THE RELATIONSHIP BETWEEN THE AILLIK GROUP AND THE HOPEDALE COMPLEX, KAIPOKOK BAY, LABRADOR

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THE RELATIONSHIP BETWEEN
THE AILLIK GROUP AND THE HOPEDALE COMPLEX
KAIPOKOK BAY, LABRADOR

by

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ABSTRACT

The Hopedale Complex, of Archean age, is a heterogeneous assemblage of banded biotite gneiss, migmatite, amphibolite and granite. A polyphase structural history that pre-dates deposition of the Aillik Group is recognised in the Complex.

The structurally overlying Aillik Group is an Aphebian volcano-sedimentary sequence comprising a lower division of metabasaltic lavas and metasediments, overlain disconformably by an upper division of conglomerate, rhyolite and acid volcanogenic sediments. The Aillik Group is in the order of 3,600 m. thick in the Kitts-Post Hill belt.

Deformation during the Hudsonian orogeny was characterised by the formation of major tectonic slides and by remobilisation of the Hopedale Complex beneath the Aillik Group, with syntectonic intrusion of a major suite of acid plutons into the Aillik Group. The first two events, D_1 and D_2, were essentially restricted to the basement-cover contact zone, and to certain discrete stratigraphic horizons in the Aillik Group that developed as tectonic slides. Intense flattening and transposition of Archean structures in the Hopedale Complex occurred in a zone up to 700 m. wide at the basement-cover boundary. The Hopedale Complex-Aillik Group unconformity was

obliterated and the contact is now marked by a concordant gradational zone of tectonically interleaved refoliated gneiss and amphibolite (Aillik Group metavolcanics). The D_1-D_2 structural zones appear to have been originally subhorizontal, and they are thought to signify essentially translative movement between basement and cover. Major D_1-D_2 thrust slices in the Aillik Group are inferred; some involve wedges of basement gneiss. There is also tenuous evidence for major nappe structures.

The culminative event was D_3, a regional east-northeast-trending shear-belt style deformation dominated by subvertical tectonic slides that replace the limbs of major folds. Metamorphic conditions were in the middle amphibolite facies. Migmatisation and anatexis of the Hopedale Complex was synchronous with and controlled by the third deformation in a zone subconcordant with the basement-cover contact. Sequential emplacement of three major acid intrusive bodies in the Aillik Group was also synchronous with D_3.

Uranium mineralisation occurs locally in D_1-D_2 tectonic slides that were major dilational zones at an early stage in their formation. It is thought that uranium was hydrothermally mobilised from the acid volcanic rocks into the D_1-D_2 dilational zones, with reduction and deposition of uranium in amphibolitic, graphite- and sulphide-bearing lithologies.

Correlation of the lower Aillik Group with the Moran and

Mugford Groups in Labrador, and with the Vallen and Sortis Groups in Greenland is suggested. The upper Aillik Group resembles Aphebian acid volcanics in the south end of the Labrador Trough, and Ketilidian supracrustal rocks in southwest Greenland.

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CHAPTER I

INTRODUCTION

Location and access

Kaipokok Bay is a long narrow arm of the Labrador Sea situated midway on the Labrador coast, approximately 120 kms. north of Lake Melville (Fig. 1). This thesis concerns the geology of an area about 30 kms. long and 5 kms. wide bordering the southeast shore of the bay.

The nearest permanent settlement is Postville, a small fishing and boat building community situated on the west shore of Kaipokok Bay. Postville takes its name from an old trading post, the remains of which can still be seen at Three Rapids, some 6 kms. south of the present settlement.

The area can be reached directly by chartered float plane from Goose Bay, and Labrador Airways runs a scheduled flight to Postville out of Goose Bay twice a week. Postville is also served by CN coastal boats operating out of St. John's. Shipping is usually delayed by coastal ice following the spring break up (early to mid June), and when an early start to summer operations is desired, equipment and supplies should be flown in. However, the coastal boat service offers a reasonably cheap method of shipping samples and equipment out of the field. Ponds usually freeze up in October, but the coastal boats can operate until late November.

Physical features

The topography of the area is of moderate relief. The main feature is a broad barren ridge trending north eastwards parallel to the coast and rising to approximately 300 m. Banded gneiss and meta-sediment have imparted a strong north east grain to the smaller scale features on this ridge. The south end of the area is dominated by Post Hill, 457 m. high, the topographic expression of a synform in an amphibolite unit. The hill is steep sided and scarp-like on its north, north east and south east faces, but the summit slopes off gently to the southwest reflecting the southwest plunge of the synform.

Lithology and structure have exerted a less obvious control on the topography of the eastern part of the area which is lower lying and has a patchy thin cover of glacial drift. The drift cover supports stands of black spruce, but a large proportion of these were destroyed by extensive fires during the summer of 1967, to the great benefit of geologists as the burnt-over outcrops have now been washed clean. Glacial drift also blankets extensive areas in the vicinity of Goula Bight and Inda Lake. Drumlinoid ridges, glacial striae and chatter marks indicate that ice movement was to the north east parallel to the regional strike. The drainage pattern is dominated by the north east grain of the topography and by major north east linears controlled by fracture zones. Minor north west trending linears are the expression of late dykes and exert a subordinate influence on stream patterns.

Excellent wave-swept outcrops occur along much of the shore of Kaipokok Bay; inland on the barren ridges there is about 90% exposure but outcrops are lichen covered. In the eastern part of the area, the exposure varies from 10-15% but paradoxically, the rocks there are generally easier to study than in the totally barren areas, because a layer of caribou moss can be peeled off the edges of outcrops, revealing clean lichen-free surfaces.

Regional setting

Labrador forms the Atlantic seaboard of the Canadian Shield, and contains a diversity of geological environments perhaps unrivalled by any other comparable area of the shield. Four structural provinces are represented: the Superior and Nain (or Nutak; Archean), the Churchill (early Proterozoic) and the Grenville (late Proterozoic) (Stockwell, 1963 and 1964; Fig. 1). In addition, a unique suite of huge mid-Proterozoic (Elsonian) anorthositic plutons and related intrusions underlies a significant proportion of Labrador, and has isotopically rejuvenated a wide belt of adjacent rocks.

The Nain or Nutak Province is a remnant of a much larger crustal block, the North Atlantic craton (Bridgewater et al., 1973a), that has remained essentially stable since the Archean, but was fragmented by Phanerozoic continental drift (Fig. 2). The craton is bordered by zones of early Proterozoic mobility that contain varying proportions of reworked Archean material and Proterozoic supracrustal sequences.

The Kaipokok Bay area lies in the boundary zone between the stable Archean block and one of the younger mobile belts on the southeast margin of the Nain Province.

The Archean rocks of the Nain Province are dominated by gneiss and migmatite with numerous mafic inclusions and abundant granodioritic and granitic material (Taylor, 1972). Two relatively narrow supracrustal belts of amphibolite including minor ultramafic bodies are interfolded with the gneiss complex west and southwest of Hopedale. Amphibolite facies metamorphism predominates, but granulite facies metamorphism is preserved north of Nain. The rocks of the southern part of the Province are generally known as the Hopedale Gneiss (Krank, 1953) or the Hopedale Complex (Sutton, 1972) though the value of such terms in preference to simply "Archean complex" is questionable. The Archean geology of the North Atlantic Archean craton contrasts strongly with the greenstone belt-granitoid batholith terrain of other Archean blocks throughout the world, e.g., the Superior Province. The high grade gneiss terrain of Labrador and Greenland probably represents a deeper structural level than do the latter areas.

In the Kaipokok Bay region on the south margin of the Nain Province (Plate 1), the Archean rocks are overlain by a supracrustal sequence of dominantly mafic and acid volcanic parentage named the Aillik Group that was deformed approximately 1600 m.y. or more ago (Gandhi et al., 1969). The Aillik Group together with a suite of Hudsonian-Elsonian intrusions forms a wedge shaped area interposed between the Nain and Grenville Provinces; this wedge has been named the Makkovic Sub-province by Taylor (1971) who regarded it as a part of the Nain Province. The limits of the Makkovic Sub-province are inadequately defined but it is clear that it represents a segment of a Ketilidian-Hudsonian mobile zone (Fig. 2; Bridgewater, 1969; Sutton et al., 1971) and as Douglas (1972) has pointed out, cannot logically be included in the Nain Province.

History of investigation

Previous work in the area occurred in two distinct phases of endeavour. The first period, from 1902-1952, involved successive reconnaissance surveys that were concerned with large segments (or all) of the Labrador coast. This was followed in 1952 by the onset of detailed geological investigations and mapping related to the search for economic mineral deposits.

The first comprehensive descriptions are those of Daly (1902) who participated in the Delabarre Expedition to the Labrador coast in 1900. He noted that gneisses, granites, gabbro and traps prevail from the Straits of Belle Isle to Cape Chidley, and recognised that these crystallines are unconformably overlain by sedimentary formations at Aillik Bay, in the Mugford Region and from Saglak Bay to Ramah. Daly described "variegated banded quartzites" and a variety of intrusions in Aillik Bay - "a veritable museum of rock types" - but did not visit Kaipokok Bay. At his next stop, Hopedale, he described and named the

Hopedale gneiss which he considered to be an important division extending for at least 193 kms. along the coast.

Kranck (1939a) surveyed the southern half of the Labrador coast and described the sedimentary rocks of the Aillik-Makkovic area in greater detail, referring to them as the "Aillik formation". He considered the "quartzite-conglomerate" Aillik formation to underlie a limited area near the coast and to "swim" in a white granite which he interpreted as the result of granitisation of the sediments. He recorded deformed quartz porphyry-like rock interlayered with the quartzite, and thought that it might represent altered deformed quartzite, or be partly igneous in origin. He differentiated the "Strawberry granite" as a later intrusion and described two post-granite sets of dykes: a lamprophyric suite, followed by a basaltic suite. In the former suite, he recognized an alnoitic carbonate-rich dyke that he later (Kranck, 1953) recognized as a carbonatite. This suite was investigated by Hawkins at Memorial University of Newfoundland (Collerson et al., 1973). Kranck (1939b) was the first geologist to compare and suggest correlations between the coasts of Labrador and Greenland (see also Kranck, 1939c).

Kranck carried out further reconnaissance in 1939 and 1949 and the first direct reference to rocks in the thesis area is by him (Kranck, 1953). He referred to mica schists and phyllitic schist with limestones occurring south of Long Island and on the west shore of Long Island. He considered these to be a facies of the Aillik formation, and mentioned strong folding and mylonitisation, and a transition into grey gneiss. He further suggested that the Hopedale gneiss west of Kaipokok Bay could represent sediments of the Aillik formation that were transformed in a deep seated environment. Krank considered the Aillik formation to be older than the sedimentary rocks that rest unconformably on the gneiss complex in the Labrador trough, and at Ramah and Cape Mugford.

Mapping in the Kaipokok-Adlavik region was carried out by members of the Douglas expedition in 1946 and 1947 (Douglas, 1953). The work was still essentially confined to coastal outcrops, and though Krank's (1939a) findings were amplified upon, no significant new relationships were revealed. They first applied the term "Aillik series" to the sedimentary rocks which were reported as a succession of conglomerate, quartzite, dolomite and mudstone. It was thought that the sediments were strongly granitised after they had been folded, and that the granitization increased southwards towards a major batholith underlying the Benedict Mountains. The Strawberry granite was considered to be related to the granitization, though Krank (1939a) had shown that it was later than these supposed effects. The shore of Kaipokok Bay between Three Rapids and Marks Bight was mapped simply as 'gneiss' except between Kitts Pond and Marks Bight Point where two patches of Aillik series limestone are shown. Schistose and gneissic altered mudstone with a rusty appearance are mentioned in the text as occurring on the south shore of Kaipokok Bay.

A large strip of the Labrador coast including Kaipokok Bay was once more examined in 1952, this time by Christie of the Geological Survey of Canada (Christie et al., 1953). The results were included on a 1 inch to 8 mile compilation map that in the Kaipokok-Makkovic region shows no improvement on earlier maps. The Aillik series is not mentioned in the accompanying descriptive notes.

Mineral exploration in central Labrador commenced in earnest after World War II in the Seal Lake area, where it was hoped that folded sedimentary rocks would prove to be equivalent to the rich iron ore-bearing formations of the Labrador Trough. Initial work in the concession soon shifted the focus of interest to base metals (Evans, 1952). A large area between Postville and the Seal Lake Concession was prospected and mapped between 1952 and 1954 by Amoco Explorations Inc., and geological reconnaissance in the coastal area was undertaken by British Newfoundland Exploration Limited (BRINEX) in 1953 and 1954. Pitchblende mineralization was found by BRINEX south of Makkovic in 1954, and this stimulated activity that led to the discovery of uranium showings on the east edge of the Seal Lake Concession by Frobisher Limited in 1955, and at the Kitts Prospect by BRINEX in 1956.

The first systematic geological mapping in the region dates from this period, and by 1958 many other uranium occurrences had been found between Makkovic and the east edge of the Seal Lake Group (Fig. 2), defining the "Labrador uranium area". Beavan (1958) summarised unpublished company data and compiled the first comprehensive geological map of this area; his map was not superseded until 1970. Volcanic rocks, including dark green flows and lavas with quartz eyes were recorded as prominent in the Aillik series, which was regarded as equivalent to the Croteau Group to the southwest (Fahrig, 1959; see Plate 1); the continuity of the Aillik and Croteau series in the central part of the area was thought to have been destroyed by metamorphism and granite intrusion. Beavan described a transitional contact between the Hopedale Gneiss and the Aillik series along Kaipokok Bay; this was regarded as evidence that the Hopedale gneiss represents a deep-level metamorphosed facies of the Aillik series. Robinson (1956b) suggested that this sharp metamorphic gradient along Kaipokok Bay was the northeasterly extension of the Grenville Front.

King (1963) mapped an area containing molybdenum mineralization on the east side of Aillik Bay, and renamed the Aillik series the Aillik Group; this revised terminology was not used again until 1969 (Barua, 1969). King recognized a zone of mylonitisation in the Aillik Group, and established a detailed chronology of pre- and post-metamorphic intrusive rocks, the latter involving six different periods of intrusion.

Gandhi et al. (1969) compiled work by BRINEX done up to 1968 in the Makkovic-Kaipokok area, and published a summary map that included the northeast end of the Kitts-Post Hill belt. They were the first to recognise the Hopedale Gneiss as migmatised Archean basement, and estimated the thickness of the "Aillik Series" to be in the order of

7620 m. (25,000 feet). The "Series" was divided into nine map units of formational status, consisting of paragneiss, conglomerate, mafic lava and six varieties of quartzite. Locally established sequences of these units could not be correlated across the whole area. Locally abundant euhedral feldspar crystals in the quartzite were interpreted as porphyroblasts, and the "granitised quartzite" of earlier workers was believed to represent recrystallised sediment. Two major plutons in the Kitts-Post Hill belt, the Long Island Gneiss and the "granite gneiss" were described; the former was considered pre-metamorphic and the latter synkinematic. K-Ar age determinations were presented and interpreted as showing that the deformation of the Aillik Series occurred in the Hudsonian orogeny about 1600 m.y. ago. Major broad anticlines and tight synclines were delineated, and the syntectonic emplacement of domes of the granite gneiss was recognized as an important element in the structural evolution of the area.

In 1969, Gandhi also prepared three useful unpublished compilation maps for BRINEX, covering the Kaipokok Bay-Big River area (1 inch = 2 miles), the Walker Lake-White Bear Mountain belt (1:50,000), and the Kitts Pond-Post Hill belt (1 inch = 2000 feet).

Bridgewater (1970) visited the Aillik Series in 1969 and for the first time recognized that the 'quartzites' are dominantly "sodic impure psammites of acid volcanic origin". Barua (1969) working in the Aillik area also considered that some of the quartzite units were acid volcanics and pyroclastics (some "spilitic") although he still described all but two units, as quartzite with feldspar and quartz porphyroblasts.

Stevenson (1970) described the 1:250,000 Rigolet-Groswater Bay map area which includes the southern two thirds of the Kitts Pond-Post Hill belt. He used the term Aillik Group, and described the lithologies in similar terms to Gandhi et al. (1969). However, he also described the acid volcanic rocks in the Walker Lake-White Bear Mountain belt that were mentioned by Beavan (1958); he found that the rhyolitic rocks were "difficult to distinguish from feldspathic quartzites" into which they locally grade. With statements such as this abounding it is difficult to understand why Stevenson did not recognize the acid volcanic origin of the "quartzites".

Clark (1970) mapped a part of the Aillik peninsula due east of Marks Bight and Long Island. He classified the "quartzites" as psammites and divided the "Aillik Series" into an older and a younger sequence separated by a phase of deformation that was considered to predate deposition of the younger sequence. Three phases of deformation in all were described, the second of which produced a major recumbent anticline facing north west. Recognition of quartz phenocrysts in one psammite unit, and the feldspathic nature of all the psammites suggested an association with "high level igneous activity", either intrusive or extrusive, or derivation from an "igneous terrain". Clark (1971) later abandoned his two-fold division of the Aillik Series when a strictly zonal development of the first phase of deformation was subsequently demonstrated (Sutton et al., 1971).

Taylor (1972) re-examined the northern part of the Kaipokok-Makkovic region as part of a regional survey, and also considered that most of the Aillik Group is composed of rocks of acid volcanic origin, dominantly porphyritic siliceous tuffs.

By 1969, the Makkovic region had been more or less completely mapped on various scales by BRINEX geologists. E.R. Morrison, M.J. Piloski, W.D. Kitts, W.D. Cowan, M.C. Barua, M.V. White, S.S. Gandhi and others all contributed to the mapping of the Kitts Pond-Post Hill belt, but their work remains in confidential BRINEX reports. The work was conducted by many different seasonal employees over a period of 15 years and so it naturally lacked continuity and interpretation. It was realised by BRINEX that despite the valuable compilations of Gandhi the region as a whole required further detailed structural and stratigraphic studies in order to assess the environment and controls of the uranium and molybdenum mineralization. To this end, BRINEX funded and supported field work in 1970 and 1971 by a research team from Memorial University consisting of J.S. Sutton (supervisor), A.M.S. Clark and B.E. Marten. Sutton investigated the Archean Hopedale Gneiss west of the Aillik Group, Clark studied the stratigraphy and structure of the Aillik Group in the Makkovic area, and the writer mapped the structure and relationships of the Aillik Group and Hopedale Gneiss in the Kitts Pond-Post Hill belt. A preliminary account of this work (Sutton et al., 1971) showed that deformation of the "Aillik series" was initiated in belts of intense flattening with some associated translative movement, and culminated in a regional penetrative deformation.

Sutton (1972) mapped the area bordering the west shore of Kaipokok Bay and recognized the polycyclic nature of the Hopedale Gneiss which he renamed the Hopedale Complex. He described an overlying younger belt of dominantly mafic metavolcanic rocks, the English River Greenstones, and showed that intense zonal refoliation of the Hopedale Complex bordering the Greenstones produced a gradational gneiss-supracrustal contact; this event was followed by a more regionally developed folding on a north-east trend. The English River Greenstones can be traced continuously around major fold closures southwest of Postville into similar rocks in the Aillik Group on Post Hill (unpublished BRINEX compilation map by S.S. Gandhi).

Clark (1974) mapping in the Makkovic area estimated the thickness of the Aillik Group to be 8,500 m., some 880 m. more than Gandhi et al. (1969). He described the group as consisting of acid volcanic rocks and associated shallow-water arkoses, tuffs and conglomerate with minor basic lavas. He grouped the map units of Gandhi et al. (1969) into five proposed new formations. However, the stratigraphic relationships of three of the new formations remain unclear, and an overall succession could not be established because of a major tectonic break (slide zone) recognised west of Makkovic. Four major deformations that were associated with major synkinematic granitic to gabbroic intrusions were recognized and assigned a Sanerutian (1600 m.y.) age; the Aillik Group and the Sanerutian episode were believed to post-date the Hudsonian orogeny.

To summarize knowledge at the initiation of this study, two main fundamental problems relating to the Aillik Group remained: Firstly, the Hopedale Complex was recognised as Archean and the Aillik Group as Aphebian in age, yet in detail the two appeared conformable. What then is the nature of the contact, and how and when did it develop? Secondly, most workers regarded the Aillik Group as being composed dominantly of quartzitic sediments, yet a few, notably Beavan (1958) and Bridgewater (1970) recognised that the Group includes at least some acid volcanics. The actual nature and stratigraphy of the Aillik Group therefore required clarification.

Purpose and techniques of the present study

This study was undertaken to determine the stratigraphic and structural evolution of the Kitts Pond—Post Hill belt, in particular the relationship between the Hopedale Gneiss and the Aillik Group. This information is necessary for evaluating the tectonic and stratigraphic environment of uranium mineralisation that occurs at five main localities along the length of the belt.

The mapping was carried out in the 1970 and 1971 field seasons (mid-June to early October) from a total of 7 fly camps; these were serviced and moved by a Bell G4 helicopter based at a BRINEX base camp near Three Rapids (Plate 2). Most of the area between Post Hill and Swell Lake was mapped at a scale of 1 inch = 1250 feet (1:15,000) and 1 inch = 1320 feet (1:15,840) using air photographs privately flown for BRINEX by Photographic Surveys Inc.; data was plotted on base maps prepared by the writer from the air photographs. The coastal zone from Goula Bight to Marks Bight was mapped at a scale of 1:24,000 using air photographs supplied by the Department of Mines and Energy, Ottawa, and plotting was on 1:24,000 base maps prepared by BRINEX; all coastal outcrops were examined in detail. In addition the areas around the Kitts Prospect and the Inda Lake-Knife Lake showings were mapped at a scale of 1 inch = 400 feet using enlargements of the 1 inch = 1320 feet air photographs. Two thousand feet of diamond drill core from the Inda Lake-Gear Lake zone were examined. Visits to the Makkovic and Michelin area were made at various times in order to examine the nature of the Aillik Group outside of the study area. On completion of the field work the data was compiled onto a 1:24,000 base map and a preliminary report was submitted to BRINEX in 1971.

The principles of small-scale structural mapping as developed by many workers, notably Wilson (1961), and the concept of facing directions of folds (Shackleton, 1958) are applied throughout. Both small and large scale structures are interpreted in terms of the theories of strain, strain variation and tectonite fabric development as expounded by Flinn (1962; 1965a) and Ramsay and Graham (1970). Fleuty's (1964a) terminology is applied to the general morphology of the folds. Special attention was paid in the field to the nature and accurate delineation of the various lithological boundaries in the area; on the basis of their characteristics many of these boundaries are recognised as tectonic slides as defined by Fleuty (1964b), and this concept forms an essential part of the geological interpretation presented here. The methods of identifying successive events in the polyphase deformed rocks that were developed by a host of workers mainly in the Scottish Highlands are used. Scrutiny of the relationship of intrusive igneous contacts to structures produced by successive events recognised by these methods are crucial in interpreting the overall plutonic evolution of the area.

The field work was supplemented by detailed petrographic study of thin sections. Minerals were identified by normal optical methods using the data of Deer, Howie and Zussman (1962). Plagioclase compositions were determined by the Michel-Levy method using a four-axis universal stage. Study of the feldspars was facilitated by the techniques of staining thin sections and slabs (Bailey and Stevens, 1960; Nold and Erickson, 1967). The main purpose of the thin section study was to determine the metamorphic mineral growth history as related to the strain history of the rocks, by examining the textural relationships of the constituent minerals and their inclusions using the principles developed and applied by workers such as Rast (1957, 1965) and Zwart (1960, 1962).

The successive phases of deformation are referred to by the notations D_1, D_2 ... etc., and folds, planar and linear fabrics produced during these phases are referred to as F_1, F_2 ..., S_1, S_2 ..., L_1, L_2 ....

etc., respectively. Successive metamorphic events that can be related to the phases of deformation are labelled MS_1, MP_1, MS_2, MP_2 ... etc., according to whether they are interpreted as synchronous with (MS), or post-dating (MP) a particular deformation phase.

Nomenclature of igneous rocks follows Williams, Turner and Gilbert (1958).

Strictly informal stratigraphic terminology is used, and is kept as simple as possible. It is felt that formalised nomenclature would be premature at this stage of investigation of the Aillik Group, especially when developed in a relatively small area.

The lithological description of each map unit includes the sequence of tectonite fabrics developed, together with the metamorphic mineral growth history, because these features form an integral part of the character of the rocks. Petrographic details are contained in Appendix A.

The structure of the area is dominated by development of tectonite fabrics in linear belts or "zones" that may be extremely narrow but continuous along strike. The term "zone" as applied in this thesis to structural elements therefore means a relatively narrow linear belt.

Summary of the geology

A summary of geological events is given in Table I.

The Hopedale Complex is recognised as Archean basement, on which the Aphebian Aillik Group was laid down (Sutton, 1972). The Hopedale Complex is a heterogeneous assemblage of banded gneisses, migmatite, amphibolite and granite that within the Kitts-Post Hill area have been largely transposed and migmatised during the Hudsonian orogeny. However a sequence of pre-Aillik Group structural and metamorphic events are recognised. Two early periods of deformation that involved intense transposition and isoclinal folding were followed by widespread migmatisation. Subsequently a penetrative tectonite fabric was imposed on the earlier structures. Events that pre-date this structural sequence cannot be deciphered, but it appears that they were superimposed upon a pre-existing high grade gneiss complex that may have included remnants of supracrustal rocks (Sutton, 1972).

The structural sequence summarised above is inferred to be of pre-Aillik Group age because the related structures are deformed by the earliest event that affects the Aillik Group.

The unconformity between the Aillik Group and the Hopedale Complex is not preserved. It has been obliterated by major structural transposition caused by basement-cover transposition during the Hudsonian orogeny.

The Aillik Group is a volcanic-sedimentary sequence comprising a lower division of metabasaltic pillow lavas and metasediments, and an upper division of conglomerate, rhyolite and acid volcanogenic sediments. The upper division is inferred to have a disconformable relationship to the lower division. The thickness of the Aillik Group within the Kitts-Post Hill area is in the order of 3,600 m.

The lower Aillik Group comprises three formations. The basal formation is the Post Hill amphibolite (1000 m.) composed of hornblende schist, believed to represent intensely deformed pillow lavas. It is not known if this formation originally rested unconformably on the Hopedale complex, or whether underlying unit(s) formerly present have been excised by Hudsonian basement-cover interaction. The Post Hill amphibolite is overlain by the metasedimentary formation (820 m.) consisting of thin bedded metasiltstone and sandstones with biotite-muscovite schist intercalations. The formation includes a pyrite-graphite member that forms a conspicuous marker horizon. The overlying Kitts pillow lava formation (910 m.) is composed of massive metabasalt pillow lavas, and it includes chert-magnetite "iron formation" members. Gabbro sills occur in the iron formation members, and are believed to be related to the basaltic volcanism.

The base of the upper Aillik Group is marked by the conglomerate formation (260 m.), a massive polymictic conglomerate containing clasts of granite, a variety of acid volcanics and acid hypabyssal intrusive rocks. At its base, the conglomerate locally includes clasts derived from the underlying Kitts pillow lava formation, indicating uplift and local erosion of the lower Aillik Group. There is no evidence for an angular unconformity and the base of the conglomerate formation is interpreted as a disconformity. The overlying rhyolite formation (300 m.) consists of massive to ignimbrite-like rhyolite. It is overlain by the banded tuff formation (300+ m.) comprising fine grained waterlain acid volcanic detritus, thin bedded in alternating shades of pale grey, pink and pale green. This formation represents the highest stratigraphic level exposed within the area.

Quartz porphyry dykes cut the early gabbro dykes in the Kitts pillow lava formation, and they are believed to be genetically related to the acid volcanics in the upper Aillik Group.

Post-Aillik Group polyphase deformation and metamorphism affected both the Aillik Group and Hopedale Complex. This orogenic episode is assigned to the Hudsonian Orogeny, for although K-Ar ages in the Makkovic area cluster around 1600 m.y. B.P. (Gandhi et al., 1969) correlations with southwest Greenland suggest that this is due to very slow post-orogenic cooling (Chapter IX). Grenville overprinting causing argon leakage may also have played a part.

Deformation during the Hudsonian orogeny was dominated by the formation of major tectonic slides, and took place in a sequence of events D_1 to D_5. Early repeated intense deformation, D_1 and D_2 were essentially localised in the contact zone between basement and cover; they effectively obliterated the Hopedale Complex-Aillik Group unconformity. The culminative event was D_3, a zonally developed penetrative deformation that was accompanied by migmatisation in the Hopedale Complex and sequential intrusion of an acid igneous suite into the Aillik Group.

D_1 and D_2 were essentially localised in a major zone along the Aillik Group-Hopedale Complex contact, and to subsidiary strata-bound horizons in the Aillik Group. The intimate association of D_1 and D_2 suggests that they were composite and related events. The principal effects of D_1 and D_2 were the transposition of banding and early structures in the Hopedale Complex into parallelism with the basement-cover boundary. This was accomplished by intense flattening and recrystallisation that gave rise to a unit of fine grained flaggy gneiss, the Refoliated Gneiss Zone (700 m.) in which Archean structural elements have been largely obliterated. The contact between the Hopedale Complex and the Refoliated Gneiss is a gradational one marked by progressive deflection of the pre-Aillik banding into parallelism with the Aillik Group contact. The contact with the Post Hill amphibolite is gradational, marked by small scale D_1 tectonic interslicing of amphibolite and gneiss. This contact, the Post Hill Slide, is associated with extreme structural thinning of the Post Hill amphibolite. The discrete strata-bound zones of D_1 - D_2 deformation in the Aillik Group are also D_1 - D_2 tectonic slides (Fiace Lake and Nakit Slides) with subsidiary movement confined to the incompetent iron formation members. A wedge or slice of the Hopedale Complex has been introduced into the Aillik Group by the Nakit Slide, and a similar but more phyllonitic wedge occurs southeast of Turnip Lake.

The D_1 - D_2 tectonic slides appear to have been essentially sub-horizontal before initiation of D_3. It is thought that they signify major translative movements between the basement and cover. The presence of major thrust slices in the Aillik Group is suggested; some of these involve basement gneiss. One major F_2 fold closure has been identified and the presence of major nappes can be further inferred from tentative structural cross-sections. The direction of tectonic transport is not known. Metamorphic conditions related to D_1 and D_2 appear to have been in the upper greenschist facies.

The third deformation, D_3, though developed regionally was again most intense in the basement-cover contact zone. The related tectonite fabric and fold axial planes are sub-vertical; fold axes plunge gently to the southwest. Tectonic slides are a major feature of the D_3 structural pattern. Systematic variations in orientation and intensity of S_3 indicate that the tectonic slides are related to major dextral shear-zone style deformation. D_3 tectonic slides replace the limbs of major related folds, the development of which can be related to shear-zone-style strain variation. This is best seen in the Post Hill Fold, a major F_3 synform. In this structure both the axial plane and the axial-planar fabric, S_3, converge in a dextral sense with, and merge into, the Witch Lake Slide. A swarm of gabbro dykes were intruded, after folding had commenced, into tensional fissures related to the dextral sense of shear. They were subsequently progressively deformed and rotated into the plane of flattening towards the Witch Lake Slide. At approximately the same time the east limb of the fold was ruptured by intrusion of the Migmatitic Quartz Monzonite parallel to S_3.

Migmatisation of the Hopedale Complex was initiated in the early stages of D_3 in a broad belt parallel to and immediately beneath the refoliated basement-cover contact. The migmatisation gave rise to the autochthonous Unlucky Head Migmatite and the para-autochthonous Brumwater Granite and Migmatitic Quartz Monzonite. A late body of leucogranite also appears to be related to this event. Metamorphic conditions during D_3 appear to have been in the middle amphibolite facies, and the migmatites are believed to reflect anatexis under relatively hydrous conditions.

