamba batholith

The Yamba batholith surrounds Yamba Lake at the southeast corner of the map area. It occupies some 500 square miles (1295 km^2) within the map area and projects at least 10 miles (16 km) southward into the Lac de Gras map area. Unlike others in the Itchen Lake region the batholith is 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. Biotite and, in some places, hornblende form 5 to 10 per cent. Biotite- and hornblende-rich remnants are present locally. Within the pluton the rocks are generally more leucocratic and vary from medium to coarse grained. In the interior and eastern parts of the batholith potash feldspar is commonly porphyritic and phenocrysts locally reach 5 cm in diameter.

Rocks of the Yamba batholith are medium grained and many 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 or epidote are local constituents, and small amounts of muscovite are typical. 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.

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. ($\lambda 87Rb = 1.39$) and 2390 ± 98 m.y. ($\lambda 87Rb = 1.47$). 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 intrusion of the batholith about 2500 m.y. ago.

Central belt batholith

The Central belt batholith (Fig. 2) underlies roughly 150 square miles (388 km^2) 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.

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. 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 km²) 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, which extends north of Coronation 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 is biotite which forms from 2 to 10 per cent but mostly about 5 per cent of the rock. 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 specimens and the red stain derived from these minerals is prominent locally. Biotite-rich inclusions and schlieren are here and there throughout the batholith, and 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 in the contact zone there is a pronounced increase in schist or gneiss layers, schlieren and inclusions. 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), usually with some larger feldspar crystals approaching 5 mm in diameter. Major minerals are quartz, microcline and plagioclase (albite to sodic oligoclase); the proportions of the two feldspars vary widely. Biotite, muscovite and chlorite are minor constituents and apatite and zircon are ubiquitous accessory constituents. Sillimanite occurs with muscovite in the granite at one locality.

The Contwoyto batholith is younger than the greywacke-turbidite succession that it intrudes. It must also postdate (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 km²) 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 and 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 heterogenous 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). Many of the megacrysts are partly buff-pink stained, which gives an erroneously high impression of the potash feldspar content 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 which suggest that the batholithic 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 and include 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 microcline and minor chlorite, muscovite and magnetite-ilmenite.

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 around 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 determine the age of the interior of the pluton radiometrically; earlier granitic rocks might be discovered. It is clear however, that the Rockinghorse batholith is at least partly and possibly largely of late Kenoran age. A minimum age of 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 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 that 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 often are stained red so that the proportion of potash feldspar to plagioclase is difficult to estimate. Feldspar megacrysts are scattered locally. Biotite, or rarely hornblende, is the principal mafic mineral but in places it 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 have a greater proportion of microline to plagioclase, a lower proportion of mafic minerals and a more sodic plagioclase than the quartz diorite, and a little muscovite.

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

Minor granitic intrusions

Minor granitic plutons at widely scattered localities within the Contwoyto and Itchen formations are clearly post–early Kenoran in age. 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, partly altered locally 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 local 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 that 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 apparently 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 around 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 2½ 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 1 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 white, biotite quartz monzonite, in part medium-grained and equigranular, but in part containing tabular euhedral phenocrysts of potash feldspar up to 5 cm long. Local white pegmatites 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 is a large pegmatite and the easternmost is fine grained, white to buff and biotite bearing. The northern body is coarse-grained, massive syenite consisting principally of pink feldspar and hornblende.

Chemical analyses of the plutonic rocks

Eleven samples from the plutonic rocks were analyzed (Table 6) to determine the range of chemical variation. Although the analyses are too few for detailed comparisons some points of interest are evident.

Among the basic plutonic rocks the metagabbro (Fuz pluton, sample 996) is chemically distinct from the west-northwesterly striking diabase dykes (Table 10) 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 sample 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 partly 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 (Fig. 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.

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 was not possible to map areas of distinctive composition although this could probably be done by mapping at a more detailed 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

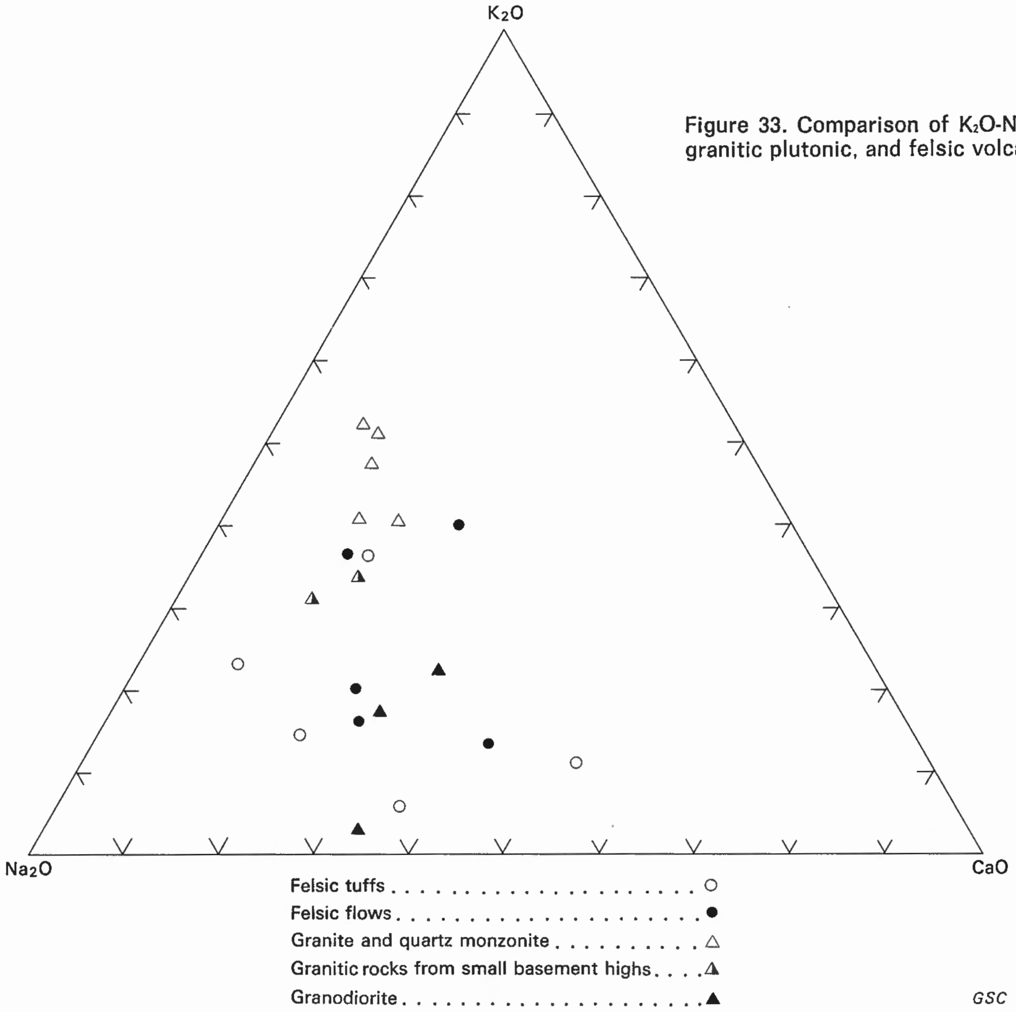


Figure 33. Comparison of K_2O-Na_2O-CaO proportions between granitic plutonic, and felsic volcanic rocks.

and Western plutonic zone plutons, and perhaps the Keskarrah batholith. The chemical analyses are consistent with this but are too few to be conclusive. Thirty-two partial analyses of specimens I collected from the Yamba batholith were made 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 7, 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 (Allan and Cameron, 1973) may provide further support for this suggestion, although potassium in the lake sediments is clearly affected by other considerations besides the composition of the local bedrock.

Potassium anomalies (ibid.) derived from lake sediments within the map area, the distribution of granitic rocks, and the relative amount of drift cover are plotted on 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 present distribution 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

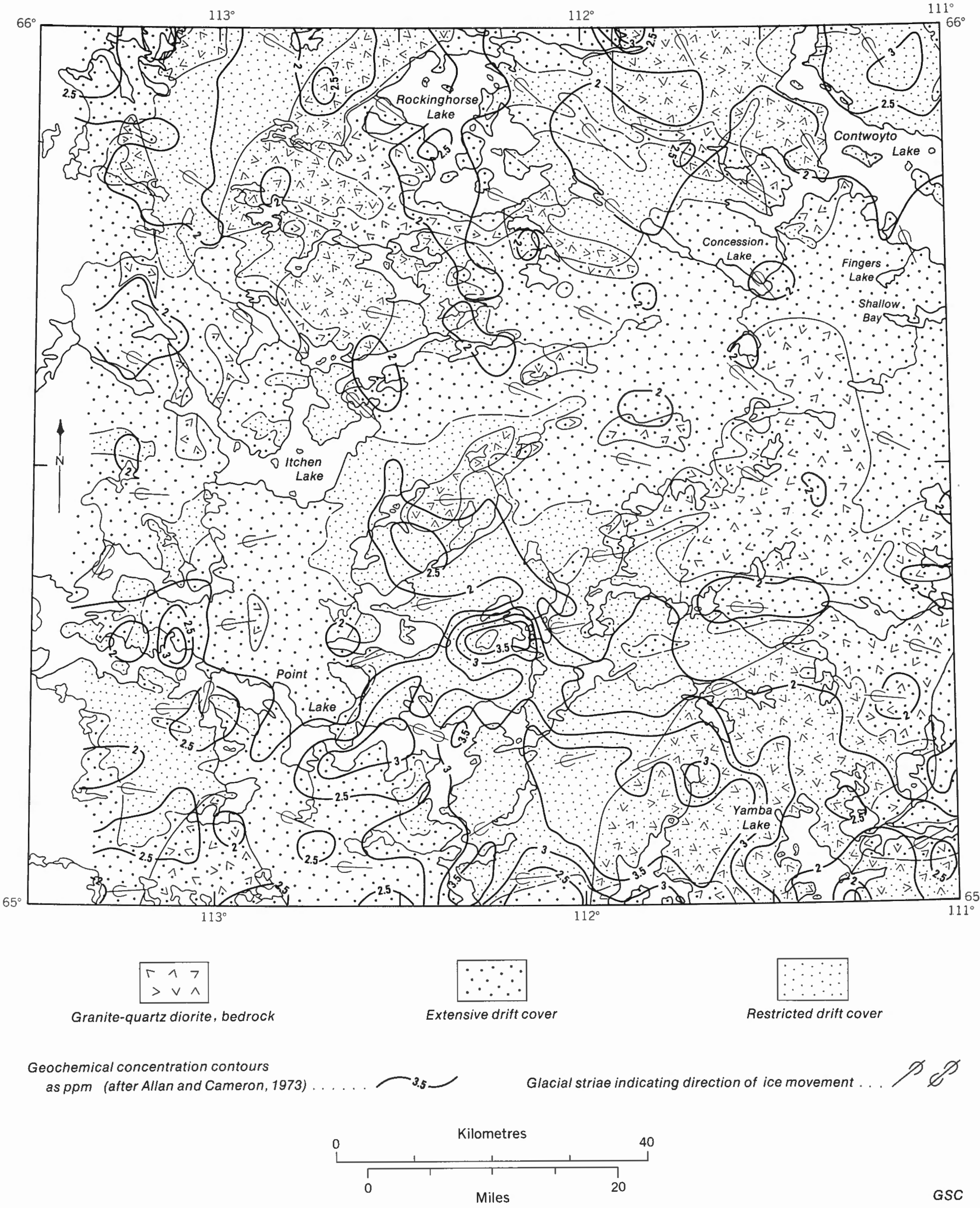


Figure 34. Distribution of drift, potassium lake-sediment anomalies, and granitic rocks.

derived from the Yamba batholith and perhaps as well from muscovite granites in the Lac de Gras area (Folinsbee, 1949) to the southeast. The northeasternmost part of Yamba batholith is blanked by drift derived from east of 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 nonpotassic drift derived from the east and perhaps a greater proportion of older nonpotassic 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 Proterozoic shales, but may also reflect increased exposure of the Contwoyto batholith.

Reconnaissance mapping and information from the limited chemical analyses and lake sediment geochemistry, suggest that the late Kenoran granitic rocks tend to be potassium-rich relative to the older granitic rocks. It also appears 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.

Summary

Granitic plutonic rocks within the map area east of the Western volcanic belt may be divided into two groups of different ages and possibly of different compositions 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 by intrusion of 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 around which remnants of the lower part of the Yellowknife Supergroup are preserved. Thus for some granitic bodies it is not known whether much or all of the granite was emplaced early in the Kenoran Orogeny and has been subjected 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. $\lambda 87\text{Rb} = 1.39 \times 10^{-11}$) 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

This group consists for the most part of supracrustal rocks probably derived from the Point Lake or Contwoyto and Itchen formations of the Yellowknife Supergroup that have been intimately intruded by granitic rocks. Some are diorite agmatites 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 suggest from which formation of the Yellowknife Supergroup 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 nongranitic phase. These subunits are listed in the following table with their inferred correlatives within the Yellowknife Supergroup.

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 seven 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 probably exist 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, wisps or lenticular bodies of biotite-rich or hornblende-rich rock are present locally, parallel with foliation. Very commonly bodies of hornblende-rich gneiss 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 and consist 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 (Table 6), 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 quartzofeldspathic 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 displayed an unusually low negative optic axial angle of about 40 degrees. Minor amounts of a pale brown amphibole, magnetite and traces of 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 lamellae locally contain cordierite crystals with andalusite as larger grains around 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 also 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 a body of serpentinite is isolated 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 upfaulting 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 iron sulphide 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. Rocks are similar 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 were not differentiated from it in this study.

The amphibolite and hornblende gneiss are mostly 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 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 (Angh)

Large bodies of agmatite composed of fragments of diorite, hornblende gneiss or basic volcanics intruded by granitic rocks lie north 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 form 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 amounts of 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 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 to 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 shows it to be somewhat more mafic and calcareous than the massive tuffs of the Point Lake Formation (Table 2).

Agmatite about the Kaskarrah 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. Contacts between the 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 appears 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- to 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, which 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. Amounts of chlorite, epidote and traces of quartz, biotite, apatite and sphene are variable. 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 3½ miles wide (5.6 km) extends for about 4½ milse (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 around 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 is distinctly less abundant in the layered rocks particularly on the east margin. There is therefore some possibility that the eastern contact may be an extension of the unconformity described at Keskarrah Bay.

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 amounts of quartz and magnetite or iron sulphide are present in places, and small amounts of carbonate, epidote and chlorite are alteration products. Trace amounts of apatite are 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 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 some exhibit a bluish colour. The hybrid volcanics are intruded by granitic rocks but in some

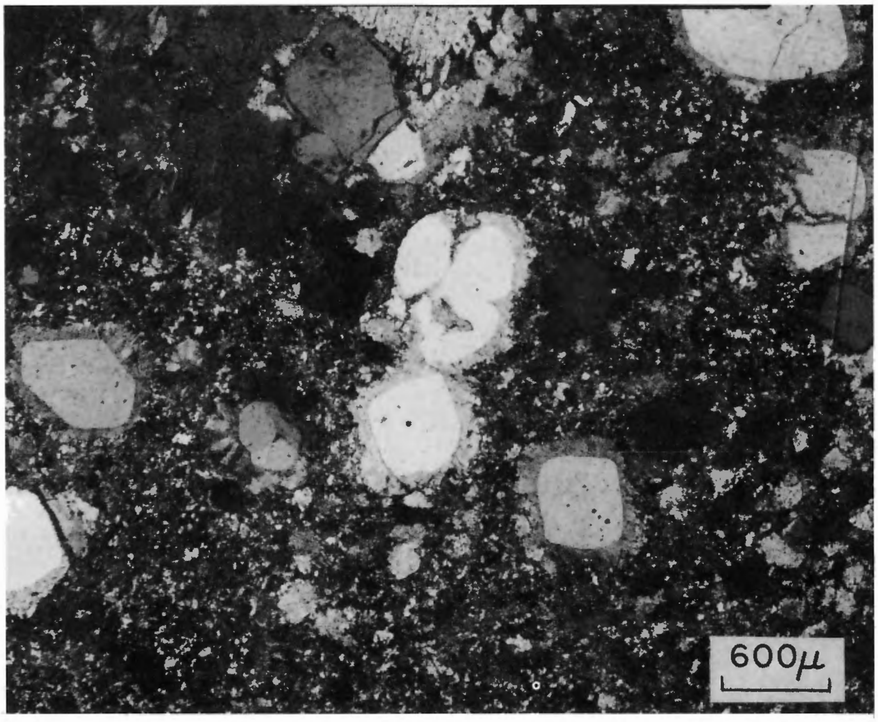


Figure 35. Quartz phenocrysts with matrix haloes in hybrid felsic volcanic rocks south of Rockinghorse Lake. GSC 202163-I.

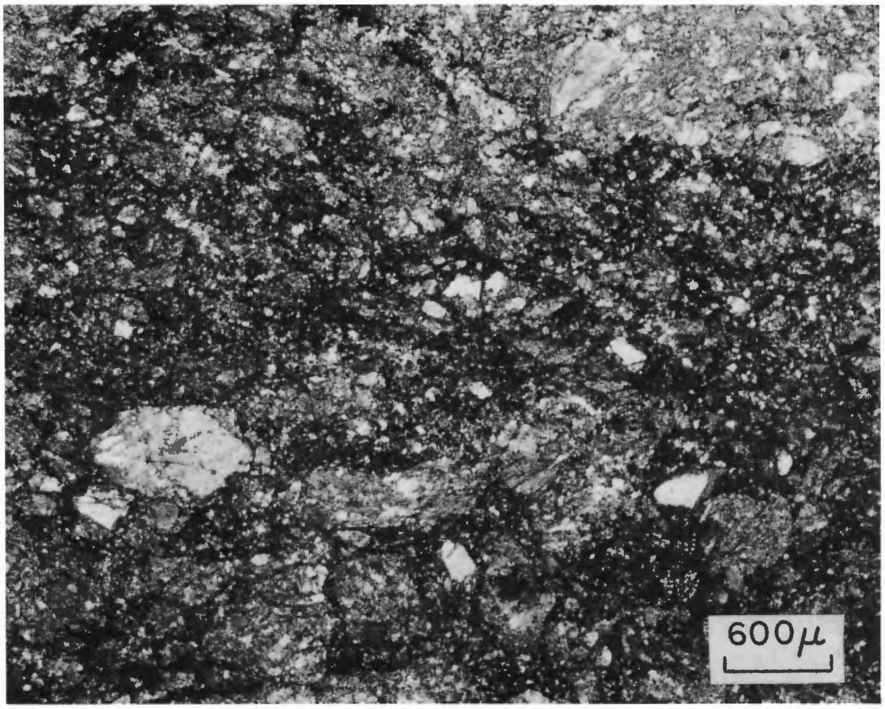


Figure 36. Felsitic breccia fragments in breccia within the shear zone east of Yamba Lake. GSC 202163-V.

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 sulphide. Scattered fragments and possible phenocrysts of plagioclase up to 1 mm in length are present. The matrix plagioclase contains flamelike 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

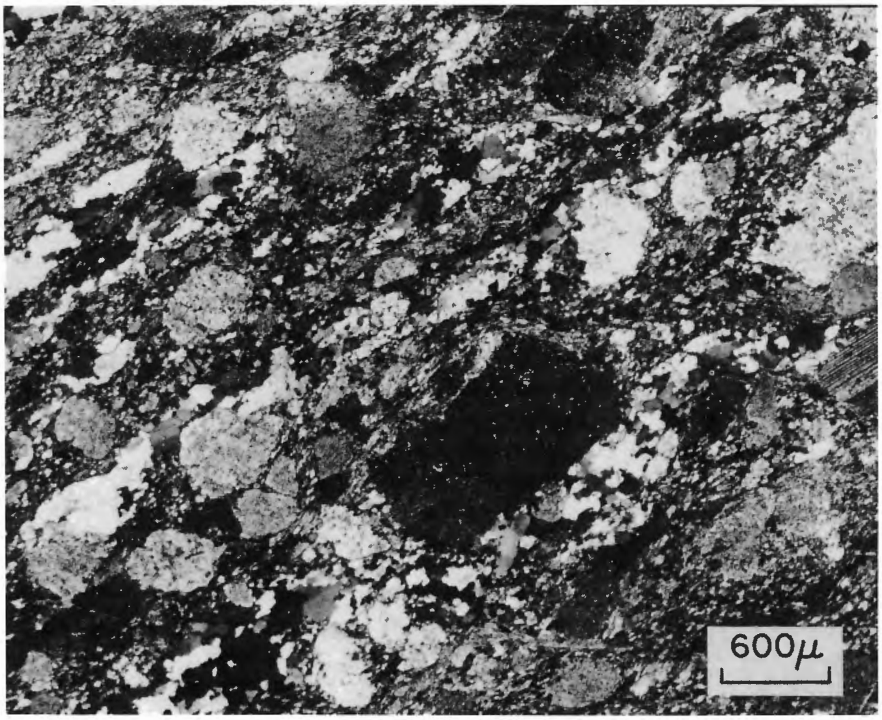


Figure 37. Blocky oligoclase megacrysts in sheared granitic rocks within the sheared zone at the east margin of the Yamba batholith. GSC 202164-S.

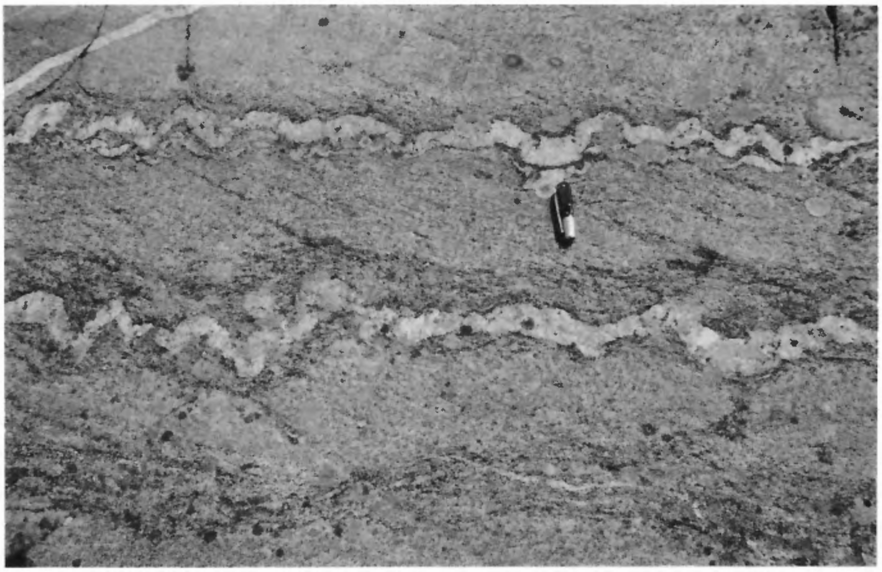


Figure 38. Lit-par-lit gneiss minimally deformed but intensely recrystallized shows segregation of granitic material from pelitic layers (?). GSC 114458.

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 (Fig. 35). Carbonate, muscovite and chlorite are common secondary products and trace apatite and zircon are local. 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 are primarily composed of quartz and calcic oligoclase with minor chlorite and biotite, and trace apatite and zircon.

An altered basic dyke intruding quartz diorite consists principally 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 0.1 to 1 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 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 be seen locally 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

Figure 39. Lit-par-lit gneiss shows granitic material in minor crosscutting veins perhaps derived from mobilization of segregations such as those shown in Figure 37. GSC 114448.

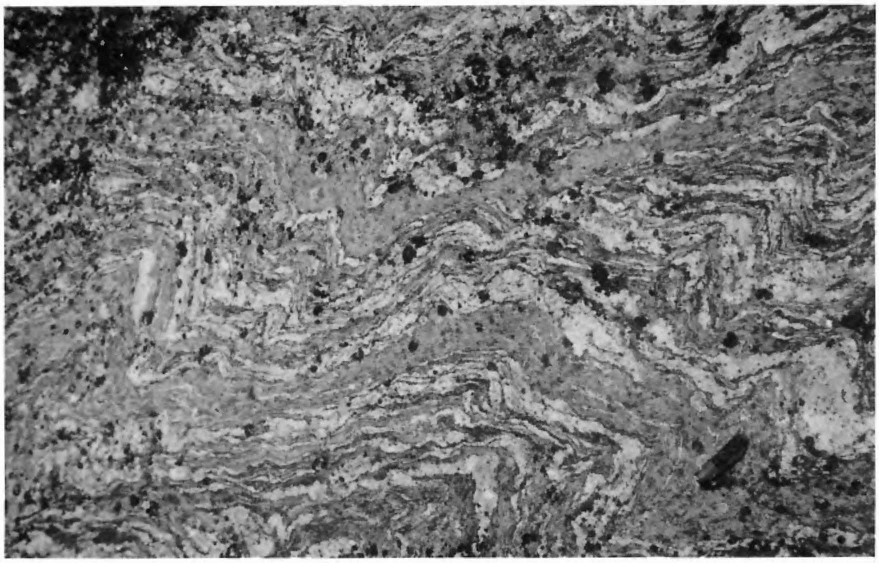


Figure 40. Ptygmatically folded lit-par-lit gneiss. GSC 114450.

composed of fragments of earlier breccia, quartz and feldspar in a very fine grained siliceous matrix containing a little chlorite, muscovite and epidote (Fig. 36). Early breccia fragments are very similar to those in which they are included and fragment boundaries are 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 muscovites 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.

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 (Fig. 37). Trace amounts of apatite, epidote and allanite are also present.

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. These rocks may have interleaved with migmatites of the greywacke-turbidite succession through intershearing of migmatite with felsic volcanic rocks originally lower in the stratigraphic section. The age of shearing is late Kenoran or younger as it has deformed surrounding granitic rocks of the Yamba batholith.

Lit-par-lit gneiss (Angb)

Lit-par-lit gneisses, as used in this report, refer to foliated, biotite-bearing, pelitic gneisses within which discontinuous, generally sheetlike, 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

Figure 41. Disrupted lit-par-lit gneiss. GSC 114458.

Figure 42. Lit-par-lit gneiss showing large granitic lenses exposed at hill tops with gently dipping pelitic schist bands exposed along their flanks. GSC 114481.

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, partly because the large granitic plutons in this region may have been emplaced mostly prior to their deposition and metamorphic grades are lower, and partly 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-sulphide 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 sulphide 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 schist locally bearing iron sulphide.

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 (Figs. 32, 38, 39) to highly deformed and almost completely disrupted gneisses (Figs. 40, 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 (Fig. 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 (Anhb and Angh)

A narrow belt of hybrid and granitic rocks, which 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 northern 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.

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 chlorite. Although the gneiss megascopically resembles some metamorphosed ultramafic rocks, a chemical analysis (Table 8) 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 originally a siliceous dolomitic metasediment.

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 (Fig. 43), but in the immediate vicinity of Point Lake amphibolite, metagreywacke and migmatite are also present. These may represent a more highly altered part of the Point Lake Formation.

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 permatite bodies, most of which are less than 50 feet (15 m) wide, are common in the map area where rocks have reached amphibolite facies grade. They are white to pinkish and are composed 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 long. 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 concentrations were detected.

Figure 43. Hornblende-biotite gneiss from the Western plutonic zone near Point Lake. GSC 121145.

In thin section the pegmatitic tourmaline shows strong pleochroism, with E colourless and O blue to olive-brown. Frequently the crystals are zoned so that when viewed parallel with O a sky-blue core is surrounded by an olive rim. Some zone boundaries are 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. com., 1974) reported 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 near other pegmatites that he sampled. 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 that gave rise to the enclosing schists.

Black tourmaline was collected from pegmatites in various parts of the map area (Fig. 44) for qualitative and semiquantitative spectrographic analysis. Crystals were crushed, inclusions excluded, and the residue analyzed in bulk. The result of these analyses are shown in Table 9. Five samples from the Contwoyto Lake region of the map area were kindly supplied by L.P. Tremblay.

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 are most common. Individual trace elements show no clear relation to geological setting but there is a suggestion that the trace element population increases in complexity (number of elements present) southwestward toward Keskarrah Bay. Additional data will be needed to confirm this trend, but further investigations

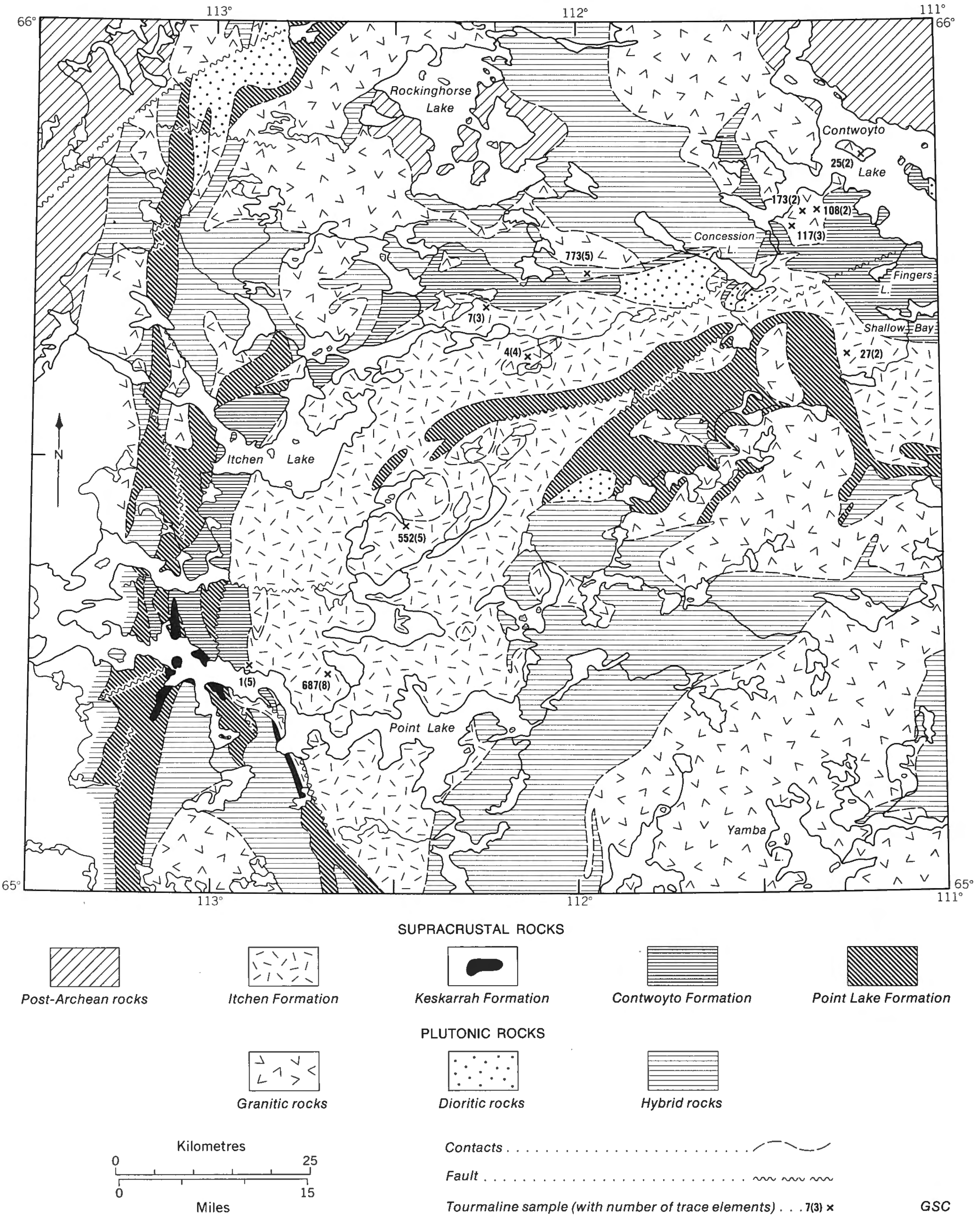


Figure 44. Localities represented by partly chemically analyzed tourmaline samples.

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 (1924) 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 (1974) into five conformable formations. These comprise: the Odjick Formation (2100 feet, 640 m), mainly argillite and quartzite; the Rocknest Formation (2300 feet, 700 m), mainly dolomite; the Recluse Formation (2000 feet, 610 m), mainly shale, argillite and siltstone; the Cowles Lake Formation (2600 feet, 792 m), mainly limestone and argillite; and the Takiyuak Formation (1200 feet, 366 m), mainly sandstone and siltstone, for a total at the east margin of the Epworth Group of about 10 000 feet (3000 m).

Mapping during the present study was carried out up to the edge of the Epworth Group in the northwest corner of the area. Description of the group is taken from Fraser (1974).

Odjick Formation

The name Odjick Formation, derived from Odjick Lake west of the Itchen Lake map area, is applied to the argillite-quartzite succession at the base of the Epworth Group (ibid.). It is about 2100 feet (640 m) thick on the east margin of the Epworth basin where it enters the map area but thickens westward to 7500 feet (2286 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 (ibid.).

Rocknest Formation

The name Rocknest Formation (ibid.) is derived from Rocknest Lake on Coppermine River west of the map area, and is applied to the predominantly carbonate succession that overlies the Odjick Formation. The formation is 2300 feet (701 m) thick along the east margin of the Epworth basin near the Itchen Lake map area but thickens to 5500 feet (1676 m) farther west. Its base 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

The name Recluse Formation is derived from Recluse Lake, the locality of the type section (ibid.). The formation consists primarily of argillite, siltstone and greywacke with minor limestone. It is about 2000 feet (610 m) thick in the eastern part of the Epworth basin near the Itchen Lake map area and thickens westward to at least 6500 feet (1981 m). Its base 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 interlaminated 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

The type section of the Cowles Lake Formation (ibid.) is at Cowles Lake in the northwest corner of the map area. There the formation consists of 2600 feet (792 m) mainly of interbedded limestone and argillite. The base 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 red occurring only in the upper half of the formation where it is interbedded with grey or greenish argillite. Argillite near the base and top of the formation contains limestone lenses or concretions, and breccia in the upper part is composed of tabular fragments of limestone in an argillite matrix. Beds of greywacke with interlaminated limestone and argillite occur just below the red argillite.

Takiyuak Formation

The name Takiyuak Formation is derived from Takiyuak Lake north of the Itchen Lake map area (ibid.). 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 1200 feet (366 m) of section is preserved.

The Takiyuak Formation consists of reddish brown sandstone locally grading into siltstone. Ripple marks are local at the base of the formation and crossbeds are 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' 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 to the original quartzite, argillite, slate, dolomite and sandstone in the Western River area, which 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 Contwoyto Lake area was divided by Tremblay (1967) into four formations, which include in ascending order: the Western River Formation (1350 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 argillites, for a total of about 2250 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 Itchen Lake map area.

The Goulburn Group is exposed at the north end of Contwoyto Lake, and on either side of Rockinghorse Lake, where only the lowermost unit, the Western River Formation, is preserved. That part of the group northeast of Contwoyto Lake was not examined 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 Gouldburn 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. The Basal Conglomerate member at Contwoyto Lake is discontinuous and the lowest beds are probably a regolith as they fill fractures in the schist below. No similar conglomerate is exposed in the eastern exposures at Rockinghorse Lake, although there may be a few feet. However, west of the lake 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 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. 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. A few thin beds of grey to white, glassy quartzite are near the base 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. Furthermore, it appears likely that the Lower Argillite member thickens westward from 285 feet (87 m) at Contwoyto Lake 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. 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 (Figs. 45, 46), is 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 here and there appear to be interbedded with argillite. These quartzite beds are reminiscent of those in the Lower Argillite member and some are 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 an 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 interbedded within the Red Siltstone member. In either case they appear to indicate a northward facies change within the inlier.

Figure 45. Isolated calcareous concretions in the Red Siltstone member at Rockinghorse Lake. GSC 114532.

Figure 46. Stromatolitic bed in concretionary argillite of the Red Siltstone member at Rockinghorse Lake. GSC 114533.

Quartzite member. 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 local 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 1 foot (0.3 m) thick and interlayered with grey-olive argillite, laminated quartzite, white quartzite and greenish greywacke. Crossbedding is local. 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. 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 pink quartzite beds and is generally sharp. The uppermost beds of the Rockinghorse Lake outlier may correlate with this member.

Burnside River Formation

Tremblay (1971) applied the name Burnside River Formation to a thick succession of pink quartzite and quartz-pebble conglomerates overlying the Western River Formation in 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 corresponds 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 chiefly 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

Tremblay (1967) suggested the name Peacock Hills Formation 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

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 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 are 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 (1.39×10^{-11} yr^{-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 up to 1555 m.y; the oldest date was 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 a Hudsonian age of 1760 m.y. The minimum age of the Epworth Group is therefore Hudsonian and correlation of Goulburn and Epworth groups (Fraser and Tremblay, 1969) suggests that this minimum age 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, which 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 Hudsonian granite along the western margin of the geosyncline was emplaced 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 2000 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, preorogenic, terrigenous phase of sedimentation (ibid.), which within the present map area represent cratonic (Goulburn) and marginal (Epworth) 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 in colour 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 shoreline. Subsequent darker 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 (ibid.). At Rockinghorse Lake these 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 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 (2100 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 are general throughout the Itchen Lake map area but they are 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 concentration of northwest trending dykes is less marked 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 was reported by Tremblay (1967) near Contwoyto Lake. All appear to dip steeply.

A few west-northwest to west-southwest striking diabase dykes are present within the northern part of the map area. These are up to 150 feet (46 m) thick and most appear to be steeply dipping although the dip of one was observed to be 55 degrees to the south. Some of the westerly striking dykes are porphyritic with plagioclase phenocrysts up to 2 cm long, 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 around 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

Three west-northwest striking diabase dykes (Table 10) were chemically analyzed. 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.

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 probably comprises the westerly striking 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, which are reported by Fraser (1974) within the Rocknest Formation 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, that is, between 1750 and 2000 m.y.

Equigranular diabase to gabbro sills have intruded the Goulburn and Epworth groups. These 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 is known to intrude the Goulburn Group in the vicinity of the sills, although they appear within the Archean rocks a few miles 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 of 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 swarm 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 1473A, section A–A_1).