The Unlucky Head Migmatite consists of ovoid rafts of Hopedale Complex gneiss and migmatite in a schlieric, nebulitic or fairly homogeneous neosome. Relationships in the rafts of gneiss show that migmatisation by partial melting was intiated along D_3 diktyonitic structures. Passive, more or less homogeneous deformation of neosome (as a crystal mush) in response to the D_3 stress is indicated by north-south orientation of the ghost banding, parallel to S_3 and approximately at right angles to the banding in the gneiss rafts, which therefore appear to have suffered little rotation. The rafts are thus inferred to preserve the pre-migmatisation strike of the Hopedale Complex. The migmatisation appears to have been controlled by mobilisation of volatiles into dilational D_3 structural zones.

The Brumwater Granite is a leucocratic biotite granite, schlieric in parts, that forms a tabular body flanking the Refoliated Gneiss Zone. It is thought to have formed by filter-press expulsion of partial melt from the Unlucky Head Migmatite, with which it has a gradational contact.

The Migmatitic Quartz Monzonite is a megacrystic quartz monzonite that includes ragged xenoliths of gneiss. It forms a tabular body that cuts the east limb of F_3 Post Hill Fold, parallel to S_3. It truncates S_2 in both the Post Hill amphibolite and the Refoliated Gneiss Zone, and is in turn foliated by S_3. It was intruded after the Post Hill Fold had started to develop.

A suite of synkinematic and igneous rocks was emplaced in the Aillik Group at approximately the same time as the migmatisation was taking place. They truncate D_1 and D_2 structural features and are themselves foliated by S_3; it is thought that intrusion was synchronous with the early stages of D_3. The earliest member, the Long Island Gneiss, is a medium grained quartz monzonite characterised by abundant mafic xenoliths; diabase and porphyritic diabase dykes were synchronous with the early stage of its intrusion. The Long Island Gneiss is cut by the Porphyritic Microgranite, a fine grained massive leucocratic rock which in the field has a rhyolitic aspect. This in turn is cut by the Monzonite, a massive coarse grained leucocratic rock that forms a major regionally subconcordant tabular pluton. The Monzonite is lithologically identical to a homogeneous phase of the Migmatitic Quartz Monzonite, suggesting a genetic link between the apparently co-eval migmatisation in the basement and magmatic intrusion into the cover rocks. Such a connection is also suggested by the Pitre Lake Granite. This is a post-D_2 and pre or syn-D_3 muscovite granite that has intruded the metasedimentary formation. It has a faint inherited gneissic structure that resembles ghost banding in the Brumwater Granite, to which it may be related.

The later deformations, D_4 and D_5, were minor events mainly developed in schistose lithologies. They are represented by a strain-slip cleavage and a sinistral set of kink bands respectively.

Uranium mineralisation occurs locally in the iron formation members of the Kitts pillow lava formation, and in the Nakit Slide. These horizons were initially major dilational zones in D_1 and D_2. It is thought that uranium was mobilised from the acid volcanic rocks into the dilational zones during D_1, with reduction and deposition of the uranium in graphite- and sulphide-bearing lithologies.

CHAPTER II

HOPEDALE COMPLEX

The Hopedale Complex consists of banded gneisses, migmatite and minor granite. It is regarded as a pre-Aillik Group basement on the basis of an extremely complex structural history that predates earliest structures in the Aillik Group, and also because two potassium-argon Archaean ages have been obtained from the terrane some 25 miles west of Kaipokok Bay (Wanless et al., 1965; Leech et al., 1963). Rocks of the Hopedale Complex occur east of Three Rapids, south and east of Goula Bight, in the Kitts Pond area and west of the Makkovic River. Exposure is very poor south of Goula Bight and west of the Makkovic River, and these areas may contain anatectites in the gneiss that are related to the Hudsonian remobilisation.

Banded gneiss

Banded gneisses of granodioritic composition are widespread in the Kitts Pond area and east of Three Rapids. Some of their features are best displayed in excellent coastal exposures of gneiss enclaves within the Unlucky Head Migmatite. They are composed dominantly of quartz and sodic andesine (An 32-38) with minor biotite and hornblende; apatite, orthite and sphene are the prevalent accessories. K-feldspar is not common and rarely forms more than 5% of the rock except in some minor bands of granite gneiss. The banding is on a 0.5 to 10 cm. scale and leucocratic quartz-feldspathic bands alternate with grey or dark grey biotite or biotite-hornblende rich bands (Fig. 3). The character of the banding varies from place to place although the mineral assemblages are identical apart from fluctuations in amount and proportions of biotite and hornblende. This variation encompasses relatively regular bands about 0.3 mm. thick showing little colour contrast, a crude streaky gneissosity on a 0.5 - 1 cm. scale. Commonly bands of leucocratic granite gneiss 1 - 20 cm. thick alternate with more thinly banded grey biotite gneiss. The variations in lithology are attributed to variations in composition of the parent rocks from which the gneisses were derived and their subsequent structural and metamorphic evolution. Granitic and pegmatitic veins both concordant and discordant to the banding are common and form an integral part of the banded gneiss. Structural relationships indicate that they are of at least three generations.

Bands of foliated amphibolite usually 10 - 40 cm. but ranging up to 10 m. in thickness are concordant with the banding in the gneisses. They are composed of 60 - 75% hornblende with zoned andesine and minor quartz, and in places show a gneissic foliation of alternating andesine rich and hornblende rich bands 2 - 10 mm. thick. Gentle pinch and swell structure is common, reflecting incipient boudinage of the bands and is associated with segregation of minor plagioclase-quartz veinlets (Fig. 3). Locally strings of lenses and pods of amphibolite around which the banding forms smooth augen reflect complete boudinage of these beds.

Amphibolite also occurs in more complex bodies that may be pod, lens or irregularly shaped and are characterised by an internal foliation oblique to and truncated by the banding of the gneisses. They usually occur in trains aligned in the banding and mineralogically and texturally they resemble the concordant amphibolites.

Early migmatite

The early migmatite consists of grey foliated granodiorite containing irregular rafts, lenses and nebulous patches of banded gneiss. It displays similar features to the Unlucky Head Migmatite within which it occurs as enclaves up to 400 m. across, but its pre-Aillik Group age is established by the contact relationships of these enclaves. The penetrative fabric in the early migmatite is truncated by the Unlucky Head Migmatite at the contacts of the enclaves (Fig. 4). The granodiorite in the early migmatite is also distinguished by its slightly darker colour.

The granodiorite is composed of calcic oligoclase, quartz and minor biotite and there are two apparently related phases differing in their percentage of biotite (Fig. 5). It contains scattered grains of magnetite up to 10 mm. in diameter surrounded by leucocratic coronas free of mafics.

Fabric

(a) Pre-Hudsonian

The banded gneisses show a very complex history of fabric development. Relics of banding preserved in boudins and intrafolial folds suggest that the gneissic banding has been transposed by intense deformation at least once.

At least two early penetrative hornblende fabrics are preserved in the amphibolite bands and complex boudins. The complex boudins contain a hornblende L-S fabric that is truncated by the external gneissosity. Locally the fabric may be weak but it is generally present. A transpositional-type banding was not noted even where it is evident that an early fabric has been transposed into a later one. The amphibolite bands concordant with the gneissosity locally show an early hornblende fabric in the noses of isoclinal folds related to a biotite hornblende fabric in the gneiss.

(b) Hudsonian

The Hudsonian S_1 fabric is not seen.

S_2 is a weak biotite fabric developed close to the foliated gneiss zone enveloping the Post Hill fold, and is also seen as a coarser biotite-muscovite schistosity in the gneiss wedge south east of Turnip Lake. It increases in intensity as the refoliated zones are approached and will be considered further in the description of the Refoliated Gneiss Zone (Chapter III).

S_3 is zonally developed in the gneiss, east of Three Rapids and in the Kitts Pond Wedge. ~~East of Three Rapids it~~ is a locally developed biotite fabric associated with L_3 crenulation ribbing of the gneissic banding. Locally it is seen superimposed upon a lineation related to the Pre-Hudsonian fabric. L_3 is also seen where there is no apparent S_3 developed. In the gneisses north of the Kitts Prospect small-scale dextral D_3 shear zones kink the gneissic banding, and north of Kitts Pont a zonal biotite fabric occurs as well.

A penetrative biotite fabric in gneiss and migmatite west of the Makkovic River is believed to be S_3 since it strikes parallel to, and appears to be continuous with S_3 in the tongue of Long Island Gneiss south west of Swell Lake. It is L-S fabric and L_3 is seen as a quartzofeldspathic rodding in the gneiss.

Pre-Hudsonian Metamorphic History

Although a long and complex Pre-Hudsonian growth history is suggested by the polyphase structural development evident in the gneiss complex, no real indication of the metamorphic conditions related to any but the last of the Pre-Hudsonian deformations is found. This is due principally to the lack of any porphyroblastic minerals within which relict mineral assemblages might have been preserved, and to extensive syntectonic recrystallisation associated with the last penetrative deformation.

While field evidence suggests that at least two periods of syntectonic growth of hornblende and plagioclase took place in the mafic rocks to form the L-S fabrics well preserved in the amphibolite boudins and bands, amphibolites generally do not appear to be sensitive indicators of metamorphic conditions. The fabrics related to the various phases including the last are texturally and mineralogically similar, and indicate that general amphibolite facies conditions prevailed during the later history of the complex. The present composition of the plagioclase (An 28) probably does not reflect the original composition related to the early growth phases, but rather adjustment to conditions during the last Pre-Hudsonian event. Locally strong normal zoning suggests that the original composition was more calcic, and hence that the earlier metamorphic events were higher grade. In the banded gneisses myrmekite that pre-dates the last penetrative deformation (see Appendix A) appears to be the only clear relic of previous mineral growth, and probably represents a minor MP event.

The early hornblende-rich pods with the green actinolite cores resemble zoned mafic pods described by Sutton (1972) in the Hopedale Complex about 20 kms. to the north of the present area. Sutton records the occurrence of relic bronzitic hypersthene of probably metamorphic origin in the cores of some of the larger boudins and suggests that the later cycle of events may have been superimposed on a pre-existing granulite facies terrane.

The last Pre-Hudsonian deformation in the Hopedale Complex was associated with major syntectonic non-porphyroblastic mineral growth that gave rise to the present mineral assemblage in the gneisses and migmatite. Biotite recrystallised to an oriented tectonic fabric, and quartz locally shows a dimensional orientation. Quartz and plagioclase generally formed a disequilibrium fabric of xenomorphic crystals. There is very little evidence of MP metamorphic effects. There may have been minor mimetic growth of biotite. It is not clear to what extent the curved and indented grain boundaries reflect boundary migration induced by Hudsonian effects, or whether the composition of the plagioclase (An 32-38) reflects adjustment to Hudsonian metamorphic conditions.

Pre-Hudsonian deformation

The early history of the Hopedale Complex is obscured in many areas by intense Hudsonian deformation and related migmatisation. Unfortunately where this is not so the quality of inland outcrops is poor and coastal exposure is almost lacking. Nevertheless, xenoliths of the Hopedale Complex within the Unlucky Head Migmatite are excellently exposed in clean coastal outcrops, and from these an indication of the structural history can be gained. A tentative sequence of events is recognized involving dyke intrusion, several periods of intense deformation, and migmatisation, but because of the discontinuous nature of the xenoliths there are many uncertainties.

Unlike a supracrustal sequence in which there is a datum (i.e., sedimentation) upon which a structural hierarchy can be based, the complexities of gneiss terrains such as the Hopedale Complex generally preclude the recognition of their ultimate origins. Watterson (1968) has commented that intense deformation tends to result in textural homogenisation of intricately folded complexes to yield deceptively simple regularly banded gneisses. Stratigraphic or intrusive discordances upon which the elucidations of a chronology are dependant, are thus effectively wiped out. This is effectively illustrated by the nature of the Hopedale Complex-Aillik Group contact. In this account, therefore, the youngest Pre-Hudsonian event is described first and labelled D-1 (i.e., D minus 1 - using deposition of the Aillik Group as a datum) followed by successively older events D-2, D-3, etc., to the point where it can only be said that these events were superimposed upon pre-existing gneisses of unknown complexity, but which may possibly have been in the granulite facies (Sutton, 1972).

(a) D-1

The last pre-Aillik event recognized in the study area was a penetrative deformation of the Hopedale Complex. This produced the widespread biotite, hornblende and mineral elongation L-S fabric in the gneisses and in the granite phases of the early migmatite (Fig. 5). In the gneisses the fabric is sub-parallel to the banding and is axial-planar to sub-isoclinal or close folds that locally refold early isoclines (Fig. 6). A locally strong mineral lineation coincides with these fold axes. Recrystallisation associated with this deformation obliterated previously preferred mineral orientations except in the amphibolites.

(b) Migmatisation

The early migmatitic granite truncates the gneissic banding and structures other than those produced by D-1. The granite appears to have developed by a process of anatexis similar to that which produced the Unlucky Head Migmatite.

(c) D-2

In places the early migmatitic granite truncates tight folds in interbanded gneiss and amphibolite, and an early hornblende fabric is folded around the hinges of these folds. This phase of folding is assigned to D-2. Many of the trains of amphibolite boudins are probably related to this deformation. Structures that may be related to this event are pods of granite gneiss and amphibolite which contain internal banding and fabric athwart to and truncated by the external banding (Fig. 7). These pods are thought to have been formed by shear-plane controlled boudinage of more competent bands into diamond shaped segments, with subsequent rotation and stringing out of these segments in the plane of flattening. The initial stage in this process is seen in the boudinage of gneiss bands in amphibolite in the contact zone of the Post Hill amphibolite (Post Hill Slide, Fig. 8) and further hypothetical stages leading to development of isolated pods are illustrated in Fig. 9.

(d) D-3

A period of intense deformation is inferred from the relic fabric in D-2 amphibolite pods, and is believed to have produced the concordant interbanding of gneiss and amphibolite by means of transportation of a pre-existing gneiss complex and discordant mafic dykes. The intensity of the deformation is suggested by the regular smooth appearance of the banding, (Fig. 3) which in places contains relics of an earlier banding in extremely attenuated isoclinal intrafolial folds.

(e) Intrusion of basic dykes

As discussed above, the composition and mode of occurrences of the amphibolite pods and bands suggests that they are relics of a suite of mafic intrusions or volcanics which on the basis of the evidence described above were intruded into or formed part of a gneiss complex prior to D-3. Although the present maximum thickness of the bands is in the order of 10 m., the amount of flattening they suffered during the inferred D-3 transportation must have been great. No quantitative estimates of the amount of deformation can be made, but by analogy with the Hudsonian reduction of the Post Hill Amphibolite from 1000 m. to 30 m. in thickness, some of the bands could represent mafic units with original thicknesses in the order of 1000 m. or more. It is therefore conceivable that relics of Archean supracrustal rocks are represented in the Hopedale Complex (cf. McGregor, 1973).

Conclusions

The Hopedale Complex records a history of probably three periods of intense deformation and one of migmatisation superimposed upon a possibly high grade gneiss complex that included mafic intrusions, and may have included supracrustal mafic volcanic sequences. Prior to the deposition of the Aillik Group, the banding in the Hopedale Complex appears to have been regular as the consequence of the intense transpositional deformations. No major structures were observed. It appears likely that the banding was moderately or steeply inclined relative to the pre-Aillik Group land surface, as it tends to strike oblique to the contact of the Aillik Group (where not re-oriented by Hudsonian deformation) east of Three Rapids, in the Kitts Pond wedge, and also in the Unlucky Head Migmatite (see Plate 5).

CHAPTER III

AILLIK GROUP

Introduction

A two-fold division of the Aillik Group has been recognized in this study (Table I). The lower division consists of basaltic pillow lavas with a formation of metasiltstones and sandstones. The upper division is composed of conglomerate, rhyolite and acid volcanogenic sediments. A disconformity is recognized between the two divisions, and this has proved to be of major importance in regional correlation and synthesis.

Summary of the stratigraphy

The Post Hill amphibolite (1000 m.), composed of hornblende schist, is the basal formation of the lower Aillik Group. The schist is believed to have been produced by intense deformation and recrystallisation of basaltic, probably pillowed, lava. The amphibolite is overlain by the metasedimentary formation (820 m.), a thin bedded meta-sandstone and metasiltstone sequence with semi-pelitic and pelitic intercalations of biotite-muscovite schist. The formation includes a distinctive gossaned graphitic member. The bedded sediments resemble an AE turbidite sequence (Bouma, 1962) though evidence of grading could not be detected. The metasedimentary formation is believed to represent deep water basinal or miogeosynclinal continental edge deposition. The metasedimentary formation is succeeded by the Kitts pillow lava formation (910 m.), composed of massive metabasalt pillow lavas. The formation includes discontinuous horizons of chert-magnetite iron formation. In general the facies of the lower Aillik Group indicates deep water conditions.

The overlying formations comprising the upper Aillik Group mark a fundamental change in depositional environment to shallow water conditions, mainly distal to an active, dominantly acid, volcanic terrain. The conglomerate formation (260 m.) locally includes detritus eroded from the underlying Kitts pillow lava formation, though the clasts are composed dominantly of a variety of acid volcanics, felsitic intrusions and granites. An angular unconformable relationship with the lower Aillik Group could not be demonstrated and does not appear to be present. The granites in the clasts are unlike any known in the Hopedale Complex. They are thought to have been derived from subvolcanic plutons in the acid volcanic terrain that, it is inferred, was being actively eroded to supply the range of volcanic detritus seen.

The overlying rhyolite formation (300 m.) consists of massive to ignimbrite-like rhyolite containing quartz, microcline and plagioclase phenocrysts. It is succeeded by the banded tuff formation (300 m.), a thin-bedded sequence of reworked, waterlain, fine-grained acid volcanic detritus, rendered distinctive by alternating pale grey, pink and pale green beds.

Internal stratigraphic relationships

The stratigraphy summarised above was reconstructed by compilation of many complex contact relationships described in this chapter. Deformation of the Aillik Group was dominated by formation of tectonic slides, an unusual structural style that has resulted in each formation of the Aillik Group being brought into contact with each other formation somewhere within the area. In many parts of the area recognition of parent lithologies depends on recognising and tracing along strike the effects of progressive deformation (e.g. pillow lavas pass laterally into hornblende schist, conglomerate into laminated psammite). A summary of the contact relationships on which the stratigraphy is based is therefore present below as an aid to understanding the detailed descriptions that follow.

The Post Hill amphibolite lies structurally above refoliated Hopedale Complex and is therefore interpreted as the basal formation of the Aillik Group. It is structurally overlain by relatively undeformed metasedimentary formation on Post Hill, and this contact is interpreted as a normal stratigraphic one.

North of Nash Lake, the south east, and hence structurally upper contact of the metasedimentary formation is marked by a very thin hornblende schist unit that, to the southwest, widens and merges into the Kitts pillow lava formation. This contact is interpreted as a D_2 tectonic slide that followed an original stratigraphic contact. On this basis the Kitts pillow lava formation is inferred to stratigraphically overlie the metasedimentary formation.

A sharp relatively undeformed contact between the Kitts pillow lava formation and the conglomerate formation occurs at two localities west of Inda Lake. The conglomerate locally includes a mafic matrix and clasts of metabasalt and metachert close to the contact, suggesting that the conglomerate overlies the pillow lavas. This relationship is confirmed by pillows showing west facing tops that occur close to the contact. The conglomerate formation is thus believed to overlie the Kitts pillow lava formation. The basal contact of the conglomerate locally truncates a metachert unit in the pillow lavas, indicating further that uplift and some erosion of the Kitts pillow lava formation occurred.

The rhyolite formation overlies the conglomerate formation south of Fiace Lake, and in the Turnip Lake area. Although the contact was not seen it is believed to be a normal stratigraphic one in both areas.

The contact between the rhyolite and banded tuff formations is a stratigraphic one marked by a horizon of interbedded marble and tuff. Cross-lamination indicates that the banded tuffs overlie the rhyolite formation.

LOWER AILLIK GROUP

MAFIC VOLCANIC FORMATIONS

Introduction

The mafic volcanics are dominantly metamorphosed basaltic pillow lavas. The lithology is consistent throughout the different map units and varies with the amount of deformation and metamorphism; it varies from fine grained massive amphibolite (undeformed), to foliated amphibolite (moderately deformed) to hornblende schist (strongly deformed).

Correlation of the map units is rendered difficult by the lack of stratigraphic contacts unmodified by tectonic sliding, by the termination of units along strike against tectonic slides or intrusive contacts, and by the lack of stratigraphic 'tops'. In the following account it is concluded that there are two major mafic volcanic formations separated by the metasedimentary formation; (a) a lower formation considered to be basal to the Aillik Group and represented by the Post Hill amphibolite consisting of hornblende schist; (b) an upper formation represented by the Kitts pillow lava formation comprising pillow lavas and hornblende schist. The Kitts pillow lava formation is described first because within it a transition from undeformed pillow lava to hornblende schist can be demonstrated. From this relationship it can be inferred that the lithologies of the lower Post Hill amphibolite were structurally derived by this process.

KITTS PILLOW LAVA FORMATION

The Kitts pillow lava formation consists of amphibolitic pillow lava and hornblende schist. It includes iron formation members near Inda Lake, Gear Lake and at the Kitts Prospect. The belt attains a maximum thickness of c. 910 m. at Punch Lake where it is relatively undeformed, and thins southwestwards as deformation intensifies to c. 485 m. at Nash Lake. Five map units are correlated with the main outcrop of the Kitts pillow lava formation on the basis of lithology and contact relationships. The evidence for these correlations is detailed in Appendix B.

1. Contact relationships

The formation is for the most part tectonically bounded by slides of D_1-D_{1-2} and D_3 age. These slides appear to cut across the stratigraphy at a low angle, for although original bedding features are absent in the pillow lavas, the iron formations at Inda Lake and the Kitts Prospect are cut out against the D_2 Nakit Slide that forms the southeast contact of the belt. This slide brings the mafic volcanics against the Banded tuff formation in the south, and the Hopedale Complex in the north.

The hornblende schist facies of the pillow lava formation is in sharp contact with the metasedimentary formation north of Nash Lake; this contact continues northwards to the Limestone Lake area, and is followed by an apophysis of the pillow lava formation. This contact is interpreted as a tectonic slide (the Fiace Lake Slide, see Chapter VI) but because of the great persistence of the hornblende schist along it, the slide probably developed on an original stratigraphic boundary between the metasedimentary formation and the pillow lava formation.

The pillow lava formation shows a relatively sharp stratigraphic contact with the Duck Pond conglomerate unit at two localities, northeast of Duck Pond and southeast of Goose Pond (Plate IV). This contact is repeated by a minor tectonic slide southwest of Duck Pond.

2. Lithology and fabric

The pillow lavas are fine-grained, dark grey to black amphibolite composed dominantly of hornblendic or actinolitic amphibole and plagioclase (An 40). Deformation is zonal and undeformed pillows up to 1.5 m. in diameter occur throughout the area; they show well preserved chilled margins and occasional interstitial white quartzite representing recrystallized chert (Fig. 10). In many places where exposure is poor and outcrops lichen-covered, the amphibolite appears massive but sectors of chilled margins indicating the presence of pillows can be found. It is therefore thought that the bulk of the formation is pillowed though massive flows may be included. Indications of bedding such as intercalated tuffs were not observed and the only stratigraphic markers are the iron formation members. Pillows showing west facing 'tops' occur 6 inches from the stratigraphic contact with the conglomerate north-west of Knife Lake (Fig. 11). This is the only way-up evidence noted, but mafic clasts in the conformable conglomerate and cross-laminations in the tuffs also indicate that the pillow lavas underlie the latter rocks.

With increasing deformation, the pillow lavas pass gradationally into hornblende schist; the latter is a fine-grained hornblende-plagioclase (An 40) rock with a platy L-S tectonite fabric. Major schist zones of D_2 and D_3 age occur and they are lithologically similar. Minor zones related to D_3 also occur and are from a few mm up to 15 m. in width. The passage across strike from amphibolite, with a weak penetrative fabric, into hornblende schist is fairly sharp in places, e.g., north of Knife Lake over about 10 m. The minor zones tend to feather out imperceptibly along strike.

Development of S_2 is restricted to the immediate vicinity of the D_2 slides. It is most clearly developed north of Nash Lake in the hornblende schist zones as a platy L-S tectonic fabric with a well defined hornblende lineation. A similar fabric and a tectonic banding (0.1 - 2 cm. scale) is developed within 5 to 20 m. of the Nakit Slide, and north of Nash Lake local zones of D_2 deformation occur within the volcanic belt (Fig. 12). At the latter locality, the banding consists of alternating amphibolitic and fine grained quartzofeldspathic layers. The latter appear to be the deformed equivalents of early plagioclase-quartz veinlets observed close to the deformed zones. In the Kitts area, S_2 occurs in the pillow lavas east of the Kitts Gabbro as a locally developed, weak to strong penetrative L-S fabric. West of the Kitts Gabbro rare rusty schist zones up to 0.5 m. wide cut otherwise undeformed pillow lavas; some parallel S_2 and are probably of D_2 age whereas others are clearly related to the D_3 Limestone Lake slide.

S_3 in the Kitts area is a very weak local fabric that only develops into a penetrative L-S tectonite within 3 - 20 m. of the Limestone Lake slide. Towards Inda Lake, S_3 becomes a more widely developed but zonal, penetrative L-S fabric, and southwest of Inda Lake the fabric intensifies further, the hornblende schist zones north of Knife Lake being of D_3 age. The cross-cutting relationship of S_3 to S_2 is only clearly seen in the Kitts and Nash Lake areas (e.g. Fig. 12); in the central part of the belt where S_3 is subparallel to the Nakit Slide it is possible that zones of D_2 tectonites may have escaped D_3 overprinting, and consequently they may have been mapped as S_3.

The metamorphic history of the Kitts pillow lava formation is discussed with that of the Post Hill amphibolite.

3. Iron formation members

Introduction

Cherty oxide-facies iron formation occurs as discontinuous horizons in the Kitts pillow lava formation, and in the pillow lavas on Anderson Ridge. The iron formations consist of banded magnetite quartzite (Fig. 13) and associated metasedimentary and volcanoclastic rocks. Weathered outcrops are commonly rusty due to the presence of minor disseminated sulphides.

The Kitts pillow lava formation includes three members: at the Kitts Prospect, the Gear Showing and Inda Lake respectively. The members are disposed en-echelon with respect to the boundaries of the formation, and have three important features in common: (i) the banded cherts form a unit along the western contact of each member; (ii) they host local uranium mineralization and, (iii) they are intensely deformed, in sharp contrast to the adjacent relatively weakly deformed pillow lavas.

Lithology and fabric

(i) Kitts Prospect member

There are three separate zones of iron formation in the vicinity of the Kitts Prospect. Two of these are separated by the tabular, sill-like Kitts Metagabbro and it is believed that together they constitute a single member - the Kitts Prospect Member - that was split by intrusion of the sill.

(a) South Showing zone

The South Showing zone attains a maximum thickness of 315 m.

It is truncated by a major slide at Limestone Lake, and lenses out south of Three Mile Creek. The member is divided into three readily distinguishable units: a western unit of banded metachert, a middle unit of graphitic, pelitic and semipelitic garnet-andalusite schist, and an eastern unit of amphibolitic psammite.

The western metachert unit consists of bands of fine grained pure quartzite and grey magnetite quartzite up to 10 cm. thick, alternating with laminae and bands of a fine grained black rock composed of tremolite, magnetite (0 - 90%) garnet and finely divided opaque material, probably graphite. Bedding is lenticular and wavy, and the unit in places shows soft-sediment pull-apart structures, chaotic brecciation and slump folding. S_2 alone is developed and is defined by dark grey streaks of magnetite in the quartzite bands; the streaks are axial planar to open F_2 folds (Fig. 14).

The middle unit is a fine grained biotite-garnet-andalusite-graphite schist containing minor disseminated pyrite. Bedding is developed on a 0.5 - 30 mm. scale. S_1 is only seen in thin section as an included fabric in garnet and amphibole. S_2 is an irregularly devloped cross-cutting biotite fabric and incipient strain-slip cleavage. S_3 largely overprints S_2 within 10 m. of the Limestone Lake D_3 slide.

The psammitic eastern unit is approximately 15 m. thick but is poorly exposed. It consists of fine grained quartz and plagioclase with randomly oriented acicular tremolite-actinolite crystals. Fine dark biotite and amphibole rich laminations spaced at 0.5 to 2 cm. intervals represent bedding. Rosettes upto 3 cm. in diameter of radiating tremolite-actinolite needles are a common and striking feature. In places the rock is crowded with small garnets (0.5 mm.); idioblastic garnets up to 2.5 cm. in diameter occur more rarely. S_2 is seen in places as a fine penetrative fabric but is frequently not apparent due to MP_2 annealing of the quartz-plagioclase fabric. S_3 is an incipient strain-slip cleavage.

(b) Kitts Main zone

The "Main Zone", as it is called on BRINEX maps, is a lenticular horizon about 500 m. long and upto 10 m. thick. It is exposed in a number of trenches east of Luncheon Lake, and is intercalated between Kitts Metagabbro on the west and mafic pillow lavas on the east. The Main Zone is composed of semipelitic schist, amphibolitic semipelite, amphibolite and black magnetite-rich rock containing uranium minerals. Uranium mineralization also occurs locally in the semipelites and in pink carbonate-pitchblende veins. The mineralised horizon varies from 0 - 4 m. in thickness. The thickness, proportion and sequence of the constituent lithologies vary considerably along strike.

The semipelites are locally banded on a 3 - 10 mm. scale and consist of quartz and plagioclase with varying amounts of biotite, amphibole and garnet. The amphibole content probably represents admixture of mafic volcanic detritus. Boudinaged bands of amphibole-pyroxene rock up to 35 cm. thick and laminated on a 1 - 10 mm. scale occur in uraniferous magnetite-semipelite.

S_1 is represented by a very fine streaky fabric composed of finely divided opaques only preserved as S_1 in amphibole and diopside porphyroblasts (Fig. 15). S_2 is the dominant fabric, a penetrative L-S fabric that cuts bedding at a very shallow angle. S_3 is only seen locally as a weak crenulation or incipient strain-slip cleavage.

(ii) Other horizons, Kitts area

The North Showing zone is a thin horizon of variably uraniferous schistose semipelite and amphibolite. It is about 130 cms. thick at the portal of the Kitts adit, and 65 cms. thick north of Kidney Pond where it disappears. In between it is exposed in trenches, and varies from 2 to 5 m. in width. Boudinaged veinlets, up to 8 mm. thick, composed of pyroxene, quartz and microcline were noted north of Kidney Pond and south of the adit. S_1 is preserved in hornblende porphyroblasts that pre-date S_2 in the North Showing zone (Fig. 16).

A 5 m. thick unit of rusty weathering fine grained graphitic schist occurs in the pillow lavas northeast of Luncheon Lake and has an exposed length of approximately 32 m. The rock contains bedding laminations on a 0.2 to 2 mm. scale, with ultra-fine laminations 0.05 mm. thick visible under the microscope.

The Kiwi Lake member is lithologically similar to the South

Showing zone but has a maximum thickness of only 3 m. (Plate 3). It appears to lens out at its south end, and terminates against the Limestone Lake Slide to the north.

(iii) Gear Showing member

The Gear Showing member is poorly exposed but appears to be a lens about 200 m. long and 57 m. thick. It consists of cherty iron formation up to 34 m. thick on the west, and an eastern unit of magnetite-rich radioactive amphibolitic sediment up to 32 m. thick. The amphibolitic rock is similar to the mafic bands in the iron formation in the South Showing member, and is composed of fine grained amphibole and magnetite with local carbonates and biotite. It contains discontinuous laminae of fine grained quartz and untwinned feldspar, and isolated shreds of interbanded quartz-feldspathic material indicating soft-sediment slump disruption of bedding. S_1 is a penetrative biotite fabric only seen in thin section in the carbonate-bearing lithology, where it is cut by an S_2 strain-slip cleavage. S_2 is dominant elsewhere as a penetrative fabric oblique to bedding.