Metamorphism

Archean supracrustal rocks within the map area show wide variations in metamorphic grade, which 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 vapour 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 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 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 cummingtonite first appears (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 exist 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 (1976). 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 affect their colour markedly 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 (ibid.). 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 is found in a lens of calcareous metasediments and anthophyllite in metamorphosed 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 is probably within the felsic volcanic rocks although diagnostic assemblages were not observed. To the north of the 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 7 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 or chlorite. Neither cordierite nor andalusite was 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 commonly are 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 lower amphibolite facies belt 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 on either side of Point Lake at the entrance of Coppermine River.

Within the pelitic rocks of the Contwoyto and Itchen formation 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 some 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-sulphide iron-formation lenses, where it is accompanied by blue-green hornblende, grunerite and quartz.

In the volcanic rocks lower amphibolite facies metamorphism is recognized with less certainty but is probably reflected in the well crystallized hornblende–calcic oligoclase assemblages without appreciable epidote that are present in the northern and extreme southern parts of the Western volcanic belt. The cummingtonite and basic plagioclase in the northeast arm of the Central volcanic belt indicate that at least lower amphibolite facies conditions were reached. In the southern arm cummingtonite was observed only 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 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 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.

Sillimanite-cordierite-muscovite–bearing assemblages characterize pelitic rocks of this zone. 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 appear 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 in the lower amphibolite facies zone 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 breakdown 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 breakdown temperature of muscovite. Thus sillimanite-microcline-cordierite and andalusite microcline-cordierite assemblages are interspersed, and both sillimanite and andalusite coexist at some localities. On the basis of Winkler's data (1967) these assemblages indicate that upper amphibolite facies metamorphism northwest of 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 suggests that still higher temperatures were attained. This assemblage appears in a calcareous band within a migmatite succession in which andalusite is present and suggests 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 usually green and plagioclase diffusely, reversely zoned. Quartz, biotite and microcline appear 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-sulphide 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 sulphide, 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, particularly in Mg:Fe ratio, could be clearly related to metamorphic grade attained as deduced from mineral assemblages in the neighbouring pelitic rocks. Limiting values for ferric iron contents in hornblende were calculated by the method of Stout (1972). The investigation (Bostock, 1977) showed, however, that the Mg:Fe ratio in the amphiboles has been affected primarily by three factors: (1) the Mg:Fe ratio of the host beds, which governs the gross Mg:Fe composition of the amphiboles, (2) the alumina content of the host beds, which affects the extent of octahedral aluminum substitution in hornblende thereby altering the distribution of magnesium and iron between the coexisting amphiboles, and (3) the crystallization of an iron-rich garnet, which shifts both accompanying amphiboles toward more magnesian compositions. A fourth factor, the oxygen fugacity, is potentially significant but requires more accurate determination of ferric iron for its evaluation.

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 subfacies. The Itchen Lake area therefore provides an unusually good opportunity for investigating the 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 11, and the localities represented are shown in Figure 47. No

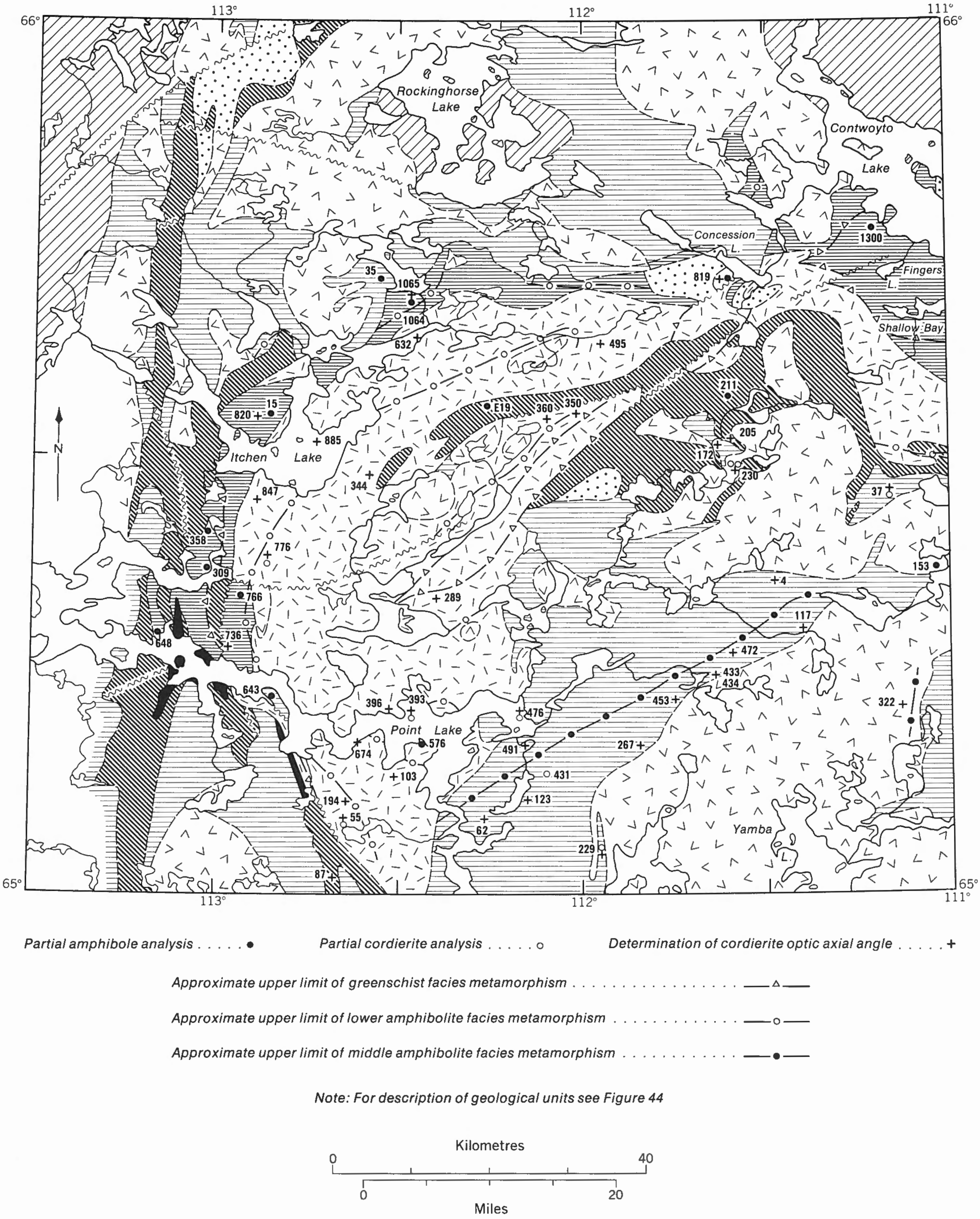
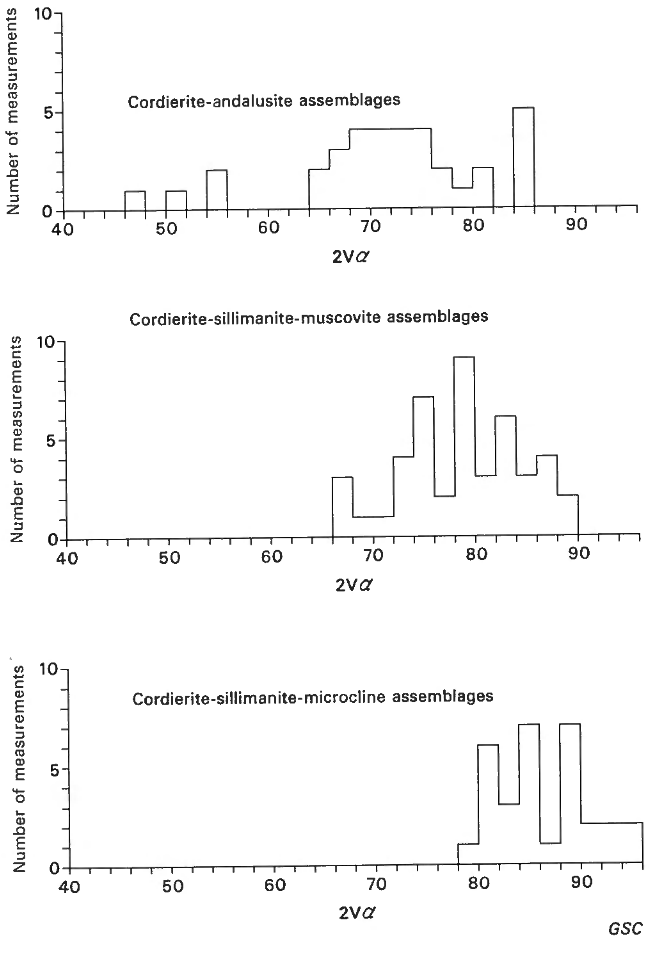


Figure 47. Localities represented by partly chemically analyzed amphiboles and cordierites.

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.

The range of 2V alpha obtained for cordierite is illustrated in histograms (Fig. 48). 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 et al. (1962). However, the upper inflection 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 (Table 12). The method used is believed accurate to within 2 to 10 per cent of the value given depending upon the element concerned and the amount present.


Cordierite-andalusite assemblages

Cordierite-sillimanite-muscovite assemblages

Cordierite-sillimanite-microcline assemblages

GSC

Figure 48. 2V alpha frequency in cordierite in three subfacies of the amphibolite facies.

Discussion. Miyashiro (1957) has shown that optical properties of cordierite including 2V alpha depend in part upon the structural state that is related to the thermal history of cordierite. Iiyama (1958) showed that natural cordierite, converted to high-temperature cordierite by heating at various pressures, lost water and increased its 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 et al. (1962) 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. On the other hand sodium 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-Si 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 usual trend locally.

The regional variation of 2V alpha of cordierite from pelitic schists within the Itchen Lake area is illustrated in Figure 49. This variation clearly is prominently affected by regional metamorphism around 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.

Comparison of cordierite from middle amphibolite facies rocks around 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 batholithic 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

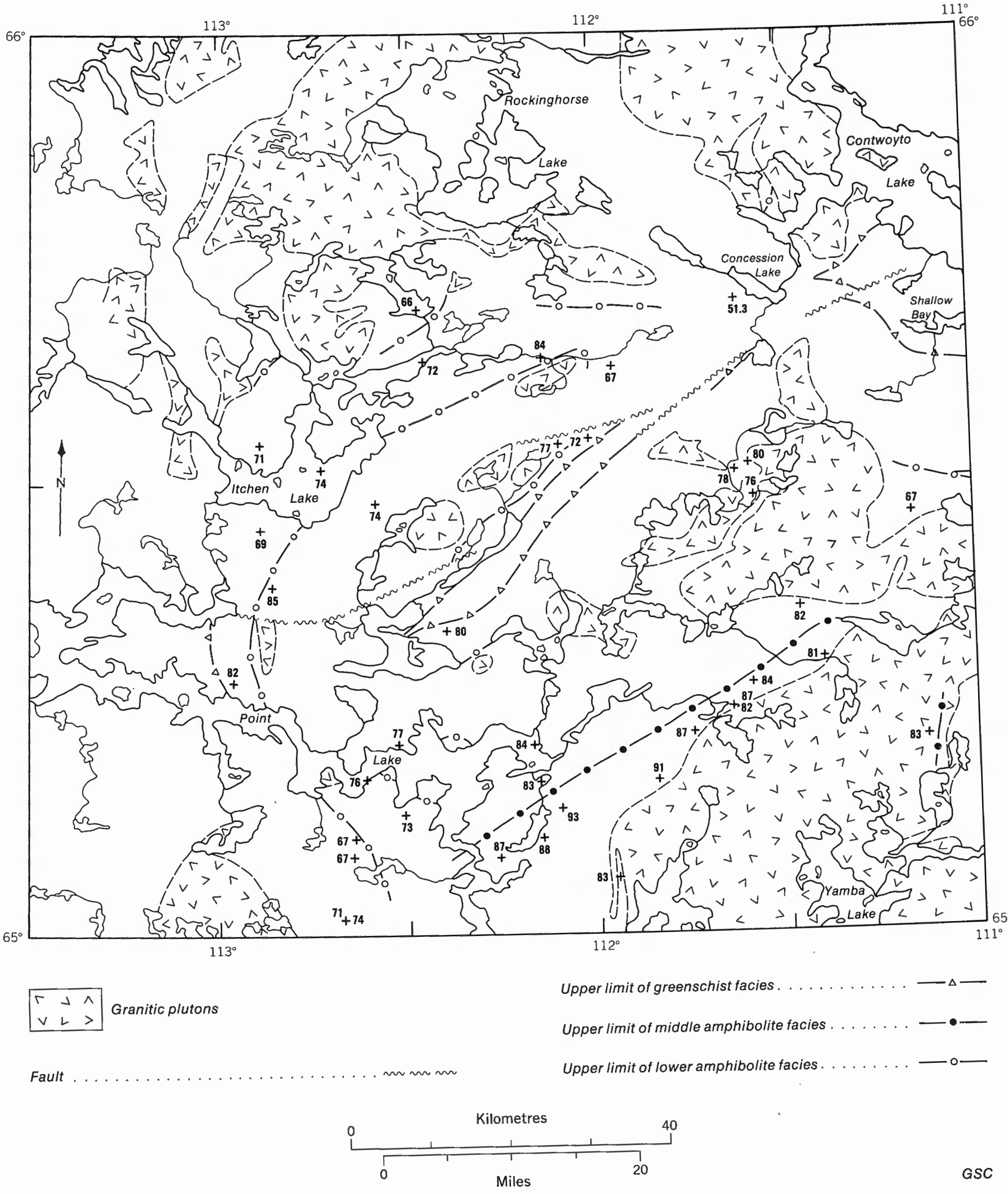


Figure 49. Variation in 2V alpha in cordierite with respect to metamorphic grade.

of better retention of water, and equilibration to lower temperature, better ordered states because of 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

Within the nodular schists of the lower amphibolite facies low optic angles in cordierite are prominent in the northern part of the map area as would be expected with relatively higher pressures during metamorphism. Two anomalously high values of 2V alpha were obtained from schists 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 13. The zircon and sphene dates in the table are based on U decay constants as follows: λ^{238} U = 1.55126×10^{-10}yr^{-1}; λ^{235} U = 9.8485×10^{-10}yr^{-1}. The Rb/Sr isochron dates given in the table are based on the smaller decay constant (1.39×10^{-11}yr^{-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 ^{207}Pb/^{206}Pb dates of 2642 ± 15 and 2637 ± 15 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 around 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, folding 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.

The Yamba batholith, which intrudes the greywacke-turbidite succession, gives an Rb/Sr isochron date of 2422 ± 98 m.y. (λ^{87}Rb = 1.47×10^{-11}yr^{-1}) or 2562 m.y. (λ^{87}Rb = 1.39×10^{-11}yr^{-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 of about 2350 ± 105 m.y. (λ^{87}Rb = 1.47×10^{-11} yr^{-1}) or 2485 m.y. (^{87}Rb = 1.39×10^{-11} yr^{-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 postemplacement 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

In most parts of the Contwoyto and Itchen formations beds typically less than 18 inches (45 cm) thick are well defined 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 (Figs. 18 and 19), but locally include scour and fill structures (Fig. 31) and load casts (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 (Fig. 9).

Foliation

In most parts of the map area planar distribution of metamorphic minerals has produced a foliation that is generally 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. The thicker accumulations of Archean volcanic Rocks (Point Lake Formation) are distributed about the margins of these batholiths 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 around 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. These bodies were emplaced 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 Central 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, is 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, saddlelike 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 downfaulted blocks of the greywacke-turbidite 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 becomes younger 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 parts 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 batholith 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 crossfolded. The northwest arm of the belt appears to be faulted along at least part of its extent against downdropped 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 southeast of Gossan Lake near the east margin of the map area where amphibolite and a few pillowed flows are present. The appearance of banded tuffs within the greywacke-turbidite succession at the east margin of the map area suggests a northwest plunging antiform in this region.

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 lithological 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 (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, around 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 outer 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 (1974) and those within the Goulburn Group at Contwoyto Lake by Tremblay (1976). The present report deals only with structures in the Goulburn Group at Rockinghorse Lake.

Beds in the Goulburn Group at Rockinghorse Lake mostly lie flat or dip gently; dips of 5 to 10 degrees are 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 (143 m) 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. The evidence for faults in this zone includes prominent lineaments where exposure is good, abrupt truncation of lithological 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 downdropped, 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 volcanic rocks of the Point Lake Formation, which comprise the oldest known rocks within the map area, over extensive areas are in contact with early Kenoran quartz dioritic to granodioritic plutons or are separated from these plutons by hybrid zones made up of mixtures of volcanic and plutonic rocks. Preliminary Rb/Sr isochron dating of gneiss of similar composition to these plutons, 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. ($\lambda^{87}\text{Rb} = 1.39 \times 10^{-11}\text{yr}^{-1}$) or 2838 m.y. ($\lambda^{87}\text{Rb} = 1.47 \times 10^{-11}\text{yr}^{-1}$) (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, since it is 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 (96 km) south of the map area, and perhaps as far north as the Arctic Coast, a distance of some 240 miles (384 km). 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 time of formation of these rocks with respect to development of the volcanic belt as a whole is not established the mylonite zone is clearly of the 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 are 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 antiform 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 exhalative deposits. The final 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 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 Great Slave Supergroup 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

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 Company Limited in 1959 and 1960. Gold-bearing amphibolites (silicate-sulphide 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 Company 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 in the Contwoyto and Point Lake regions, Giant Yellowknife Mines in the Point Lake region, Canadian Nickel 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 Figure 50 and the locations of showings examined during the current work are given in Table 14. Interest in the area has been renewed since Texasgulf Inc.

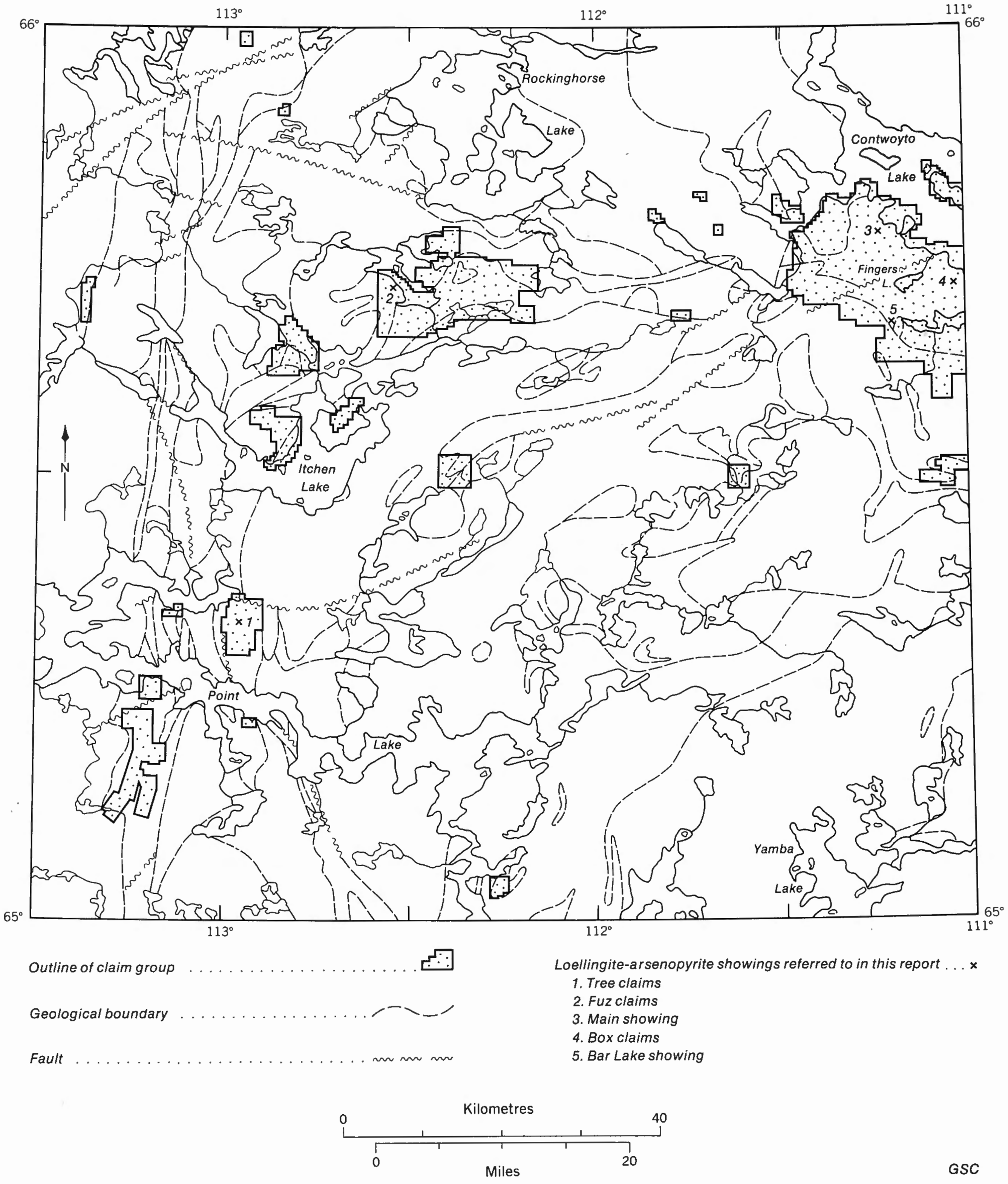


Figure 50. Regions staked prior to 1974 within the Itchen Lake map area.

discovered zinc-copper-lead-silver mineralization immediately northwest of Itchen Lake in 1975.

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 quartzofeldspathic gneiss discovered since field work for this report was done; gold-arsenopyrite-loellingite deposits associated with sulphide-silicate iron-formation facies; and niccolite-pyrrhotite at the contact of a small metagabbro body with silicate-sulphide 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 chalcopyrite 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 there a pillow breccia contains oxide facies iron-formation as a matrix like that in the adjacent Contwoyto Formation. This breccia is 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 lithological 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 exhalative base metal sulphide deposits. In the Itchen Lake area, however, available stratigraphic information 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 sulphide 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 developed 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) sulphide 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.

Chalcopyrite-pyrrhotite related to early basic volcanism

Minor amounts of chalcopyrite accompany pyrrhotite in dark slate and greenschist exposed in shallow trenches along the west margin of the Western volcanic belt 6 miles (9.6 km) 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 2 miles (3.2 km) 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 about equal amounts of coarser grained chalcopyrite and pyrrhotite are concentrated along a few minor fractures. Further description of this occurrence is given by McGlynn (1973).

Minor chalcopyrite and pyrrhotite are found 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 approximately 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.

Base metals associated with felsic volcanism

Sphalerite-chalcopyrite-pyrite near Itchen Lake

An important discovery of zinc-copper-lead-silver mineralization about 2 miles (3.2 km) northwest of Itchen Lake (approximately 65°39′N, 112°49′W) was made by Texasgulf Inc. in the summer of 1975 (P.L. Money, pers. com., 1975). The deposit does not outcrop but is beneath a small lake known to Texasgulf as 'Izok' Lake. Its presence was suggested by mineralized float and was discovered 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 (427 m) 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 ounces per ton silver. The host rocks are quartzo-feldspathic gneisses probably of volcanic origin that have undergone polyphase deformation. A typical section of the central zone (provided by Texasgulf) is shown in Figure 51.

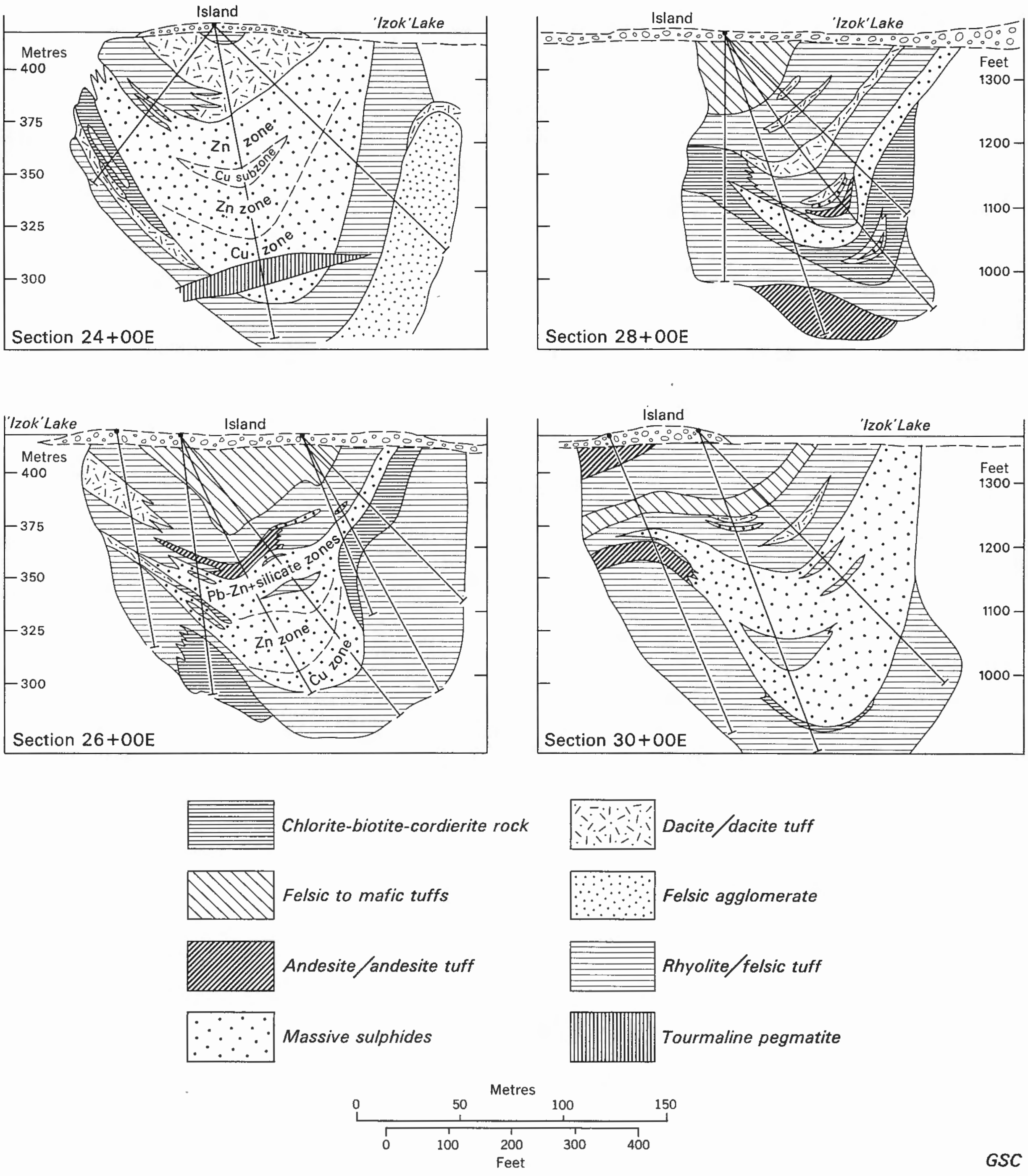


Figure 51. Representative section of the central zone, 'Izok' Lake base metal deposit (after Money and Heslop, 1976, Texasgulf Inc.).

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 uniformity. 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°, 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 is 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 [see Fig. 52] 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 indi-

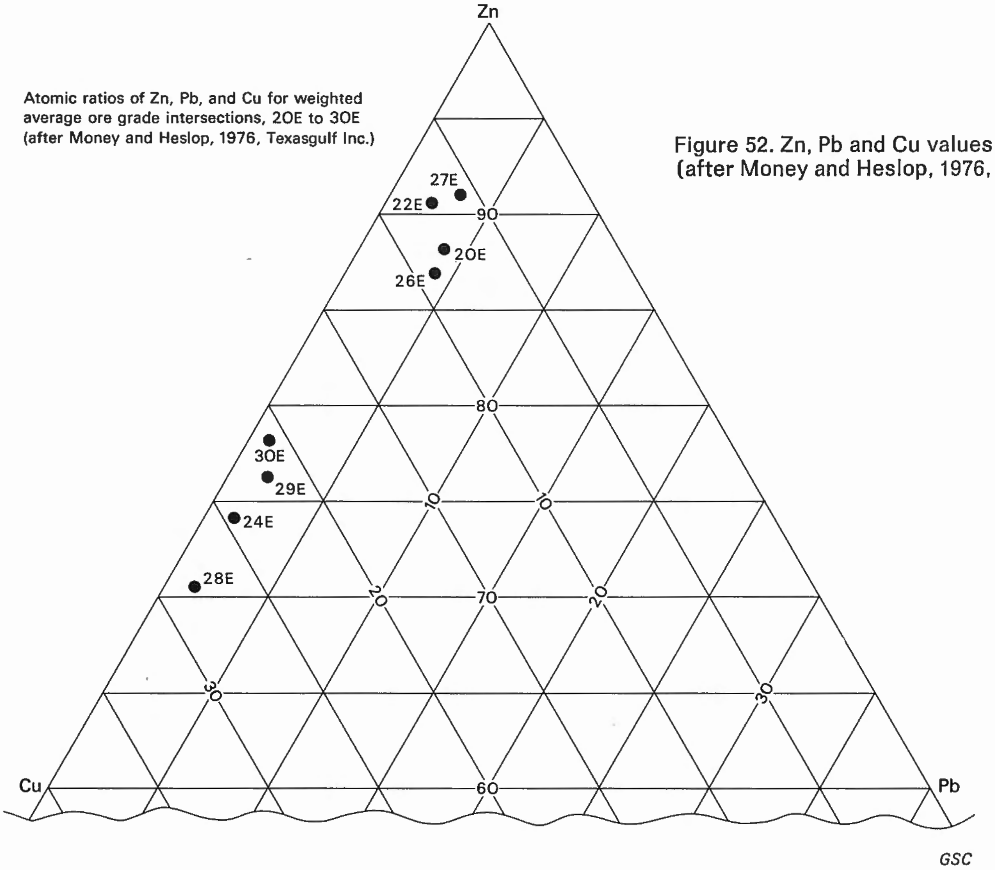


Figure 52. Zn, Pb and Cu values for the central zone, 'Izok' Lake (after Money and Heslop, 1976, Texasgulf Inc.).

cates 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-mobilization.

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 commonly are ¼″ or more.

Some more recent details of the deposit (P.L. Money, pers. com., 1977) are as follows:

1. As of the end of 1976 over 12 million tons of indicated ore grading 13.7% Zn, 2.82% Cu, 1.42% Pb, and 2.05 oz/ton Ag had been drilled off. This ore occurs in the main (central) zone, north zone and northwest zone. The strike length of the main zone has been extended to 2000 feet (610 m), the north zone to 700 feet (213 m), and the northwest zone to 1500 feet (457 m).
2. The main, north and northwest zones are interpreted as synclinal remnants of an originally continuous oval massive sulphide body of the order of 3000 feet (915 m) long and 1000 feet (305 m) wide prior to folding.
3. Other massive and disseminated sulphide zones are present on the south shore of 'Izok' Lake. They probably represent the same stratigraphic horizon as the main zones.
4. Drilling in 1976 showed that variations in sulphide thickness are at least partly due to thinning on fold limbs and thickening in fold troughs. However, it is considered likely that original variations in sulphide thickness helped to localize fold axes. The feature previously interpreted as a volcanic cone or ridge in the main (central) zone between line 26E and 28E may in fact be an anticlinal 'cross' fold (localized by an originally thin part of the sulphides?).
5. Sulphide zoning confirms that the main (central) zone overlies or was near a vent. The overall grade for the main zone is 3.54% Cu, 1.18% Pb and 14.0% Zn, whereas the grade for the northwest zone is 1.72% Cu, 1.88% Pb and 13.1% Zn. Within the northwest zone the Zn content increases away from the main zone. On line 12E the change is from 4% to 7.5% to 25.2%. On line 16E it is 9% to 13.8% to 19%. This trend to concentration of Cu near the source and of Zn away from it has been documented for many other volcanogenic sulphide deposits.
6. The amphibolite at 'Izok' Lake unconformably overlies the massive sulphides and their felsic volcanic host rocks. It is uncertain whether the amphibolite is a locally crosscutting metagabbro sheet or a thick metabasalt flow deposited on an irregular erosional surface.

Sphalerite-chalcopyrite-pyrite at Point Lake

On the south shore of Point Lake a little over 1 mile (1.6 km) northwest of Keskarrah Bay, sphalerite with pyrite is disseminated 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 semiconnected 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, 1 metre thick by at least 40 metres long, which contains massive sulphides (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 ounces per ton silver and trace (less than 0.010 ounce per ton) gold.

As a result of Henderson's (1975) report Noranda Mines Limited conducted a geophysical survey of the area and drilled three holes in the area of most favourable response. Two of the holes intersected narrow sulphide bands containing noneconomic sulphide mineralization. The third hole drilled directly under the showing intersected 0.9 m (core length) of sulphides assaying 4.83 per cent zinc, 1.59 per cent copper, 0.2 per cent lead, 0.02 ounce 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 N5° 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 the 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

Pyrrhotite and pyrite with minor chalcopyrite are disseminated 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 plutonic rocks are stained red over an area probably in excess of 1 square mile (2.59 km^2) 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 5 miles (8 km) 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 are 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 sulphide iron-formation in the hybrid rocks, or to hydrothermal activity which accompanied emplacement of the Contwoyto batholith.

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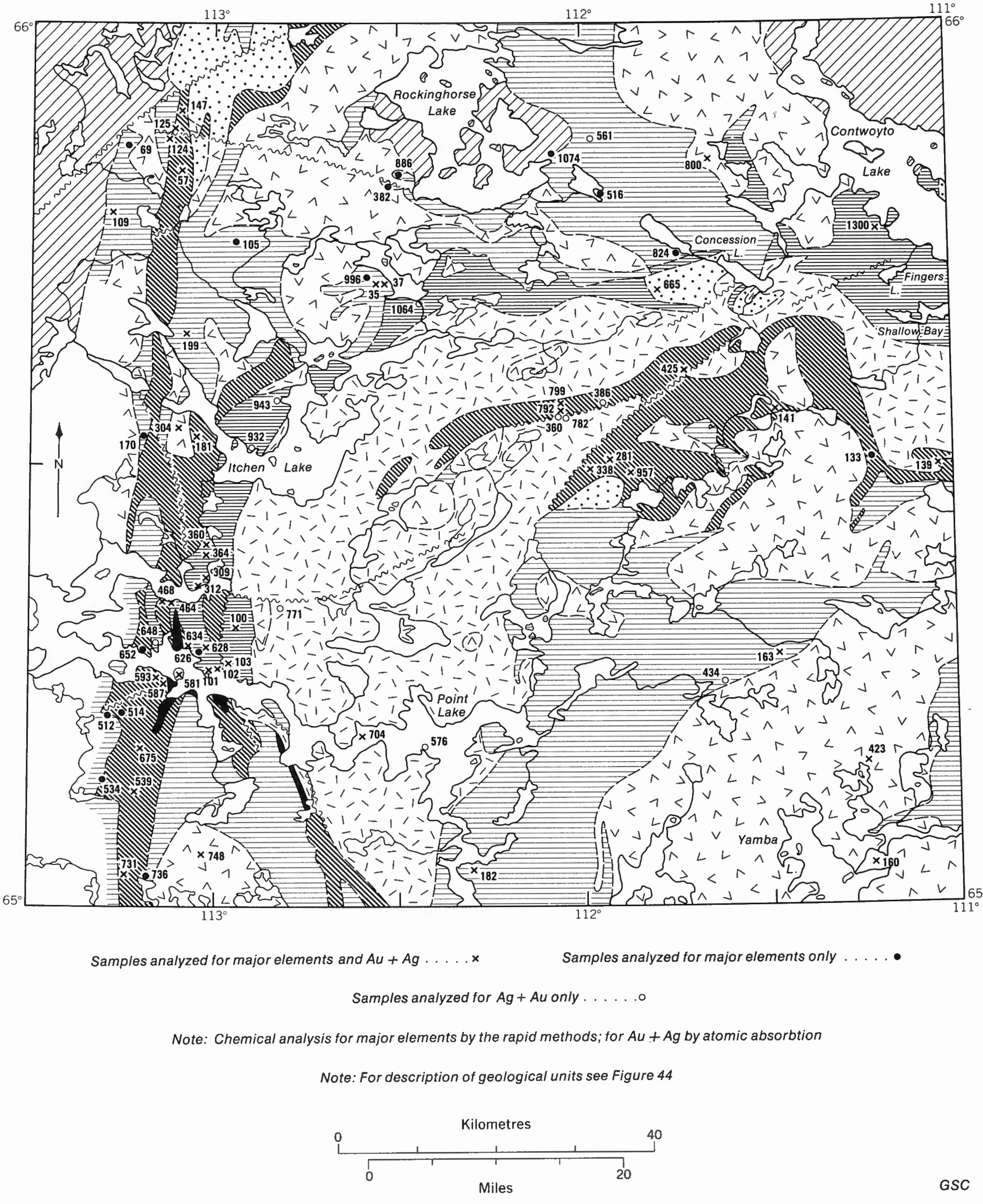
[1] W.R. Inman, Chief Chemist, Mines Branch [now CANMET, Department of Energy, Mines and Resources], Ottawa.



Samples analyzed for major elements and Au + Ag . . . . . ×

Samples analyzed for major elements only . . . . . ●

Samples analyzed for Ag + Au only . . . . . .○

Note: Chemical analysis for major elements by the rapid methods; for Au + Ag by atomic absorbtion

Note: For description of geological units see Figure 44

Figure 53. Distribution of chemically analyzed rock samples from the Itchen Lake area.

Figure 54. View northwestward, across part of the washed-down area at the Main showing, Contwoyto Lake (1966). GSC 121089.

Figure 55. Arsenopyrite-pyrrhotite-loellingite patches in banded silicate-sulphide iron-formation at the Main showing, Contwoyto Lake. Pale grey mineral in bands and intergrown in patches is pyrrhotite. GSC 200211-G.