A cherty iron formation unit approximately 16 m. thick croups out on the side of a ridge west of Henry Lake. It is identical to the units in the South Showing and Gear members, and may be on the same stratigraphic horizon as the latter member.

(iv) Inda Lake member

This member closely resembles the South Showing member in that it has a western iron formation unit, an eastern clastic unit and an early gabbro intrusion along its eastern contact analogous to the Kitts Gabbro. The iron formation unit (Fig. 13) is up to 8 m. thick. The clastic unit is poorly exposed but appears to be up to 16 m. in thickness and to consist of amphibolitic semipelites and semipelite. About 280 cms. of black fine grained radioactive amphibolitic schist (similar to the uraniferous rock at the Gear Showing) is exposed in a trench a few feet from the inferred contact between the iron formation and the clastic unit. The rock is finely laminated (0.2 - 3 mm. scale) and contains some radioactive laminae and pyroxene-microcline boudins (70 x 30 mm.); a few grains of purple fluorite c.1 mm. in diameter are locally conspicuous.

Three poorly exposed iron formation and metasedimentary horizons occur northwest of Inda Lake camp, and terminate sharply on the east, probably against a D_3 slide zone. The northern horizon consists of 6 m. (exposed) of cherty iron formation and the two others of black fine grained biotite semipelitic schist with rusty weathering radioactive spots and minor cherty iron formation bands and lenses.

Banded cherty iron formation also occurs as lenses up to 8 m. thick along the conglomerate-pillow lava contact west of Inda Lake. This contact is strongly deformed in the south, but north of Duck Pond an irregular contact between quartzite and amphibolite is exposed. Lack of structural complications indicates that this is a stratigraphic contact.

S_1 has not been detected in the Inda Lake member, and S_2 is a penetrative fabric subparallel to bedding. S_3 is a locally developed strain-slip cleavage.

Metamorphic history

The characteristic metamorphic feature of the iron formation members is the development of early pyroxene bearing assemblages. However these assemblages have been largely overprinted during the dominant MS_2 and MP_3 mineral growth episodes. Interpretation of the mineral growth history is complicated by the variable development of the L-S tectonite fabrics that serve as markers in the stages of mineral growth. The metamorphic history is summarised in Table II.

MS_1

The only vestiges of the MS_1 mineral assemblage that remain are the minute oriented opaque rods and particles included in MP_1 amphibole and garnet (Figs. 15, 16 and 17). The very fine grained nature of the included S_1 fabric indicates that the MS_1 mineral assemblage was also very fine grained.

MP_1

MP_1, was a phase of strong annealing and metamorphic growth that appears to have largely obliterated the MS_1 fabric. The earliest stage of MP_1 was polygonisation of quartz and feldspar, followed by growth of porphyroblastic amphibole (Figs. 15 and 16) and diopside. This appears to have been followed by growth of garnet porphyroblasts containing straight inclusion trails (S_1) of opaque rods, and also small early MP_1 amphibole porphyroblasts (Fig. 17). Segregations of quartz-diopside and quartz-diopside-microcline are of the same age. Chloritoid of MP_1 age has also been noted in the South Showing zone.

MS_2

MS_2 led to the development of the dominant penetrative biotite fabric in the semipelitic rocks, and the amphibole-biotite fabric in the amphibolitic rocks. Quartz and plagioclase occasionally occur in a sutured disequilibrium mosaic, the former strained and the latter strongly zoned, but this MS_2 effect is generally obscured by subsequent annealing. MP_1 amphibole porphyroblasts are broken down marginally to fine grained amphibole crystallographically aligned in S_2. Garnets show MS_2 overgrowths containing curved S_1 trails continuous with the straight inclusion trails of the MP_1 cores (Fig. 18). Some MP_1 garnets were boudinaged during D_2 with the development of transverse quartz-filled fractures.

MP_1 diopside shows only minor breakdown to amphibole; in boudins in the Gear Showing member this is only total in a marginal rim 1 - 2 mm. wide (Fig. 19). Even in a part of the Inda Lake member where D_2 was intense, the diopside has merely been broken down to an aggregate of smaller crystals streaked out on S_2. Stubby tourmaline schist at the South showing, Kitts area. Elsewhere it occurs as a rare accessory MS_2 mineral.

MP_2

MP_2 metamorphic effects appear to be weak, with secondary polygonisation of the quartz-plagioclase mosaic and growth of narrow inclusion-free idioblastic rims on the pre-MP_2 garnets. Minor nucleation of MP_2 garnet also occurred separately with growth of small inclusion-free idiomorphic crystals.

MS_3

MS_3 is zonally developed and is chiefly limited to growth of biotite flakes that lie athwart S_2 and define a strain-slip type of tectonite fabric. The biotite contains straight inclusion trails (S_2) of fine grained dust. Growth of lenses of pyrite, up to 0.7 mm. long, aligned in S_3 also occurred. MS_3 recrystallisation of biotite almost obliterates S_2 close to the Limestone Lake slide zone.

MP_3

Although D_3 had a rather restricted development in the iron formation zones, MP_3 was a more widespread period of porphyroblastic growth and textural readjustment, particularly of pre-exising quartz-plagioclase fabrics.

The andalusite porphyroblasts are of MP_3 age and include both S_2 and S_3 as straight inclusion trails of opaque rods and occasional biotite flakes (Fig. 20). The idiomorphic forms contain dendritic zones crowded with fine graphite particles (Fig. 21). Rare fibrolite was noted in association with the andalusite. MP_3 garnet occurs as idiomorphic crystals from 2 to 2.5 mm. in diameter, and although generally free of inclusions they include occasional MS_3 lenses of pyrite. The staurolite is subidiomorphic and contains S_1 of fine graphite particles (S_2), and although S_3 is not developed where the staurolite occurs (South Showing, Kitts) it is believed to be MP_3 because of the associated occurrence of MP_3 andalusite and muscovite porphyroblasts.

The muscovite porphyroblasts are about 2 mm. long, and contain fine graphitic inclusions in graphitic lithologies. The crystals are unoriented and have ragged terminations. Though of widespread occurrence they always post-date S_3 where S_3 is developed, and the replacive relationship to the MP_3 andalusite also demonstrates their MP_3 age.

Acicular MP_3 tremolite-actinolite occurs in the psammite unit of the South Showing zone close to the Limestone Lake Slide, but elsewhere was not identified with certainty. Quartz-plagioclase fabrics underwent MP_3 annealing to a subpolygonal mosaic where S_3 is developed; elsewhere the presence locally of MP_3 porphyroblastic minerals suggests that the MP_3 annealing is probably superimposed upon MP_2 effects, though two stages cannot be distinguished by textural criteria.

Minor MP_3 effects include the development of idiomorphic faces on MS_3 pyrite and occasional growth of idiomorphic pyrite porphyroblasts up to 4 mm. in diameter.

Undifferentiated MP effects

Locally parts of the iron formation members at or near the contacts with undeformed pillow lavas appear to have escaped all deformation, and show isotropic fabrics reflecting static mineral growth of amphibole; garnet and minor biotite. These fabrics probably reflect the combined effects of MP_1 and MP_3 since elsewhere the most important periods of amphibole and garnet growth were related to these stages.

Late MP effects

Subsequent irregularly developed kinking probably represents D_5 but was not accompanied by any constructive metamorphic growth. Local chloritisation of biotite may reflect this event or could be related to late-stage MP_3 effects.

POST HILL AMPHIBOLITE

The amphibolite forming Post Hill is composed of fine grained hornblende schist lithologically similar to the hornblende schist zones in the Kitts-Nash Lake belt. It attains a maximum thickness of 1000 m. in the nose of the Post Hill fold and thins to c. 240 m. on the west limb. The basal contact is with Refoliated Gneiss of the Hopedale Complex. It is gradational over about 20 - 100 m. and consists of amphibolite interbanded with fine grained flaggy gneiss on a 0.5 to 15 cm. scale. The Post Hill amphibolite is structurally overlain by the metasedimentary formation in apparent stratigraphic conformity.

Lithology and fabric

As in the schist zones in the Kitts-Nash Lake belt, no relic pillows or other primary structures were recognized but the rock contains dark, more hornblende rich bands 0.2 - 1 cm. thick spaced at about 1 - 3 cm. intervals. These are parallel to the schistosity and may represent flattened chilled margins of pillows which they resemble both in hand specimen and under the microscope.

One intense penetrative L-S tectonic fabric is developed. Although there is no evidence of earlier metamorphic growth, this fabric is referred to S_2 because it is related to isoclinal folds in tectonically interbanded amphibolite and gneiss in the lower contact zone. S_2 is uniformly developed throughout the formation but was nowhere observed to fold the hornblende-rich bands.

Kink bands that kink S_2 but are folded by S_3 occur locally northeast of Post Hill. They appear to be of local significance only and are not ranked as a separate deformation phase in the overall structural scheme of the area.

S_3 varies in style from gentle microfolds with wavelengths of 0.5 - 1 mm. to a strain-slip cleavage (1 - 5 mm. scale) to chevron style folds with axial planes spaced up to 5 cms. apart. It is irregularly developed, and is lacking in many outcrops. S_2 has been transposed locally into the plane of S_3 to produce a penetrative S_3 within c. 300 m. of the Migmatitic Quartz Monzonite contact.

A zone of hornblende schist intervenes between the Hopedale Complex and the metasedimentary formation from Witch Lake to the shore of Kaipokok Bay. Although very thin, from 3 to 35 m., the zone is lithologically identical to the Post Hill amphibolite and shows identical contact relationships. It is therefore believed to be equivalent to the Post Hill amphibolite but to have been extremely attentuated by combined D_1, D_2 and D_3 effects.

D_1 is represented by interbanding of gneiss and amphibolite on a 0.5 - 10 cm. scale. S_2 is an L-S hornblende fabric that is only penetrative northwest of Nash Lake in the vicinity of the Watts Lake slide and related fold; to the northeast it becomes transposed into S_3, a penetrative L-S fabric, and is only preserved in occasional augen visible in outcrops (Fig. 22) and in thin section. S_2 also occurs in small scale D_3 slide zones. Southwest of the Watts Lake slide and fold, S_2 is also transposed into a penetrative S_3, and is only represented by inclusion trails in MP_2 plagioclase porphyroblasts

(Fig. 23).

S_4 is a crenulation cleavage on a 1 - 5 mm. scale but is not commonly developed. S_5 dextral kink bands on a 3 - 10 mm. scale are more widespread and south of Witch Lake are associated with large scale monoclinal flexures.

Mafic volcanics of unknown stratigraphic position: map unit 10

Occurring southwest of Witch Lake this unit is lithologically identical to the other hornblende schist units, but its contact relationships are not known. It crops out as a horizon within the rhyolites, but whether it is stratigraphically interlayered or tectonically emplaced is not clear since the contacts are not exposed. Southwest of Witch Lake it appears to join up with the Post Hill amphibolite, though this is in the Witch Lake Slide zone and there are many minor lenses of hornblende schist in the vicinity.

Metamorphic history of the Mafic Volcanic formations

The earliest recognizable metamorphic minerals are related to D_2, and there are no relict textures to suggest that recrystallization or fabric development occurred during D_1. However, it appears that this is due to the metamorphic insensitivity of the mafic volcanics since the pelitic rocks in the iron formation zones record evidence of MS_1 and MP_1 mineral growth. Nevertheless, the overall lack of relict M_1 textures even where later overprinting was not intense, suggests that M_1 was a low grade event probably restricted chiefly to the basement-cover contact zone. The metamorphic mineral growth history of the mafic volcanic formations is summarised in Table III.

MS_2

This event led to the growth of fine-grained hornblende defining S_2 and growth of plagioclase and minor quartz. Magnetite developed in minute rods oriented in S_2. Where S_3 is the dominant fabric, MS_2 hornblendes are occasionally seen as inclusions in the MP_2 plagioclase porphyroblasts (Fig. 23).

MP_2

Minor growth of unoriented hornblende crystals occurred; some are porphyroblastic but most are approximately the same size as the MS_2 hornblendes. On Post Hill, the porphyroblasts are strained by D_3 kinking. Some secondary polygonisation and regrowth of the MS_2 plagioclase and quartz to a subpolygonal fabric took place, and locally small MP_2 plagioclase porphyroblasts developed (Fig. 23).

The aggregate of epidote and diopside that encrusts pillows south of Inda Lake appears to be of MP_2 age as it is strained and the diopside is marginally corroded by MS_3 hornblendes. In this locality, there is no evidence that any MS_2 growth preceded the MP_2 recrystallization.

The age of the felted isotropic fabric in the undeformed pillow lavas is uncertain since its relationship to S_2 and/or S_3 was not seen in thin section. It probably reflects the combined effects of MP_2 and MP_3.

MS_3

In general, MS_3 effects appear to have been rather similar to the MS_2 effects. However, the grain size of the MS_3 hornblendes (0.1 - 3 mm.) is greater than that of the MS_2 hornblendes (0.1 mm.), and the pleochroism of the former appears to be slightly stronger. Both these features suggest that MS_3 was a slightly higher grade event than MS_2.

Biotite, sericite and microcline developed in the small scale schist zones described above; this assemblage indicates local MS_3 K-metasomatism.

MP_3

MP_3 led to the development of a subpolygonal plagioclase (An 40) fabric. There was minor growth of unoriented amphibole prisms where MS_3 was previously developed. In the undeformed pillow lavas, the actinolitic amphibole porphyroblasts may be in part of MP_3 age since MP_3 was the most important period of porphyroblastic growth.

Later metamorphic effects

Widespread but sporadic sericitisation of plagioclase, local replacement of plagioclase by fine-grained fibrous prehnite, and chloritisation of biotite may be related to D_4 or D_5. The thin veinlets of prehnite and scapolite noted above are probably also related to these events.

METASEDIMENTARY FORMATION

The metasedimentary formation occurs in two separate outcrop areas: (a) the core of the Post Hill fold, and (b) a roughly linear belt extending north-eastwards from Watts Lake to the shore of Kaipokok Bay. The two outcrops are correlated on the basis of lithological similarity, the presence of a distinctive sulphide and graphite bearing marker horizon, and the similarity of their contact relationships.

The formation is composed dominantly of psammites and semipelites. A rusty weathering graphitic member upto 60 m. thick occurs approximately 250 m. above the western (basal) contact. The formation attains a maximum thickness of c. 820 m. west of Punch Lake, but is structurally thinned to a few metres in the Witch Lake Slide. The metasediments are structurally and apparently stratigraphically underlain by the Post Hill amphibolite. The contact is sharp and where not too intensely deformed (as on Post Hill), appears to be a normal stratigraphic one. Metamorphic mineral growth was less pronounced in the core of the Post Hill Fold then elsewhere, but the grade of metamorphism does not appear to have been appreciably lower. The different tectonic histories of the formation in the Post Hill Fold and in the belt northeast of Watts Lake is also emphasised by the absence of pegmatite and the presence of gabbro dykes in the former, and the absence of gabbro dykes and ubiquitous presence of pegmatite lenses and bodies in the latter.

Lithology and fabric

The lithology is uniform throughout the formation with no major variations from base to top, apart from the occurrence of the sulphide and graphite bearing member.

Psammites and Pelites

The psammites and semipelites in the Post Hill fold are pale to dark grey cleaved and phyllitic siltstones composed of quartz, plagioclase and biotite with accessory opaque minerals. Tourmaline and apatite, garnet and chloritoid occur locally. The metasediments are laminated, and interbedded on a 0.1 - 40 cm. scale. Psammitic laminae in the semipelitic siltstones tend to be lenticular in form. In places the laminae are accentuated by fine graphitic dust. Clastic texture is clearly preserved (Fig. 24).

Southwards from the core of the Post Hill fold the siltstones pass with increasing intensity of D_3 deformation and metamorphism into recrystallised psammites and semipelitic schists that are also the typical lithology of the formation northeast of Watts Lake (Fig. 25). The recrystallisation has resulted in obliteration of the clastic texture, but the mineralogical composition is the same. Minor pelitic intercalations occur composed of biotite-muscovite schist. The formation includes some fairly massive faintly bedded grey psammite units up to 20 m. thick in the upper part of the sequence west of Fiace Lake; the Fiace Lake Showing occurs in one of these units.

Apparently lenticular units up to 10 m. thick of quartz-muscovite schist with numerous grey quartz lenticles occur at many places along the contact with Post Hill amphibolite northeast-wards from Watts Lake. The quartz lenticles are 0.5 cm. thick and elliptical in the plane of the schistosity, with an average maximum long axis of c. 2.5 cm. Rarely they are up to 10 cm. thick and have a mylonitic-type foliation. The quartz-lenticle schist is believed to be a tectonic schist and its significance is discussed in Chapter VI.

Graphitic member

The sulphide and graphite-bearing member is composed of black graphitic slate, graphitic semipelitic schist and psammite, all with minor pyrite (< 8 percent) that on weathering causes outcrops to be stained a rusty brown colour. Up to 2 percent magnetite is common and pyrrhotite, galena and arsenopyrite are recorded from the member west of the Kitts Prospect (Cowan, 1968). The graphitic slate is best exposed in the Post Hill Fold; it retains its fine slaty fabric adjacent to the Witch Lake slide even though fabrics in the other metasediments are coarser. In the zone extending southwestwards from the shore of Kaipokok Bay the psammitic units form linear ridges while the graphitic pelite units are eroded and weathered. Here also the pelites retain their fine grained nature despite the coarse schistose texture of the non-graphitic beds. It appears that the fine graphite particles inhibited grain boundary movement and metamorphic mineral growth. (cf. Voll, 1960, p. 512).

The psammites and semipelites interbedded in the member are of the same lithology as in the rest of the formation except for the presence of graphite and pyrite in small amounts (trace to 3 percent). Metamorphic mineral growth was not inhibited in these lithologies as it was in the graphitic slate. An outcrop of fine breccia was noted in this member on Post Hill. It consists of tabular and lensoid fragments of pale fine grained quartz-plagioclase-biotite siltstone in a dark graphitic siltstone matrix. The tabular shape of the clasts is largely primary and not the result of tectonic deformation (Fig. 26). Some are well rounded and show soft-sediment fissuring with intrusion of matrix (Fig. 27). The matrix includes black slivers of graphitic pelite oriented parallel to bedding and S_2.

Fabric

There is no evidence to suggest that S_1 was ever developed in the metasedimentary formation. S_2 in the core of the Post Hill Fold is a fine penetrative biotite fabric (Fig. 28). Towards the Witch Lake Slide it dominant. The mineral growth history is summarised in Table IV.

MS_2

In the Post Hill Fold MS_2 resulted in strongly oriented growth of biotite flakes. Magnetite grew in tiny rods oriented parallel to the biotite flakes. MS_2 quartz fabrics are not preserved. In the belt north-east of Watts Lake the MS_2 mineral assemblage is only preserved as inclusion trails in MP_2 and MS_3-MP_3 minerals. MP_2 garnet porphyroblasts show straight inclusion trails of elongate quartz blebs and magnetite (Fig. 29), and MS_3-MP_3 plagioclase crystals rarely show curved inclusion trails of relic mica flakes.

MP_2

The chief observed effects of MP_2 growth are porphyroblasts of garnet and plagioclase, and polygonal quartz and plagioclase. MP_2 garnet porphyroblasts showing straight inclusion trails of S_2 occur on Post Hill.

Northeast of Watts Lake some garnet porphyroblasts show a later growth stage. The plagioclase porphyroblasts are only preserved in the Post Hill Fold where they were noted close to the contact with the Post Hill amphibolite; they show well developed straight inclusion trails of S_2.

becomes overprinted by S_3, and in the belt north-east of Watts Lake is only preserved as an included fabric in garnet porphyroblasts and plagioclase crystals. S_3 is a fine strain-slip cleavage (0.1 - 0.5 mm. scale) in the core of the Post Hill Fold (Fig. 28). Towards the Witch Lake slide it intensifies, transposing S_2 into a penetrative L-S tectonite fabric. In places S_3 is defined by fine (0.2 mm. scale) alternating psammitic and micaceous laminae that developed during transposition of S_2 into S_3 by migration of quartz and feldspar into the hinge areas of crenulations (cf. Rast, 1966). In the belt north east of Watts Lake S_3 is a penetrative schistosity in the semipelites and a biotite fabric in the psammites; L_3 is a mica, quartz and feldspar mineral lineation.

S_4 is a relatively coarse angular kink-band of chevron-type crenulation cleavage, with axial planes of crenulations spaced at 1 - 10 mm. intervals. In the micaceous psammites and semipelites it produces an incipient transpositorial banding. S_4 is ubiquitous but varies considerably in intensity. S_5 is a crenulation cleavage similar in style to S_4, but is more sporadically developed.

Metamorphic history

As in the mafic volcanic there is no evidence of pre-D_2 mineral growth. MS_2 mineral assemblages are clearly preserved in the core of the Post Hill Fold; in other localities MS_3 recrystallisation was

MS_3

In the core of the Post Hill Fold MS_3 gave rise to recrystallisation of biotite along the axial planes of the S_3 strain-slip cleavage (Fig. 28) and breakdown of the quartz and plagioclase to a disequilibrium fabric of xenomorphic crystals. Minor recrystallisation of magnetite to rods oriented in S_3 also took place, and pyrite recrystallised to xenomorphic form.

Southwards towards the Witch Lake Slide, and in the belt north-east of Watts Lake more intense MS_3 effects led to a general break-down and regrowth of pre-existing fabric elements. Biotite and muscovite completely recrystallised in strongly oriented flakes. In the semi-pelitic lithologies migration of quartz from the limbs of strain-slip type microfolds took place in the early stages of MS_3 resulting in a transpositional lamination (Figs. 30, 31). In the psammites quartz and feldspar developed a disequilibrium mosaic of xenomorphic grains. The MS_3 quartz-feldspar fabric is preserved in the thick psammite units west of Fiace Lake which in general suffered a lesser degree of deformation and recrystallisation; the plagioclase is more sodic (An 28) and there was little subsequent annealing of the fabric.

Some garnet porphyroblasts show continuous MP_2-MS_3 growth with curved inclusion trails in the MS_3 zone continuous with the straight trails of the MP_2 cores (Fig. 29). The MS_3 overgrowths are uncommon, and no garnets that nucleated at fresh sites during MS_3 were observed.

Minor MS_3 effects include growth of elongate grains of magnetite oriented in S_3. Very minor growth of tourmaline prisms oriented in S_3 also took place.

MP_3

The chief effect of MP_3 was annealing of the quartz and feldspar fabrics to produce a subpolygonal mosaic. Rarely, plagioclase crystals in the semipelitic schists overgrew F_3 microfolds in S_2 and preserved S_2 as an included fabric.

The plagioclase growth may have been initiated in MS_3 but the major period of growth appears to have been of MP_3 age. The plagioclase and quartz grains tend to be elongated in the semipelites where sandwiched between mica flakes.

Growth of MP_3 chloritoid and muscovite occurred locally in semi-pelite in the Post Hill Fold. The chloritoid prisms and muscovite flakes are randomly oriented but the latter show some mimetic growth parallel to MS_3 biotite (Fig. 32).

Minor MP_3 effects include growth of unoriented tourmaline prisms and idiomorphic pyrite crystals.

Later metamorphic effects

Both D_4 and D_5 crenulations gave rise to MS straining of quartz grains with development of strain shadowing and primary polygonisation.

This was followed by partial MP recrystallisation of the strained grains to a subpolygonal quartz mosaic. No other constructive metamorphic effects were related to D_4 and D_5, but local retrogression of biotite to chlorite occurred.

UPPER AILLIK GROUP

Introduction

Formations assigned to the upper Aillik Group record a major change in source area and depositional environment. The base of the conglomerate formation marks the break from deep water accumulation of pillow lava and terrigenous sediment (possibly turbidite facies) in lower Aillik time, to shallow water deposition of clastics derived mainly from an active acid volcanic terrane, that was in turn being actively eroded, subaerial extrusion of rhyolites. This major break indicates that the contact between the upper and lower Aillik Group is a disconformity. Although angular unconformable relationships cannot be demonstrated, there is evidence of local erosion of the Kitts pillow lava formation as the conglomerate formation was being deposited.

The time span re[illegible] by the disconformity is not clear, but it could be consid[illegible]he nature of granite clasts in the conglomerate indicates tha[illegible]y were not derived from the Hopedale

Complex; indeed no detritus derived from Archean basement has been recognised in the area. The association of the granite clasts with acid hypabyssal and volcanic clasts on the other hand suggests that they were derived from eroded subvolcanic plutons. Post-lower Aillik Group uplift, plutonism and volcanism in an area distal to the Kitts-Post Hill area is inferred.

CONGLOMERATE FORMATION

The conglomerate is massive and consists of dominantly acid volcanic and granitic clasts in a psammitic matrix. It occurs in two main zones, one extending from Turnip Lake to Gear Lake and the other from southwest of Duck Pond to Fiace Lake. Outcrops possibly related in part to the latter zone occur between Fiace Lake and Limestone Lake. A lens of conglomerate identical in lithology to the above occurs west of Watts Lake between the rhyolites and banded tuff formations. Other minor outcrops were noted 1 km. southeast of Turnip Lake, and locally on the contact between the gabbro sill and refoliated gneiss north of Jacques Lake. The Turnip Lake-Gear Lake conglomerate is bounded by intrusive contacts on the south east, except south of Inda Lake where it appears to have a stratigraphic contact with pillow lavas. Local abundance of amphibolitic clasts and matrix in the conglomerate close to the contact suggests that it stratigraphically overlies the pillow lavas. The contact with the rhyolite is sharp and may be either a flow or intrusive contact. The conglomerate unit has a maximum thickness of c. 260 m.

The Duck Pond conglomerate appears to be in stratigraphic contact with a cherty iron formation bordering the mafic volcanics north east of Duck Pond. Southwest of Duck Pond this contact is intensively deformed and repeated by a tectonic slide, but due north of Turnip Lake deformation is less and the conglomerate is in sharp, apparently stratigraphic contact with west-facing pillow lavas. The northwestern contact is a major tectonic slide which gradually cuts out the conglomerate to the south-west. The stratigraphic relationships of the Duck Pond conglomerate to the banded tuff and conglomerate between Fiace Lake and Limestone Lake is obscured by drift cover northwest of Fiace Lake. Conglomerate is locally interbedded with banded tuff but there are also two massive units that converge at Kiwi Lake. The eastern unit is separated from the mafic volcanics by the Limestone Lake slide and it appears to have a conformable stratigraphic contact with banded tuffs on the west. Cross lamination in the latter rocks suggests that the conglomerate underlies the banded tuffs. The conglomerate unit west of Kiwi Lake is banded on the west by a major D_3 slide, and on the east by a branch of this slide; between these two slides in the north there is a section of apparently conformable contact with banded tuffs. The eastern conglomerate unit may be correlateable with the Duck Pond and Turnip Lake—Gear Lake units, since there is evidence to suggest that the banded tuffs west of Limestone Lake are correlateable with the lower contact zone of the main Nash Lake belt of banded tuffs. The western conglomerate unit may be a tectonic repetition of the eastern one.

Lithology

The conglomerate is polymictic, the clasts being composed dominantly of acid volcanics and granite. It is entirely unbedded and massive in all outcrops seen, but one boulder east of Turnip Lake shows three graded units each about 30 cm. thick with laminated sandy tops. The cobbles are subrounded to subangular and average 8 cms., but range up to 40 cms., in diameter (Fig. 33). They are composed of, in order of abundance, fine grained psammite, felsite, quartz and feldspar porphyry, granite and less commonly grey quartzite (metachert) and amphibolite. Amphibolite cobbles are locally abundant, e.g., in places near the contact with pillow lavas south of Inda Lake. The cobbles generally touch one another but in places are matrix supported. The matrix is psammite, similar in lithology to the psammite clasts. It is frequently pale greenish in colour due to the presence of epidote and tremolite actinolite; the latter minerals are abundant where epidote amphibolite clasts are common. Locally the matrix contains up to 8% haematite, e.g., on north shore of Kiwi Lake, and variable amounts of carbonate.

The fine grained psammites occur in shades of grey and are similar in lithology to the banded tuffs though lacking in well developed bedding; they are believed to be sediments derived from acid volcanics. The felsite, quartz and feldspar porphyry clasts are similar to lithologies occurring in the Rhyolite Formation. The granite is unlike any occurring within the Hopedale Complex, and no foliated or gneissic clasts that could have been derived from the basement were seen. The fine grained quartzite is identical to the metachert of the iron formation zones associated with the pillow lavas underlying the conglomerate. The amphibolite clasts differ from the normal lithology of the pillow lavas in being composed of epidote, tremolite-actinolite and quartz rather than the hornblende-plagioclase assemblage of the mafic volcanic formations. The lens of conglomerate occurring between the rhyolite and banded tuff formations southwest of Watts Lake is similar to the above description although occupying a higher stratigraphic level.

Fabric

No tectonite fabric related to the first deformation was recognised. S_2 is locally developed as a mylonitic banding and extreme flattening of the cobbles within 2 - 3 m. of the D_2 slides southwest of Duck Pond. S_2 was noted cutting across previously flattened clasts north of Kiwi Lake, suggesting that S_2 may have been more widely developed, but no other textural evidence survives. Elsewhere a single penetrative fabric, S_3, occurs. It is irregularly developed and in the Turnip Lake-Gear Lake belt areas of undeformed conglomerate are found; elsewhere S_3 varies from weak to moderate intensity as shown by the amount of flattening of the cobbles (Fig. 34). S_3 is particularly intense southwest of Duck Pond, and close to the D_3 slide in the vicinity of Limestone Lake; in these areas the pebbles are so flattened that the rock takes on a lenticular banded appearance.

The metamorphic history of the conglomerate formation is described below together with that of the rhyolite and banded tuff formations.

RHYOLITE FORMATION

Rhyolite of extrusive origin occurs in two belts: a) southeast of Witch Lake and b) from southwest of Turnip Lake to Gear Lake. These two belts differ somewhat in lithology; the former exhibits clastic and flow textures while outcrops in the latter are chiefly homogeneous. The rocks appear to vary from rhyolite to rhyodacite in composition. Evidence from the banded tuff formation discussed below suggests that the rhyolite formation occupies a stratigraphic position above the conglomerate and below the banded tuffs. The formation probably has a maximum thickness of approximately 300 m.

(i) Lithology

Witch Lake Belt

The belt southeast of Witch Lake consists of tough fine grained flow banded and laminated rhyolites with scattered phenocrysts of K-feldspar and plagioclase (< 2 mm. in diameter) and lensoid quartz. The banding, on a 0.1 - 4 cm. scale, is discontinuous and is in alternating shades of grey, pink, pinkish grey and buff. The bands may show extremely fine internal colour laminations on a 0.2 mm. scale. The rhyolite occurs in units up to 7 m. thick separated by dark grey intermediate horizons generally 1 - 2 m. thick within which patchy minor uranium mineralization occurs (The Witch Lake Showing). The horizons are of andesitic composition and are composed of plagioclase phenocrysts (An 30) 0.2 to 1 mm. in diameter in a fine-grained biotite- or chlorite-quartz-feldspar-carbonate groundmass that is usually schistose. The rock is usually fairly homogeneous and the horizons probably represent flows but in places, notably where weak uranium mineralization occurs, fragmental-texture is developed. This may be the results of autobrecciation, or the rock could be a lithic tuff. Lithic fragments are outlined by anastamosing black, more biotitic, magnetite-rich zones. The fragments may be of similar lithology to the above described rock or may be composed of definitely igneous textured interlocking plagioclase laths with minor interstitial biotite and opaques.