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 sulphide 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 (Fig. 50). In the present reconnaissance, grab samples were selected for gold and silver analysis from each of the Archean lithologies exclusive of sulphide iron-formation (for distribution see Fig. 53) to see what distribution of these elements might obtain in rocks of this age in the Itchen Lake area. The analyses (Table 15) 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 perhaps slightly higher in the supracrustal rocks, especially those of the Contwoyto Formation. Gold concentrations are shown to be significant in samples 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 sulphide iron-formation facies because gold, if present in the environment, commonly concentrates in sulphides, especially pyrite (Jones and Fleischer, 1969).

Silicate-sulphide 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 sulphide 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 unweathered samples were difficult to obtain 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 sulphide facies iron-formation at widely scattered localities within the Contwoyto Formation.

Description of the principal gold-arsenopyrite-loellingite occurrences. The Tree claims (Fig. 50) of Giant Yellow-

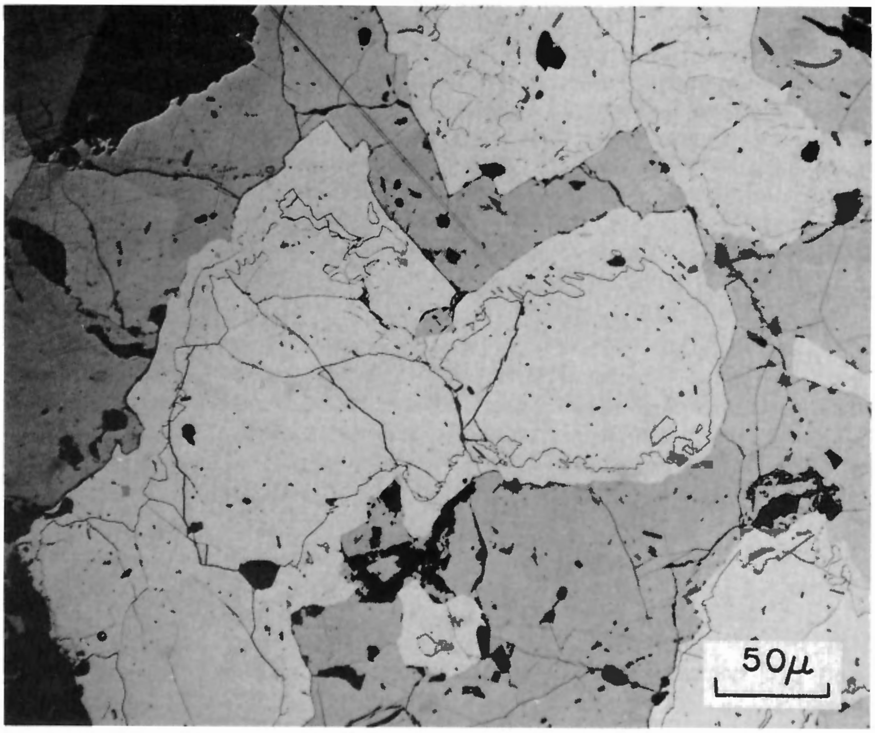


Figure 56. Loellingite-rich arsenopyrite-loellingite from the Fuz claims. Light-coloured phases are loellingite surrounded by arsenopyrite rims. Grey areas are pyrrhotite and black are silicates. GSC 200211-I.

knife Mines are located in rolling drift-covered country between the arms of Point Lake. A few frost-heaved exposures of banded silicate-sulphide 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 at least two silicate-sulphide iron-formation zones up to 0.3 m or more thick that 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 (Fig. 50) of Canadian Nickel Company are located in more rocky terrane about 7 miles (11 km) southwest of Rockinghorse Lake immediately to the east of the Fuz metagabbro. One or more bands of

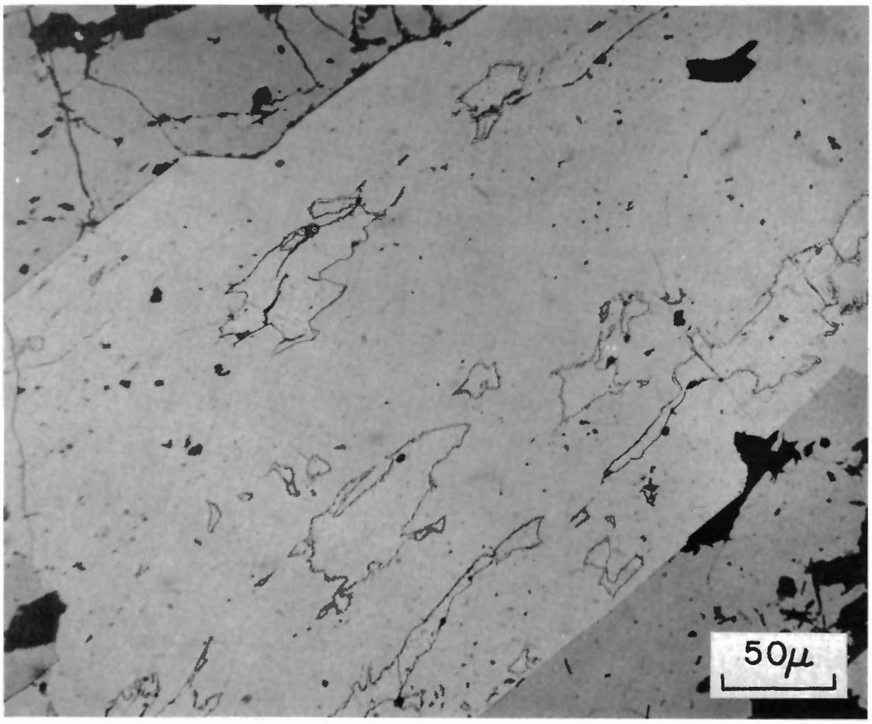


Figure 57. Arsenopyrite-rich arsenopyrite-loellingite from the Main showing. Minerals present are as in Figure 56. GSC 200823-D.

silicate-sulphide 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 crosscutting 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 (Fig. 50) 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 (Fig. 54). 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.

The Main showing consists of a principal silicate-sulphide iron-formation layer containing arsenopyrite-loellingite–rich beds, which 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 sulphide-bearing iron-formation lie some 800 feet (245 m) 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 long (Fig. 55). More rarely they appear in patches independent of bedding or in crosscutting veins. Arsenical patches may be diamond shaped or anhedral and are mostly intergrowths of arsenic minerals with pyrrhotite. Patches are generally elongate more or less parallel with layering in the host rocks, including some in gashlike lenses, but discordant masses are known.

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 (Figs. 55, 56 and 57). 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 sulphide 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 sulphide-rich iron-formation (Fig. 55).

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 (Fig. 58); in still other samples no late pyrite is evident but short tiny cracks of subequal length penetrate surrounding pyrrhotite at right angles from grain boundaries and fractures.

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 at the boundaries between arsenopyrite and loellingite (Fig. 59). 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 often 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 sulphide boundaries. Gold at intersilicate boundaries is prominent in one sample from the Fuz claims.

Chemical investigation of metallic minerals

Trace elements. Attempts were made to obtain ground separates of the metallic minerals of the sulphide iron-formation to determine the partition of trace elements gold, silver, nickel and cobalt. Pyrrhotite was found to be readily extractable by magnetic means. However, loellingite and arsenopyrite 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 Art Page of the Metallic Minerals Research Laboratory of CANMET. 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 nonfloat of 7.9 grams of 50 per cent arsenopyrite were obtained (Page, 1968). Spectrographic analyses gave the results shown in Table 16. 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.

Electron probe analyses of one sample each from the Fuz claims, from the Main showing and from the Tree

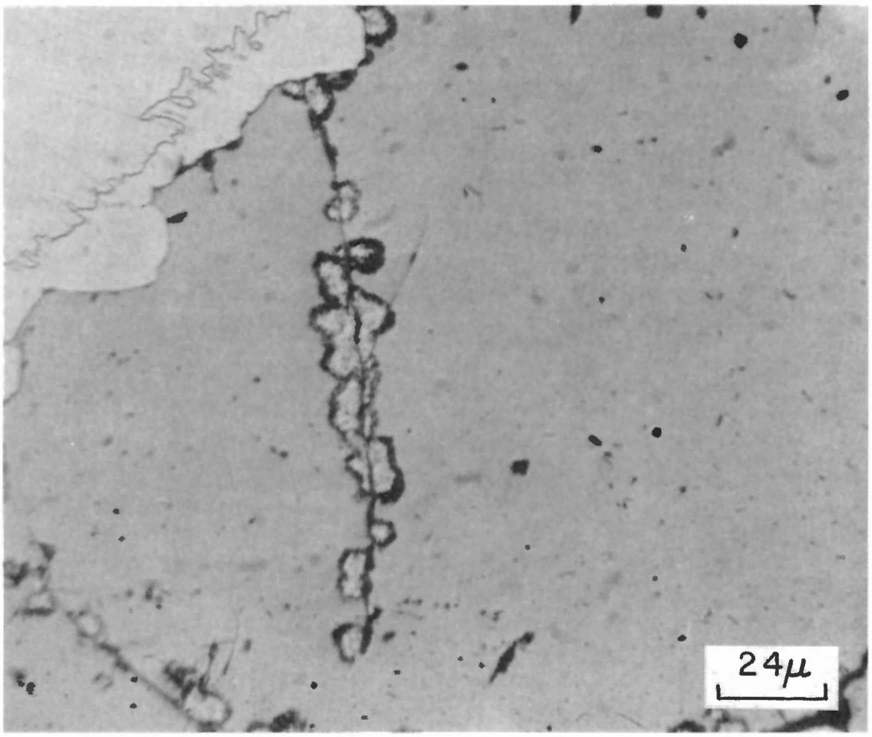


Figure 58. Pyrrhotite locally shows late alteration to pyrite along fractures and grain boundaries, Main showing (see Fig. 54). GSC 200823-E.

claims were made for nickel (Table 17). 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.

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 (Table 18). Grains were analyzed by making a line scan at 1 micron per second across individual grains with averages calculated at 10-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

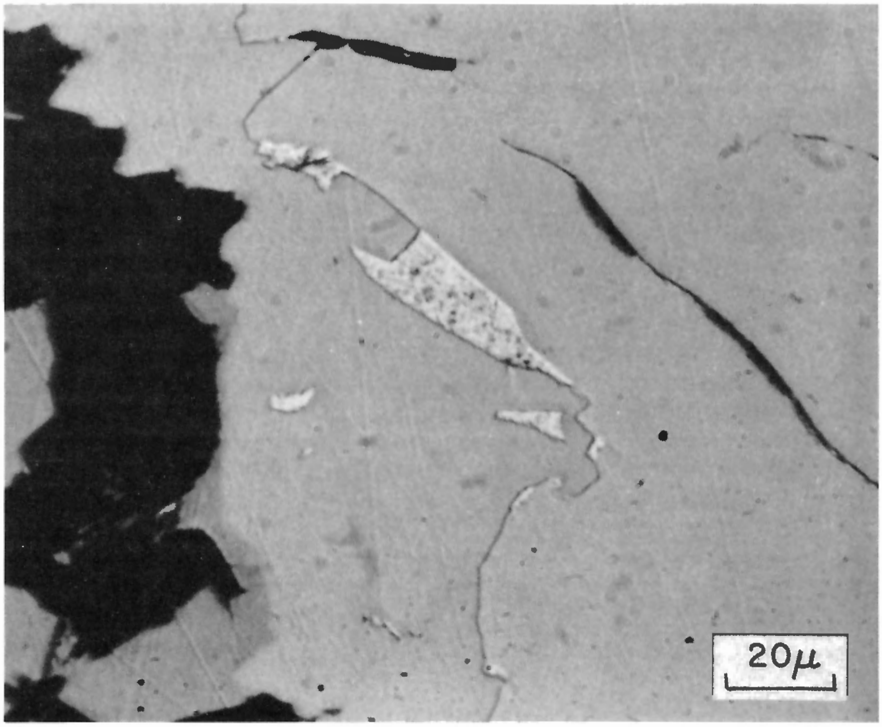


Figure 59. Gold (white) is concentrated at the boundary between loellingite and arsenopyrite, Fuz claims. GSC 200823-C.

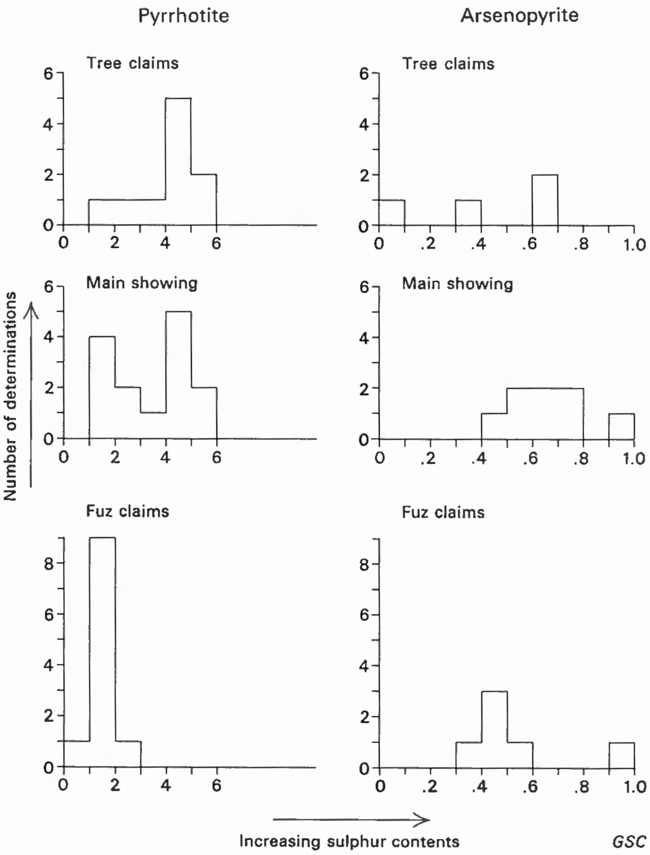


Figure 60. Relative sulphur content in pyrrhotite and arsenopyrite.

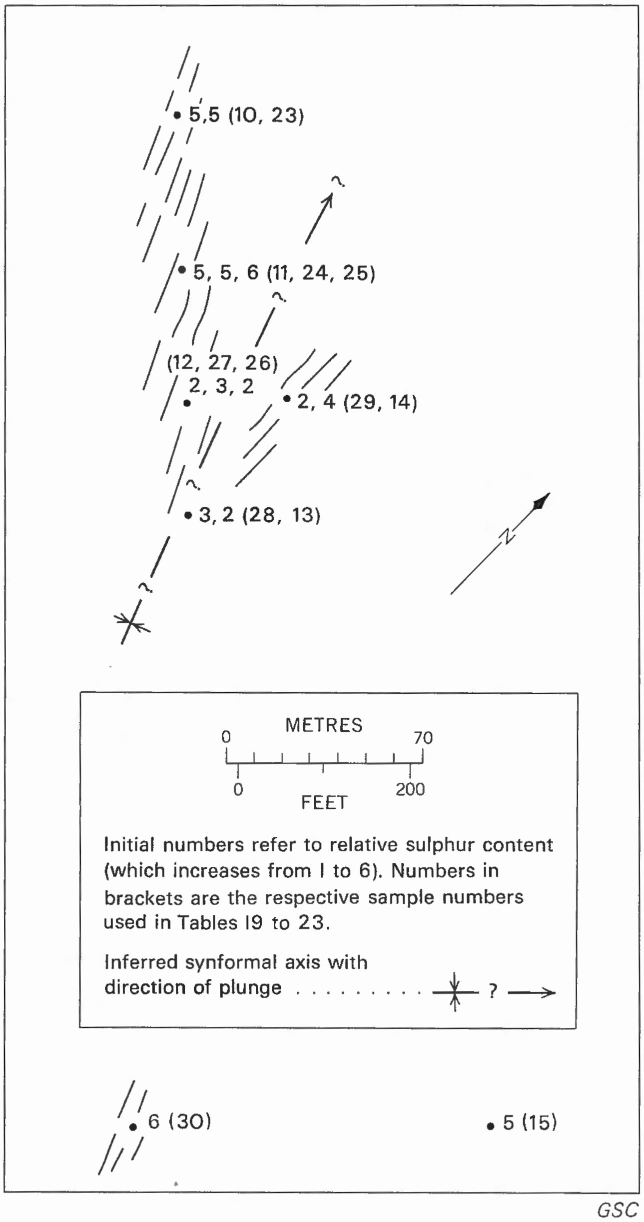


Figure 61. The Main showing, indicating the distribution of sulphur-poor pyrrhotite.

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.

Sulphur in arsenopyrite and pyrrhotite. The principal mineral of sulphide iron-formation in the Itchen Lake area is pyrrhotite but where metamorphic grade is low (Box claims) pyrite is predominant. This suggests that much or all of the sulphide facies may have been originally pyrite-rich but has lost sulphur during metamorphism. It is thus of interest to examine the relative sulphur contents of pyrrhotite at progressively higher metamorphic grades to see whether there is evidence of continued sulphur 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 19 and are illustrated in Figure 60. At the same time relative sulphur contents of 17 arsenopyrites were estimated from d-spacings by the method of Morimoto and Clark (1961) (Table 20).

Pyrrhotite is clearly predominantly hexagonal in the Fuz claims and therefore sulphur poor. In the Main showing the pyrrhotite type distribution appears to be bimodal with the hexagonal (sulphur-poor) type predominant in samples from near the nose of a fold structure (Figs. 60 and 61), 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.

The distribution of sulphur in arsenopyrite shows a pattern that resembles that of sulphur in pyrrhotite but is less well defined possibly because fewer samples were examined. Arsenopyrite from the Main showing appears to be relatively higher in sulphur than that from the Fuz claims. Sulphur content of arsenopyrite from the Tree claims is not distinctive if the low sulphur sample from the southern extremity is excluded (analogous to the sulphur-low pyrrhotite samples from the same location). Arsenopyrite from the nose of the fold structure at the Main showing may be sulphur-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 sulphur content, the loss of sulphur is probably reflecting more than the increase in metamorphic grade alone. The apparent deficiency of sulphur in pyrrhotite from the fold nose at the Main showing may reflect a greater structural dilatancy and hence a greater facility for sulphur 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 sulphur-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 21) in a general way match the sulphur 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 sulphur is depleted in pyrrhotite and possibly in arsenopyrite as well (Fig. 56). High proportions of arsenopyrite relative to loellingite (Fig. 57) occur chiefly where sulphur 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 sulphur 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 sulphur and deformation necessary to disrupt the armouring effect or arsenopyrite haloes formed early about loellingite.

Discussion

The stratigraphic relations of oxide, silicate and sulphide facies iron-formation lenses in the Itchen Lake area relate these lenses to the terminal phase of Point Lake volcanism, possibly to volcanic activity associated with the Keskarrah Formation conglomerates. This suggestion is similar to that of Goodwin (1973), which was based mainly on volcanic associations in Superior Province. There also gold has been concentrated primarily in the sulphide 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 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-sulphide 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 environment of sulphide facies iron-formation deposition was favourable for precipitation of arsenic minerals, or the already deposited iron-formation beds provided a favourable host for replacement by arsenic minerals. These alternatives differ significantly in that syngenetic precipitation of arsenic could have occurred near the upper interface of the sulphide-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 host rich in iron sulphide.

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 or pyrrhotite (for example see Fig. 62). 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 sulphide iron-formation facies it therefore seems likely that the loellingite was also syngenetic.

Metamorphism of sulphide 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

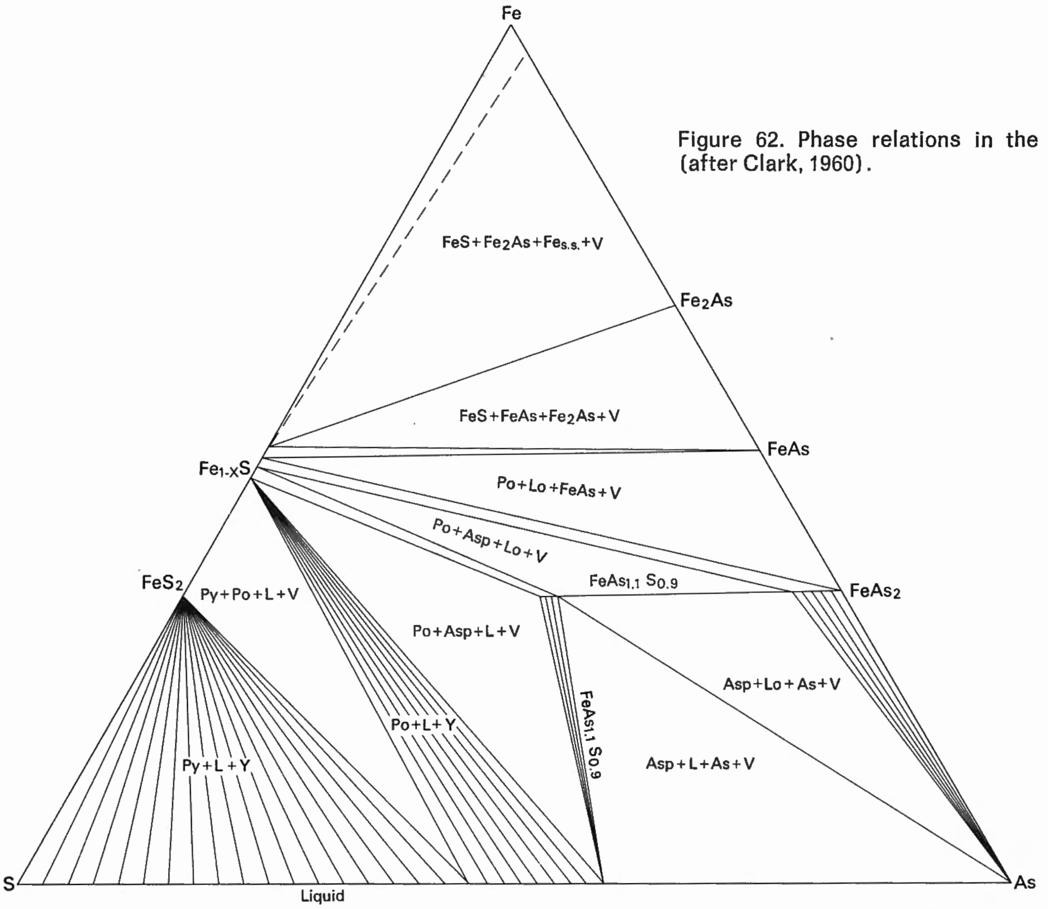


Figure 62. Phase relations in the system Fe-As-S at 600°C (after Clark, 1960).

After Clark, 1960 GSC

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, sulphur that evolved from sulphides in iron-formation during metamorphism was in part able to leave the system and pyrite, which may originally have been the predominant sulphide, was converted by pyrrhotite. Investigation of the frequency of pyrrhotite types has suggested that the proportion of the sulphur-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 sulphur. Retention of some mobile sulphur through the metamorphic maximum and into the period of retrogression is perhaps suggested by local replacement of pyrrhotite by pyrite along grain boundaries of, and fractures within, pyrrhotite.

The data of Clark (1960) indicate that the invariant point (702 ± 3°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 sulphide iron-formation lenses that it contains. Unusually high gold concentrations appear to be confined to those iron-formation lenses in which arsenic is also concentrated. 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. However, high gold concentrations with similar gold-silver ratios (Table 18) occur 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 sulphur 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 for 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 sulphide 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 with some other metamorphosed Archean sulphide facies iron-formations 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 sulphide-rich iron-formation sediment. During metamorphism these centres were converted to loellingite patches that reacted externally with sulphur-bearing vapour 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 sulphur-bearing vapour 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 breakdown 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 about 500 feet (150 m) in width having presumably been repeated by folding. Semiquantitative 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 sulphide iron-formation lenses within the Contwoyto Formation (Table 16) 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-sulphide facies iron-formation is exposed about 300 feet (90 m) south of the gabbro and similar rocks may well occur at depth along the contacts of the gabbro. 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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Tables

The chemical analyses for Tables 1 to 10 were performed by the Rapid Methods staff, Analytical Chemistry Section, Geological Survey of Canada, and the trace element analyses by K.A. Church of the Analytical Chemistry Section, except as noted otherwise.

Table 1. Chemical analyses of mafic volcanic rocks from the Point Lake Formation

Sample:	675	125a	539	587	731	634	57	147b	593	652	133a	799a
Major elements (%)												
SiO_2	44.8	46.5	46.7	50.0	50.9	51.3	56.1	59.1	49.5	48.4	50.4	52.5
TiO_2	0.85	1.14	0.78	0.97	0.80	1.37	1.29	1.17	0.77	0.81	1.73	1.12
Al_2O_3	15.1	14.6	15.2	14.6	15.2	19.7	16.0	16.2	16.8	15.7	13.6	14.6
Fe_2O_3	2.3	3.3	2.3	1.6	1.2	0.6	0.5	1.3	0.2	1.3	0.3	2.5
FeO	11.9	10.5	8.2	10.1	10.9	5.7	8.4	6.8	10.8	10.2	13.4	8.5
MgO	7.1	7.1	5.7	8.0	6.0	5.4	3.4	3.4	7.4	7.3	4.8	5.4
CaO	9.9	8.8	14.7	9.2	11.0	4.2	7.2	5.9	11.3	12.5	11.4	8.3
Na_2O	2.5	2.7	1.3	3.4	3.0	6.2	3.9	3.9	2.8	2.1	2.6	3.8
K_2O	4.8	2.0	3.1	3.0	1.4	3.4	0.6	1.2	0.3	0.4	0.6	0.4
H_2O	0.2	1.3	0.4	0.2	0.3	0.1	1.2	1.9	1.5	1.6	1.7	1.3
MnO	0.23	0.22	0.18	0.21	0.29	0.14	0.16	0.13	0.20	0.20	0.23	0.20
P_2O_5	0.07	0.20	0.07	0.08	0.06	0.11	0.25	0.29	0.06	0.05	0.33	0.20
CO_2	0.7	0.1	2.9	0.8	0.1	2.9	0.1	0.1	0.2	0.6	0.8	<0.1
Total	100.5	98.4	101.5	102.2	101.2	101.1	99.1	101.4	101.8	101.20	101.9	98.8
Trace elements (ppm)												
Cr	44	210	270	23	110	420	NF	NF	430	350	20	130
V	650	710	610	580	540	640	380	400	570	520	1000	280
Ni	58	77	100	120	76	130	<20	NF	130	100	47	47
Co	37	44	33	38	40	43	<20	<20	41	38	38	39
Zn	110	140	170	160	140	120	170	160	120	140	74	ND
B	NF	3.6	2.2	NF	NF	NF	2.2	2.2	NF	NF	3.6	ND
Mo	1.4	NF	NF	NF	1.3	NF	NF	NF	1.4	NF	NF	ND
Ag	0.25	0.076	0.15	0.10	0.077	0.075	0.11	0.22	0.20	0.15	0.15	ND
Au	ND	.005	<.005	<.005	0.005	<.005	<.005	<.005	<.005	0.020	.035	ND
Normative analyses (cation equivalents)												
Q	0	0	0.4	0	0	0	6.9	10.7	0	0	0	2.0
C	0	0	0	0	0	2.3	0	0	0	0	0	0
Or	1.3	8.1	2.5	1.2	1.8	0.6	3.7	7.2	1.8	2.4	3.7	2.4
Ab	23.9	25.4	12.4	31.0	27.3	56.9	36.2	35.5	25.0	19.2	24.0	35.2
An	31.3	25.0	36.7	24.3	27.5	20.6	25.2	23.5	32.2	32.8	24.4	22.3
Di	9.0	9.0	19.6	10.6	11.4	0	3.6	1.8	8.7	14.1	10.6	9.0
He	7.4	6.5	12.9	6.5	10.6	0	4.4	1.6	6.7	9.9	14.8	6.1
En	2.0	0.9	7.0	6.2	6.2	0.9	7.9	8.6	4.2	4.3	6.7	10.9
Fs	1.7	0.7	4.6	3.8	5.8	0.4	9.6	7.5	3.2	3.0	9.4	7.4
Fo	10.7	11.3	0	8.2	3.7	10.8	0	0.0	8.8	6.8	1.2	0
Fa	8.8	8.1	0	5.0	3.4	4.9	0	0.0	6.8	4.8	1.7	0
Mt	2.6	2.9	2.5	1.7	1.3	0.6	0.1	1.4	0.2	1.4	0.3	2.7
Il	1.3	1.7	1.2	1.4	1.1	2.0	1.9	1.7	1.1	1.1	2.5	1.6
Ap	0.2	0.4	0.2	0.2	0.1	0.2	0.5	0.6	1.4	0.1	0.7	0.4

NF not found. ND not determined.

Sample	Rock description
675	Dark green, fine-grained metabasalt; west part of Western volcanic belt about 2 miles (3.2 km) south of Point Lake.
125a	Dark green, fine-grained metabasalt; near north end of Western volcanic belt.
539	Medium green, fine-grained metabasalt; upper part of Western volcanic belt about 8 miles (13 km) south of Point Lake. Contains microscopic calcite veins.
587	Medium green, fine-grained pillowed metabasalt; upper part of Western volcanic belt on south shore of Point Lake.
731	Dark green, fine-grained metabasalt; near south end of Western volcanic belt.
634	Grey, medium fine grained metamugearite; within Keskarrah Formation on north shore of south arm of Point Lake.
57	Dark green, fine-grained meta-andesite; about 7 miles (11 km) south of north end of Western volcanic belt.
147b	Dark green, fine-grained meta-andesite; near north end of Western volcanic belt.
593	Dark green, fine-grained metamorphosed mafic tuff on south shore of Point Lake near west edge of Western volcanic belt of Point Lake (corresponds compositionally to basalt).
652	Dark green, fine-grained metamorphosed mafic tuff; near west edge of Western volcanic belt on north shore of south arm of Point Lake (corresponds compositionally to basalt).
133a	Dark green, medium-grained schistose amphibolite (mafic tuff?) eastern part of Central volcanic belt.
799a	Dark green, medium fine grained schistose metabasalt; north arm of Central volcanic belt.

Table 2. Chemical analyses of felsic volcanic rocks from the Point Lake Formation

Sample:	338	281	957	181	141	425	Mean	199	792	139	124a	882	886	147a
Major elements (%)														
SiO_2	67.2	69.7	69.8	71.1	73.2	73.9	70.8	59.4	68.7	67.8	69.7	71.0	76.0	74.1
TiO_2	0.21	0.60	0.50	0.42	0.28	0.34	0.39	0.88	0.32	0.61	0.25	0.25	0.07	0.20
Al_2O_3	16.4	13.2	13.4	15.6	14.1	14.3	14.5	17.3	13.5	15.1	17.0	15.1	13.5	13.6
Fe_2O_3	<0.1	0.4	1.0	1.3	0.9	0.2	0.6	1.5	1.1	0.5	0.1	0.7	0.7	0.4
FeO	3.0	3.7	3.4	2.1	1.7	2.0	2.7	5.9	2.8	3.9	1.7	1.0	0.3	1.9
MgO	0.6	1.5	1.5	1.1	0.5	1.5	1.1	3.6	3.4	1.0	1.5	1.7	0.4	0.7
CaO	2.5	4.0	2.0	3.3	0.8	1.4	2.3	6.3	1.4	7.0	1.8	1.7	0.2	1.3
Na_2O	5.5	4.2	4.7	5.4	5.1	1.8	4.5	4.4	3.7	1.8	5.6	0.2	2.8	4.1
K_2O	1.5	1.2	1.7	0.5	1.7	2.1	1.5	1.4	3.0	0.5	1.2	4.3	3.1	3.2
H_2O	0.9	1.0	0.7	0.7	0.5	1.9	1.0	1.0	1.2	1.2	1.0	2.4	1.5	0.6
MnO	0.04	0.10	0.06	0.06	0.04	0.05	0.06	0.12	0.04	0.12	0.05	0.02	<0.02	0.05
P_2O_5	0.06	0.17	0.11	0.09	0.03	0.16	0.10	0.14	0.05	0.18	0.06	0.15	<0.02	0.02
CO_2	0.5	1.4	0.1	0.4	0.3	<0.1	0.5	0.1	<0.1	1.2	<0.1	2.3	<0.1	0.2
Total	98.4	101.2	99.1	102.1	99.2	99.7		102.0	99.2	100.9	100.0	100.8	98.6	100.4
Trace elements (ppm)														
Cr	NF	NF	NF	NF	<20	NF	–	32	NF	25	NF	NF	NF	26
V	33	60	NF	38	39	25	–	190	NF	170	30	<20	NF	70
Ni	NF	NF	NF	<20	NF	NF	–	35	NF	<20	NF	14	14	NF
Co	NF	NF	NF	NF	NF	NF	–	31	NF	NF	NF	NF	NF	NF
Zn	33	68	ND	52	24	32	–	100	ND	100	26	12	<10	11
B	7.9	0.89	ND	3.2	0.91	13	–	1.1	ND	5.3	3.8	8.7	7.5	1.6
Mo	<0.50	<0.50	ND	<0.50	1.4	<0.50	–	NF	ND	1.6	<0.50	1.0	<1.0	1.8
Ag	0.075	0.17	ND	0.080	0.069	0.25	–	0.069	ND	0.13	0.10	0.12	0.14	0.065
Au	.005	.005	<.005	<.005	<.005	.005	–	<.005	<.005	.005	<.005	ND	ND	.010
Normative analyses (cation equivalents)														
Q	19.9	27.4	26.2	26.0	31.9	47.8	28.9	7.0	24.6	36.0	23.5	45.4	45.5	30.8
C	1.5	0	0.5	0.4	2.8	7.9	1.7	0	1.9	0	3.7	8.4	6.0	1.2
Or	9.1	7.3	10.3	2.9	10.3	13.0	9.0	8.2	18.1	3.1	7.1	26.4	19.2	19.2
Ab	50.5	38.6	43.2	48.0	46.7	17.0	41.0	39.1	33.9	16.9	50.2	1.9	26.3	37.2
An	12.3	13.9	9.4	15.6	3.8	6.2	10.9	23.1	6.8	33.2	8.5	7.7	0.9	6.4
Di	0	1.9	0	0	0	0	0	3.2	0	0.6	0	0	0	0
He	0	2.2	0	0	0	0	0	2.3	0	1.0	0	0	0	0
En	1.7	3.3	4.2	3.0	1.4	4.3	3.1	8.2	9.6	2.6	4.1	4.9	1.2	2.0
Fs	4.4	3.8	4.1	1.8	1.7	2.7	3.4	5.8	3.3	4.8	2.3	0.8	0	2.5
Mt	0.1	0.4	1.1	1.3	1.0	0.2	0.6	1.6	1.2	0.5	0.1	0.8	0.6	0.4
Il	0.3	0.9	0.7	0.6	0.4	0.5	0.6	1.2	0.5	1.0	0.3	0.4	0.1	0.3
Ap	0.1	0.4	0.2	0.2	0.1	0.4	0.2	0.3	0.1	0.4	0.1	0.3	0	0
Hm	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0

NF not found. ND not determined. Ag analyses by Bondar Clegg and Co. Ltd.

Sample	Rock description
338	Fine-grained, grey-white metadacite with subhedral quartz and plagioclase phenocrysts; central south arm of Central volcanic belt.
281	Fine-grained, grey, slightly foliated metadacite with a few plagioclase phenocrysts; Western volcanic belt near Itchen Lake.
957	Fine-grained, grey metadacite with slightly porphyritic quartz and plagioclase; southern arm of Central volcanic belt.
181	Fine-grained, grey, massive metadacite; Western volcanic belt near Itchen Lake.
141	Fine-grained, grey-white metarhyolite with albite glomerocrysts up to 3 mm across; felsic tuff overlying Central belt batholith.
425	Fine-grained, grey, slightly greenish metadacite with bluish quartz eyes and muscovite porphyroblasts up to 0.5 mm diameter; Central volcanic belt, south arm.
Mean	Average of first 6 analyses representing typical felsitic volcanic rocks in lower part of Point Lake Formation.
199	Massive, grey, medium fine grained meta-andesite west of Itchen Lake.
792	Grey, schistose, medium fine grained metadacite (tuff?); north arm of Central volcanic belt.
139	Light grey-green, medium fine grained, metamorphosed calcareous tuffaceous sediment containing scattered hornblende and garnet; east end of Central volcanic belt.
124a	Finely and lenticularly laminated, pink and grey, cherty mylonite with pods and stringers of quartz-potash feldspar up to 12.7 mm thick parallel with foliation; represents finer grained material free of stringers; northern part of Western volcanic belt along contact between Western plutonic zone and Western volcanic belt.
882	Very fine grained, buff-grey metadacite containing brecciated embayed quartz phenocrysts and muscovite porphyroblasts.
886	Massive, fine-grained, buff-grey, porphyritic metarhyolite containing bipyramidal quartz phenocrysts surrounded by matrix quartz haloes; hybrid zone south of Rockinghorse Lake.
147a	Dark grey, very fine grained, porphyritic metadacite containing embayed quartz and plagioclase phenocrysts; within mafic volcanic pile near north end of Western volcanic belt.

Table 3. Chemical analyses of serpentinite and metagabbro

Sample:	512	736b	170	534c	514a
Major elements (%)					
SiO_2	38.7	40.4	40.9	47.0	47.2
Cr_2O_3	0.76	0.37	0.04	0.02	0.05
TiO_2	0.22	0.16	0.17	0.70	0.72
Al_2O_3	4.43	3.96	3.4	13.3	14.8
Fe_2O_3	3.1	1.4	4.8	0.8	1.1
FeO	7.3	7.6	5.6	10.6	10.4
MgO	33.8	34.1	35.1	10.3	10.4
CaO	0.31	1.17	1.0	9.20	10.3
Na_2O	0.74	0	0.1	1.96	2.14
K_2O	0.04	0.01	<0.1	1.20	0.38
H_2O	11.2	10.8	10.8	2.9	2.3
MnO	0.18	0.17	0.17	0.22	0.20
P_2O_5	0.05	0.04	0.12	0.10	0.07
CO_2	0	0	0.1	0	0
S	0.12	0.13	ND	0.07	0.06
Total	100.95	100.31	102.40	98.37	100.12
Trace elements (ppm)					
Ba	10	0	ND	110	20
Sr	0	0	ND	95	110
Rb	0	0	ND	25	0
Zr	0	0	ND	0	0
V	ND	ND	0	ND	ND
Ni	1500	1800	140	230	290
Co	ND	ND	9.2	ND	ND
Zn	28	32	100	48	71
B	ND	ND	15	ND	ND
Mo	ND	ND	0	ND	ND
Ag	ND	ND	14	ND	ND

ND not determined.