Rhyolite with a more streaky lithology is common in the northern part of the belt suggesting a facies change; it contains grey lenticular clasts up to 2 cms. long and 5 cms. thick, resulting in the streaky aspect, and larger more abundant phenocrysts (up to 6 mm. in diameter).

The quartz phenocrysts are pale milky blue in hand specimen and are ovoid or lenticular in shape. The feldspar phenocrysts are andesine-oligoclase and microcline in varying proportions. The laminae and lenses form augen around the phenocrysts. In general the rock resembles an ignimbrite in hand specimen, but it has been strongly deformed and it has not been possible to separate primary eutaxitic textures from the products of tectonic flattening. No textures diagnostic of ignimbrites were observed in thin section but in view of the degree of recrystallisation it is unlikely that any such textures would have survived.

Turnip Lake-Gear Lake belt

The rhyolite is a fine-grained homogeneous, pale buff or pale pinkish-grey rock with phenocrysts of quartz, microcline and plagioclase. In general the flow textures typical of the Witch Lake rhyolite were not observed except for fine colour laminations locally north east of Turnip Lake, and a colour banding on a 5 cm. scale on the north east side of Gear Lake. The homogeneous texture is more typical of the intrusive rhyolite of the area, but the precisely concordant nature of the contacts as well as the locally developed flow banding suggest an extrusive origin. Outcrop is generally poorer than in the Witch Lake belt and it is possible that the more massive parts of flows have resisted erosion.

(ii) Fabric

Only one tectonic fabric is developed; this is correlated with S_3 and is an L-S fabric defined by flattened and stretched lithic fragments, quartz phenocrysts, and, where deformation is very strong, by feldspar phenocrysts also. In thin section, biotite flakes showing a moderate degree of preferred orientation in S_3 are also seen. S_3 is zonally developed in the Turnip Lake-Gear Lake belt and many outcrops appear wholly undeformed. An S_5 incipient strain-slip cleavage is locally developed south of Witch Lake.

BANDED TUFF FORMATION

The banded tuff formation consists of fine-grained reworked acidic tuffs, thinly bedded in alternating shades of grey, pink and green. Marble is interbedded with the tuff in a horizon along the contact with the rhyolite, and at Limestone Lake.

The main outcrop is in a belt centred on Nash Lake and extending from Gear Lake to west of Jacques Lake. A small remnant of this belt occurs 1 mi. northeast of Gear Lake. Northwest of the mafic volcanics banded tuffs occur in two separate areas: a) between Fiace Lake and Kiwi Lake, and b) a thin unit extending from Limestone Lake to Kitts Brook.

The Nash Lake belt of banded tuffs is bounded on the northwest by tectonic slides between Gear Lake and Watts Lake, but southwest of Watts Lake has a conformable stratigraphic contact with the rhyolites. The southeast boundary of the formation is an intrusive contact between Nash Lake and Jacques Lake, but further northeast it has a stratigraphic contact with rhyolites. The contact with the rhyolites on both the northwest and southeast sides of the belt is marked by a unit of interbedded marble and tuff, and in each case there is limited way-up evidence indicating that the tuffs stratigraphically overlie the rhyolites. It thus appears that the banded tuffs occupy a synclinal structure, and the present thickness of the formation is probably in the order of 300 m.

The banded tuffs between Fiace Lake and Kiwi Lake are in a poorly exposed and tectonically complex area. Both the western and eastern boundaries are major tectonic slides, and a third tectonic slide may extend from the west side of Kiwi Lake and transect the area. The banded tuffs in this area are considered to be equivalent to those in the Nash Lake belt, even though thin structural and stratigraphical relationships are not clear, because of lithological similarity, and because of the apparent stratigraphic conformity of the mafic volcanics and conglomerate in the southwest.

The slice of banded tuffs at Limestone Lake is bounded chiefly by major tectonic slides of D_3 age but appears to have a stratigraphic contact with conglomerate at Limestone Lake. It has a maximum thickness of 70 m. at Limestone Lake but thins northwards to lens out north of Kitts Brook. The slice includes a horizon of interbanded tuff and marble along its eastern contact; this horizon is identical to the one along the contact of the formation in the Nash Lake belt, and no other marble bands were noted within the main body of the formation. It thus appears probable that the Limestone Lake slice is correlateable with the lower contact zone of the banded tuff formation.

Lithology and fabric

The banded tuffs are feldspathic sediments composed principally of plagioclase, microcline, quartz, hornblende, carbonates, muscovite and diopside. Bedding is on a 0.1 to 10 cm. scale, and the bedding planes are generally laterally continuous and parallel. The grain size varies from medium silt to medium sand grade and the degree of sorting is good. Cross-lamination is scarce and was only observed at four localities (Fig. 35). Individual beds vary in colour from light grey and grey to shades of pink and green reflecting variations in composition that produce a variegated colour banding.

Grey beds reflect a preponderance of quartz, plagioclase and opaques, while the pink and green colours are due to concentrations of microcline, and amphibole and/or diopside respectively. Pale grey colours predominate but in places pale green hornblendic bands are common; they tend to be lenticular in form. Evidence of contemporaneous disturbance is seen locally in disruption and inclusion of shreds of the hornblendic sediment in the pale grey or pink feldspathic material. Fine rhyolitic breccias occur in the banded tuffs about 250 m. north east of Fiace Lake. Pebbly bands and conglomerate are locally interbedded with the banded tuffs between Fiace Lake and Kiwi Lake (Fig. 36).

The marble bearing horizon along the lower contact of the formation in the Nash Lake belt and at Limestone Lake consists of generally alternating beds, 1 to 30 cm. thick, of fine grained laminated tuff, calcareous tuff, sandy marble and marble. The horizon varies from 4 to 20 m. in thickness; marble beds locally attain a thickness of 1 m., and west of Watts Lake there is an 8 m. unit of bedded marble. The marble is fine to medium grained and white to pale grey in colour. At Turnip Lake subrounded pebbles and cobbles of granodiorite up to 10 cm. in diameter occur sparsely scattered in the marble.

S_2 is only developed close to the D_2 Nakit slide, and in the slide-bounded fold northeast of Watts Lake where it is an indistinct, very fine penetrative fabric (Fig. 37). S_3 is a widely but variably developed very fine penetrative fabric defined by elongate quartz and feldspar grains; S_3 is most strongly developed southwest of Watts Lake where it occurs as a very fine almost slaty cleavage in fine grained tuffs. S_4 is only seen in the calcareous tuff and marble bands due to the ductility of the carbonate crystals; in these horizons it is a penetrative fabric defined by elongate calcite grains and minor sericite, and is occasionally developed in like manner southwest of Watts Lake.

Metamorphic history of the conglomerate, rhyolite and banded tuff formations

Textures in these three formations record a relatively simple mineral growth history principally because of the predominantly quartz-feldspathic nature of the rocks and lack of porphyroblastic, lepidoblastic and nematoblastic minerals (except in parts of the Banded Tuff Formation). Except locally, all the textures are related to D_3 and it appears that either D_2 did not affect the bulk of the three formations, or else D_2 fabrics were so weak as to be easily overprinted by later recrystallisation. Since no tectonic fabrics are in evidence where S_3 is not developed, it appears that the former is the case. The metamorphic history is summarised in Table V.

MS_2

MS_2 growth is only recorded in banded tuff and conglomerate close to the locus of major D_2 sliding between Watts Lake and Limestone Lake (Fig. 37). Oriented biotite and muscovite flakes cut by MS_3 micas are the only surviving elements of the MS_2 assemblage.

MP_2

No textural evidence for MP_2 growth was seen.

MS_3

MS_3 is most prominent in the banded tuff formation in which growth of oriented prismatic hornblende and more stubby idiomorphic diopside crystals are oriented to define the S_3 L-S tectonite fabric. Minor prismatic epidote associated with orthite and locally biotite and muscovite flakes are also aligned in S_3. Quartz and feldspar grains occasionally show a dimensional orientation in S_3 but generally the MS_3 fabric has been annealed. MS_3 feldspar-feldspar grain boundaries are irregular and indented. Some plagioclase phenocrysts in the rhyolites show MS_3 polygonisation, and less commonly untwinned K-feldspar phenocrysts are partly broken down to a xenomorphic microcline mosaic. Quartz phenocrysts in the rhyolites show strong D_3 straining and total or partial breakdown to a mosaic with indented grain boundaries, and smaller MS_3 quartz blebs are dimensionally oriented in S_3. Calcite developed a fabric of dimensionally-oriented grains but this is only rarely preserved. Magnetite and haematite recrystallized in discrete xenomorphic or subidiomorphic crystals and in minute rods oriented in S_3. Inclusion-free subidiomorphic crystals of garnet 0.2 mm. in diameter were noted in banded tuffs at one locality southeast of Witch Lake; they are inferred to be of MS_3 age since MP_3 recrystallisation is weak.

MS_3 recrystallisation was of a lower grade in the conglomerate unit between Turnip Lake and Gear Lake, and is characterised by the assemblage albite-epidote-tremolite actinolite, though textural relationships are generally similar.

MP_3

MP_3 effects were weak with secondary polygonisation only well developed in quartz mosaics replacing quartz phenocrysts, and calcite mosaics in the marble bands. Subpolygonal and polygonal fabrics with triple points resulted. Quartz feldspar fabrics in the banded tuffs and rhyolite groundmass are occasionally annealed to subpolygonal mosaics. Local MP_3 effects include development of poikiloblastic hornblende and unoriented prisms of tremolite-actinolite. MP_3 microcline overgrowing diopside and the MS_3 quartz biotite fabric was noted. A few poikiloblastic prisms of tourmaline were noted in the marble horizon at Kitts Brook. Pyrite locally recrystallised in cubic form (0.1 - 2 mm.).

Later metamorphic effects

Partial chloritisation of biotite is common and locally is complete, e.g., south of Witch Lake. It may be a late MP_3 effect or could be related to D_4 or D_5.

MS_4 recrystallisation of calcite in the marble horizon is widespread and resulted in a preferred dimensional orientation defining S_4; it was accompanied locally by very minor growth of sericite flakes. Quartz recrystallised in S_4 in crenulations but these are rarely developed.

In the south of the area where D_5 is widely developed, straining of MP_3 quartz grains gave rise to undular extinction and sutured grain boundaries (stress-induced boundary migration).

CHAPTER IV

REMOBILISED HOPEDALE COMPLEX

Introduction

Contact and structural relationships show that the Hudsonian cycle of events gave rise to intense zonal deformation of the Hopedale Complex producing a refoliated gneiss zone between basement and cover, a subsequent period of migmatisation and the formation of chiefly autochthonous and para-autochthonous granites.

REFOLIATED GNEISS ZONE

A zone of intensely foliated gneiss sheathes the contact of the Hopedale Complex with the Aillik Group. It attains a maximum thickness in the order of 700 m. where it envelops the Post Hill fold. A zone of identical gneiss occurs within the Hopedale Complex north of Watts Lake, and although not at present associated with the Aillik Group, the contact may represent the keel of an early infold of cover rocks into basement. Two bands of similar lithology occur on the north side of Jacques Lake. The Hopedale Complex is also refoliated close to the contacts with the two hornblende schist units southeast of Turnip Lake.

Refoliated banded gneisses and intensely deformed granites can be distinguished within the zone, and their Hopedale Complex parentage is recognisable. From west of Kitt's Pond to north of

Nash Lake refoliated banded gneisses dominate, but foliated granites are prominent in the zone enveloping Post Hill. In the latter zone a prominent horizon of quartzitic mylonite is included.

The contact with the Hopedale Complex is obscured by the anatectic Brumwater granite southwestward from Julies Harbour, but it is seen east of Three Rapids. Here it is gradational; the banding in the Hopedale Complex swings into parallelism with the Aillik Group contact with increasing deformation towards the contact. This transposition is accompanied by reduction in scale of the banding, smoothing out of irregularities and breakdown of textures thereby reducing grain size. The contact with the Aillik Group is a gradational interbanded one in which gneiss and amphibolite are interleaved.

(i) Gneiss

The Refoliated Gneiss is composed of quartz, andesine, minor biotite and accessory apatite and sphene. The overall mineralogy is thus rather similar to that of the Hopedale Complex gneisses, but the grain size averages 0.2 mm. as against 0.5 mm. or more in the latter rocks. Some grey bands can look very similar to the psammites in the metasedimentary formation but on wet or polished surfaces a faint mottling indicates the pre-existing coarser grain size. Regular banding in shades of pale grey and grey on a 0.3 - 10 cms. scale with fine laminations 1 mm. thick is common, particularly towards the

Aillik Group contact (Figs. 38 and 76). A general lack of leucosome veining and regularity of strike contrasts with the Hopedale Complex, but the gneissic character of the banding is still very much apparent (Fig. 39) particularly when viewed down the plunge of the L_2 lineation. Although like the Hopedale Complex the refoliated gneiss is deficient in K-feldspar, some pale bands contain up to 25% microcline and include microcline crystals up to 1 cm. in diameter; these appear to represent the pegmatitic leucosomes prevalent in the Hopedale Complex that have been flattened into the plane of the banding. Isoclinally folded relic pegmatites can also be recognised (Fig. 40).

Concordant amphibolite bands and lenses 8 - 30 cm. thick occur in the gneisses in places, and rarely are up to 3 m. thick. They show a penetrative hornblende fabric and commonly include quartzofeldspathic veins showing complex isoclinal folds. No pod-like forms or boudins as are common in the Hopedale Complex were recognised but the lenses may represent strongly flattened boudins.

(ii) Foliated granite

Grey strongly foliated homogeneous granodiorite is the most common lithology (Fig. 41). It is composed of quartz, sodic andesine, subordinate microcline and biotite, and although resembling in outcrop the granodiorite associated with the early migmatite no pre-Aillik Group fabric that might indicate a correlation is preserved. The early fabric may have been completely overprinted by the Hudsonian fabric, since darker more biotite rich lineated examples that may be equivalent to the darker phase in the early migmatite strengthen the comparison.

Coarsely porphyritic microcline granite underlies a small area in the refoliated zone 900 m. north of Three Rapids Base Camp. It consists of prismatic and ovoid microcline, and some andesine megacrysts up to 5 cm. long, and white lenses 2 - 8 mm. long of granular quartz and feldspar in a grey finely schistose and lineated groundmass. The rock is identical to porphyritic granite described by Sutton (1972) cropping out on the west shore of Kaipokok Bay directly opposite; Sutton regarded the granite as the youngest pre-Aillik Group intrusive phase in the Hopedale Complex.

The most intensely foliated granite was noted east of Three Rapids close to the Aillik Group contact where it occurs interbanded in refoliated gneisses. It contains extremely fine pink weathering streaky laminations less than 1 mm. and commonly only 0.1 mm. thick, alternating with grey laminations. The pink laminations are lensy but even the thinnest are continuous for up to 4 cms., and represent broken down and flattened microcline crystals. They consist of very fine grained quartzo-feldspathic mosaic and contain ovoid marginally granulated microcline augen in their thickest parts (Figs. 42 and 43).

(iii) Quartzitic Mylonite

The Quartzitic Mylonite consists of very fine grained white porcellanous quartzite composed dominantly of quartz with 6% muscovite and minor epidote, chlorite after biotite, and tourmaline (Fig. 50). It contains pale greenish and grey coloured bands 1 - 10 cm. thick (Fig. 44). The mylonite occurs in a concordant horizon up to 62 m. thick that fingers out progressively to the west and east. The contacts are marked by zones of quartz-muscovite-feldspar schist 15 cms. to 4 m. in thickness. The schist contains grey quartz lenticles up to 3 cm. long. The refoliated gneiss passes gradationally over 4 - 30 cms. into the schist, and the textural development of the schist and quartzite has been obscured by MP_1 porphyroblastic feldspar growth and intense penetrative D_2 deformation. The contact between the schist and Quartzitic Mylonite is relatively sharp (Fig. 45).

(iv) Contact relationships with the Aillik Group: the Post Hill Slide

The Refoliated Gneiss has a gradational contact with the Post Hill amphibolite. The gradation takes place in a zone up to 100 m. thick in the nose of the Post Hill fold, but only 3 - 17 m. thick on the west limb, and east of Brumwater Lake. Refoliated gneiss is interbanded with hornblende and hornblende-biotite schist on a 0.5 - 20 cm. scale (Figs. 46, 47 and 124). The bands tend to be lenticular, and lenticular units of gneiss up to 10 m. thick may be included in the contact zone. The gneissosity within the refoliated gneiss bands is approximately concordant with the contacts of the bands.

(v) Fabric

D_1 gave rise to the interbanding of amphibolite and gneiss and was associated with the transposition of banding in the Hopedale Complex into subparallelism with the contacts between gneiss and amphibolite. These planes therefore represent S_1 surfaces but a related S_1 tectonite fabric is only preserved as an included hornblende fabric in occasional plagioclase porphyroblasts. The banding in the refoliated zone is regarded as a relic Hopedale Complex banding that has been transposed into S_1 since east of Three Rapids the dextral swing recording the transposition has been mapped out.

An S_1 tectonite fabric is preserved in the quartz-muscovite-feldspar schist associated with the quartzitic mylonite. S_1 is seen as a muscovite fabric folded round the hinges of F_2 microfolds, and as an included fabric of muscovite flakes in plagioclase porphyroblasts (Fig. 48). S_1 is also defined by the quartz and quartzo-feldspathic lenticles in the schist, and small S_1 biotite flakes within these lenticles are folded round F_2 microfolds. The concordant quartzite bands in the schist and the colour bands in the quartzitic mylonite also represent S_1 planes; the colour bands are believed to be derived from original lithological variations within the Hopedale Complex from which the mylonite was derived.

S_2 is the pervasive penetrative fabric in the refoliated zone and is defined by a preferred orientation of biotite flakes, lensed feldspar crystals and lensoid quartz aggregates. In some of the deformed granites it is emphasised by lensed and stretched clots of biotite flakes, and in the amphibolite bands it is a penetrative fabric in hornblende and biotite. S_2 varies from an L-biassed L-S fabric in the structurally lower parts of the refoliated zone, to an $S > L$ fabric in the more intensely deformed parts close to the Aillik Series contact. In the quartz-muscovite schist S_2 is the penetrative muscovite schistosity, and in the quartzite is defined by a preferred dimensional and crystallographic orientation of fine quartz grains and is only apparent in thin section.

S_3 is a microscopic penetrative fabric defined by scattered fine biotite flakes that overgrow S_2, and it is not generally visible in hand specimens. However in some outcrops L_3 is a very prominent lineation in the plane of S_2, and is caused by crenulation of S_2 and of elongated L_2 lenses of quartz and quartz-feldspar aggregates. L_2 appears to lie very close to L_3 in most places.

Open to tight F_4 folds are developed in the refoliated gneiss east of Julies Harbour but were not associated with constructive metamorphic growth, and show no related fabric. Minor kink bands and crenulation cleavages related to D_5 are developed locally in the quartz-muscovite schist, and in the hornblende schist of the contact zone.

(vi) Metamorphic history

The only fabric element of the Hopedale Complex that is recognised in the refoliated zone is the banding, in transposed form, defined by variations in biotite content. The present mineral assemblages are dominated by MS_2 and MS_3 recrystallisation, but field and limited textural criteria suggest that the chief formative recrystallisation was related to MS_1. In general, MP effects were weak but there are indications that significant MP_1 porphyroblastic growth occurred. Table VI summarises the mineral growth history.

MS_1

D_1 resulted in major transposition and development of the mylonite horizon; and MS_1 must have been associated with major break-down of pre-existing textures in the Hopedale Complex. Only part of the MS_1 mineral assemblage is preserved locally, and little can be deduced about the metamorphic conditions. Hornblende is preserved as an included fabric in occasional plagioclase porphyroblasts in the contact zone (Fig. 49).

MS_1 muscovite occurs in the muscovite quartz schist in relic crenulations and as an included fabric in oligoclase porphyroblasts. MS_1 fibrolite is occasionally included in MS_2 epidote in the quartzitic mylonite (Fig. 366).

MP_1

Porphyroblastic growth of oligoclase occurred in the quartz muscovite schists (Fig. 48), MP_1 andesine developed to a minor extent in amphibolite bands in the contact zone (Fig. 49). Relatively coarse relic crystals of oligoclase and microcline in the gradational rock between quartz-muscovite schist and re-foliated gneiss contrasts with the prevailing fine textures in the latter rock which suggests that they may also represent MP_1 porphyroblasts.

MP_1 porphyroblasts are thus only noted in the schistose rocks where they can be recognised by their included S_1 minerals fabrics. It is possible that they are also developed in the phyllosilicate poor gneisses and granites of the refoliated zone where the criterion of included fabrics is lacking.

MS_2

MS_2 gave rise to growth of biotite in an oriented fabric in the gneisses (Fig. 50) and to muscovite forming a strong schistosity in the mylonite horizon. Growth of strongly oriented hornblende crystals occurred in the amphibolite bands. MS_2 appears superficially to be responsible for the recrystallisation of coarse quartz and feldspar crystals to fine grained mosaics (e.g., Fig. 43) but evidence discussed above suggests that MS_1 must have been largely responsible for this breakdown. The second deformation may therefore have oriented an MS_1 quartz-feldspar fabric into S_2, but its intensity suggests that MS_2 must have been associated with renewed breakdown of feldspar relics that survived MS_1.

Minor MS_2 effects include growth of tourmaline needles aligned in L_2 and recrystallisation of epidote, orthite, sphene and opaques in the plane of S_2 (e.g., Fig. 51).

MP_2

There is little evidence for MP_2 mineral growth. MP_2 oligoclase porphyroblasts overgrow S_2 in the quartz muscovite schist. It is surprising that MS_2 sutured quartz grain boundaries in the adjacent quartzitic mylonite show little sign of annealing, though MP_2 idiomorphic overgrowths on epidote occur.

MS_3

MS_3 is weakly developed in the refoliated gneiss zone enveloping Post Hill where it gave rise to growth of scattered oriented biotite flakes, and some straining and development of sub-boundaries in quartz grains. MS_3 biotite and minor hornblende developed in the amphibolite bands in the contact zone, but in general the MS_2 hornblende shows little tendency to recrystallise, and neither does the MS_2 muscovite in the quartz-muscovite schist zones. Very minor growth of muscovite did occur in places.

East of Brumwater Lake MS_3 was more intense and has largely obliterated the MS_2 fabric apart from the amphibolite bands where only local recrystallisation of hornblende has occurred. Biotite recrystallised completely during MS_3 to an orientated tectonite fabric, and quartz and feldspar recrystallised destroying the strong MS_2 streakiness (Fig. 52).

MP_3

MP_3 effects were weak and appear to be restricted to minor incomplete polygonisation of quartz and feldspar, and local growth of ragged unoriented muscovite porphyroblasts 0.3 mm. in diameter.

Later metamorphic effects

D_4 and D_5 where developed are associated with no constructive metamorphic effects but give rise to straining of quartz and suturing of quartz grain boundaries. Chloritisation of biotite appears to be related to these events also.

THE UNLUCKY HEAD MIGMATITE

The Unlucky Head Migmatite underlies a large irregular area centred on Unlucky Head with a smaller area occurring some 3 kms. to the southwest. Structural relationships described below indicate that the migmatisation was a Hudsonian event that postdated D_1 and D_2 and partly pre-dated and was partly synchronous with D_3. In describing the migmatite, terminology summarised by Mehnert (1968) is used as it is for the most part descriptive and without genetic implications.

(i) Lithology

The Unlucky Head Migmatite consists of rounded or ovoid rafts of Hopedale Complex gneiss and migmatite, "floating" in schlieric, nebulitic or fairly homogeneous neosome (Figs. 53, 54 and 55). The rafts vary from pods about 30 cms. in diameter to areas of partially migmatised gneiss several hundred metres across. However they are commonly in the order of 3 - 7 m. in diameter.

(a) The rafts

The gneissic banding within the rafts commonly strikes approximately east-west. Although in places the banding is regular and undeformed, the rafts generally show well developed diktyonitic structure. The diktyonitic structure consists of kink style folds resembling small-scale shear zones (Ramsay and Graham, 1970) with many of the kink planes occupied by diffuse granitic leucosome (Figs. 56 and 57). They show a dominantly sinistral sense of displacement. The kink zones are spaced at 10 - 40 cm. intervals and strike fairly constantly north-south, cutting the gneissic banding obliquely or at right angles. The gneissic banding often shows concentric style folding between the kink planes (Fig. 57). In some rafts the kink zones are early and are truncated at the margins of the rafts (fig. 58), but generally the granitic material in the axial planes merges along strike with the neosome (Fig. 59). In most rafts the gneissic banding also shows a sinistral swing into the contacts that are subparallel to the kink zones, reflecting the style of deformation in these zones (Figs. 60 and 61).

Small rafts or pods of amphibolite 30 cms. to 2 m., and occasionally up to 9 m. in diameter are common. Some are recognisable segments of disrupted bands of amphibolite (Fig. 62; see also Fig. 72). Others occur in clusters up to 6 m. across of irregular pods that contain agmatitic leucosomes that pre-date the enveloping neosome (Fig. 63). These clusters appear to represent early (Archean) boudins within the Hopedale Complex that have been disrupted by remobilisation of the granitic veins. The pods have marginal biotitic selvages 1 - 10 cms. wide in which hornblende is largely replaced by biotite (Fig. 64). The amphibolite-granite contacts are commonly cuspate, with convex lobes of granite moulded into the amphibolite (Figs. 64 and 62).

The larger bodies of gneiss within the migmatite (e.g., immediately west of Julies Harbour) show similar diktyonitic structure, but on a larger scale. The kink folds are more irregular, and the kink planes are occupied by irregular veins of granite up to

40 cm. thick (Fig. 65). More prominent however are co-axial planar and clearly related open to tight folds with wave lengths of 2 - 5 m. (Fig. 66), the limbs of which are occupied by irregular and lensoid sheets of granite and nebulitic granite up to 1 m. thick (Fig. 67). Some granite veins are folded by these folds, and others cut across and post-date them. Although the folds are relatively simple in profile they refold early folds and have subhorizontal variable plunges so that these "porpoising" folds cropping out on irregular surfaces give rise to complex interference patterns (Fig. 68). Nevertheless towards contacts with the neosome the complexities suggest that more than simple refolding is involved (Fig. 69) and marked inhomogeneities in the deformation are indicated that appear to be responsible for the chaotic structure in some small rafts (Fig. 70).

(b) The neosome

The neosome is a pale grey nebulitic granite composed of quartz, microcline, plagioclase (An 20) and minor biotite. Ghost banding displaying a good degree of coherence and continuity is usually apparent (Figs. 71 and 72). It strikes roughly north-south, roughly at right angles to the gneissic banding in the rafts around which it sweeps to form prominent augen (Figs. 53 and 58). Biotitic schlieren (melanosome) up to 1 cm. thick and 1 m. long concordant with the ghost banding are prominent locally and are associated with wispy lenses of gneiss (palaeosome) having diffuse contacts with the enveloping ghost banded material (cf. Figs.9, 56 and 60). With gradual fading in the clarity of the ghost banding, the granite passes into fairly homogeneous faintly nebulitic rock (Figs. 70 and 73).

There appears to be a distinct relationship between the internal structure of the rafts, the nature of their contacts and the character of the neosome. Where the relic banding in the neosome is strong with prominent schlieren, the rafts show strongly developed diktyonitic structure and the contacts are not sharply defined (Fig. 61). The dominant ghost-banded lithology has relatively sharply defined contacts with the rafts, which show marginal kinking of the gneissic banding and moderately developed diktyonitic structure. Where the neosome is fairly homogeneous contacts are sharply defined (in places agmatitic) and diktyonitic structure is generally absent within the rafts (Figs. 73 and 55).

The neosome can be clearly distinguished from the early migmatite that forms part of the Hopedale Complex, on the basis of lithology and fabric (Figs. 58 and 74).

(ii) Fabric

The gneiss rafts show all the fabric elements of the Hopedale Complex, and the last vestiges of the complex fabric of the gneiss is seen within the neosome as variations in biotite content defining the ghost banding. In addition a weak biotite tectonite fabric, S_3, is developed throughout the neosome, and also within the leucosome veins in the rafts. S_3 is strongest towards the southeast, but falls off in intensity towards the northwest where it is not discernable in many outcrops. It is [illegible] developed in the amphibolite pods as a crenulation cleavage affecting the Hopedale Complex hornblende fabrics (Fig. 64). S_3 is axial planar to the kinks and related folds in the diktyonites, and is also subparallel to the general trend of the ghost banding in the neosome.

Growth of MS_3-MP_3 biotite is the only element in the post-Archean metamorphic history of the Unlucky Head Migmatite that can be clearly discerned on the basis of textural criteria (Table VII). The marginal alteration of amphibolite rafts to form biotitic selvages is the most obvious feature, visible in outcrop (Figs. 64, 140 and 141).

THE BRUMWATER GRANITE

The Brumwater Granite occurs in an apparently concordant tabular body of variable width flanking the Refoliated Gneiss Zone, and broadens out west of Brumwater Lake. It is a leucocratic biotite granite or adamellite (Fig. 75), composed of quartz, microcline, oligoclase and minor biotite with scattered microcline megacrysts from 5 - 20 mm. in diameter. The Brumwater Granite is essentially identical in mineralogy and texture to the homogeneous neosome in the Unlucky Head Migmatite, but on average it contains about 15% more K feldspar. Diffuse pegmatitic and aplitic lenses are common, and scattered magnetite eyes up to 7 mm. in diameter surrounded by leucocratic coronas are locally prominent.

Nebulitic patches showing ghost banding are common, and ragged xenoliths of gneiss usually 1 - 4 m. in diameter with wispy gradational contacts are also widely distributed; with an increase in the proportion of the xenoliths the granite merges into the Unlucky Head Migmatite.

Two xenoliths of quartzitic mylonite were noted in the granite near the west end of Brumwater Lake. One, situated about 120 m. southwest of the lake, is at least 6 m. thick and appears elongate in the direction of the foliation in the granite, but the dimensions of the other are not known. The quartzite is banded and is lithologically identical to the quartzitic mylonite in the Refoliated Gneiss Zone on Post Hill, though it includes scattered plagioclase and microcline porphyroblasts up to 2 mm. in diameter and forming about 8% of the rock. The quartz is in a subpolygonal mosaic of 0.1 - 0.2 mm. grains. The xenoliths are assumed to be derived from the D_1/D_2 Quartizitic Mylonite of the Refoliated Gneiss Zone as this striking and unusual lithology has not been observed elsewhere in the Hopedale Complex.

The contact with the Unlucky Head Migmatite is gradational, and is marked by an increase in size and number of gneiss xenoliths and by more widely developed ghost banding in the granite. Northeast of Brumwater Lake the gradation occurs over about 10 - 20 m. but to the southwest is very indefinite.

The Brumwater Granite has an interfingering migmatitic contact with the refoliated gneiss, gradational over about 3 m. The granite truncates the fine D_1-D_2 banding in the refoliated gneiss (Fig. 76). This relationship and the presence of the D_1/D_2 quartzitic mylonite indicates that the granite post dates the second deformation of the Hudsonian orogeny.

The granite bodies in the Kitts Pond Wedge of the Hopedale Complex are lithologically identical to and show the same features as the Brumwater Granite. One occurs northeast of Kitts Pond, and the other occupies the southwestern tip of the basement wedge between Gear Lake and Henry Lake. The latter occurrence has an intrusive contact with the Kitts-Nash Lake mafic volcanics and appears to have formed in situ, obscuring the D_1/D_2 tectonic slides bounding the Hopedale Complex at this locality.