Sample	Rock description
512	Band 30 feet (9 m) wide of light brown weathering, sea-green, fine-grained serpentinite, mostly of serpentine with about 25% chlorite and trace of amphibole.
736b	Brown weathering, sea-green, very fine grained serpentinite, mostly of serpentine with about 15% chlorite, 10% tremolite and trace carbonate.
170	Band 30 feet (9 m) wide, possibly discontinuous, of sea-green, very fine grained serpentinite, mostly of serpentine with about 15% chlorite, 10% magnetite and 5% anthophyllite.
534c	Dark green, coarse-grained amphibolite, mostly of blue-green hornblende with 10% andesine-labradorite and traces of chlorite, epidote and muscovite.
514a	Dark green, slightly foliated, coarse-grained amphibolite, mostly of hornblende with about 35% labradorite and traces of magnetite and epidote.

Table 4. Chemical analyses of oxide and silicate iron-formation facies

	Oxide facies				Silicate facies							
Sample:	581b	464c	312	628	360a	364a	364b	309	1300a	35	1300c	1300b
Major elements (%)												
SiO_2	41.5	42.0	44.3	48.5	45.0	45.7	46.5	48.3	50.1	52.7	57.5	63.7
TiO_2	0.63	0.12	0.17	0.14	0.15	0.18	0.23	0.25	0.39	0.14	0.43	0.21
Al_2O_3	9.2	4.4	5.4	4.2	4.6	5.3	6.5	6.7	7.1	3.7	9.9	3.9
Fe_2O_3	16.8	36.3	31.0	26.1	4.7	4.8	4.9	4.6	1.3	5.0	1.8	1.6
FeO	11.5	12.2	14.7	14.5	37.7	36.7	31.7	28.6	27.8	29.1	23.2	22.6
MgO	6.8	1.5	1.3	1.7	3.2	3.7	3.9	5.0	3.3	3.3	2.5	3.2
CaO	9.8	1.7	1.4	0.9	2.3	2.6	4.6	2.8	9.1	4.5	2.2	4.5
Na_2O	0.8	0.7	0.2	0.2	0.3	0.3	0.4	0.3	0.5	0.2	0.2	0.3
K_2O	0.2	0.3	0.1	1.1	0.1	0.1	0.2	0.3	0.2	0.2	0.1	0.1
H_2O	2.4	0.5	1.1	0.8	2.2	2.1	2.1	2.3	2.0	1.6	2.2	1.5
MnO	0.29	0.14	0.10	0.10	0.09	0.12	0.13	0.17	0.09	0.13	0.05	0.07
P_2O_5	0.08	0.09	0.15	0.18	0.21	0.14	0.11	0.12	0.18	0.21	0.10	0.22
CO_2	1.0	2.2	0.2	2.8	<0.1	0.1	0.2	0.3	<0.1	0.2	<0.1	<0.1
C	<0.5	<0.5	<0.5	<0.5	0.24	<0.5	0.16	<0.5	<0.5	<0.5	<0.5	<0.5
S	0.005	<0.01	<0.01	<0.01	0.06	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total	101.0	102.2	100.2	101.2	100.8	102.0	101.6	99.7	102.1	101.0	100.2	101.6
Trace elements (ppm)												
Cr	67	NF	21	21	NF	54	26	41	74	31	79	30
V	340	NF	68	NF	NF	100	NF	95	90	NF	100	56
Ni	43	NF	NF	NF	NF	<20	NF	<20	35	NF	34	27
Co	33	NF	NF	NF	NF	<20	NF	NF	<20	NF	<20	<20
Zn	10	18	55	37	<10	40	42	90	ND	160	ND	ND
B	NF	NF	NF	NF	<0.7	NF	NF	NF	ND	4.7	ND	ND
Mo	NF	NF	NF	NF	NF	NF	NF	NF	ND	NF	ND	ND
Ag	0.05	0.08	0.06	0.05	<0.05	0.14	0.25	0.44	ND	0.096	ND	ND

NF not found. ND not determined.

Because of high iron content analyses for iron are considered semi-quantitative.

Sample	Rock description
	Oxide facies iron-formation:
581b	Fine-grained, blue-grey oxide facies iron-formation containing some epidote from matrix of pillow breccia within Keskarrah Formation on south shore of Point Lake.
464c	Fine-grained, finely laminated, blue-grey siliceous oxide facies iron-formation; south shore, north arm Point Lake.
312	Fine-grained, patchy, blue-grey oxide facies iron-formation; north shore, north arm Point Lake.
628	Fine-grained, grey, slaty (lean) oxide facies iron-formation near north shore, south arm Point Lake.
	Silicate facies iron-formation:
360a	Fine-grained, green, banded amphibolite along river between Point and Itchen lakes.
364a,b	Fine-grained, green, banded amphibolite; near north shore, north arm Point Lake.
309	Fine-grained, green, banded amphibolite; north shore, north arm Point Lake.
1300a	Dense, dark green amphibolite; Main showing near Contwoyto Lake.
35	Medium-grained, dark green, banded amphibolite near southeast margin of Fuz metagabbro pluton. Shows microscopic alteration of amphiboles to talc.
1300c	Richly garnetiferous, grey-green amphibolite; Main showing at Contwoyto Lake.
1300b	Grey-green, siliceous amphibolite; Main showing at Contwoyto Lake.

Table 5. Chemical analyses of the greywacke-turbidite succession

Sample:	100	102	704	101	103	464b	468b
Major elements (%)							
SiO_2	49.4	54.7	56.3	58.4	63.4	64.6	69.8
TiO_2	0.82	0.76	0.82	0.71	0.71	0.64	0.56
Al_2O_3	21.0	22.1	22.6	18.8	16.9	15.8	13.3
Fe_2O_3	12.8 *	1.0	0.1	0.8	1.0	0.1	0.4
FeO	<0.5	6.1	6.6	7.8	6.2	4.4	6.5
MgO	4.3	2.7	3.9	3.5	3.2	4.3	2.7
CaO	2.4	1.6	1.4	2.4	1.2	1.1	2.2
Na_2O	3.9	3.1	2.7	2.6	2.8	2.5	2.7
K_2O	4.3	3.9	3.5	3.4	2.4	2.5	1.1
H_2O	2.5	2.7	2.1	2.8	3.5	3.3	2.1
MnO	0.15	0.08	0.08	0.13	0.09	0.04	0.1
P_2O_5	0.16	0.1	0.12	0.11	0.12	0.11	0.07
CO_2	0.2	0.1	0.3	0.1	0.3	0.3	<0.1
C	1.83	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Total	103.8	98.9	100.5	101.6	101.8	99.7	101.6
Trace elements (ppm)							
Cr	190	310	260	210	240	270	68
V	240	500	260	280	310	240	180
Ni	100	620	110	66	48	48	24
Co	38	20	38	<20	<20	<20	<20
Zn	87	180	100	130	75	82	100
B	2.2	69	30	180	55	53	1.7
Mo	NF	2.3	NF	2.1	0.66	0.52	0.87
Ag	0.38	0.14	0.07	0.17	0.12	0.26	0.09

* total iron. NF not found.

Sample	Rock description
100	Biotite, garnet schist (Contwoyto Formation) containing scattered garnet porphyroblasts (2.5 mm) and polycrystalline biotite porphyroblasts (2 mm) in matrix of quartz, plagioclase and biotite. Opaque minerals are very fine grained.
102	Andalusite, cordierite schist (Contwoyto Formation) containing cordierite porphyroblasts (5 cm), andalusite porphyroblasts (10 mm) and biotite (2.5 mm) in quartz-plagioclase matrix (0.1 mm); minor muscovite, chlorite and opaques with accessory tourmaline and apatite.
704	Andalusite, cordierite schist (Itchen Formation) containing porphyroblasts of cordierite (3 cm) and of andalusite (2 cm) in quartz-plagioclase-biotite matrix (0.1 mm).
101	Blue-grey slate, Contwoyto Formation.
103	Blue-grey slate, Contwoyto Formation.
464b	Grey greywacke, Contwoyto Formation, containing quartz, muscovite, albite or oligoclase; minor chlorite, carbonate, and accessory opaques, apatite and tourmaline.
468b	Fine-grained, grey greywacke, Contwoyto Formation.

Table 6. Chemical analyses of the plutonic rocks

Sample:	996	665	109	163	423	748	800	304	182	33	160
Major elements (%)											
SiO_2	48.5	62.2	70.8	70.8	72.0	72.7	73.0	75.2	75.8	76.0	76.0
TiO_2	2.09	0.49	0.30	0.49	0.27	0.65	0.36	0.22	0.14	0.24	0.17
Al_2O_3	9.4	17.1	15.9	16.0	14.3	14.6	15.7	13.3	15.6	11.9	13.1
Fe_2O_3	1.5	1.4	0.9	0.2	0.3	1.2	0.4	0.7	0.2	0.1	0.2
FeO	14.5	3.2	1.3	2.3	1.7	2.3	1.6	1.4	0.5	2.2	0.9
MgO	13.7	3.1	<0.5	1.3	<0.5	0.5	<0.5	<0.5	<0.5	<0.5	0.6
CaO	6.6	4.0	2.6	2.5	1.1	3.1	1.3	1.2	1.7	0.9	0.8
Na_2O	1.8	5.2	5.1	4.8	3.7	4.4	4.3	4.7	4.7	3.1	3.5
K_2O	0.4	3.0	0.1	1.5	4.4	2.1	3.9	2.6	3.3	4.2	4.6
H_2O	2.7	0.9	0.5	0.5	0.5	0.4	0.4	0.3	0.2	0.4	0.4
MnO	0.23	0.08	0.04	0.03	0.03	0.06	0.03	0.05	0.02	0.04	0.02
P_2O_5	0.33	<0.02	0.04	<0.02	0.09	0.11	0.17	<0.02	<0.02	0.03	0.03
CO_2	<0.1	0.2	0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1
Total	101.8	100.9	97.7	100.4	98.5	102.1	101.2	99.7	102.2	99.1	100.4
Trace elements (ppm)											
Cr	1400	77	NF	NF	NF	NF	<20	NF	NF	NF	NF
V	630	140	52	70	NF	72	71	NF	NF	NF	NF
Ni	470	31	NF	NF	NF	NF	NF	NF	NF	NF	NF
Co	580	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF
Zn	200	66	54	77	45	80	68	23	13	80	27
B	10	12	4.6	3.3	NF	4.3	7.2	2.1	1.9	5.0	4.2
Mo	NF	NF	NF	8.6	NF	0.85	2.5	NF	NF	3.4	<0.50
Ag	0.30	0.056	0.10	0.20	0.28	0.10	0.071	<0.05	0.10	0.088	0.23
Au	<0.005	<0.005	<0.005	<.005	<.005	0.015	0.005	<0.005	<0.005	<0.005	<0.005
Normative analyses (cation equivalents)											
Q	0	6.0	32.3	26.3	28.1	28.6	26.6	31.5	28.2	35.7	32.6
C	0	0	3.1	2.2	1.9	0	2.6	0.7	1.3	0.8	1.1
Or	2.4	17.5	0.6	8.9	26.6	12.3	22.8	15.5	19.0	25.4	27.4
Ab	16.5	46.0	47.0	43.0	33.9	39.2	38.2	42.4	41.1	28.5	31.7
An	16.7	14.2	13.0	12.3	5.0	13.8	5.3	5.9	8.1	4.4	3.8
Di	6.1	3.0	0	0	0	0.3	0	0	0	0	0
He	3.0	1.2	0	0	0	0.4	0	0	0	0	0
En	26.4	6.9	1.4	3.6	1.4	1.2	1.4	1.4	1.3	1.4	1.7
Fs	13.2	2.8	1.1	2.8	2.1	1.7	1.7	1.5	0.5	3.1	1.1
Fo	6.8	0	0	0	0	0	0	0	0	0	0
Fa	3.4	0	0	0	0	0	0	0	0	0	0
Mt	1.6	1.4	1.0	0.2	0.3	1.2	0.4	0.7	0.2	0.1	0.2
Il	3.0	0.7	0.4	0.7	0.4	0.9	0.5	0.3	0.2	0.3	0.2
Ap	0.7	0	0.1	0	0.2	0.2	0.4	0	0	0.1	0.1

NF not found.

Sample	Rock description*
996	Hornblende gabbro (Fuz pluton), dark green, brown weathering, medium grained, massive, equigranular, consisting of actinolitic hornblende, cummingtonite, andesine labradorite, opaques, biotite, apatite and muscovite.
665	Hornblende granodiorite (Concession pluton), pinkish grey, medium grained, massive, consisting of hornblende, oligoclase, quartz, microcline, chlorite, epidote, muscovite and magnetite with accessory allanite, zircon, apatite and sphene. Quartz forms fine-grained mosaic between other major minerals.
109	Chlorite granodiorite (Western plutonic zone), buff-pink, medium grained, massive, consisting of oligoclase, quartz, microcline, chlorite, biotite and epidote with accessory magnetite, sphene, apatite and zircon. Local amphibolite inclusions.
163	Biotite granodiorite (migmatites near contact of Yamba batholith), buff-grey, medium grained, massive, consisting of oligoclase, quartz, biotite, muscovite, epidote and chlorite with accessory leucoxene and apatite.
423	Biotite granite (Yamba batholith), pink-white, massive, medium grained, consisting of microcline, quartz, albite, biotite, muscovite and chlorite with accessory zircon.
748	Biotite-hornblende granodiorite (Keskarrah batholith); pink-buff, massive, medium grained, consisting of oligoclase, quartz, biotite, epidote, hornblende, microcline, sphene and muscovite with accessory magnetite, apatite and zircon. Sphene unusually abundant in zoned euhedral crystals with brown rims and colourless cores.
800	Biotite-quartz monzonite (Contwoyto batholith), buff-white, medium grained, massive, consisting of microcline, oligoclase, quartz, biotite, muscovite and chlorite with accessory apatite and zircon.
304	Biotite granodiorite (minor pluton south of west arm, Itchen Lake), pink, medium grained, massive, consisting of quartz, albite, oligoclase, microcline, biotite, chlorite and epidote with accessory sphene and zircon.
182	Biotite granodiorite (small body of quartz-plagioclase gneiss, east end of Point Lake), pink-white, fine grained, locally very faintly foliated, consisting of oligoclase, quartz, microcline, biotite and chlorite with accessory zircon.
33	Biotite granite (within migmatite near Fuz gabbro), coarse grained massive, equigranular, consisting of microcline, quartz, oligoclase, biotite, chlorite and muscovite with accessory apatite and sphene.
160	Biotite granite (Yamba batholith), pink-white, medium grained, massive, consisting of microcline, oligoclase albite, quartz, biotite, muscovite, chlorite, epidote and accessory zircon.

* Minerals listed in order of decreasing abundance.

Table 7. Statistics for 32 partial chemical analyses of small samples from the Yamba batholith

	Fe_2O_3 (total)	MnO	TiO_2	CaO	K_2O	SiO_2	Al_2O_3	MgO
Mean	1.75	0.01	0.26	1.22	5.17	70.50	16.91	0.64
standard deviation	0.75	0.01	0.16	1.22	1.59	3.27	1.90	0.50
range	2.90	0.04	0.74	6.80	6.90	16.10	12.40	2.10

Table 8. Chemical analysis of a siliceous dolomitic metasediment from the hybrid rocks, Sample 69

Major elements	Per cent	Trace elements	Ppm
SiO_2	48.2	Ba	25
Cr_2O_3	0.12	Sr	130
TiO_2	0.34	Rb	0
Al_2O_3	3.7	Zr	3
Fe_2O_3	1.9	Ni	210
FeO	5.7	Zn	38
MgO	18.0		
CaO	17.2		
Na_2O	0.84		
K_2O	0.17		
H_2O	2.2		
MnO	0.23		
P_2O_5	0.14		
CO_2	0.1		
S	0.11		
Total	98.95		

Table 9. Spectrographic analyses of tourmaline

Sample	10–100%	1–10%	0.1–1%	.01–0.1%	<.01%	Setting
1	Si, Al, Fe	B, Mg	Na (0.7), Ca (0.1), Ti (0.1)	Cr (.02), Mn (.05)	Be (<.001), Cu (<.007), Sr (<.005)	Knotted schist (marginal lower amphibolite facies)
687	Si, Al	Fe, B, Mg	Ca (0.2), Ti (0.2)	Na (.07), Mn (.05), Cr (.02), Sc (.015), Cu (.01)	V (.007), Ni (.005), Ag (.005), Sr (<.005)	Knotted schist hybrid, tourmaline at margins of pegmatite
773	Si, Al	Fe, B, Mg, Na	Ca (0.2), Ti (0.2)	Mn (.05), Cr (.015), Sc (.01)	Cu (.005), Sr (<.005)	Granodiorite (Concession pluton, see Table 1)
4	Si, Al	Fe, B, Mg	Ca (0.2), Ti (0.3)	Mn (.05), Cr (.02)	Cu (.007), Sr (<.005)	Quartz monzonite (minor intrusion)
7	Si, Al	Fe, B	Na (0.7), Mg (0.3), Ca (0.2), Ti (0.1)	Mn (.07), Sc (.01)	Cu (.002)	Knotted schist (lower amphibolite facies)
552	Si, Al	Fe, B, Mg		Ca (.07), Na (.07), Ti (.05), Mn (.05), Cr (.03), Sc (.015)	Cu (.007), Ni (.005)	Knotted schist (middle amphibolite facies)
117*	Si, Al	Fe, B	Mg (0.5), Ti (0.2)	Ca (.05), Mn (.03), Cr (.02)	Cu (.007), Be (<.001)	Fine-grained granitic phase of Contwoyto batholith
108*	Si, Al	Fe, B, Mg, Na	Ti (0.5), Ca (0.1)	Mn (.03)	Be	Contwoyto batholith (schist inclusions undigested)
173*	Si, Al	Fe, B, Na	Mg (0.3), Ca (0.1)	Ti (.07), Mn (.01)	Cu (<.002)	Contwoyto batholith (schist inclusions undigested)
27*	Si, Al	Fe, B, Mg, Na	Ca (0.3), Ti (0.2)	Mn (.03)	Cu (.005)	Biotite gneiss (lower amphibolite facies)
25*	Si, Al	Fe, B, Mg, Na	Ca (0.2), Ti (0.1)	Mn (.05), Cu (.01)		Contwoyto batholith (digested schist inclusions)

* Specimens supplied by L.P. Tremblay.

Spectographic analyses by K.A. Church, Analytical Chemistry Section, Geological Survey of Canada.