(i) Fabric

A single penetrative L-S fabric that can be correlated directly with S_3 is developed and is defined chiefly by lensed quartz grains and oriented biotite flakes. It forms augen around the microcline megacrysts and is weak in the west but intensifies towards the contact with the Refoliated Gneiss Zone where it becomes L-biassed. It can be traced through the Refoliated Gneiss Zone into S_3 in the contact with the Aillik Group; this is clearly demonstrated on the map north of Nash Lake, S_3 cuts the banding in the quartzite xenoliths. S_4 is a fracture cleavage seen locally in the shore section northeast of Julies Harbour. It is zonally developed (Fig. 75) and the S_4 planes are spaced at 2 - 4 mm. intervals and show on the rock surface as fine dark hair lines. The planes are occupied by fine granular quartz, feldspar, chlorite and epidote.

The metamorphic mineral growth history is essentially similar to that of the Unlucky Head Migmatite and Migmatitic Quartz Monzonite; growth of MS_3-MP_3 biotite is only clearly defined element, apart from minor late effects (Table VII).

MIGMATITIC QUARTZ MONZONITE

(i) Introduction

The Migmatitic Quartz Monzonite is an elongate tabular body consisting of irregular rafts (up to 10 m.) of gneiss floating in a coarse grained heterogeneous, dominantly quartz monzonitic host (Fig. 77). It differs from the Unlucky Head Migmatite in both composition and structural relationships of thegneiss enclaves.

The northwestern contact is an intrusive one, but on the southeast the migmatitic body is separated from the Witch Lake Slide by a narrow zone of mylonitized quartz monzonite. The intrusive contact with the Post Hill Amphibolite is exposed at one locality, and is irregular. S_2 in the amphibolite is sharply truncated against the contact (Fig. 78). Irregular tongues intrude the amphibolite along S_2 in a zone a few metres wide adjacent to the boundary. Related contact metamorphic effects are negligible and S_2 in the amphibolite retains its coherency to within 2 - 3 mm. of the contact (Fig. 79). North of Watts Lake the intrusion truncates the northerly striking belt of refoliated gneiss. At the north end of the body the contact with the major refoliated gneiss zone maps out as partly concordant and partly cross-cutting, with irregular lenses and veins of quartz monzonite in the gneiss close to the contact. The intrusion appears to have wedged the refoliated gneiss away from the Witch Lake Slide zone.

The cross-cutting relationship of the intrusive contact to S_2 in the Post Hill amphibolite, and to the Refoliated Gneiss indicates a post-D_2 age for the Migmatitic Quartz Monzonite. The structural relationship of the intrusion to the Post Hill fold, and the development of S_3 within the intrusive body indicates an early syn-D_3 age of emplacement.

(ii) Lithology

Although quartz monzonite appears dominant, the composition varies from quartz diorite to granodiorite and locally granite, though quartz rarely exceeds 15%. Quartz diorite and granitic phases intertongue close to the exposed contact with the Post Hill amphibolite. The rock is coarse-grained, with subhedral to anhedral microcline and plagioclase crystals averaging 7 mm. in diameter, but often reaching 1 cm. and occasionally 2 cm. in size. Quartz averages 10% and the other constituent minerals are biotite (10%) and accessory sphene, epidote, and orthite. The rock is foliated to a variable degree, and the feldspars in hand specimen often have a granular texture due to partial breakdown to fine grained mosaics (Fig. 80).

The rafts of gneiss have a variable distribution, and areas of quartz-monzonite virtually devoid of xenoliths occur in the southwest part of the intrusion around Witch Lake, in the bulge due south of Goula Bight and in the northeast tip of the body. The rafts of gneiss vary from about 1 m. to 10 m. in size and are irregular in shape and have ragged interdigitating contacts. They contrast with the form of the rafts in the Unlucky Head Migmatite, and do not show diktyonitic structure. Faint relic banding is seen in the quartz-monzonite in places, and contacts with the gneiss tend to be gradational and wispy (Fig. 81). Amphibolite bands in the gneiss are marginally altered to biotite where in contact with the quartz monzonite, as are the margins of isolated amphibolite xenoliths (Fig. 77).

Xenoliths of hornblende schist identical to the Post Hill amphibolite occur close to the contact with that formation (Fig. 79) and one xenolith of the quartzitic mylonite was noted 2 kms. northeast of Witch Lake.

Dark grey to black mafic bands averaging 3 cms. thick with diffuse contacts were noted in the quartz monzonite where the contact with the Post Hill amphibolite is exposed. They consist of hornblende, biotite and plagioclase and are well developed in the tongues of quartz monzonite invading the amphibolite. Within these tongues they follow the contacts and have clearly been affected by magmatic flow. They may possibly have originated by marginal assimilation of Post Hill amphibolite xenoliths, but this appears unlikely in view of the negligable contact metamorphic effects. A more likely source of contamination appears to be a suite of diabase dykes in the quartz monzonites that parallel S_3 and appear to be near synchronous with intrusion of the migmatitic quartz monzonite. These dykes in turn are probably part of the syn-D_3 gabbro dyke swarm on Post Hill.

At the contact with the hornblende schist unit marking the Witch Lake Slide zone, the quartz monzonite becomes intensely foliated and passes over about 30 cms. into a fine grained grey very thinly laminated mylonite, 20 cms. to 2 m. thick (Fig. 82). A zone of similar mylonite 10 m. thick occurs within the quartz monzonite at the northeast corner of Witch Lake, and is parallel to S_3 (Fig. 83). Southwest of Witch Lake the intrusion narrows, and is intensely foliated, passing into finely laminated grey phyllonite or mylonite. However a 6 m. thick horizon of intensely foliated quartz monzonite can still be recognised 2 km. southeast of Witch Lake in contact with the attentuated eastern limb of the Post Hill Fold.

(iii) Fabric

Although the intrusion post-dates D_2, S_3 locally shows two stages of development. The mylonite zone at the northeast corner of Witch Lake reflects an early D_3 event as on the margins, the strongly foliated quartz monzonite shows flattened quartz grains and an early biotite fabric folded tightly by a second schistosity. Tight folds in the mylonitic laminations with an axial planar biotite fabric also occur within the zone. A similar composite history of D_3 tectonite fabric development is seen in the mylonite on the contact with the Witch Lake Slide, wherein the gradation from quartz-monzonite to mylonite, S_3 is a strain-slip cleavage (Fig. 84). A similar relationship is occasionally seen in local zones throughout the intrusion, but generally the second of these fabrics is the only one developed.

Thus outside the mylonite zones S_3 is a simple penetrative L-S fabric defined by flattened quartz and feldspar crystals and biotite aggregates, and also by a preferred orientation of biotite flakes. The intensity varies from weak to moderate and in the latter case the linear element is clearly defined by stretched biotite aggregates.

S_4 is a local coarse crenulation of S_3, best developed at the northeast end of the intrusion. At the northeast end of Witch Lake anastomosing mylonitic shear zones 1 - 4 cms. thick cut weak S_3 in quartz monzonite and are believed to represent S_4 (Fig. 85). S_5 is a local crenulation cleavage (1 cm. scale) developed in the mylonitic zones only.

The metamorphic mineral growth history is essentially similar to that of the Unlucky Head Migmatite and Brumwater Granite; growth of MS_3-MP_3 biotite is the only clearly defined element, apart from minor late effects (Table VII).

LEUCOGRANITE

A diamond shaped body of leucocratic biotite granite with sharply defined contacts occurs northeast of Goula Bight. The body may be partly sheet like, as a gently dipping contact with gneiss was seen near the shore, though some inland contacts appear steep. The granite is homogeneous, and is composed chiefly of perthitic microcline and quartz with 20% oligoclse, 8% biotite and accessory muscovite, myrmekite, epidote and apatite. The texture is hypidiomorphic granular with subhedral microcline megacrysts up to 8 mm. long.

The granite sharply truncates the Refoliated Gneiss Zone and therefore post-dates D_2. It is cut by a weak biotite tectonite fabric that is correlated with S_3 on the basis of its parallelism with S_3, and because S_3 is the only post D_2 fabric in the area that is associated with constructive metamorphic growth. A few pegmatites up to 3 mm. thick composed of a graphic microcline intergrowth occur parallel to S_3.

The granite appears to represent a late syn-D_3 intrusion and is believed to be a late-stage derivative of the Brumwater Granite; for this reason it is described as part of the Remobilised Hopedale Complex. It may be equivalent to leucogranite sheets described by Sutton (1972) in the Hopedale Complex northwest of Kaipokok Bay.

CHAPTER V

INTRUSIVE IGNEOUS ROCKS

Introduction

A great variety of intrusive igneous rocks occur within the area. They show a wide range in composition and lithology and in their relationships to structural features. They are broadly classified as Prekinematic, Synkinematic and Postkinematic to the Hudsonian orogeny on the basis of their relationships to tectonite fabrics and structural elements. Detailed mapping and observation of their contacts wherever possible proved critical in this respect.

The Prekinematic intrusive rocks appear to be related to the mafic and acid volcanics in the Aillik Group. The major Synkinematic intrusives are temporally related to the migmatisation of the Hopedale Complex that occurred pre- and syn- the third deformation D_3. There is some evidence to suggest that the major bodies of synkinematic intrusive rocks represent partial melts from the basement that were mobilised and intruded into the cover rocks. However the very large volume of intrusive rock involved does present a problem to this hypothesis, and a detailed geochemical study would be required to develop it further.

PREKINEMATIC INTRUSIVE ROCKS

METAGABBRO

(i) Kitts Metagabbro

The Kitts Metagabbro occurs in a massive uniform sill composed of tremolite-actinolite and oligoclase showing a relic igneous texture (Fig. 86). It separates the Kitts Main Zone showing from the South Showing Zone, indicating that these units formed a single iron formation member prior to intrusion of the sill. The maximum thickness is 350 m. and the sill thins markedly in the south; it is truncated in the north by the Limestone Lake Slide. A crude pre-metamorphic banding on a 2 - 4 cm. scale weathers out about 450 m. south of the Kitts adit, and appears to represent relic igneous layering. Two small bodies of identical metagabbro have been mapped in the pillow lavas west of the main sill, and other minor occurrences have been noted throughout the Kitts-Nash Lake Belt of mafic volcanics.

S_1 is developed in a one metre wide zone at the contact with the Kitts Main Zone; it is an L-S tectonite fabric of oriented tremolite-actinolite and elongate relic plagioclase crystals. It is most intense at the contact where it is at a low angle to, and is truncated by S_2 in the iron fomration. Away from the contact the fabric diminishes in intensity and dies out, curving into obliquity with the contact as it does so in the manner of a dextral shear zone.

S_2 is developed in local shear zones 2 - 5 cms. wide as an L-S fabric or oriented fibrous tremolite-actinolite; these are particularly prominent at the south end of the body. Apart from the local zones of S_1 and S_3 the metagabbro appears largely undeformed.

(ii) Inda Metagabbro

The Inda Metagabbro is a sill about 75 m. thick that follows the southeast contact of the Inda Lake iron formation member, and it is thus similar in relationships to the Kitts Metagabbro. It terminates bluntly northwest of the Inda Lake Camp, and is out against the Nakit Slide at Knife Lake.

It differs mineralogically from the Kitts Metagabbro in that the plagioclase is more calcic (andesine) and blue-green hornblende occurs in place of tremolite-actinolite. Where unfoliated, the rock is identical in field aspect to the Kitts Metagabbro but unlike the Kitts body a penetrative foliation, S_2, is irregularly developed. No evidence that S_1 had existed previously was seen. Within about 10 m. of the contact with the iron formation member intense deformation has reduced the metagabbro to a fine-grained grey hornblende-plagioclase rock in which vague streaky mottling is the only relic of the original gabbroic texture. In a trench at the Inda Lake Showing this rock contains black radioactive amphibole-garnet-pyrite veinlets up to 2 cms. thick concordant with the foliation. The veinlets include pods up to 1.5 cms. in diameter composed of diopside, altered marginally to tremolite-actinolite, around which the tectonite fabric forms augen.

S_2 becomes more pervasive towards the Nakit Slide, and at Knife Lake the metagabbro passes into amphibolite-albite-orthite-sericite-carbonate schist. S_3 was not identified in the metagabbro.

(iii) Metamorphic history of the metagabbros

Events are summarised in Table VIII.

The only evidence for MS_1 mineral growth is from the Kitts Metagabbro where it was restricted to the contact where it gave rise to growth of oriented amphibole crystals and recrystallisation of plagioclase.

In the Kitts Metagabbro there is evidence that MP_1 resulted in initial alteration of the igneous pyroxene to a felted aggregate of fibrous amphibole. This is indicated by pre-S_3 diopside porphyroblasts that occur on the contact of a quartz porphyry dyke, that have overgrown and include fibrous amphibole; the diopside is inferred to be late MP_1 age as it pre-dates S_3, and MP_1 diopside occurs in the iron formation members. In the Inda Metagabbro it is inferred that development of the diopside in the contact zone was an MP_1 event as it pre-dates S_2.

MS_2-MP_2

No metamorphic events related to D_2 were recognised in the Kitts Metagabbro, but in the Inda Metagabbro MS_2 was the main period of mineral growth and gave rise to the oriented hornblende fabric and recrystallisation of the plagioclase. Static post-MS_2 effects in the Inda Metagabbro resulted in replacement of the diopside by tremolite, mimetic growth of the hornblende and annealing of the plagioclase to a subpolygonal mosaic. It is suggested that these effects are related to MP_3 rather than MP_2 since MP_3 was generally the stronger phase and hornblende crystals have mimetically grown across epidote veinlets that are pre-S_3 in age.

MS_3-MP_3

MS_3 growth was not recognised in the Inda Metagabbro, but mineral growth that may have been related to MP_3 has been described above. In the Kitts Metagabbro MS_3 was restricted to growth of fibrous tremolite-actinolite in the shear zones. Recrystallisation of the MP_1 fibrous amphibole aggregate to the large poikilitic crystals appears to have been an MP_3 event, as widespread MP_3 mineral growth occurred in other rocks of the Kitts area, though it is possible that MP_2 played a part.

The age of the saussuritisation in the Kitts body is not clear, but it is probably a late MP_3 event as prehnite veins post-date S_3. Local breakdown of the oligoclase in the Kitts body to a fine-grained mosaic appears to be a late cold-working effect probably related to D_4.

QUARTZ PORPHYRY

Quartz porphyry intrusions occur chiefly in the Kitts-Nash Lake mafic volcanic belt, where they are restricted to the areas between Gear Lake and the Kitts Prospect, and Knife Lake and Duck Pond. Quartz porphyry dykes cut and therefore post-date the metagabbros.

The largest intrusion extends from Flace Lake to the South Showing, and appears to be a transgressive sill connecting with a smaller sill within the South Showing iron formation unit. The intrusion at Henry Lake appears also to be essentially subconcordant. The quartz porphyry north of the Kitts adit appears to intrude the Hopedale Complex, though the actual contact was not seen, and it is separated from the North Showing zone by the Nakit Slide with which it has a gradational schistose contact. Two minor dykes of quartz porphyry cut the Kitts Metagabbro and the Main Zone; one attains a maximum thickness of c. 55 m. Other dykes of similar size intrude the Hopedale Complex east of the South Showing.

A sill up to 50 m. thick occurs in the Inda Lake iron formation zone at Knife Lake. This sill is attenuated to the southwest by the Nakit Slide. Minor dykes up to 6 m. thick intrude the Inda Metagabbro and occur on its contact with the mafic volcanics. North of the Inda Lake iron formation member many irregular bifurcating dykes or sills intrude the mafic volcanics.

The major concordant horizon of quartz porphyry that occurs between the conglomerate and banded tuff formations from Nash Lake to Gear Lake is lithologically similar to the definite intrusive phases, but because there is some evidence for an extrusive origin it has been described above with the rhyolite formation.

(i) Lithology

The quartz porphyry is a homogeneous white weathering pale grey or buff rock composed of phenocrysts of quartz, plagioclase and microcline averaging 3 - 5 mm. in diameter, set in a fine-grained quartzo-feldspathic groundmass that includes minor biotite and muscovite. The feldspar phenocrysts are subhedral and although some quartz phenocrysts show corroded bipyramidal forms they are usually ovoid (Fig. 87). While quartz phenocrysts are usually most abundant, the feldspars are locally dominant. The biotite in places occurs in aggregates 1 - 3 mm. in diameter that are inferred to represent brokendown primary hornblende or pyroxene phenocrysts. Staining indicates that K-feldspar is dominant in the groundmass. Amoeboidal garnet porphyroblasts up to 3 mm. in diameter occur northeast of Kidney Pond and have been noted in the sill at the South Showing (Fig. 88).

(ii) Fabric

Tectonite fabrics are zonally developed; for example the bulk of the largest intrusion is only weakly foliated and often appears undeformed. Strongly developed tectonite fabrics generally only occur adjacent to the major tectonic slides.

The earliest tectonite fabric seen is correlated with S_2 in the adjacent iron formation members. No evidence for S_1 is preserved as porphyroblastic minerals are rarely developed in the intrusion. North of the Kitts adit S_2 is a penetrative L-S schistosity developed within 1 - 3 m. of the contact with the Nakit Slide. It is defined by oriented biotite flakes and stretched phenocrysts, and away from the contact occurs in schistose zones 5 - 20 cms. wide and as a weak more pervasive tectonite fabric. S_2 occurs as a local L-S fabric in the sill in the South Showing Zone, and as an intense L-S fabric in the Knife Lake Sill.

S_3 is developed in rusty schistose zones up to 3 m. wide in the quartz porphyry northeast of Kidney Pond (see Fig. 142); near the contact with the mafic volcanics S_3 is axial planar to folds in S_2, but further northeast the schist zones develop into slides that dextrally offset minor S_2 zones and the Hopedale Complex-quartz porphyry contact. Towards the Limestone Lake Slide S_3 becomes a more pervasive L-S to L-biassed fabric, and S_2 on the Nakit Slide contact is transposed into S_3. In the Fiace Lake, South Showing and Henry Lake intrusions S_3 is a locally developed weak penetrative L-S fabric. However S_3 becomes locally intense within 70 m. of the Limestone Lake Slide on the shore of Fiace Lake, and intense inhomogeneous development of S_3 within 6 m. of the slide gives rise to a banding and lamination, and the quartz porphyry passes into a banded psammitic rock. S_3 is only locally developed in the intrusions of the Inda Lake area. No tectonite fabrics post-dating S_3 have been seen.

(iii) Metamorphic history

Metamorphic events are summarised in Table VIII.

There is no surviving textural evidence to indicate whether any mineral growth related to MS_1 and MP_1 took place. MS_2 gave rise to growth of oriented biotite and muscovite flakes, recrystallisation of the quartz and to a lesser extent feldspar phenocrysts to subgrains, and recrystallisation of the groundmass to a dimensionally oriented quartz-feldspar fabric. MP_2 effects cannot be assessed with certainty because of widespread MP_3 overprinting, but where

S_2 only is developed MP effects were weak with only minor polygonisation of the quartz and feldspar mosaics and recrystallisation of pyrite.

MS_3 mineral growth was basically similar to the MS_2 growth, but was more intense giving rise to coarser mica, quartz and feldspar fabrics. Everywhere the amount of flattening was not great (Fig. 87). MS_3 recrystallisation of pyrite led to a minor migration of pyrite into S-planes in the S_3 schist zones. MP_3 annealing of quartz and feldspar to give subpolygonal mosaics was widespread, and was accompanied in places by growth of randomly orientated muscovite flakes. Locally very rapid growth of MP_3 garnet occurred, encroaching along grain boundaries and engulfing many quartz and feldspar grains (Fig. 88). Some late MP_3 overgrowths free of inclusions were formed on the early skeletal crystals.

ORIGIN OF THE PREKINEMATIC INTRUSIVE ROCKS

The association of metagabbro sills with the mafic volcanics in the Kitts and Inda Lake areas suggests that they represent co-magmatic intrusions related to the mafic volcanics.

The quartz porphyry dykes in the mafic volcanics are lithologically identical to porphyry clasts in the stratigraphically overlying conglomerate formation, to parts of the rhyolite formation, and to clasts in rhyolitic breccias in the banded tuff formation northeast of Fiace Lake. This close relationship suggests that the dykes were related to the acid volcanism, though there is no evidence to indicate that any were actual feeders. The latter possibility exists in the case of the major transgressive sill at Fiace Lake which is spatially associated with rhyolitic breccias and minor quartz porphyry bodies in the adjacent banded tuffs, but the relationship is obscured by tectonic slides and lack of outcrop.

SYNKINEMATIC INTRUSIVE ROCKS

GRANODIORITE

Concordant bodies of granodiorite occur in the metasedimentary formation within about 70 m. of the contact with Refoliated Gneiss Zone from the shore of Kaipokok Bay to west of Fiace Lake. They have not been observed further south. They are up to 7 m. thick and appear discontinuous, suggesting that the bodies form a string of boudins. It is shown below that these bodies pre-date D_2, and it appears probable that intrusion was related to D_1 or early D_2 movements by analogy with abundant early pegmatite bodies associated with the Refoliated Gneiss Zone - Aillik Group contact (see. Fig. 119).

(i) Lithology and fabric

The granodiorite is fine grained, averaging 0.5 mm. in grain size, but on polished surfaces a pale mottling indicates relic coarser grains about 1.5 mm. in diameter. The mineral composition varies from calcic oligoclase (55%), quartz (35%) and biotite (10%) to sodic andesine (55%), quartz (35%), biotite and hornblende (10% mafics).

Intrusion of the granodiorite pre-dates D_2 as it is cut by early pegmatite veins that have been isoclinally folded by D_2. These folds are cut by later pegmatite veins that have been moderately to isoclinally folded and boudinaged by D_3 with an associated penetrative L-S to L tectonite fabric, S_3, that has completely overprinted S_2.

(ii) Metamorphic history

Although field evidence indicates that metamorphic mineral growth related to D_2 must have occurred, no textural evidence of this survives, and the present assemblage is related to MS_3 growth. MS_3 gave rise to growth of biotite and hornblende with a preferred orientation and to recrystallisation of quartz and plagioclase forming grains having a weak preferred dimensional orientation parallel to S_3. Minor MP_3 annealing occurred.

Local mortar texture along grain boundaries affecting the quartz, biotite and plagioclase occurs near the shore of Kaipokok Bay and is believed to be related to D_4 cold working.

PITRE LAKE GRANITE

A concordant tabular body of leucocratic gneissic muscovite granite, 6 kms. long and 230 m. wide, occurs in the metasedimentary formation north of the Kitts Prospect. It has sharp intrusive contacts gradational over 1 - 10 mm., and granite and pegmatite offshoots occur locally within 5 m. of the contact. These offshoots truncate bedding and F_2 folds in the metasediments. The granite is cut by S_3 and its contact is locally folded by F_3 folds; the timing of the intrusion was therefore post-D_2 and pre or syn-D_3.

(i) Lithology and fabric

The granite is composed of microcline (42%), andesine (An 34, 25%), quartz (25%), muscovite and minor biotite (8% micas). A faint gneissic structure on a 0.5 - 1 cm. scale is apparent in most outcrops and is defined by slight variations in biotite content. The banding, together with a local very weak subparallel mica fabric strikes at an angle to the general northeast trend of the intrusion, but within 1 to 10 m. of the contact it swings in a sinistral sense into S_3 in the metasediments. The banding thus appears to be parallel to a refracted S_3 fabric.

Locally the granite contains lenticular xenoliths of psammite and semipelitic schist identical to lithologies in the metasedimentary formation. These are up to 3 m. long and 1 m. thick, and are subconcordant with the banding. Minor assimilation of the xenoliths is shown by marginal granitic lenses interleaved with micaceous bands. Some wispy biotitic schlieren were also noted.

(ii) Origin and significance of the banding

In places tight folds are seen with axial planes parallel to the general strike of the banding and S_3. Locally early relic fold closures are folded round these folds. The gneissic fabric is thus an early relic feature, and it most closely resembles the nebulitic ghost banding in the Brumwater Granite.

In accounting for the present attitude of the gneissic banding relative to the contacts, two points must be considered. Firstly, in a tabular pluton formed by intrusion of a semicrystalline magma, flow fabrics would be aligned parallel to the contacts. Secondly, the present attitude of the banding cannot result from the deformation of a flow-oriented fabric after the pluton had solidified, as this would be associated with an intense tectonite fabric and not the very weak one that exists. It is therefore concluded that emplacement took place in the early stages of D_3, and homogeneous deformation of the still plastic semi-consolidated body reoriented an inherited gneissic structure into parallelism with a refracted S_3 fabric.

(iii) Metamorphic history

The only metamorphic mineral growth that can be distinguished was related to MS_3 which was associated with growth of weakly-oriented muscovite and biotite flakes. This is more clearly seen near the contacts where a weak dimensional preferred orientation of quartz is also developed.

MAFIC INTRUSIONS

The synkinematic mafic dykes described below appear to form a related suite, as they were all intruded in the same time interval.

(i) Metagabbro dykes

An arcuate swarm of syn-D_3 metagabbro dykes occurs in the Post Hill area. They vary from 0.5 to 20 m. in thickness and some can be traced continuously for a distance of about 600 m.; some irregular branching sheets occur in the metasediments north of Witch Lake. Differential erosion of the dykes has produced a prominent set of arcuate photolinears convex to the east. The swarm is concentrated west of the summit of Post Hill in the amphibolite where the dykes strike east-west, and from there they curve into the metasediments in the axial region of the Post Hill fold. A total swing of over 90° is thus involved, accompanied by a change from discordant relationships in the northwest to concordant relationships in the southeast. A related set of dykes strike northeast in the Migmatitic Quartz Monzonite from Witch Lake to west of Watts Lake and have been preferentially eroded to form linear bogs that define another set of photolinears. Other metagabbro bodies related to the main suite occur as concordant lenses or sheets in the Refoliated Gneiss Zone west of Witch Lake and on the north flank of Post Hill.

The dykes truncate S_2 and have been marginally foliated by D_3. Intrusion of the dyke swarm was related to D_3, and not to an interval between D_2 and D_3 because they have not actually been folded around the F_3 Post Hill fold, and they intrude the syn-D_3 Migmatitic-Quartz-Monzonite. Also southwest of Witch Lake they are seen intruded parallel to the axial planes of F_3 folds with S_3 affecting their margins. The structural significance of these relationships is discussed in Chapter VII.

(a) Lithology and fabric

The discordant dykes that cut the Refoliated Gneiss Zone and the Post Hill amphibolite are massive and where undeformed they show chilled margins (Fig. 8). The metagabbro is composed of plagioclase laths (oligoclase and andesine) and an aggregate of amphibole, biotite, epidote, quartz and chlorite pseudomorphing ophitic pyroxene. The grains size varies from 1 to 3 mm. depending on the dyke thickness. Some of the dykes are sparsely porphyritic (plagioclase phenocrysts) and one dyke was noted with a central finer grained phase containing scattered plagioclase phenocrysts up to 6 mm. long.

As the dykes curve into the axial zone of the Post Hill fold a penetrative foliation, S_3, develops ~~in marginal~~ zones a few cms. wide. Some evidence suggests that at least locally S_3 had a composite, two stage history in the border zones; a sill in the Refoliated Gneiss Zone north of Post Hill appears to have had an early tectonite fabric parallel to the contacts in zones 10 cms. wide along the contacts, that has been transposed into a more pervasive cross-cutting fabric.

The marginal zones of foliation become wider southward towards Witch Lake where they vary from 1 to 3 m. in width. The cores of all but the thin dykes remain undeformed and still retain relic ophitic texture, but the pyroxene is pseudomorphed by amphibole occurring in both large poikilitic crystals and fine grained aggregates (Fig. 90). Epidote and biotite which is prominent further northwest, occurs in minor amounts. The plagioclase laths remain essentially unaltered except for slight sericitisation and vary from andesine to labradorite in composition. Towards the margins of the dykes the plagioclase laths first develop sub-boundaries, and then recrystallise into lensoid aggregates which together with lensoid hornblende aggregates and minor biotite flakes define the foliation (Fig. 91). In this manner the relic ophitic texture is gradually lost, and nearer the contacts of the dykes recrystallisation of hornblende and subsidiary biotite occurs, and the mottling inherited from the original igneous texture is obliterated. A hornblende schist virtually identical to the hornblende schists in the mafic volcanics is the final product (Fig. 92). South of Witch Lake these affects become more intense, and even the cores of the dykes become foliated; the thinner dykes are made over completely to hornblende schist.

The dykes in the Migmatitic Quartz Monzonite are parallel to S_3 and show the same textural transformation from undeformed cores to foliated margins. A metagabbro dyke showing identical lithology and relationship to those described above occurs in Banded Tuff west of Nash Lake. It is about 6 m. wide and is parallel to S_3; the core is massive but the margins are strongly foliated over widths of about 40 cm. A 2 km. long metagabbro dyke that terminates against a fault north of Jacques Lake also appears to be related to the Post Hill suite. It is up to 30 m. in width and is locally porphyritic. Relic ophitic texture is still visible though S_3, to which the dyke is parallel, is well developed throughout.

In general the textural changes observed in passing from undeformed cores to foliated margins are similar to the stages in the Laxfordian metamorphism of dolerites in the Northwest Highlands of Scotland described by Sutton and Watson (1951). However their stage 1 in which pyroxene is still present is not observed, and the secondary amphibole is not associated with significant amounts of quartz as in the Laxfordian examples.

(ii) Plagioclase Porphyry

The Plagioclase Porphyry is essentially a metadiabase crowded with plagioclase phenocrysts. It occurs in three elongate bodies concordant to, and associated with the contacts of the Long Island Gneiss. The best defined of these bodies, occurring southeast of Turnip Lake, is up to 110 m. thick and over 3 km. long. South of Turnip Lake a contact is exposed, and Long Island Gneiss is seen to intrude the Plagioclase Porphyry (Fig. 93). To the west the body terminates bluntly within the Long Island Gneiss, and to the east is truncated by the Quartz Monzonite. The contact with the Hopedale Complex and Hornblende Schist unit may originally have been intrusive but has probably been modified by the continuation of the fault extending from Anderson Lake.

The larger body further south is very poorly exposed and its contacts cannot be closely defined. Only one contact is exposed, that with the Quartz Monzonite at a locality near the west end of the intrusion where the Plagioclase Porphyry appears to pre-date the Quartz Monzonite. Two lenses of Refoliated Gneiss are included in the intrusion near the eastern end of its mapped extent. The Plagioclase Porphyry has sharp apparently intrusive contacts with the Refoliated Gneiss which appears to occur in large rafts.

The contacts of the relatively small body that occurs about 2 km. northeast of Penguin Lake are not exposed. Although it is about 60 m. thick it terminates sharply on the east and west suggesting intrusive truncation by the Long Island Gneiss.

The age of intrusion of the Plagioclase Porphyry is indicated to be post-D_2 by the inclusion of Refoliated Gneiss in the southernmost unit, and by the apparent intrusive cross-cutting relationship of the tabular body south of Turnip Lake to S_2 in the Hopedale Complex and hornblende schist unit. A pre- or syn-D_3 age is indicated by the development of D_3 in the Plagioclase Porphyry.

(a) Lithology and fabric

The Plagioclase Porphyry is composed of randomly oriented euhedral saussuritised plagioclase phenocrysts up to 2.5 cm. long, though averaging 1 cm. in length, set in a fine grained dark grey groundmass of hornblende, oligoclase and locally biotite, with accessory sphene, epidote, ilmenite and apatite (Fig. 94).

A few scattered irregular hornblende aggregates 5 mm. in diameter also occur; these probably represent altered pyroxene phenocrysts. The phenocrysts and groundmass are usually in approximately equal proportions, but parts of the intrusions are non-porphyritic and consist of fine-grained amphibolite identical petrographically to the groundmass of the porphyry and containing scattered hornblende blebs 3 - 8 mm. in diameter.

A penetrative L-S fabric correlated directly with S_3 is locally developed. Where S_3 occurs the plagioclase phenocrysts become aligned in S_3, and biotite retrogressed to chlorite is a prominent constituent of the groundmass. No evidence for any earlier or later tectonic fabrics was seen.

(iii) Minor metadiabase bodies

A sparsely porphyritic metadiabase (amphibolitic) body occurs on the contact between the Long Island Gneiss and the outlier of banded tuffs 1.5 kms. northeast of Gear Lake (Fig. 95). Its contact with the Long Island Gneiss is highly irregular with intertonguing of the two lithologies (Fig. 96) and it is impossible to judge which is the later intrusive; both show the same tectonic fabric, S_3. Other minor bodies occur in the Long Island Gneiss close by, and show similar contact relationships (Fig. 95). It appears from the map pattern and from the contact relationships that the diabase was intruded first followed shortly afterwards by the Long Island Gneiss along the same general plane of weakness before the diabase was solidified and brittle.

Other highly irregular metadiabase dykes occur in the Long Island Gneiss on the northwest shore of Marks Bight. Some are over 40 m. long and 5 m. thick and branch irregularly. They have been folded by D_3 and contain S_3, a hornblende biotite fabric, but in places show relics of an earlier tectonite fabric. The dykes appear to represent early intrusions into the Long Island Gneiss that were possibly synchronous with its emplacement. Similar metadiabase dykes occur on a small scale in the Hopedale Complex to the west, close to the contact with the major Post Hill Slide zone; these dykes are cut by only one penetrative hornblende fabric.

The metadiabase bodies above cannot directly be shown to post-date D_2, but they are regarded as syntectonic intrusions because of an apparent genetic relationship with the Long Island Gneiss.

(iv) Metamorphic history of the mafic dykes

Metamorphic mineral growth in the mafic intrusives was related to D_3, and shows essentially the same pattern in all three groups (Table IX). MS_3 gave rise to growth of hornblende and biotite in a preferred orientation, and to partial or complete breakdown and recrystallisation of the plagioclase crystals and phenocrysts to fine grained aggregates. MP_3 affects were weak with minor annealing of the plagioclase mosaics. The saussuritisation of the plagioclase and chloritisation of the biotite in the Plagioclase Porphyry appears to be a late MP_3 effect.

Alteration of the primary pyroxene in the metagabbro dykes of the Post Hill area appears to have taken place in three stages during

D_3. The initial alteration was to a fine-grained aggregate of amphibole. This aggregate appears to have been subsequently recrystallised to form the larger poikilitic crystals; biotite growth was probably related to both of these stages. On some dyke margins these events were probably represented by growth of amphiboles and biotite in a preferred orientation to define an early D_3 tectonite fabric. The early growth stages were overprinted by growth of oriented subidiomorphic amphiboles and biotite that define the main S_3 fabric in the foliated margins. This event was associated with the recrystallisation of the plagioclase to a fine-grained aggregate.

MP_3 effects gave rise to annealing of the plagioclase aggregates to form subpolygonal grains. Minor mimetic growth of hornblende in the schistose parts may also have occurred. Chloritisation of amphibole and biotite is locally prominent in the northwest and may have been a late MP_3 event.

LONG ISLAND GNEISS

The Long Island Gneiss (Gandhi et al., 1969) is a medium grained homogeneous grey quartz monzonite. It occurs on the east side of the Kitts-Post Hill belt in a series of intrusions that extend from Marks Bight to Jacques Lake. These intrusions are separated from one another by later intrusive rocks and appear originally to have formed one continuous body concordant with the regional strike. Although the Long Island Gneiss is not a gneiss, the name is retained in this account as it is established in the literature.

The Long Island Gneiss intrudes the Aillik Group and Hopedale Complex northeast of Inda Lake; southwest of Inda Lake the Monzonite intervenes along this contact. A chilled margin 1 cm. wide is developed against the Aillik Group and Hopedale Complex, the contact with which is very sharp (Fig. 97). The Kitts Pond wedge of Hopedale Complex is gradually cut out by the contact to the north, and on Long Island, the type locality, Long Island Gneiss intrudes the continuation of the Post Hill Slide, marked by the amphibolite unit that occurs on the west contact of the Metasedimentary formation. A tongue of Long Island Gneiss intrudes the Hopedale Complex southwest of Swell Lake. As noted above, the Long Island Gneiss also intrudes the Plagioclase Porphyry.

The contacts with the Porphyryitic Microgranite and Monzonite are also sharply defined but with no observed chilling of the Long Island Gneiss, and evidence described below indicates that the Long Island Gneiss is the oldest of these three intrusives. The contact with the Porphyritic Microgranite is knife sharp, and is generally regular with little interdigitisation and no brecciation. The contact with the Monzonite is exposed at a locality 1.5 km. southwest of Watts Lake where it is gradational over about 15 cm.

A sill of Long Island Gneiss occurs in the banded tuffs at Watts

Lake, and is bounded on the southeast by the Watts Lake Slide. A minor tabular body associated with quartz monzonite and a metagabbro dyke north of Jacques Lake; its eastern contact with Refoliated Gneiss is not exposed, but there is no indication of strong deformation in the Long Island Gneiss close to the Refoliated Gneiss, and an intrusive contact is inferred.

The Long Island Gneiss is inferred to post-date D_2, because its contact truncates and is chilled against a D_2 tectonic slide separating Banded Tuffs from the Hopedale Complex in a critical area about 1.5 km. northeast of Gear Lake (Fig. 95). Widespread development of S_3 in the Long Island Gneiss indicates that it was intruded pre- or syn-D_3.

(i) Lithology and fabric

The lithology of the Long Island Gneiss is very uniform throughout the entire area. It is composed of euhedral to subhedral partly saussuritised andesine-albite phenocrysts 4 mm. in diameter partly mantled by microcline, and hornblende-biotite eyes 3 - 5 mm. in diameter in a groundmass (0.1 mm. grain size) of plagioclase, microcline, quartz, hornblende and biotite (Figs. 98 and 99). Sphene, ilmenite, epidote and apatite are accessory constituents. The phenocrysts and mafic eyes give the rock a mottled appearance in outcrop (Fig. 100). Total content of plagioclase is approximately 40%, of microcline 30% and of quartz, about 15%. Biotite and hornblende are present in approximately equal proportions and together total

15-20% of the rock.

The Long Island Gneiss is characterised by the ubiquitous presence of scattered subangular xenoliths composed of fine-grained grey amphibolite or medium grained dioritic rock. The xenoliths are lensoid and average 12 cm. in length. though they range from 2 cm. to 1 m. in size; their long axes are aligned subparallel to S_3. Their elongate shape is partly primary and not all related to tectonic flattening as in many cases the long axes lie at an angle to S_3 (Fig. 101). The xenoliths are generally sharply defined, but some of the dioritic types are partly absorbed and ghost-like relics are seen.

A single weak to moderate penetrative fabric, S_3, is developed in the Long Island Gneiss. It is defined by elongation of the hornblende-biotite eyes, and by a weak preferred orientation of hornblende and biotite in the groundmass. In some areas S_3 is not developed in many outcrops.

PORPHXRITIC MICROGRANITE

Two separate bodies of microgranite, one in the Penguin Lake area and one west of Anderson Lake, occur essentially within the Long Island Gneiss and are not in contact with the Aillik Group or Hopedale Complex except where faulted. Contacts with the Long Island Gneiss are knife sharp and although no marginal chilling of the microgranite was observed, other evidence indicates that it intrudes the Long Island Gneiss. Xenoliths of Long Island Gneiss occur in the tongue of microgranite that nearly bisects the block of Long Island Gneiss west of Swell Lake. About 450 m. north of the east end of this tongue, a single xenolith of Long Island Gneiss was observed in the microgranite 3 m. from the contact (Fig. 102a) and due west of Swell Lake the contact of the microgranite truncates a pegmatite dyke in the Long Island Gneiss (Fig. 102b). Minor dykes of microgranite were noted in the Long Island Gneiss west of Swell Lake. Little evidence for the relative ages is seen in the body west of Anderson Lake, but due south of Watts Lake, where the contact is locally irregular a xenolith of Long Island Gneiss was observed in the microgranite.

Since the Porphyritic Microgranite intrudes the Long Island Gneiss and is also cut by S_3 it is inferred to be of post D_2 and pre- or syn-D_3 age.

(i) Lithology and fabric

The microgranite is leucocratic and though commonly it contains subhedral plagioclase phenocrysts 2 - 4 mm. in diameter (Fig. 103), in places it is even-grained and nonporphyritic (Fig. 104). It is pale pink-grey when fresh and weathers to a pinkish-white colour. The overall composition is dominantly that of an adamellite, but it is locally granitic where phenocrysts are absent. The phenocrysts are zoned, with oligoclase (An 28) cores and albite rims, and where the rock is non-porphyritic a few scattered microcline phenocrysts occur. The groundmass is 0.1 - 0.2 mm. in grain size and consists of xenomorphic grains of microcline, plagioclase and quartz, with biotite only present in accessory amounts (5%).

The microgranite is generally massive though it often shows a very faint laminar fabric on weathered surfaces, and in places a faint banding is developed; these are thought to represent primary flow structures. Due north of Swell Lake a faint banding on a 2 - 4 cm. scale weathers out, and trends oblique to the intrusive contact with the Long Island Gneiss; it is scarcely visible on fresh surfaces and appears to be due to subtle variations in proportions of quartz and mafics. A well defined streaky laminar gneissic structure that augens around phenocrysts occurs locally due east of Penguin Lake, and is defined by concentrations of mafics and by thin quartz stringers (1 - 2 mm. wide). The structure is believed to have been produced by flow of contaminated intrusive material, as in the tongue of microgranite in the Long Island Gneiss partially assimilated xenoliths and schlieren of Long Island Gneiss are flattened and stretched resulting in a similar crude layering. A good banding on a 1 - 3 cm. scale is locally developed in a 50 m. wide zone along the contact with the Long Island Gneiss southeast of Watts Lake; the zone appears to extend for only 300 m. along the strike, and is thought to have been formed by flow of marginally contaminated intrusive rock.

One penetrative tectonite fabric correlated with S_3 is irregularly developed in the microgranite and is generally observed to be coincident with the banding interpreted as flow structure. S_3 varies from a very weak, almost imperceptible fabric to a strong L-S foliation with stretched phenocrysts defining the linear element.

MONZONITE

The Monzonite occurs in a subconcordant tabular body of variable thickness (30 - 900 m.) that extends from Jacques Lake to Swell Lake, with breaks in exposure east of Watts Lake. Two lesser bodies also tabular in form occur, one about 1 km. south of Turnip Lake, and one adjacent to the metagabbro dyke north of Jacques Lake.

The contacts between the Monzonite and its country rocks are only exposed at three localities. Sharp intrusive contacts with banded tuffs were observed at two points (1 km. southwest of Watts Lake and 1 km. east of Watts Lake); minor chilling of the Monzonite to medium grain size occurs at the contacts, but apart from local epidotisation no alteration or contact metamorphism of the banded tuffs was observed. The Monzonite has a gradational contact zone 15 cms. wide with Long Island Gneiss at a point 1.5 km. southwest of Watts Lake, and the relative ages of the two intrusives are not apparent there. However rare xenoliths of Long Island Gneiss up to 1 m. long occur in the Monzonite west of Swell Lake, and the map pattern clearly shows that the Monzonite post-dates the other intrusive rocks in the area. Since it is also locally cut by S_3^*, the time of emplacement is inferred to have been post D_2 and pre- or syn-D_3.

(i) Lithology and fabric

The Monzonite (Fig. 105) is a coarse grained leucocratic rock with an average mode of plagioclase (40%), microcline (30%), quartz (10%) and hornblende, biotite and accessories (15%). However there is a variation from leucodiorite to quartz monzonite composition, and west of Swell Lake the rock is locally granitic. The plagioclase forms euhedral prisms that are mantled by the K-feldspar, and the mafic minerals occur in aggregates 5 mm. in diameter. In outcrop the monzonite appears massive, uniform and devoid of primary structures.

A weak to moderate penetrative L-S to L-biassed tectonite fabric correlated with S_3 is developed west of Swell Lake. It is of variable intensity, and is defined by flattened and stretched biotite and hornblende aggregates. Further southwest the Monzonite is mostly unfoliated except for local weak development of S_3. Local sharply defined foliation zones up to 3 m. wide occur west of Jacques Lake, and are believed to be related to D_5.

There is a very striking lithological resemblance between the Monzonite and the homogeneous phase of the Migmatitic Quartz Monzonite in the Witch Lake area. The significance of this is discussed below.

METAMORPHIC HISTORY OF THE LONG ISLAND GNEISS, PORPHYRITIC MICROGRANITE AND MONZONITE

These three intrusions all show identical mineral growth histories that were essentially related to MS_3; MP_3 effects were of minor importance, and no other constructive metamorphic mineral growth occurred (Table IX). Where the rocks were not significantly strained by D_3, growth of hornblende and biotite in randomly oriented crystals occurred, and only minor adjustments of quartz and feldspar grain boundaries appear to have taken place. The zoning of the plagioclase phenocrysts is probably a primary igneous feature. Where D_3 straining occurred hornblende and biotite grew in a preferred orientation that defines S_3, and breakdown and regrowth of quartz and the feldspars took place to a degree dependent on the amount of total strain.

Minor MP_3 annealing of quartz and feldspar aggregates to sub-polygonal mosaics took place. As in the Plagioclase Porphyry the saussuritisation of plagioclase and chloritisation of biotite appears to be a late MP_3 event.

PEGMATITES AND PEGMATITIC GRANITE

At least three generations of pegmatites that post-date the deposition of the Aillik Group are locally abundant in the area. They vary from granodioritic to granitic in composition, depending on the dominant feldspar of the host rock, and they contain accessory biotite and muscovite; graphic texture is only rarely developed. They are ubiquitous in the metasedimentary formation from the Nash Lake area northeastwards, and are most abundant west of Duck Pond.

Gently buckled microcline-plagioclase-quartz pegmatites with accessory biotite (3 cm. books) and magnetite crystals (1 cm. in diameter) occur in the Long Island Gneiss (Fig. 100) but are generally not common. Some of these pre-date intrusion of the Porphyritic Microgranite (Fig. 102) but on the ridge east of Penguin Lake locally abundant pegmatites post-date both the Long Island Gneiss, and the Porphyritic Microgranite, but are folded by F_3.

At the east end of Inda Lake, muscovite, granite and pegmatite dykes up to 40 m. thick occur in the conglomerate, Long Island Gneiss and Porphyritic Microgranite. They strike northeast and coalesce to form a body of pegmatitic granite, in which small northeast-trending slivers of country rock are preserved. Locally a crude fabric parallel to S_3 in the country rocks is seen.

ORIGIN OF THE SYNKINEMATIC INTRUSIVE ROCKS

The Long Island Gneiss, Porphyritic Microgranite and Monzonite are spatially related and were intruded sequentially in the same time interval during the Hudsonian orogenic cycle. They also show close compositional and petrographical similarities; these three intrusive rocks are therefore regarded as forming a three-phase hypabyssal complex of which the Long Island Gneiss is the earliest and dominant phase. Subordinate mafic intrusions, Plagioclase Porphyry and minor metadiabase bodies, appear to have been intruded immediately preceding emplacement of the hypabyssal suite. The metagabbro dykes in the Post Hill area are allied to these mafic intrusions.

The abundant and characteristic xenoliths in the Long Island Gneiss can be accounted for by inferring intrusion first of the mafic phase, followed immediately by intrusion of the granodioritic phase through the same channelways. Mafic xenoliths could thus have been plucked continuously from the walls of these channelways.

Evidence described above indicates that intrusion of the complex occurred post-D_2 and pre- or syn-D_3. The regional concordance and lack of structural complications of the three main phases, best illustrated by the Monzonite, suggest that the intrusion was syn-D_3. It is therefore apparent that intrusion into the Aillik Group of an igneous suite of overall granodioritic composition coincided with migmatisation and production of granodioritic partial melts in the Hopedale Complex below the Refoliated Gneiss Zone. This suggests that partial melts derived from anatexis of the basement were mobilised during D_3 and intruded into the cover rocks.

Support for this hypothesis comes from the gneissic character of the Pitre Lake Granite. It has been argued that the gneissic structure is an inherited feature that was present at the time of emplacement, and it closely resembles the relic banding in the Brumwater Granite. The Pitre Lake Granite is therefore interpreted as an anatectised portion of the basement, and it shows that at least some basement material has been mobilised into the cover rocks. A further connecting link is provided by the lithological similarity of the Monzonite and the homogeneous portion of the Migmatitic Quartz Monzonite.

POSTKINEMATIC INTRUSIVE ROCKS

NET-VEINED DIORITE

Net-veined diorite occurs in abundant sheets usually 1 - 3 m. thick that dip gently westwards. They are responsible for most of the irregular photo linears that are transverse to the main structural trend in the area. In many places they are flat lying and form an interconnected network that crops out in a complicated pattern, as around Kidney Pond north of the Kitts Prospect (Plate 3). Many dykes have vertical offshoots that trend in a northeasterly direction.

The dykes have sharp, planar chilled contacts that truncate all structural elements in the area, with the possible exception of the late northeast trending fault zones, their relationship to which was not seen. In places lithological contacts in the country rocks are displaced by up to 12 m. across dykes, e.g., 170 m. north of Kidney Pond, without slickensiding or cataclasis indicating that relative movement occurred at the time of intrusion.

(i) Lithology

The diorite is medium grained and mesocratic, composed of 65% plagioclase (andesine–oligoclase), 20% hornblende, 10% biotite and 5% accessories (quartz, epidote, sphene, opaques and carbonate). Some of the dykes are homogeneous, but many show a regular faint banding on a 2 - 6 cm. scale parallel to the contacts; this is interpreted as flow layering (Fig. 106). In addition the median portion of many dykes contains a ramifying network of more leucocratic diorite veins that break the diorite up into polygonal blocks which in the absence of leucocratic material could be fitted together like a jig-saw puzzle (Fig. 106). The leucocratic material is petrographically identical to the diorite in the blocks but contains a smaller proportion of mafics. The contacts of the two phases are well defined, but in places diffuse irregular blocks that do not obviously fit together have gradational contacts.

(ii) Origin of the net-veining

Several explanations have been advanced in the past to account for net veins of acidic material in basic dykes. These include (i) fluidised emplacement of the granite veins (Reynolds, 1954); (ii) simultaneous intrusion of basic parent magma and acidic residual magma (Wells, 1954); (iii) formation of contraction cracks by rapid cooling, followed by penetration of the granitic material along contraction cracks and planar shear fractures (Windley, 1965).

The net-veined diorite dykes in the Kitts Post Hill area differ from the examples discussed by the above authors in having a smaller proportion of leucocratic material, and a simpler relationship of the leucocratic material to the diorite. In view of this, and also the slight compositional difference between the two phases it does not appear necessary to invoke a two magma or metasomatic mechanism. The agmatitic aspect of the net-veined portions suggests dilation. Field evidence shows that relative movement of the walls of the dykes occurred before ultimate solidification of the magma and it is suggested that associated dilation of partly crystallised magma mush in the central portions of the dykes took place with residual liquid collecting in the fractures.

A composite diorite-granodiorite body 1 km. long and with an exposed width of 50 m. crops out on the shore of Kaipokik Bay 2 km north of Kitts Brook where it has intruded the metasedimentary formation; the contact is sharp and it post-dates all structures in the country rock. It includes an early coarse dioritic phase (1 cm. grain size) containing diffuse pegmatitic patches that trend in a north northeast direction; this phase has been intruded by leucocratic biotite adamellite, and intrusion breccias involving xenoliths of both country rock and diorite are developed along the margin of the body (Fig. 107). Field relationships indicate that the adamellite intruded the diorite before complete crystallisation of the latter had taken place, and thereis some net veining of the diorite in both the main body and large xenoliths.

The composite intrusion may be related to the diorite dykes though exact equivalence in age cannot be shown. Thus although the net veined structure of the dykes does not itself appear to require near-synchronous emplacement of two magmas, the relationships shown by the composite body suggest that this mechanism may indeed have played a part.

FELSITE

Pink aphanitic felsite occurs in rare irregular dykes from 10 cm. to 10 m. in thickness. They cut and therefore post date the net-veined diorite dykes. The felsite consists of euhedral phenocrysts of K-feldspar and saussuritised plagioclase 0.5 mm. in diameter, with scattered green biotite aggregates that pseudomorph prismatic amphibole crystals up to 1 mm. long, in a microcrystalline quartzo-feldspathic groundmass of cherty aspect. Fine granules of sphene, epidote and haematite are disseminated throughout the groundmass.

CHAPTER VI

MAJOR TECTONIC SLIDES

Introduction

Because tectonic slides (ductile faults) form in close connection with folding and metamorphism, they are not associated with obvious brecciation or cataclasis (Fleuty, 1964a). They may be marked by a zone of characteristic lithology and fabric ("slide facies"), e.g., the Iltay slide on the Moine-Dalradian boundary in Scotland (Rast, 1958), but in many places slide planes are not attended by distinctive lithological or textural features, e.g., the Sgurr Beag slide in the Moinian rocks of Scotland (Tanner, 1971). The recognition of a tectonic slide therefore depends upon a knowledge of the stratigraphy of an area, and upon the demonstration of transgressive and cross-cutting relationships. Both of these criteria have been applied in the Kitts-Post Hill area and as a result, many of the major lithological boundaries are classified as slides (Plate 5). The lithologies alone of these zones would not warrant their recognition as slides, but generally they exhibit significant lithologic and textural characteristics that distinguish them from the map units they bound or transect. In this chapter, the nature of the slide zones is discussed, and their lithologies are described where appropriate. However, in some cases, certain map units and contacts interpreted as slides here have already been described in Chapters III and IV where lack of lithological distinctiveness and association with other map units of essentially structural origin, e.g., the Refoliated Gneiss Zone, have made this treatment more logical.

Although associated with great thinning and excision of map units, some of the slide zones do not fall within Fleuty's (1964b) definition of the term in that they cannot be shown to be related to the formation of major folds. However, ~~the nature of~~ the variation of strain across some of the zones (described in Chapter VII) suggests that they ~~lie~~ in the axial regions of major shear zones (Ramsay and Graham, 1970) and can thus be related to folding of a special type.

D_1-D_2 TECTONIC SLIDES

POST HILL SLIDE

This contact zone was the locus of intense D_1 and D_2 deformation that gave rise to structural convergence between basement and cover, with refoliation of the contiguous Hopedale Complex and thinning of the basal amphibolitic formation of the Aillik Group. The latter effect was of extremely variable intensity along strike, as shown by the attenuation of the Post Hill amphibolite from 1000 m. on Post Hill to 30 m. northwards from Watts Lake. The gradational contact between the amphibolite and Refoliated Gneiss (Figs. 46 and 47) has been described in Chapter IV, and it is apparent that the interleaving of gneiss and amphibolite cannot have been produced by interfolding however intense. Translational movements on a plexus of braided planes are believed to have resulted in tectonic interslicing of amphibolite and gneiss (Fig. 108).

It is therefore inferred that the gradational boundary between the basement and cover is a tectonic slide, and the quartzitic mylonite unit is interpreted as a related slide within the gneiss. Northwards from Watts Lake the Post Hill amphibolite is almost completely excised and a tectonic schist containing quartz lenticles (Chapter III) is developed in the metasedimentary formation on the contact with the hornblende schist unit; this indicates that here the slide zone includes all of the Post Hill amphibolite.

FIACE LAKE SLIDE

This slide forms the contact between the metasedimentary formation and the Kitts-Nash Lake belt of mafic volcanics, and locally it brings the banded tuffs in contact with the metasediments north of Fiace Lake. It can be traced from the Limestone Lake area to the west limb of the Watts Lake fold where it is truncated by the Watts Lake Slide. From the Nash Lake area northward it is marked by a persistent unit of hornblende schist averaging 7 m. in thickness that represents the 950 m. thick pillow lavas forming the Kitts pillow lava formation. In the Nash Lake area, the hornblende schist unit joins the Kitts-Nash Lake belt, and the zone of hornblende schist related to the slide broadens southwestwards.

The hornblende schist is lithologically identical to the other hornblende schist units in the area derived from mafic lavas, and has been described in Chapter III. Its contact with the metasedimentary formation is sharp, and interbanding of the two lithologies has only been noted in the hinge zone of the Watts Lake fold; there the interbanding is on a 0.2 - 3 cm. scale, and the contact is gradational over 3 m. The metasediments on the contact likewise show no unusual lithological features. The conglomerate has developed a fine mylonitic type banding and lamination in a zone up to 5 m. wide on the contact with the hornblende schist unit, and also where the conglomerate is locally in direct contact with the metasediments, e.g., southwest of Kiwi Lake. In the latter case, the contact is gradational over 10 - 20 cms, and the gradational zone is greenish tinged due to the presence of hornblende. The relationship of the Kitts volcanics to the metasedimentary formation suggests that the Flace Lake Slide follows an original stratigraphic contact between the metasediments and the volcanics; for example, even where the hornblende schist is absent from the slide, the greenish tinge of the slide zone suggests that it was formerly present.

In the southwest, there is no evidence that any tectonite fabrics related to D_1 were ever developed in the slide zone, and the penetrative fabric in the hornblende schist is correlated with S_2. Northwards this fabric is transposed into S_3 which in turn is seen to post-date the mylonitic banding in the conglomerate. The Fiace Lake Slide is therefore of D_1 or D_2 age.

NAKIT SLIDE

The Nakit Slide extends from west of Nash Lake to the Kitts area, and its name is derived from a fusion of these two terms. It terminates against the Limestone Lake Slide and the Watts Lake Slide in the north and the south respectively. The Nakit Slide forms the southeastern and lower contact of the Kitts pillow lava formation, but appears to slightly transgress stratigraphic boundaries viz. the iron formation members. The lithology of the slide zone depends on the rock type that is juxtaposed against the volcanics, and on this basis two sectors, the northern and southern, are distinguished in which the Hopedale Complex and the banded tuff formation respectively abut against the mafic volcanics. Fabric relationships in the slide zone that indicate a D_1 and D_2 age are clearly defined with respect to S_3 near the north and south extremities, but are not clear in the central portion due to poor exposure and the zonal development of sub-parallel S_2 and S_3 tectonic fabrics.

<u>(a) Northern sector</u>

In this sector, the slide zone varies from 1 - 4 m. in width, and is only exposed near Kidney Pond and in Three Mile Brook. Near Kidney Pond the slide forms the contact between the North Showing zone and the Quartz Porphyry; the North Showing zone is strongly schistose, and the quartz porphyry is also schistose in a zone 1 - 3 m. wide along the actual contact which is gradational over 1 - 30 cm. The penetrative fabric in this area is correlated with S_2, and evidence for MP_1 mineral growth in the North Showing zone close to the contact with the quartz porphyry suggests that S_2 has overprinted an S_1 fabric. An S_3 strain-slip cleavage overprints S_2 due north of Kidney Pond.

In the Three Mile Brook area, the slide consists of a western zone of schistose mafic volcanics 5 - 10 m. wide and an eastern zone of strongly foliated gneiss 10 m. wide in which relic gneissic banding is parallel to the slide; these two zones are separated by a median band of tremolite-actinolite rock 40 cms. wide. The dominant fabric is S_2, but the tremolite-actinolite rock shows an unoriented MP_2 fabric of radiating acicular crystals overprinted by a weak S_3 defined by oriented amphibole. The slide is obscured at Henry Lake by a granite that shows an intrusive contact with schistose mafic volcanics; the granite is believed to be related in origin to the Brumwater Granite.

(b) Southern sector

Where the Nakit Slide forms the contact between the banded tuff formation and the mafic volcanics, the slide zone consists of 4 - 8 m. thick unit of amphibolite and pink or grey psammite (often calcareous) interbanded on a 0.1 - 2 cm. scale (Fig. 109). Lithologically, there is little to distinguish this sector of the slide zone from a sedimentary transition between the two formations. However, a major tectonic break is indicated by overall stratigraphic relationships, by presence of the sliver of basement on the contact north of Inda Lake, and by the cross-cutting relationship to the Inda Lake iron formation member and metagabbro.

The Inda Metagabbro becomes schistose towards the slide zone, and southwestwards it passes into a brown weathering, banded amphibole-garnet schist at Knife Lake. This rock is composed of tremolite-actinolite, orange-brown garnet (melanite?), muscovite, quartz, epidote and dumortierite. Northeast of Knife Lake, the schistose metagabbro is a more typical hornblende-plagioclase schist. The penetrative fabric in this area is S_2, and it is axial planar to tight folds in the banding in the slide zone; this banding is interpreted as a D_1 structure. S_3 is in the form of widely spaced (1 - 2 cm.) sinuous biotitic folia.

The sliver of basement northeast of Inda Lake is only exposed in two strippings. It consists of strongly foliated and crushed granodioritic gneiss, composed of sodic andesine (An 32) quartz, hornblende and diopside with accessory magnetite, ilmenite and sphene.

The original coarse plagioclase crystals have been strained, kinked and partly recrystallised to fine-grained aggregates around which hornblende and diopside (in a preferred orientation) form augen. Relic pegmatite bodies up to 1 m. thick are represented by fine-grained quartzofeldspathic rock containing sparse mafic streaks. There is evidence for two intense deformations in the sliver of basement; streaks of hornblende and diopside representing an early fabric are folded by the penetrative fabric, and early tight folds in the pegmatite have been refolded. It appears that these events represent D_1 and D_2 respectively, since S_3 is weakly developed in the Inda Lake area.

The slide zone near Nash Lake includes lenses of a banded dark grey hornblende-diopside-epidote-biotite-microcline rock with fine grained disseminated uranium minerals. The uranium minerals are commonly included within the hornblende, and are surrounded by brown pleochroic haloes; the mineral(s) could not be identified. The banding is believed to represent S_1 and the hornblende and diopside occur in weakly oriented prisms that define a faint fabric, S_2, that is occasionally observed axial planar to tight folds in the banding. S_3 is a penetrative biotite fabric that is axial planar to folds in the banding and S_2. Adjacent banded tuffs show isoclinal F_2 folds and late D_2 small scale slides (Figs. 121 and 122).

(c) The Anderson splay

This slide is not exposed except where it forms the contact between the outlier of banded tuffs and the Hopedale Complex 1.5 km. northeast of Gear Lake (Fig. 95). The contact is marked by a band of hornblende schist up to 25 m. thick that shows a platy laminar fabric; the adjacent banded tuffs have an intensely deformed appearance in outcrop (Fig. 110) and in thin section show a strong, fine hornblende fabric parallel to bedding. In places, the amphibolite is a pale green colour due to local abundance of diopside. The laminar fabric in the amphibolite is a composite S_1/S_2 fabric, and it is truncated by the contacts of the Long Island Gneiss and minor porphyritic diabase bodies (Fig. 95). S_3 is a crenulation or strain-slip cleavage in the amphibolite, and is the penetrative fabric in the post-D_2 intrusive rocks.

In the Hopedale Complex, S_2 is developed in a zone up to 130 m. wide parallel to the slide, and takes the form of small scale dextral shear zones that offset the approximately east-west banding in the gneiss. Amphibolitic material has been mobilized into the shear zones from amphibolite bands in the gneiss (Fig. 111). The granodioritic bands in the gneiss are composed of a fine-grained mosaic of quartz and albite, with the outlines of original coarse grains picked out by wisps of tremolite-actinolite. The amphibolitic material consists of a fine-grained felted aggregate of tremolite-actinolite with patches of diopsite and epidote, and minor biotite interleaved with dumortierite. The tremolite-actinolite appears to replace, and therefore post-date the diopside.