Table 10. Chemical analyses of diabase dykes

	WNW striking dykes				Mackenzie dykes*					
Sample:	516	824	105	Mean	FA 179	FA 139	FA 129	FA 415	FA 138	Mean
Major elements (%)										
SiO_2	48.1	48.8	51.7	49.53	48.8	50.10	50.10	50.2	50.80	50.00
TiO_2	2.55	2.75	1.81	2.37	2.35	2.40	3.39	3.23	3.25	2.92
Al_2O_3	12.7	14.8	17.2	14.9	11.70	12.05	12.90	13.3	13.45	12.68
Fe_2O_3	<0.1	0.5	<0.1	0.23	3.48	2.80	2.31	2.2	2.66	2.81
FeO	16.8	12.3	13.1	14.06	12.21	11.65	13.89	12.8	11.73	12.46
MgO	5.7	5.1	2.6	4.47	4.65	3.25	4.25	3.6	3.65	3.88
CaO	10.0	8.4	6.2	8.20	9.50	8.00	8.70	8.6	8.15	8.59
Na_2O	2.5	3.1	4.0	3.20	2.85	3.19	2.99	2.8	3.45	3.06
K_2O	0.6	1.5	2.3	1.47	0.95	1.45	0.80	1.0	1.50	1.14
$H_2O_{(T)}$	1.8	1.3	2.3	1.80	2.10	1.70	1.40	1.8	1.10	1.62
MnO	0.24	0.19	0.17	0.20	0.25	0.25	0.24	0.22	0.18	0.23
P_2O_5	0.29	0.63	0.43	0.45	ND	ND	ND	ND	ND	ND
CO_2	<0.1	0.7	0.1	0.3	0	0.21	<0.1	<0.1	0.8	–
Total	101.4	100.1	102.0	101.2	98.8	97.1	101.0	99.8	100.0	99.4
Trace elements (ppm)										
Cr	30	55	NF	42						
V	900	600	160	553						
Ni	48	28	NF	38						
Co	45	36	23	35	Not determined					
Zn	157	240	160	186						
B	NF	NF	7.8	–						
Mo	0.57	1.2	9.1	3.6						
Ag	0.26	0.097	0.16	0.17						
Normative analyses (cation equivalents)										
Q	–	–	–	–	0.6	2.4	1.3	3.3	0.6	1.7
C	–	–	–	–	–	–	–	–	–	–
Or	3.7	9.2	13.8	8.9	6.0	9.3	4.9	6.2	9.2	7.1
Ab	23.2	28.8	36.6	29.5	27.3	31.0	27.9	26.5	32.2	29.0
An	22.4	22.8	22.6	22.5	17.4	15.4	20.2	21.9	17.4	18.5
Di	8.8	6.2	1.3	5.2	12.8	8.9	8.5	7.6	8.9	9.3
He	12.8	6.7	3.4	7.8	13.5	13.1	11.2	10.9	10.7	11.9
En	4.8	4.8	1.5	3.5	7.3	5.2	7.9	6.7	6.0	6.6
Fs	7.0	5.1	3.7	5.3	7.7	7.7	10.5	9.5	7.2	8.5
Fo	5.3	5.0	3.9	4.9	0	0	0	0	0	0
Fa	7.7	5.4	9.7	7.4	0	0	0	0	0	0
Mt	0.11	0.54	0.11	0.2	3.9	3.2	2.5	2.4	2.9	3.1
Il	3.7	4.0	2.6	3.4	3.5	3.6	4.9	4.8	4.7	4.3
Ap	0.63	1.4	0.92	1.0	0	0	0	0	0	0

ND not determined. NF not found.

* Mackenzie dyke analyses from W.W. Fahrig (pers. com., 1975) represent dykes within and near Itchen Lake map area. Ferric iron quoted to one decimal place represents a single analysis; to two decimal places, the average of two analyses from separate parts of the dyke.

Sample	Rock description
516	Fine-grained diabasic texture; major pyroxene, plagioclase, saussurite and magnetite-ilmenite; trace amphibole and apatite. Dyke width 75 ft (23 m).
824	Diabasic texture with porphyritic plagioclase; contains major plagioclase, hornblende, epidote, saussurite, minor biotite, chlorite; trace carbonate and altered opaques. Dyke width 60 ft (18 m).
105	Fine-grained diabasic texture; contains major plagioclase, pyroxene, minor chlorite, biotite, quartz and trace hornblende, apatite and K-feldspar, the last as interstitial intergrowths with quartz. Dyke width 80 ft (24 m).

Table 11. Optic axial angles of cordierite

Sample	Optic angle measurement	Mean	Standard deviation
Lower amphibolite facies			
55	66, 68	67.0	1.1
87a	70, 73	71.5	2.1
87b	70, 75, 76	73.7	4.2
194	66, 69	67.5	2.1
289	80, 81	80.5	0.7
495	64, 67, 69	66.7	3.1
632	71, 72, 73	72.0	1.2
736	79, 84, 84	82.3	2.2
819	47, 50, 54, 54	51.3	5.5
820	68, 71, 75	71.3	4.2
847	65, 73	69.0	5.7
885	74, 75	74.5	0.7
Mean of means 70.6			
Middle amphibolite facies			
4	82, 82	82.0	0
37	67, 68	67.5	0.7
103	72, 73, 74, 74	73.3	1.5
172	76, 76, 78, 84	78.5	5.5
205	78, 78, 84	80.0	4.6
230	75, 78	76.5	2.1
344	72, 74, 75	73.7	1.9
350	71, 74	72.5	2.1
360	74, 78, 80	77.3	3.9
393	76, 79	77.5	2.1
453	82, 82, 87	83.7	3.9
472	80, 82, 86, 88	84.0	6.0
476	81, 82, 88	83.7	5.0
491	78, 86, 86	83.3	6.2
674	72, 78, 79	76.3	5.0
776	84, 85, 85	84.7	0.8
1065	66, 67	66.5	0.7
Mean of means 77.7			
Upper amphibolite facies			
62	85, 88, 88, 89	87.5	2.5
117	80, 80, 81, 85	81.5	3.5
123	88, 88	88.0	0
229	81, 81, 83, 86	82.8	3.5
267	89, 92, 92	91.0	2.3
322	78, 84, 84, 85	82.8	4.7
431	90, 95, 95	93.3	3.9
433	83, 85, 86, 90	86.0	5.5
434	81, 82, 84	82.3	1.9
Mean of means 86.2			

$2V\alpha$ measured in thin section with the universal stage. The locations from which samples were obtained are shown in Fig. 53.

Table 12. Partial chemical analyses of cordierite

	Lower amphibolite facies		Middle amphibolite facies					Upper amphibolite facies		
Sample:	819	55	37	230	393	476	776	229	267	431
					(%)					
Na_2O	1.0	0.8	0.5	0.1	0.3	0.2	0.2	0.1	0.2	0.2
K_2O	0.01	0.01	0.01	0	0.01	0.01	0.01	0	0.01	0.01
MgO	7.1	6.1	7.6	11.0	6.9	6.9	8.0	7.2	7.3	7.3
FeO	7.3	7.9	8.3	5.0	7.8	8.6	8.1	8.0	10.6	9.0
MnO	0.23	0.28	0.33	0.10	0.25	0.26	0.32	0.27	0.17	0.22
Areas	3	3	3	3	3	3	3	4	4	2
Spots	14	20	19	18	24	32	23	16	22	12
$2V\alpha$ (mean)	51.3	67.0	67.5	76.5	77.5	83.7	84.7	82.8	91.0	93.3

Analyses by electron probe by G.R. Lachance, Geological Survey of Canada. The locations from which samples were obtained is shown in Fig. 47.

Table 13. Summary of radiometric ages from the Itchen Lake area

Lithology	Pb 207/206	Rb/Sr whole rock isochron	K/Ar muscovite	K/Ar biotite	K/Ar whole rock
			(million years)		
Massive and banded tuffs, Point Lake Formation		2350±105[c]			
Early Archean granitic rocks	2642±15[a] (zircon) 2637±15[b] (sphene)			1815±55[j]	
Late Archean granitic rocks		2422±98[d]	2495±70[e] 2530±80[f]*	1890±70[k] 2075±65[l]	
Keskarrah Formation conglomerate			2660±75[g] 2560±75[h]		
Knotted schist, Contwoyto and Itchen formations			2275±60[i]	2125±60[m] 2350±80[n]	
Metagabbro					1865±235[o]
Porphyritic diabase					1570±115[p] 1240±80[q]
Diabase sills					1555±135[r] 965±58[s] 1255±110[t]
Westerly striking diabase dyke					902±106[u]
Mackenzie dykes					1335±185[v] 1200±135[w]
Porphyritic** andesite flows, Epworth Group					1740±200[x] 1600±135[y]

* Rocks dated to east of map area. **Rocks dated to west of map area.

[a] R.K. Wanless (pers. com., 1975), $\lambda^{238}U = 1.55126 \times 10^{-10}$ yr^{-1}. [b] Ibid., $\lambda^{235}U = 9.8485 \times 10^{-10}$ yr^{-1}. [c,d] Wanless, R.K. and Loveridge, W.D. (1978), $\lambda^{87}Rb = 1.47 \times 10^{-11}$ yr^{-1}. Others all Wanless et al., as follows: [e] 1973, p. 39; [f] 1965, p. 53; [g] 1967, p. 56; [h] 1970, p. 39; [i] 1968, p. 70; [j] 1972, p. 42; [k] 1965, p. 56; [l] 1967, p. 58; [m] 1972, p. 44; [n] 1967, p. 57; [o] 1968, p. 69; [p] 1970, p. 38; [q] 1970, p. 39; [r] 1967, p. 59; [s] 1970, p. 38; [t,u] 1968, p. 68; [v] 1965, p. 44; [w] 1970, p. 46; [x] 1966, p. 38; [y] 1967, p. 58.

Table 14. Ore-mineral showings of the Itchen Lake area referred to in this study

Showing	Type	Occurrence	North latitude	West longitude
Nickel			° ′	° ′
1. Itchen Lake	niccolite-pyrrhotite	Fracture filling at gabbro contact	65 33	112 51½
Gold				
1. Inco (Main showing)	pyrrhotite-pyrite-arsenopyrite-loellingite-Au	Arsenical sulphide iron-formation	65 46	111 14
2. Bar Lake			65 40	111 13
3. Box claims*			65 42	111 01
4. Fuz claims			65 42½	112 32
5. Tree claims			65 19	112 57
Zinc-copper				
1. Point Lake	pyrite-sphalerite-chalcopyrite	Siliceous zone in basic volcanics	65 38	112 48
2. Texasgulf	Zn-Cu-Pb-Ag	In quartzofeldspathic gneiss	65 16	113 06
Copper				
1. Point Lake south	pyrrhotite-chalcopyrite	Disseminated and as fracture fillings in intravolcanic slates, greywacke amphibolite or greenschist	75 10½	113 13½
2. Point Lake central (S)			65 13½	113 12½
3. Point Lake central (N)			65 16	113 9½
4. Point Lake north			65 22½	113 12½
5. Itchen Lake	pyrrhotite-chalcopyrite	Sulphide iron-formation in quartzofeldspathic gneiss	65 33	112 48½
6. Coppermine River			65 2½	112 16
7. Contwoyto batholith (N)	pyrrhotite-pyrite-chalcopyrite	Disseminated in hybrid granodiorite gneiss	65 53½	111 51
8. Contwoyto batholith (W)	chalcopyrite	Carbonate vein cutting minor greenstone body	65 49	111 57

* Location of sample collected by E. Hornbrook is approximate only.

Table 15. Gold and silver analyses of grab samples from the Itchen Lake area

Sample	Au (ppb)	Ag (ppm)
Mafic flows (Point Lake Formation)		
675	20	0.6
731	5	0.2
147	<5	0.8
593	<5	0.5
57	<5	0.5
125	<5	0.2
587	<5	0.8
539	<5	0.5
634	<5	1.1
Felsic flows and tuffs (Point Lake Formation)		
141	30	0.1
124a	10	0.4
957	5	0.4
338	5	0.3
181	<5	0.2
139	<5	1.0
281	<5	0.7
425	<5	0.6
199	<5	0.6
792	<5	0.5
Greywacke slate and schist (Contwoyto and Itchen formations)		
100[1]*	800	1.5
101*	20	0.9
464*	20	0.7
102*	20	0.9
468*	15	0.8
704*	<5	0.8
103*	<5	0.6
771**	<5	0.8
576**	<5	0.7
Granite, quartz monzonite and granodiorite		
748	15	0.2
800	5	0.2
163	<5	0.3
109	<5	0.2
160	<5	0.2
33	<5	0.3
304	<5	0.1
182	<5	0.1
423	<5	0.1
Oxide and silicate iron-formation (Contwoyto Formation)		
309a	160	0.6
628[2]	50	0.5
1300a	45	0.2
309b	40	0.4
1300b	20	0.3
1300c	20	0.7
943	15	1.7
364	10	0.3
932	10	0.4
312[2]	10	0.6
464[2]	10	0.6
360a[2]	10	0.2
1064	<5	0.3
561	<5	0.5
648[2]	<5	0.3
Calcareous rocks		
434c	10	1.2
434b	5	1.1
626[3]	<5	4.6
782	<5	1.1
386[3]	<5	2.5
360	<5	2.3

* Samples from Contwoyto Formation. **Samples from Itchen Formation. [1] Graphite-bearing schist marginal to silicate facies iron-formations. [2] Oxide facies iron-formation. [3] Limestone and marble.

Gold and silver determinations by atomic absorption by Bondar Clegg and Co. Ltd. Standard deviations, based on replica analyses and internal standards, are reported as follows: gold, 5–100 ppb 21.6%, > 100 ppb 10.2%; silver 19.5%. Locations sampled are shown on Fig. 54.

Table 16. Trace element analyses of flotation separates of arsenical sulphide iron-formation

Sample	Ni	Co	Cu	Ag	Au
Loellingite (rich)			(ppm)		
45	100	NF	20	NF	NF
40	200	NF	20	150	3000
22	500	200	<10	NF	NF
Arsenopyrite (rich)					
45	150	NF	15	NF	NF
40	200	NF	30	300	7000
22	300	NF	<10	10	NF
Pyrrhotite					
45	NF	NF	20	NF	NF
40	NF	NF	<10	NF	NF
22	NF	NF	15	NF	NF

NF not found.

Spectrographic analyses by R. Cross and F. Hill, Geological Survey of Canada. Limits of detection: Ni∼100, Co∼100, Cu∼10, Ag∼10, Au∼1000 ppm.

Table 17. Trace nickel content in arsenopyrite, loellingite and pyrrhotite

Sample	Showing	Arsenopyrite	Loellingite	Pyrrhotite
			(ppm)	
19	Fuz claims	1000	6000	2000
23	Main showing	3000	5000	3000
45	Tree claims	<1000	<1000	ND

Electron probe analyses by G.R. Lachance, Geological Survey of Canada.

Table 18. Average gold and silver content of microscopic gold grains at the Fuz claims and at the Main showing

Sample	Gold	Silver	Total	Au/Ag
Fuz claims		(%)		
4	78.6	17.3	95.9	4.54
6	85.3	11.3	96.6	7.55
18	–	(18.0)*	–	–
19	82.0	17.9	99.9	4.58
Main showing				
23	86.9	13.3	100.2	6.53
25	–	(18.0)*	–	–
26	87.1	11.7	98.8	7.44
28	80.1	16.4	96.5	4.88

* Approximate silver content due to small size of gold grains.

Electron probe analyses by A.G. Plante, Geological Survey of Canada. The locations of the Fuz claims and of the Main showing are given in Fig. 50 and Table 16.

Table 19. Pyrrhotite type distribution in three deposits of arsenical sulphide iron-formation

Tree claims		Fuz claims		Main showing	
Sample	Pyrrhotite type	Sample	Pyrrhotite type	Sample	Pyrrhotite type
1	H<<M	5	H>M	10	H<<M
2	H<<M	6	H>M	11	H<<M
3	H<M	7	H>M	12	H>M
4	H≈M	8	H	13	H<M
40	H>M	9	H>M	14	H<M
41	M	18	H≈M	15	H<<M
42	H<<M	19a	H>M	23	H<<M
43	H<<M	19b	H>M	24	H<<M
44	M	20	H>M	25	M
45	H<<M	21	H>M	26	H>M
		22	H>M	27	H≈M
				28	H≈M
				29	H>M
				30	M

H entirely hexagonal. M entirely monoclinic.

Structural type determinations by D.G. Fong, Geological Survey of Canada. The locations of the Tree claims, Main showing and Fuz claims are given in Fig. 50 and Table 16.

Table 20. Relative sulphur content in arsenopyrite from arsenical sulphide iron-formation

Sample	Sulphur
	(atomic %)
Tree claims	
40	33.05
41	33.60
42	33.60
43	33.30
Fuz claims	
18	33.40
18a	33.92
19	33.46
20	33.40
21	33.30
22	33.57
Main showing	
23	33.50
24	33.76
25	33.67
26	33.50
27	33.76
28	33.46
29	33.50
30	33.98
Bar Lake showing	
37	32.55

Analyses by D.G. Fong, Geological Survey of Canada. Distribution of sample sites at the Main showing is given in detail sketch, Fig. 62.

Table 21. Arsenopyrite/loellingite ratios and gold distribution in polished sections of arsenical sulphide facies iron-formation

Specimen	Ratio	Gold grains					Location
		Per 50 mm traverse*	At arsenopyrite-loellingite boundary	In arsenopyrite	In loellingite	In silicates	
				(%)			
46	0.48	0.3	100	–	–	–	Box claims
37	17.8	4.0	–	75	25	–	Bar Lake showing
43	14.9	0.4	100	–	–	–	Tree claims
23	2.2	142	63	25	11	0.1	
24	3.4	0.6	67	33	–	–	
25	5.2	25	56	44	–	–	
26	0.45	15	80	20	–	–	Main showing
27	1.2	21	88	2	10	0.2	
28	2.9	129	76	15	7	–	
29	6.2	99	66	28	6	–	
30	58.1	5	43	57	–	–	
18	2.1	5.8	62	35	3	–	
19	1.3	17	72	17	3	8	
20	0.46	1.0	80	–	20	–	Fuz claims
21	0.49	0.4	100	–	–	–	
22	0.79	4.0	72	–	28	–	

* Gold counts were made by counting each gold grain that came into view in a succession of traverses across polished sections under 600 magnification. Traversing was stopped when 50 mm of arsenopyrite-loellingite had been intercepted except where gold contents were low. Sections 27 and 29 provided only 30 mm of this intercept. The iron sulphide in the specimen studied from Box claims is almost entirely pyrite.

Box claims lie along east margin of map area near Contwoyto Lake within greenschist facies zone. Bar Lake showing lies to southwest of Contwoyto Lake some 6 mi (10 km) southwest of Main showing astride greenschist-amphibolite facies zone boundary. Tree claims lie between north and south arms of Point Lake within lower amphibolite facies zone. Main showing lies near Contwoyto Lake some 4 mi (6.4 km) northwest of Fingers Lake within but near upper boundary of greenschist facies zone. Fuz claims from which specimens studied were taken lie on southwest side of dumbell-shaped lake 8 mi (13 km) southwest of Rockinghorse Lake within middle amphibolite facies zone.

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(principal references italicized)