WITCH LAKE SLIDE

This slide represents the culmination of D_1-D_2 structural attenuation and is essentially a merger of the Post Hill Slide and the Fiace Lake Slide, rather than a separate structural entity. The merger takes place in the Watts Lake fold, and to the southwest the three lower formations of the Aillik Group form a structurally condensed sequence only 60 to 115 m. in thickness. The slide appears to be responsible for the absence of the conglomerate formation, and locally the rhyolite formation, in the area west of the Watts Lake Slide. The Witch Lake Slide was rejuvenated in the third deformation following initiation of the Post Hill fold.

(a) Description

The hornblende schist units of the slide zone are described in Chapter III as they show no distinguishing lithological features. The unit representing the Post Hill amphibolite is the most persistent one though it thins to only a few meters in places, whereas the unit correlated with the Kitts volcanics lenses out northwest of Watts Lake. The median unit of psammite and pelite equivalent to the metasedimentary formation differs from the normal lithology of that formation in that bedding is on a finer scale (0.1 - 2 cm.), is more regular, and the grain size is finer. In addition, bands of compact very fine-grained semipelite with an extremely fine regular phyllitic schistosity occur. Lenses of calcite 1 mm. long, and thin quartz stringers 2 - 10 mm. long concordant with the dominant foliation are common. Lenticles of grey quartz up to 4 cm. long and 8 cm. thick are common in a zone 3 m. thick close to the contact with the hornblende schist unit west of the Watts Lake fold, and show boudinaged intrafolial folds. Tourmaline is also common close to this contact, both as an accessory mineral and as a major component of some lenses. Contacts between the metasedimentary unit and the hornblende schist units are of the gradational interbanded type, characterized by fine laminations and extremely tight isoclinally refolded isoclinal folds.

The contact of the Witch Lake Slide zone with the rhyolite and banded tuff formations was not seen but appears to be sharp; these formations are intensely foliated within 5 m. of the inferred position of the contact. On the west, the slide is in contact with the Migmatitic Quartz Monzonite for much of its length, but a section of the Refoliated Gneiss Zone is preserved in the north. Here, the contact with the refoliated gneiss is generally gradational and interbanded, but in places is marked by a zone of coarse muscovite schist (Fig. 112) up to 6 m. thick that grades westwards into the normal refoliated gneiss lithology; other zones of identical schist occur within this section of refoliated gneiss which also includes bands of hornblende schist that appear to represent infolded or tectonically intersliced remnants of the slide zone. The refoliated gneiss in this area is characterized by complex minor structures produced by tight F_3 refolding of F_2 folds and D_2 pegmatite boudins.

The syn-D_3 Migmatitic Quartz Monzonite post-dates the formation of the main D_1-D_2 elements of the Witch Lake Slide, but the slide was rejuvenated during the third deformation and was responsible for extreme attentuation of the east limb of the Post Hill fold southwest of Witch Lake. In the north, the contact of the Migmatitic Quartz Monzonite with the refoliated gneiss west of the slide shows no sign of intense foliation, but 2 km. to the south where in direct contact with the slide zone, the Quartz Monzonite becomes intensely foliated and passes over about 30 cm. into a thinly banded fine-grained mylonitic rock up to 2 m. thick in gradational contact with the hornblende schist unit (Fig. 82). Marginal mylonitisation becomes more intense in the Witch Lake area, and southwest of Witch Lake strongly foliated Quartz Monzonite passes into a structurally complex mylonite zone in which products derived from the Migmatitic Quartz Monzonite, metasedimentary and rhyolite formations cannot be distinguished. The mylonite is petrographically simple rock composed of fine-grained quartz, feldspar and biotite with accessory sphene, epidote and orthite and has been described in Chapter IV.

(b) Fabric

The interbanding of hornblende schist with refoliated gneiss and metasediment is believed to have been produced by D_1, and the bands are therefore regarded as S_1 planes. S_2 is locally preserved in the hinge zone of a fold in hornblende schist about 1.3 km. northeast of Watts Lake, where it is a penetrative laminar L-S schistosity defined by hornblende. Elsewhere, S_2 is transposed into S_3 and is only preserved in MP_2 plagioclase porphyroblasts in the hornblende schist units (Fig. 23). S_3 is the dominant penetrative fabric in the slide zone, and in the metasedimentary unit it has totally overprinted S_2. In the mylonitic contact zone of the Migmatitic Quartz Monzonite, S_3 shows a two-stage history described in Chapter IV. S_4 is a strain-slip cleavage locally developed west of Watts Lake, and S_5 is a crenulation or kink-band style cleavage widely developed southwest of Witch Lake.

D_3 TECTONIC SLIDES

LIMESTONE LAKE SLIDE

The Limestone Lake Slide can be traced from the west shore of

Long Island to Fiace Lake and is partly a rejuvenation of D_1-D_2 slides. It is divided into two sectors that differ in their structural histories: (1) a northern sector with a prior D_1-D_2 history that forms the boundary between the metasedimentary formation and the Hopedale Complex north of Kidney Pond, and (ii) a southern sector with a D_3 history only that forms the west boundary of the Kitts pillow lava formation from Fiace Lake to Kidney Pond. In the northern sector, the slide zone is marked by a hornblende schist unit 4 - 25 m. thick that represents the structurally attentuated Kitts pillow lava formation. At Kidney Pond, this hornblende schist unit bifurcates, marking the point of division of the slide into the two sectors. The east branch swings into the Nakit Slide and merges with the stratigraphically lower portion of the Kitts pillow lava formation, while the west branch merges along strike with a 'slice' of pillow lavas. The slice of pillow lavas sharply truncates the Kitts Metagabbro and the South Showing zone, and lenses out at Kiwi Lake. South of Kiwi Lake, the Limestone Lake Slide forms the contact between the Kitts volcanics and conglomerate (in the north), and banded tuff (in the south). The slide appears to die out in quartz porphyry south of Fiace Lake.

At Kitts Brook, a thin wedge of banded tuffs intervenes between the hornblende schist unit and the metasedimentary formation; the contact between the banded tuffs and the metasediments is interpreted as a splay of the Limestone Lake Slide.

(a) Northern sector

The hornblende schist unit as noted in Chapter III is characterized by a composite S_2/S_3 fabric and by the presence of epidotic lenses and boudins (Fig. 113). The Nakit Slide swings into the Limestone Lake Slide with no visible truncation in the Kidney Pond area, and S_2 becomes crenulated and then transposed into S_3. The northern sector therefore appears to be a rejuvenated part of Nakit Slide, and also of the Fiace Lake Slide.

East contact

The contact between the hornblende schist unit and the Hopedale Complex is only exposed in the shore section in the north of the area. Here the banding in the gneiss is transposed from the general northwesterly strike into parallelism with the slide zone; the transposition takes place gradually over about 300 m. with a dextral sense of movement, and the gneiss within 2 m. of the hornblende schist unit is transformed into a streaky rock with dark hornblende-biotite-epidote-bearing lenticles (Figure 114). Only one mineral growth phase defining S_3 is preserved in the gneiss. However, contact relationships of minor irregular porphyritic diabase dykes indicate that the refoliation and transposition was related to both D_2 and D_3; some 7 m. from the a mylonitic aspect suggesting very intense deformation and drawn out isoclinal folds occur. S_3 is the earliest tectonite fabric preserved and is a weak preferred orientation of actinolite or hornblende parallel to bedding. S_4 is a weak preferred dimensional orientation of quartz and feldspar grains, but is more strongly developed in the calcareous horizons.

The splay of the Limestone Lake Slide that forms the west contact of the banded tuffs from Kitts Brook southwards is exposed in the Limestone Lake area (Plate 3). Here, it is sharply defined and is generally marked by a thin (10 - 30 cm.) zone of actinolite-biotite schist that west of Limestone Lake, is up to 6 m. thick; tourmaline is locally prominent in the slide-zone (Fig. 116). The dominant fabric in the schist is S_3, a laminar transpositional type L-S fabric defined by the actinolite and biotite. S_2 is frequently preserved in crenulations between S_3 folia, and is also preserved in the hinge zones of folds in tourmaline-rich laminae (Fig. 116). The junction with the Fiace Lake Slide is not exposed. Further south where the slide swings into the conglomerate, the slide zone is composed of very finely laminated quartz-feldspar-epidote mylonite (Fig. 117) at least 3 m. thick. The mylonitic laminations represent S_3, and no earlier tectonite fabric is preserved in the adjacent conglomerate. This sector is therefore of D_3 age only.

slide their contacts sharply cross-cut strongly shredded gneissic banding and clearly post-date some of the refoliation. The dykes show only one penetrative fabric, S_3, and nearer the contact with the hornblende schist the irregularities in the contacts are smoothed out as S_3 increases in intensity.

West contact

The west contact is thought to represent a rejuvenation of the Fiace Lake Slide. The contact of the hornblende schist unit with the metasedimentary formation, and with the banded tuffs south of Kitts Brook is not exposed, but it appears to be sharp. However, the west contact of the unit is exposed in the shore section to the north, where a minor splay of the slide, and a warp in the hornblende schist unit accommodates a wedge of banded tuffs in sharp contact with the unit. The splay bounding the banded tuffs on the west consists of 20 m. of thinly banded and laminated actinolite-biotite-sillimanite schist; the lamination is a composite S_2-S_3 fabric, and the sillimanite tends to be concentrated on microscopic D_3 slide zones (Fig. 115). The banded tuffs, of which a 20 m. thickness is exposed, include minor fluorite-bearing marble bands up to 20 cm. thick, and many beds are slightly calcareous. They consist of the microcline-plagioclase-quartz-hornblende or actinolite-epidote assemblage typical of the banded tuffs throughout the area. The bedding in places has

(b) Southern sector

The laminar transpositional-type S_3 fabric in hornblende schist unit dies out immediately south of bifurcation at Kidney Pond and the unit passes into a fine-grained amphibolite showing moderately flattened pillows and a weak penetrative fabric, S_3 (Plate 3). The west contact of the pillow lava 'slice' may represent an original stratigraphic boundary as it is conformable with lenses of meta-chert in the pillow lavas and with the conglomerate-banded tuff contact. But localized intense deformation with an S_3 schistosity along the contact suggests modification of the contact by tectonic sliding, and to the north and south the contact merges with the Limestone Lake Slide.

The east contact of the pillow lava 'slice' represents the main plane of the Limestone Lake Slide, and is marked by a schistose zone 2 - 4 m. thick. S_3 in the pillows intensifies within 2 - 3 m. of the slide zone, the west margin of which is a hornblende schist in which there is evidence of only the one tectonite fabric, S_3. The lithology of the median and eastern portions of the slide varies according to the lithologies that the slide truncates on the east. North of Limestone Lake, the median portion of the slide consists of a lensoid unit 1 m. thick of semipelitic biotite-garnet-graphite schist identical to the metasediments in the South Showing zone; the east margin is an actinolite-zoisite schist (with S_3) that grades into coarse massive metagabbro. The metasediments show a dominant S_3 schistosity and in places an early transpositional S_2 fabric is preserved. They contain composite MP_2-MS_3-MP_3 garnet porphyroblasts as well as separately nucleated MP_3 garnet crystals.

Both margins of the slide zone are composed of hornblende schist south of Limestone Lake where the slide forms the contact between identical pillow lavas. However, the median portion of the slide zone consists of a dark epidote-actinolite psammite with irregular lenticular banding on a 2 - 10 mm. scale. The rock is lithologically identical to intensely deformed conglomerate that occurs in the slide to the south where the slice of pillow lavas lenses out and the slide forms the contact between conglomerate and the Kitts volcanics. The conglomerate grades into the banded rock as deformation flattens clasts into lenses and, nearer the slide, into intensely drawn out form producing the lenticular banding. MP_3 recrystallisation has been strong in the intensely deformed conglomerate with growth of epidote and actinolite, but S_3 survives as a preferred orientation of fine flakes of chlorite after biotite.

The Limestone Lake Slide is poorly exposed between Kiwi Lake and Flace Lake, but appears to be essentially the same in character as the section between Kiwi Lake and Limestone Lake. An intense penetrative S_3 fabric is developed in outcrops of the pillow lavas close to the inferred position of the slide. Intense inhomogeneous development of S_3 in quartz porphyry at Fiace Lake has given rise to a tectonic banding on a 0.2 - 2 cm. scale within 5 m. of the slide, and in the slide zone exposed at the lake shore the porphyry is transformed into a fine-grained psammitic rock of which a 4 m. thickness is exposed.

(c) Minor related slides

Two minor D_3 slides that are related to the transposition of the Nakit Slide into the Limestone Lake Slide occur in Quartz Porphyry northeast of Kidney Pond (Plate 3). They offset the Quartz Porphyry-Hopedale Complex contact in a dextral sense, and the slide plane of the larger one is occupied by a syn-D_3 metagabbro dyke in which S_3 is a penetrative fabric. The other slide zone is occupied by schistose quartz porphyry 1 - 2 m. thick in which the schistosity is S_3.

The South Showing zone has been locally thinned by four minor D_3 slides subparallel to S_3 that offset the northeast contact of the iron formation zone in a dextral sense. The slide zones which are poorly exposed appear to be narrow (1 m.), and show a penetrative S_3 biotite-muscovite fabric that overprints S_2. No trace of their continuation was observed in the Kitts Metagabbro or in the pillow lavas.

WATTS LAKE SLIDE

The Watts Lake Slide truncates the east limb and axial plane of the Watts Lake fold, and takes the place of an antiform complementary to this fold. The rhyolite-banded tuff formation contact is repeated northeast of Watts Lake, and southwest of Watts Lake the slide appears stratigraphically concordant and forms the boundary between the Long Island Gneiss and banded tuff formation.

The slide is not exposed in the north where it cuts the Refoliated Gneiss Zone. Elsewhere, although the actual slide plane was not observed, at several points northeast of Watts Lake, a gap in outcrop of only 0.7 m. separates hornblende schist on the west from intensely deformed banded tuffs on the east. S_2 in the hornblende schist unit swings into parallelism with the slide within about 10 m. of the plane, in a dextral sense. An intense streaky mylonitic-type laminar fabric is developed in the banded tuffs approximately 5 - 10 m. of the slide; this fabric, S_3, is defined chiefly by concentrations of ilmenite and sphene granules, and stringers of fine quartz grains, and a similar fabric is developed in the sliver of rhyolite northeast of Watts Lake.

A moderate penetrative S_3 in the Long Island Gneiss at Watts Lake becomes very intense 120 m. from the slide. The transition from moderately to intensely deformed rock takes place over about 10 m. and within this zone intensely flattened xenoliths are still visible

(Fig. 118), but closer to the slide the Long Island Gneiss is transformed to a fine-grained pinkish rock with an intense regular streaky laminar S_3 fabric parallel to the slide plane. The laminar aspect of S_3 is due to extreme flattening of phenocrysts and xenoliths. The Long Island Gneiss sill thins southwest of Watts Lake and is represented solely by the intensely deformed zone approximately 90 m. thick.

Rejuvenation of Witch Lake Slide

Although this slide is principally a D_1-D_2 structure it was rejuventated during D_3, causing transposition of S_2 into S_3, and mylonitisation of the Migmatitic Quartz Monzonite. The D_3 effects are most intense southwest of Witch Lake.

CHAPTER VII

HUDSONIAN OROGENY

Introduction

A sequence of deformational events has been identified in the area using the concepts referred to in Chapter I. These events fall naturally into two fundamental divisions: those that pre-date and those that post-date deposition of the Aillik Group. The events that pre-date the Aillik Group naturally only could affect the Hopedale Complex, and together with the radiometric and sedimentological data, serve to demonstrate that this complex formed a sialic basement to the Aillik Group (Chapter II). The pre-Aillik Group events are believed to be of Archean age, and the post-Aillik Group events are referred to the Hudsonian orogeny (Ghandi et al., 1969; see also discussion in Chapter IX).

Structural interpretation is hindered by lack of stratigraphic 'tops' in the Aillik Group. Nevertheless, it is evident from the pattern of map units that large scale folds of conventional form do not appear to be important in the structural framework of the area. Rather, it is this same pattern that shows clearly the dominating influence of major tectonic slides which in turn reflect and are subordinate to the nature of the basement-cover boundary zone. It is thus the interaction between basement and cover that determined and controlled the structural evolution of the area during the Hudsonian Orogeny.

Structural data are not presented stereographically in this account because the culminative Hudsonian event (D_3) gave rise to a pronounced structural grain, so that structural elements can be readily appreciated from the map.

Deformation of the Aillik Group and Hopedale Complex took place in a sequence of five events, D_1 to D_5. Effects of the first two events, D_1 and D_2, were essentially restricted to the basement-cover contact zone that developed as a major zone of transposition and tectonic thinning. D_1 and D_2 deformation in the Aillik Group was restricted to the upper and lower contacts of certain formations, and to certain incompetent horizons (iron formation members); these discrete zones of deformation are recognised as tectonic slides. Major related fold closures are tentatively interpreted, and it is also inferred that wedges of the Hopedale Complex were introduced into the Aillik Group along D_1-D_2 tectonic slides. It appears that D_1 and D_2 were composite and related events that reflect essentially horizontal translation of the Aillik Group over the Hopedale Complex.

The third deformation, D_3, was the culminative event. It is developed on a regional scale, though the most intense effects are seen in the basement-cover boundary zone. Metamorphic conditions were in the middle amphibolite facies. The overall D_3 structural style is dominated by subvertical tectonic slides that replace the limbs of major folds. The associated penetrative tectonite fabric is subvertical and shows a zonal variation in intensity; locally it is absent and parts of the Aillik Group remain totally undeformed. Migmatisation and anatexis of the Hopedale Complex was associated with, and controlled by, the third deformation. Synchronous intrusion of an acid igneous suite into the Aillik Group occurred. The inter-relationship of S_3, the D_3 tectonic slides and syn-D_3 mafic dykes indicates that the third deformation was controlled by major-shear-zone style strain regimes.

The later deformations, D_4 and D_5, were minor events that were associated with constructive metamorphic mineral growth. D_4 is represented by a strain-slip cleavage, and D_5 by kink bands.

THE FIRST DEFORMATION - D_1

(i) Minor structures

(a) Tectonic intercalations

The interbanding of amphibolite and gneiss in the Post Hill Slide and of amphibolite and psammite in the Nakit Slide is of structural origin (Figs. 46, 47 and 109) and has been described in Chapter VI.

(b) Tension gashes

The pegmatite bodies that occur in a string adjacent to the Post Hill Slide in the Refoliated Gneiss Zone from the Nash Lake area northeastwards are interpreted as occupying D_1 tension gashes, by virtue of their unique position relative to the Slide zone (Fig. 119). The quartz lenticles and veins that occur in the metasedimentary formation along the contact with the Post Hill Slide and that are also locally abundant in the Witch Lake Slide are likewise interpreted as being of D_1 tensional origin.

(c) Folds

No folds that can be unambiguously related to D_1 were found but in the envelope of the Post Hill Fold where overprinting by D_3 is weak, tight pre-S_2 folds in the Refoliated Gneiss Zone occur in places (Fig. 41). These folds may represent F_1 Hudsonian folds, or could be inherited structures belonging to the pre-Aillik Group structural events in the Hopedale Complex.

(ii) Fabric

The fine flaggy banding in the Refoliated Gneiss Zone (Figs. 38 and 176) represents relic Hopedale Complex gneissic banding that was tranposed into parallelism with the basement-cover boundary during the first deformation. This is shown by parallelism of the banding with the intercalated amphibolite bands in the Post Hill Slide, and the fine banding is therefore regarded as a D_1 fabric element. In the Quartzitic-Mylonite unit, S_1 is the mylonitic colour banding; in the associated schist S_1 is locally preserved as a penetrative muscovite schistosity between the S_2 planes, and also as an included muscovite fabric in MP_1 plagioclase porphyroblasts (Fig. 48). Locally within the Post Hill Slide, S_1 occurs as an included hornblende fabric in MP_1 plagioclase porphyroblasts.

In the Aillik Group S_1 only appears to have developed in the iron formation members, in which it is preserved as an included fabric of minute opaque particles in MP_1 garnet and hornblende porphyroblasts (Figs. 15, 16 and 17).

The nature of S_1, as referred to the L-S fabric system cannot be assessed from the few relics that have survived transposition into S_2.

(iii) Major structures

The Post Hill, Witch Lake, Fiace Lake and Nakit Slides are the only major structures related to the first deformation that are recognised in the area. They are considered further in the description of D_2 as they appear to have evolved as composite D_1-D_2 structures.

THE SECOND DEFORMATION - D_2

The effects of the second deformation, like the first, are restricted to the highly deformed basement-cover contact zone and to discrete stratabound tectonic slides in the Aillik Group. Deformation (including D_1 effects) within these zones was extremely intense and resulted in the flattening, transposition and recrystallisation of basement rocks to form the Reconstituted Gneiss Zone, and also in the tremendous thinning, excision and repetition of supracrustal strata associated with the tectonic slides.

The intimate association of D_1 and D_2 suggest that they may have represented two continuous phases in what may be regarded as a composite event, such as the D_1 event in the Caledonian of North Mayo, Ireland (Sutton, 1972). Nevertheless, because of the identification of separate mineral growth phases and the widespread folding of the D_1 tectonite fabric by D_2, their two separate labels are retained in this study.

(i) Minor structures

(a) Folds

Minor F_2 folds occur in the tectonic slide zones and the metasedimentary formation, i.e. units which are characterised by interbanded contrasting lithologies. The structurally homogeneous Post Hill amphibolite lacks F_2 folds, and they are rare in the Reconstructed Gneiss Zone. Tight F_2 folds are developed in the South Showing iron formation zone at Kitts.

F_2 minor folds are best seen in the Post Hill Slide where in most cases they are essentially unmodified by later deformations. Gneiss layers show intrafolial folds in the D_1 banding and the alternating gneiss and amphibolitic layers are tightly to isoclinally folded (Fig. 46). In the northeast-ward continuation of this slide to the Julies Harbour area these folds are refolded and their style obscured by tight F_3 structures: interference patterns are best seen in the envelope of the Watts Lake fold where the F_3 folding was not so intense (Fig. 120). Mesoscopic F_2 folds, best viewed from the air, are developed in the large pegmatite bodies adjacent to the Post Hill Slide (Fig. 119).

In the Nakit Slide tight F_2 folds refolded by F_3 in interbanded amphibolite and psammite (Fig. 109) and have also been observed in the adjacent banded tuffs at a locality near Nash Lake where they are isoclinal and gently plunging (Fig. 121). A small-scale late D_2 slide gently truncates the F_2 folds in the banded tuff and resembles a sedimentary wash-out (Fig. 122).

(b) Boudins

Ovoid boudins up to approximately 6 m. in diameter occur in the syn-D_1 pegmatite bodies and have been folded by F_3; they are interpreted as D_2 structures though some may have been formed in the late stages of D_1 (Fig. 120). Boudins of similar style occur in the banded tuffs at Limestone Lake. The boudins of coarse grained clinopyroxene in the iron formation members are also interpreted as D_2 structures. Diamond-shaped boudins of gneiss are produced by D_2 flattening in the Post Hill Slide (Fig. 8).

(ii) Tectonite fabric

S_2 forms the dominant penetrative fabric in the Post Hill area where subsequent recrystallisation associated with D_3 was minimal. It is an L-S tectonite defined in the Refoliated Gneiss Zone by biotite and lensed feldspar crystals and quartz aggregates, and in the Post Hill amphibolite by hornblende. In the metasediments on Post Hill S_2 is a fine penetrative biotite fabric that southward becomes overprinted by S_3.

To the east and northeast of Post Hill S_2 is largely transposed by S_3 but it is locally prominent in hornblende schist in the Watts Lake fold, in schistose zones in the Kitt's volcanics north of Nash Lake and in the iron formation members. In the metasedimentary formation it only survives as an included fabric in garnet and plagioclase crystals. However in the upper Aillik Group (conglomerate banded tuff, rhyolite formations) there is little evidence that S_2 was ever developed except in proximity to the tectonic slides (e.g., mylonitic banding in conglomerate against the slide northwest of Duck Pond).

(iii) Major structures

Stratabound tectonic slides initiated in D_1 and rejuvenated in D_2 form the principal element of the major D_2 structure. Only one major fold related to the second deformation has been mapped: the banded tuffs are inferred to occupy a major syncline west of Nash Lake on the basis of repetition of the rhyolite formation and limited 'tops' from cross-lamination. Although the axial trace of this fold cannot be accurately located, it appears to either strike into or merge with the Nakit Slide at Nash Lake, and it is therefore believed to be of D_1 or D_2 age. It is of pre-D_3 age as S_3 cut across the inferred axial trace of the fold. No minor structures or tectonite fabric related to the folding were observed.

THE THIRD DEFORMATION - D_3

The third deformation was the culminative structural event and its effects were imprinted throughout the entire area, though they were again most intense in the basement-cover contact zone. Pre-existing fabrics were transposed, though not always entirely re-crystallised, by D_3 which is responsible for the prevailing structural grain of the area. The post-Archean migmatisation in the Hopedale Complex gneisses was synchronous with, and to a large extent controlled by, the development of third phase structures.

(i) Minor folds

(a) Style and distribution

The style and distribution of F_3 minor folds reflects their relationship to (a) major D_3 structures, (b) the intensity of S_3, and (c) lithology of host rock. They are widely developed in a zone straddling the basement-cover boundary, principally in the Post Hill Fold and the Watts Lake Fold, and also in units where lithologies of contrasting ductility are interbanded - notably the metasedimentary formation and the major tectonic slides.

The F_3 folds in the metasedimentary formation northeast of Inda Brook are very tight and have an asymmetric Z style; because of the shallow plunges, the folds appear extremely attenuated in horizontal outcrop surfaces (Fig. 123). Southwest of Inda Brook, they are more prominent reflecting the influence of the Watts Lake Fold as a discordance between banding and S_3 develops.

F_3 minor folds in the Hopedale Complex vary from gentle warps to open and close folds, and in the Unlucky Head Migmatite lake, a variety of forms: diktyonitic kinks (Fig. 57), tight folds in the gneiss rafts and more open warps (Figs. 66 and 67).

In the zone of intense deformation along the basement-cover boundary zone the F_3 minor folds are very tight and generally show an assymetric Z style; because of the shallow plunges, the folds appear extremely attenuated in horizontal outcrop surfaces. In the Refoliated Gneiss Zone, small-scale tectonic slides in places replace part or all of one limb of the folds.

closely reflecting the style of the major fold structures described below. The geometry of the F_3 folds is often complex, indicating interference with F_2 folds (Fig. 124). The F_3 minor folds are most prominent within the sphere of influence of the Watts Lake fold (Fig. 120).

F_3 minor folds vary in style structurally up the axial plane of the Post Hill Fold. In the north gentle warps and open folds with wave lengths of up to 4 m. occur in the Refoliated Gneiss and Post Hill amphibolite. Southwards in the metasedimentary formation the folds gradually become tighter towards the Witch Lake Slide in which they are isoclinal southwest of Witch Lake.

East of the basement-cover boundary zone, F_3 minor folds are rare in the Aillik Group. The exceptions are the major tectonic slides and the iron formations.

Intrafolial folds are characteristic of the intensely deformed basement-cover boundary zone. They occur in lens-shaped pods of stacked folds around which the banding and S_3 forms smooth augen (Figs. 125 and 126). The amplitude of the folds thus decreases away from centre of each pod to zero at the ends (Fig. 127). Also the axial plane of each fold in the pod converges with and merges into the exterior fabric towards the margins of the pods. In some examples, an early fabric (S_1/S_2) can be seen folded around the fold hinges.

(b) Interference patterns

Superimposition of F_3 minor folds on F_2 minor structures are prominent in the Watts Lake fold and generally produce the type III interference patterns of Ramsay (1962) though locally type II is seen. Compression of D_2 pegmatite boudins in this area has produced some spectacular F_3 folds by squeezing of banded rock from between the boudins (Fig. 120). Northeast of Inda Brook, where the F_3 folds are very tight, pre-existing fold structures are very difficult to detect, but their presence can be inferred in places from the outcrop pattern of the F_3 folds (e.g., Fig. 124).

(ii) Tectonite fabric

S_3 is the most regionally pervasive tectonite fabric in the area; it is an L-S tectonite and is essentially sub-vertical with a regional ENE Trend. Although D_3 was the culminative structural event, S_3 is not uniformly developed and shows considerable variation in intensity and to some extent, trend. Nevertheless, these variations show an overall systematic relationship to the major D_3 tectonic slides: S_3 in many places intensifies and its strike gradually converges with that of the slides as the latter are approached. This is best illustrated in the area between Unlucky Head and Nash Lake, in the Post Hill area and northeast of Kitts Pond. The pattern of S_3 fabric development resembles that in shear zones described by Ramsay and Graham (1970), the significance of this is discussed later.

The nature and distribution of S_3 in each of the map units has been described above and is summarised briefly here. From the Hopedale Complex eastwards to the contact with the Aillik Group, S_3 shows a change from a barely recognisable or a weak preferred orientation of the biotite flakes to a moderately-developed penetrative biotite and lensed-quartz-grain fabric in the Brumwater Granite, to an intense penetrative fabric in the Refoliated Gneiss Zone. In the Aillik Group, S_3 is intense and penetrative in a zone up to 1 km. wide flanking the Refoliated Gneiss Zone. Eastwards, S_3 becomes markedly zonal in development, notably in the Kitts pillow lava formation and also in the conglomerate and rhyolite formations in the Turnip Lake area and northeastwards. Many outcrops show no tectonite fabric and primary features such as pillows and boulders show no indication of strain, even where neighbouring outcrops are intensely deformed.

S_3 is most homogeneously developed in the Long Island Gneiss, particularly in the Marks Bight area.

The linear element of the D_3 fabric is most apparent in amphibole-bearing lithologies in which it is defined by a preferred orientation of amphibole prisms. It is coincident with the axes of F_3 minor folds and has a consistant west south-west moderate plunge.

(iii) Major folds and tectonic slides

There are three major fold structures in the area; Post Hill Fold, the Watts Lake Fold and the Kitts Fold. Field relationships show these to be spatially and temporally related to major D_3 tectonic slides. This is most clearly demonstrated by the structure of the Post Hill Fold which will be described first. In each case, the tectonic slide partly (Post Hill, Watts Lake) or wholly (Kitts) replaces one limb of the fold.

(a) The Post Hill Synform

The Post Hill Synform is inferred from stratigraphic considerations discussed previously to be a synclinal structure. It folds D_1-D_2 fabric elements and plunges 50 - 60° southwards. S_3 is axial planar to the fold, and forms a cleavage fan between the summit of Post Hill and Watts Lake. The axial trace of the synform and the Witch Lake Slide merge together at the southwest end of Watts Lake. Tracing S_3 from north to south along the axial trace of the fold, it develops from a coarse crenulation or strain-slip cleavage (Post

Hill amphibolite) into a fine strain-slip cleavage and then phyllitic schistosity at Witch Lake.

The Post Hill gabbro dyke swarm clearly does not wholly pre-date D_3, and yet the dykes become progressively deformed towards the core of the fold. The dyke swarm was therefore intruded during the early stages of the folding; this is confirmed by relationships in the core of the Post Hill Fold where gabbro dykes are axial planar to F_3 folds (Fig. 128).

Intrusion of the Migmatitic Quartz Monzonite in which S_3 is zonally developed is also inferred to be a syntectonic event related to the folding. Truncation of S_2 at its contact indicates a post-D_2 age (Figs. 78 and 79) and it intrudes the east limb of the Post Hill Synform essentially parallel to the axial plane of the structure.

Interference of the Post Hill Fold with an element of D_2 structure is indicated by the wrong sense of vergence of S_3 to part of the west limb of the fold in the area immediately northeast of Three Rapids Base Camp. The rapid thinning of the Post Hill amphibolite in this area cannot be related to D_3 as there is no corresponding intensification of S_3, and it is inferred that a large scale D_2 pinch and swell structure has been folded by F_3. The postulated development of the Post Hill Fold is summarised in Fig. 129.

(b) Watts Lake Fold

The structure of this fold is complex as it appears to have been localised where major D_2 tectonic slides caused pinching out of the Kitts pillow lava formation. Relationships at the nose of the synform are clear: here the composite S_2 fabric and D_2 slides are folded around the hinge zone, S_3 is a strain-slip cleavage axial planar to the fold which plunges 40° southwest, and the east limb of the fold is truncated by the Watts Lake Slide which appears sub-parallel to S_3 and to the axial plane. The axial trace of the fold is obscured by heavy drift cover to the southwest, where it is inferred to be truncated by the Watts Lake Slide.

(c) The Kitts Fold

The D_3 Limestone Lake slide replaces a greater part of the fold than in the other major D_3 structures; the Kitts fold is essentially a semi-fold in which the Limestone Lake Slide replaces the west limb and half of the hinge zone. Unlike the Post Hill and Watts Lake Folds, the Kitts Fold is a sideways-facing structure with minor F_3 folds and L_3 intersections plunging subvertically or steeply to the northeast or southwest.

<u>(iv) Faulting</u>

The Quartz Monzonite is cut and displaced sinistrally by a prominent fault south of Nash Lake. The fault is exposed and is a zone of crushed, epidotised and quartz veined rock up to 70 m. thick that includes a slice of relatively fresh quartz monzonite. The fault zone is foliated by S_3 and as the fault plane is subparallel to this fabric it appears that the faulting may have been related to brittle failure during the third deformation. The Jacques Lake fault, which is represented by a shattered epidote and quartz veined zone, may represent the continuation of the Nash Lake Fault.

SYN-D_3 MIGMATISATION

Origin of the Unlucky Head Migmatite and Brumwater Granite

(i) Introduction

Opinion on the origin of migmatites in the past was strongly divided between those who maintained that migmatite formation was related to metasomatism especially through the addition of potassium, and the advocates of partial anatectic melting of the host rocks in situ; the whole problem has been reviewed by Mehnert (1968). More recently, experimental work in natural systems, for example, James and Hamilton (1969), Brown and Fyfe (1970), and Brown (1970), has provided sound physico-chemical data showing that partial melting can occur readily in the earth's crust. The formation of migmatites by anatexis is thus no longer hypothetical and opinion has tended to polarise towards this view. On the other hand migmatisation by metasomatism is still postulated where analytical data points to such an origin (e.g., Brown, 1971) but the real importance of diffusion in regional metamorphism is still not known (Pitcher and Flinn, 1965) and it is an open question as to whether metasomatism can form migmatites on a large scale.

(ii) Interpretation of field observations

Relationships in the Unlucky Head Migmatite show that the diktyonitic structure in the gneiss rafts represents the initial stage of the migmatisation, with formation of granitic neosome along the kink planes. That the migmatisation was a syntectonic event is indicated by the constant orientation of the diktyonitic structure, its consistent sinistral sense of movement, and the weak axial planar biotite fabric and associated co-axial planar folds. The axial planar fabric is clearly traceable through the migmatite and the Brumwater Granite into S_3 in the Aillik Group, demonstrating that the migmatisation took place during the third deformation. Also evidence described above shows that the Brumwater Granite is of post-D_2 age (Fig. 76).

The attitude, form and structure of the relic banding in the neosome relative to the banding in the gneiss rafts clearly shows that the neosome was mobile, and sharp agmatitic and intrusive relationships indicate that it was in a semi-magmatic state, probably that of a crystal mush. For these reasons the migmatisation is believed to have been an anatectic process. The biotite selvages of the amphibolite xenoliths appear to represent a hydration reaction and suggest that the partial melt, if not water saturated, had a considerable water content. Stages from partial to nearly complete melting appear to be represented by the schlieric neosome, the ghost banded neosome and the nebulitic granite respectively. Evidence of active mobilisation and expulsion of partial melts is seen in the sharp veins and dykes of granite cutting the larger gneiss enclaves. Intrusion of partial melt into the non-anatectic country rock is also indicated where non-diktyonitic gneiss rafts occur with sharp or agmatitic contacts against relatively homogeneous neosome.

Nevertheless, although ghost banding is often chaotic, its coherence and general parallelism with S_3, and the way it augens around gneiss rafts shows that the neosome behaved more of less homogeneously in response to D_3. This is also born out by the general east-west strike of the gneissic banding in the rafts which indicates that little rotation of the rafts has occurred, and they seem to preserve the pre-anatexis trend of the Hopedale Complex. King (1965) in a review of the evidence for metasomatic migmatisation argues that the apparent mobility of the leucocratic material can be ascribed to behaviour of a plastic solid rather than of a melt as there is a lack of evidence for turbulent flow. But turbulent flow cannot be expected of a confined partially melted body as the regular orientation of flow fabrics in many epizonal intrusives clearly shows. The relationship of the banding to S_3 is thus considered consistent with the neosome being in a state of crystal mush, but the D_3 stress field must have persisted until the neosome crystallised in order for the oriented biotite tectonite fabric to grow in the neosome.

King also suggests that metasomatic replacement takes place essentially without disturbing the geometry of the host rock, and cites fold closures outlined by relic banding in evenly granitised gneiss as evidence. However relationships in the neosome of the Unlucky Head Migmatite suggests that such evidence is ambiguous especially if only a part of the whole migmatite is viewed. Apparent relic structures in the ghost banding are seen in places (Fig. 71) but it can be inferred that the crystal mush retained a degree of coherency.

Partial melting <u>in situ</u> cannot change the bulk composition of a discrete part of a rock without some process of differentiation affecting a separation of melt from the residue. In the case of a hydrostatic stress field, surface tension effects and gravity may lead to separation but in syntectonic migmatisation filter-press action on a crystal mush appears to be a viable mechanism. The

Unlucky Head Migmatite grades with increasing homogenisation into the Leucocratic Brumwater Granite, but the more potassic composition of the latter shows that it cannot have formed by complete in situ anatexis of the Hopedale Complex. Rather its intrusive relationships against the Refoliated Gneiss Zone suggest that the Brumwater Granite formed by filter-press expulsion during D_3 of partial melt from the migmatite with accumulation at a higher structural level, and it is not necessary to invoke an unknown source of potassium. The outcrop pattern at the west end of Brumwater Lake mirrors the F_3 folds in the Refoliated Gneiss Zone, and the broader width of the granite outcrop here suggests that the partial melts were preferentially mobilised into the cores of these folds.

It is concluded therefore that the field evidence indicates that the Unlucky Head Migmatite and the Brumwater Granite have an anatectic origin.

(iii) Formative conditions of the Unlucky Head Migmatite

Experimental evidence shows that partial melts of granitic composition can be expected to form in the earth's crust in a variety of lithologies under a variety of hydrous and anhydrous P-T conditions. But it is also apparent that the role of volatile components in nature is one of the most important and least understood factors in this process. Melting processes have been considered as taking place in closed isochemical systems, and migmatisation has consequently been largely regarded as a function of temperature, a "thermal accident" in the earth's crust (Elder, 1968). Bailey (1970) suggests that this is implausible and that pressure variations within mobile zones will lead to migration of volatiles into zones of lower pressure. If anhydrous assemblages in the lower pressure zones are at P-T conditions in between the "wet" and "dry" melting ranges, partial or complete melting could result.

The Unlucky Head Migmatite appears to have been formed with adequate free water as indicated by the "hydrated" biotitic selvages of the amphibolite xenoliths. The mineral assemblages in the schlieren or "restite" portions and in the rafts points to moderate amphibolite facies conditions. Although there is a lack of critical index minerals in the migmatite, the presence of staurolite, andalusite and locally sillaminite in the Aillik Group west of the Kitts Prospect suggests temperatures around 500°C or above, and water pressures in the order of about 2.5 K bars. This indicates a geothermal gradient of approximately 60°/km and as the region of the Unlucky Head Migmatite is at present about 3 km. structurally below the cover rocks at the Kitts Prospect, temperatures in the former region could very possibly have been around 650°C.

(a) Source of volatiles

Evidence described above indicates that the partial melt in the Unlucky Head Migmatite was water saturated, but it was also noted that basement gneisses subjected to several cycles of deep seated deformation and metamorphism probably contain little if any free water. Dehydration of hydrous phases in deeper levels of the crust may have occurred during D_3, and the resultant water may have migrated to higher structural levels. However no evidence of dehydration reactions has been reported from the Hopedale Complex terrane west of Kaipokok Bay.

It appears likely that water could have been introduced through the pre-Aillik Group erosion surface along unloading joints and tension fractures. As subsequent burial proceeded apace with deposition of the cover rocks much of this water would have been expelled, but it is suggested that significant amounts may have been retained in alteration products (chloritised biotite, scapolite veinlets, etc.). This captive groundwater would readily have come available with onset of moderate grades of metamorphism. Minute fluid inclusions reported to be nearly ubiquitous in metamorphic and igneous rocks (e.g., Roedder, 1958) are another possible source of volatiles. Voll (in Pitcher, 1965) has noted that large numbers of liquid inclusions in strained quartz grains are absent from recrystallised new grains and have presumably diffused along grain boundaries. It is apparent that such included volatiles, which under static conditions would remain immobile and passive, can be released by deformation to interphase boundaries. Many minute ovoid inclusions are visible under high power in the quartz and feldspar of the gneisses, but it is not certain that they consist of fluid, and their quantitative significance is also unknown.

(b) Influence of D_3 and conclusions

Both the small scale features and the map pattern indicate that D_3 exerted a controlling influence on the migmatisation. It is suggested that this was primarily as a result of mobilisation and concentration of volatiles into favourable structural zones. Water under the prevailing metamorphic conditions would have been highly mobile tenuous fluid that would have moved along dislocations generated by D_3 in a direction controlled by the strain energy of the rock (Spry, 1969; Flinn, 1965). Strain energy is due to the elastic strain component of the deformation, and would have been greatest in the diktyonitic kink planes and zones of folding, causing a concentration of volatiles and hence partial melting in these zones. Ptygmatic-like folds related to diktyonitic structure in places indicates very inhomogeneous behaviour of the same bands of gneiss in different parts of a raft (Fig. 57), and suggest that the rock was weakened close to the kink planes by an intergranular film of partial melt or fluid.

Another possibility to be considered is the effect of such localised zones of high strain energy in a rock with homogeneous volatile distribution at P/T conditions close to those necessary for partial melting (i.e., disregarding movement of volatiles). The release of strain energy may have raised the temperature to the minimum for partial melting, but it appears likely that any temperature rise by this means would have been small since D_3 was relatively mild in the Unlucky Head Region. The melting capacity of the strain energy would have been very limited, and readily absorbed by the rock bordering the diktyonitic zones.

Thus although there are some ambiguities in interpreting the relationship, D_3 appears to have controlled the migmatisation by mobilising and concentrating volatile components, thereby endowing a portion of the Hopedale Complex with a significant melting capacity at relatively moderate temperatures.

(iv) Origin of the Migmatitic Quartz Monzonite.

As noted above the intrusion post-dates D_2 and was synchronous with D_3. It resembles the Brumwater Granite only in the general character of its xenoliths, and a basically similar origin is suspected. Its intrusive relationships show that it achieved a higher degree of mobility in response to D_3, and may therefore have been formed before the Brumwater Granite. The overall composition and compositional inhomogeneities contrast with the Brumwater Granite, and it appears that early migmatisation produced melts of granitic composition. This sequence is common in migmatitic terranes and has been cited as evidence against anatectic origin of migmatites by King (1965), because experimental anatexis show a directly opposite sequence; melting commences with a granitic fraction and proceeds towards a granodioritic composition. But there is no reason why partial melting should not take place in different levels of the crust at different times during a single orogenic event. Melting would be expected to occur first at deeper levels in response to rising isotherms, and the greater pressures and probable dry conditions there would be expected from the experimental data to yield melts of intermediate composition. The lithology of the Migmatitic Quartz Monzonite is comparable with such an origin and its compositional variations can be accounted for by local variations in host rock composition and available volatiles.

THE FOURTH DEFORMATION - D_4

The fourth deformation is not developed regionally and did not produce any large-scale modification of the earlier structures. D_4 minor structures are largely restricted to the metasedimentary formation and adjacent tectonic slides from the area of the Watts Lake Fold northeastwards.

S_4 is a weak to strong crenulation cleavage with no associated constructive metamorphic growth. In places, recrystallisation and migration of quartz from limbs to crests of microfolds has occurred producing a transpositional banding (cf. Nicholson, 1967). S_4 has a constant NNE strike and is subvertical; it cuts pre-existing fabrics and folds at a small angle with a constant sense of vergence (Fig. 130).

All F_4 folds are on a small scale and do not affect the geological boundaries. They are ubiquitous in the metasedimentary formation, and are well developed in the Post Hill Slide northeast of Julies Harbour. The F_4 folds are close to tight and cause type III interference patterns with F_3 folds. Post-D_3 tourmaline pegmatites seen in the shore section northeast of Julies Harbour have been boudinaged by D_4 and show an L_4 tourmaline lineation (Fig. 131).

THE FIFTH DEFORMATION - D_5

The fifth deformation was a kink-band-style deformation, and its effects are largely confined to those lithologies with a well developed planar foliation. Its effects are more widespread than those of D_4, and large scale D_4 structures are locally developed.

S_5 is represented by sinistral kink-bands that when closely spaced pass into a chevron style crenulation-cleavage best developed in the metasedimentary formation. Like S_4, it was not associated with any constructive metamorphic growth. Locally it develops into a transpositional banding by migration of quartz from the kink zones. S_5 strikes approximately east-west, and shows a constant sense of vergence to the earlier fabrics (Fig. 131).

F_5 minor folds are monoclinal warps with amplitudes ranging up to 10 m., and the plunges are sub-vertical or steep west-southwesterly. Tight F_5 folds occur locally in incompetent layers of the metasedimentary formation; these folds pass rapidly along their axial-planes into monoclinal folds in the adjacent more competent units (Figs. 25 and 131).

D_5 is well developed between Anderson Lake and Three Rapids, and large scale monoclinal warps are developed south of Witch Lake. A fault has developed parallel to the axial-plane of one of the largest of these, and has a horizontal component of sinistral displacement of approximately 170 m. The fault zone is exposed and consists of a zone of vein quartz 1 - 6 m. wide with haematite staining and epidotisation of the adjacent rocks.

POST-D_5 EVENTS

(i) Faulting

The only fault that cannot be related to the Hudsonian events occurs on the west side of Post Hill. The sub-vertical fault zone is eroded out forming a gulley and a photolinear. The block north of the fault appears to have moved west and/or down relative to the south-side.

The fault cutting the Inda Lake zone is believed to be due to relative movement of the walls of a sub horizontal net-veined diorite sheet at the time of intrusion, rather than a true fault. A smaller-scale example of this is seen 180 m. north of Kidney Pond in the Kitts area, where a vertical contact is displaced approximately 25 m. by a fresh, unsheared, gently dipping diorite sheet.

(ii) Fracture zones

A number of pronounced photo-linear features occur in the south-west part of the area. The most prominent of these extends from Witch Lake through Brumwater Lake to Julies Harbour and is marked by a steep sided valley or gulley occupied by linear swamps and ponds; a section of this linear coincides with a sector of the Watts Lake Slide west of Nash Lake. A few scattered outcrops in the feature show minor brecciation and quartz stockwork. There is no displacement of geological contacts associated with the fracture zones, though limited, strictly vertical, movement may have occurred.

CONCLUSIONS

Prior to the deposition of the Aillik Group a sequence of events involving dyke intrusion, at least three phases of deformation and anatexis were superimposed upon a sialic complex of unknown character to form the Hopedale Complex - a heterogeneous assemblage of banded gneiss, migmatite, granodiorite and granite of Archean age.

The Hudsonian events that followed deposition of the Aillik Group were essentially characterised by two contrasting strain regimes: (i) early discrete zones of movement (D_1-D_2) upon which was superimposed, (ii) horizontal compression with vertical planes of flattening and moderately inclined directions of extension (D_3).

The first and second deformations occurred in a major zone at the basement-cover contact, and in subsidiary stratabound zones (tectonic slides) that follow the boundaries of major lithological units in the Aillik Group. It is inferred from these relationships that the D_1-D_2 tectonic slides were essentially subhorizontal. This is in accord with the type III interference patterns produced by superimposition of F_3 folds with vertical axial planes on F_2 folds. Extreme tectonic thinning and excision of rock units by the D_1-D_2 slide zones together with their association with early tensional features (pegmatite bodies, quartz lenticles) indicate that they are analagous to shear zones (Ramsay and Graham, 1970). However, strain variation comparable to that described by Ramsay and Graham (1970) cannot be outlined due to D_3 overprinting, except in the area northeast of Three Rapids where banding in the Hopedale Complex swings into the Reconstituted Gneiss Zone.

D_1-D_2 transposition, flattening and recrystallisation of the Hopedale Complex immediately underlying the Aillik Group gave rise to the Reconstituted Gneiss Zone. The pre-Aillik Group structural complexity was wiped out in this zone, and the presumed unconformable relationship between basement and cover was obliterated. There is evidence that at the same time wedges of basement gneiss were thrust into the Aillik Group (Kitts Pond and southeast of Turnip Lake).

The structural effects related to the D_1-D_2 zones suggest that translational movements occurred on the essentially subhorizontal zones. Also limited stratigraphic evidence indicates that locally where formations have been brought into contact by a tectonic slide, they both face away from the slide ("back to back"), e.g., along the Nakit Slide in the Nash Lake area. These relationships suggest the presence of D_1-D_2 thrust slices and possibly of overturned nappes in the Aillik Group (Plate 6).

The <u>third deformation</u> was marked by vertical foliation and fold axial planes, and by renewed formation of major tectonic slides. Although it was more regionally pervasive than the earlier events, the third deformation was inhomogeneous on a mesoscopic to megascopic scale. The D_3 strain variation as indicated by variation in intensity and orientation of S_3 relative to the D_3 tectonic slides is comparable to the shear belt style of deformation described by Ramsay and Graham (1970). Interpretation of the tectonic slides as shear zones provides a unifying framework for the D_3 structural elements described above. The best example of this is provided by the relationship of the Post Hill Fold to the Witch Lake Slide.

The gabbro dyke swarm on Post Hill was intruded after folding had started and is interpreted as filling tensional fissures that formed as the Witch Lake Slide was initiated parallel to the shearing direction, and at 45° to S_3, the plane of flattening. The tensional fissures were oriented at 45° to the Witch Lake Slide in response to dextral translation. As deformation in the shear belt progressed the dykes were transposed into S_3 to a degree dependent on the amount of strain. The variation in strain is reflected in the orientation and intensity of S_3. Hence the dykes swing from an approximately easterly trend into the shear zone and show a total rotation of more than 90°. Maximum strain occured at a late stage within the Witch Lake Slide causing attenuation of both limbs of the Post Hill Fold. Figure 129 summarises these postulated relationships.

CHAPTER VIII

URANIUM MINERALISATION

Introduction

Uranium mineralisation in the Aillik Group has been described by Beavan (1958) and Barua (1969), and has been briefly summarized by Little and Ruzicka (1970), Allen (1971) and Ruzicka (1971). The mineralisation was described as occurring within sediments, tuffs and volcanics, mainly confined to certain stratigraphic zones but also showing a close relationship to foliation planes, shear zones and fractures. The known occurrences fall within fairly well defined stratigraphic-structural zones: these are the Walker Lake - White Bear Mountain belt, the Kitts-Post Hill belt, the Cape Makkovic - Present Lake belt, and three zones in the Shoal Lake area (Fig. 2). Beavan (1958) recognised the Aillik Group as forming part of a uranium metallogenic province that extends to the Seal Lake area. He classified the uranium occurrences as follows:

(a) Mineralisation in fracture and shear zones in volcanic rocks;

(b) Mineralisation in sedimentary rocks;

(c) Mineralised fault zones;

(d) Radioactive minerals in granitic rocks.

Allen (1971) regarded the mineralisation as essentially syngenetic, and suggested that it may have been derived from acid volcanics and tuffs within the Aillik Group, or alternatively may have been derived from erosion of Archean rocks. Ruzicka (1971) discussed the showings in more detail and recognized syngenetic and epigenetic mineralisation of five types corresponding essentially to Beavan's (1958) classification.

Uranium mineralisation in the Kitts-Post Hill belt occurs at six main localities between Kitts Pond and Witch Lake. These are the Kitts Prospect, and the Gear, Inda Lake, Knife Lake, Nash Lake and Witch Lake Showings. In addition, there are other occurrences of minor economic importance, e.g., the Fiace Lake Showing.

The Kitts Prospect was discovered in 1956 by W.D. Kitts who also discovered many other minor occurrences between Julies Harbour and Fiace Lake, and in the Post Hill area (1956-1957). Diamond drilling and an exploratory adit completed by BRINEX in 1958 proved the existence of a small but relatively high grade deposit at the Kitts Propsect. BRINEX resumed exploration in 1967 with a helicopter borne gamma-ray spectrometer survey. Ground follow-up in 1968 and 1969 resulted in the discovery of the other important showings, which were mapped on scales of 400, 100 and 40 feet to the inch. By 1970, diamond drilling of the Gear Showing the zone between the Inda Lake and Nash Lake Showings and the Witch Lake Showing had been completed.

The uranium mineralisation occurs in three distinct stratigraphic and structural settings:

(a) within iron formation members of the Kitts pillow lava formation (Kitts Prospect, Gear Showing, Inda Lake Showing)

(b) in the "Nakit" tectonic slide (Knife Lake Showing, Nash Lake Showing)

(c) inter-flow horizons in rhyolites (Witch Lake Showing).

This study suggests that the important deposits were formed by early syntectonic mobilization of uranium from acid volcanic rocks into major zones of shearing represented by the Nakit Slide and the incompetent iron formations. However, some ambiguity does exist regarding a possible syngenetic origin of the mineralisation in the iron formations.

GEOLOGY OF THE SHOWINGS

URANIUM MINERALISATION IN THE IRON FORMATION MEMBERS

Uranium mineralisation occurs in fine-grained black amphibolitic semipelite (Kitts Prospect, Inda Lake Showing) and in a more quartzo-feldspathic amphibole-rich metasediment (Gear and Inda Lake Showings). Apart from the principal showings and occurrences, local rusty weathering radioactive spots are common in the iron formations. The mineralised lithologies contain minor sulphides and graphite. The iron formations are the loci of early D_1-D_2 shear zones.

The iron formations show intensely developed D_1-D_2 tectonite fabrics, in marked contrast to the adjacent pillow lavas. This indicates that shear zones were localised in these incompetent members in response to the major D_1-D_2 translational movements that occurred at the basement-cover contact. Beavan (1958) recognised the mineralised structure in the Kitts Prospect as a zone of shearing. The rocks, notably the semipelitic lithologies show a strong penetrative composite S_1-S_2 schistosity, locally overprinted by an S_3 strain-slip cleavage or schistosity.

The higher grade mineralisation occurs in the amphibolitic semipelite, a dense fine-grained laminated schist described as an argillite by Beavan (1958). The mineralised argillite at the Kitts Prospect attains a local thickness of approximately 7 m., and consists of hornblende, minor diopside, epidote, plagioclase, quartz and carbonate. Lower grade mineralisation is contained in metasiltstones composed of quartz and plagioclase with varying amounts of biotite, amphibole and garnet. Graphite is prominent in both argillite and metasiltstones as disseminated very fine-grained particles included in the constituent minerals. Both the argillite and amphibolitic metasediment contain 2 - 15% magnetite, together with minor amounts of pyrite, pyrrhotite and chalcopyrite; traces of molybdenite have also been reported from the Kitts area. Fluorite occurs locally, tourmaline is abundant in a 60 cm. wide zone in the South Showing, Kitts area, and microcline is locally prominent in early diopsidic boudins.

The uranium is contained in disseminated very fine-grained particles that are included in MP_1 amphibole and MP_1-MS_2 biotite grains indicating a pre- or syn-D_1 age of the mineralisation. The uranium mineral is reported to be pitchblende (Beavan, 1958). The particles are surrounded by dark brown pleochroic haloes, and where they are abundant the amphibole and biotite are partially metamict; the amphibole is altered to a brown colour, and the biotite is pleochroic from pale brown to black. The radioactive particles tend to be concentrated on composite S_1-S_2 schistosity planes and locally coalesce to form seams of pitchblende. Pitchblende also occurs in veins associated with quartz-carbonate gangue. Ruzicka (1971) reported 0.5% and 0.3% vanadium from the Gear and Inda Lake Showings respectively, though, surprisingly, BRINEX does not appear to have assayed for this element.

Some mobilisation of uranium occurred during the third deformation, D_3. Small scale shear zones that cut the iron formations and adjacent volcanics and metagabbro are commonly rusty weathering and radioactive. This is most clearly demonstrated in the Kitts area, where small scale D_3 shear zones cutting the Hopedale Complex are rusty weathering and radioactive. The South Showing, having a strike length of approximately 500 m. occurs in a zone of major D_3 deformation related to an inferred D_3 slide or shear zone; the mineralisation appears to have been controlled in part by this structure. Radioactivity occurs on S_3 planes of schistosity, and in places, pyrite grains have nucleated in small scale D_3 shears within the zone.

URANIUM MINERALISATION IN TECTONIC SLIDES

(i) D_1-D_2 Slides

Uranium deposits occur in the Nakit Slide at three main localities where the banded tuff formation is brought into contact with the Kitts pillow lava formation. These are the Nash Showing, the Nash Showing - West Extension, and the Knife Lake Showing. All three showings have identical characteristics: they occur in interbanded amphibolite and psammite that comprises the slide zone. The uranium occurs in very fine-grained disseminated particles that are mostly included within hornblende grains. The uranium is preferentially concentrated in the amphibolite bands that contain the assemblage hornblende-diopside-epidote-biotite-microcline-carbonate. The hornblendes which poikilitically enclose the uranium mineral(s) are of MS_2 age; they define the S_2 fabric which, in places, can be observed axial planar to tight folds in the banding which in turn is believed to represent the D_1 fabric. Both the D_1 banding and S_2 are cut and folded by S_3, notably along the Nash Lake - West Extension Showing.

Numerous spots of high radioactivity occur in the Nakit Slide between Gear Lake and the Kitts area, but the slide zone is narrow (usually less than 1.5 m.) in this sector and the occurrences are not economically important, except for the Kitts North Showing. This showing occurs in fine-grained hornblende schist, part of a thin iron formation unit in the volcanics that is transgressed by the Nakit Slide; it has all the characteristics of the other showings in the Kitts area.

Minor showings were reported by Walter Kitts in 1957 east of Julies Harbour in rocks that appear to correspond to the Post Hill Slide, but these occurrences were not seen by the writer. Minor spots of radioactivity occur in the Fiace Lake Slide.

(ii) D_3 Slides

The Limestone Lake Slide contains local spots of radioactivity along its entire length. The most prominent zone occurs in its northern extension on the west shore of Long Island, where the slide is marked by a radioactive gossan less than 3 m. wide that can be traced for 80 m. along strike. Minor spots of radioactivity are also related to the Watts Lake Slide in the linear feature north-east of Watts Lake.

URANIUM MINRALISATION ASSOCIATED WITH RHYOLITES

Rhyolite flows of ignimbritic aspect are separated by dark grey intermediate horizons in the Witch Lake area. The dark horizons are 1 - 2 m. in thickness and contain patches of low grade uranium mineralistion, the most significant zone of which constitutes the Witch Lake Showing. The dark horizons are composed of moderately schistose andesite, and though usually homogeneous, they are fragmented in places, notably at the Witch Lake Showing. There, lithic fragments are outlined by anastamosing black biotite-magnetite-rich zones. This rock superficially resembles chloritic alteration pipe material found beneath Archean massive sulphide ore bodies (Sangster, 1972), but the presence of clasts of differing composition suggests that the anastamosing feature is a product of autobrecciation.

The uranium bearing mineral(s) appears to be in finely disseminated form, though no radioactive grains were identified with certainty in thin section. The matrix of the "autobreccia" contains extremely fine-grained particles; this material is probably a uranium mineral. The mineralised rock contains up to 60% carbonate in places, and pyrite and chalcopyrite are present in minor amounts.

OTHER MINOR OCCURRENCES

(i) Fiace Lake Showing

Patchy zones of radioactivity occur in local rusty weathering pyritic-semipelitic schist units in the metasedimentary formation west of Fiace Lake. Nearby, a pale grey psammite unit includes a zone of uranium mineralisation. These occurrences together constitute the Fiace Lake Showing; the radioactive zones are narrow (under 3 m. in width) and do not extend for more than 10 m. along strike. The mineralisation in the psammite occurs in thin irregular dark biotite-amphibole rich zones 1 - 3 cm. wide associated with deformed white quartz veins and stringers. The dark zones are subparallel to the dominant foliation (S_3) but intersect in an irregular fashion. The association with quartz veins suggests that they are fractures of early tensional origin. The rusty weathering schist units are identical in lithology to units in the pyrite-graphite bearing semipelitic member of the Metasedimentary Formation; this prominent marker horizon also contains local spots of radioactivity.

(ii) Jacques Lake Showing

Pegmatites throughout the map area generally show radioactivity that is above average background values though not markedly anomalous. However, one major body of pegmatite north of Jacques Lake is strongly radioactive, and is known as the Jacques Lake Showing. It is approximately 8 m. wide and 160 m. long, but was not examined in detail.

ORIGIN OF THE MINERALISATION

The volcanic and intrusive rocks in the area show normal relative abundances of uranium (as judged by gamma ray spectrometer counts) that are essentially related to their percentage of silica and alkalies (Rankama and Sahama, 1950). Thus, the mafic pillow lavas and amphibolite have the lowest levels of background radiation, granodioritic intrusions such as the Long Island Gneiss have intermediate levels, and the highest average values are encountered in rhyolite, quartz porphyry and feldspar porphyry (at least twice the levels of the mafic rocks). The metasediments show moderately low levels of radiation, including the iron formation members which, away from the anomalous zones have levels that are about equal to those in the adjacent pillow lavas. The Hopedale Complex averages readings that are a little lower than those in granodioritic intrusions in the Aillik Group.

There is, thus, a fairly clearly defined, lithologically controlled bulk distribution of uranium in the Kitts–Post Hill belt. Nevertheless, the most important deposits show no direct relationship to those rocks – the rhyolites – having the highest proportion of uranium.

(i) Age of mineralisation

The primary concentration of uranium into the mineralised zones occurred either before or during the first deformation, D_1. This is shown by the inclusion of the radioactive minerals in the oldest preserved metamorphic hornblende crystals which are of MP_1 age. A U-Pb isotopic age of 600 ± 30 m.y. was reported by Beavan (1958) for pitchblende from the original discovery locality south of Makkovic. This is believed to be a spurious age caused by lead leakage, or it could represent the age of a local generation of pitchblende remobilised by a suite of 500 - 600 m.y. lamprophyre dykes (Leech et al., 1963).

(ii) Genetic features of the mineralisation

The most important uranium deposits all show two features in common: they are hosted by tectonic slides and zones of shearing, and they are spatially associated with the Kitts pillow lava formation. In addition, many of the deposits contain fluorite, microcline and tourmaline, minerals indicative of hydrothermal activity. Deposits in the iron formations and minor occurrences in the metasedimentary formation are associated with graphite and sulphide bearing rocks. The Witch Lake Showing appears to be directly related to rhyolite flows. All of these features are believed to be of genetic significance: the relationship to tectonic slides and hydrothermal minerals indicates that most of the deposits are epigenetic though the association with sulphide-graphite bearing rocks suggests that some may be syngenetic.

(iii) Relationship to tectonic slides

The tectonic slides represented major dilational zones at least during the early stages of their formation (see Chapter VI). Migration of fluids into the tensional zones occurred, as shown by the associated quartz and pegmatite veins, and since uranium is readily soluble and highly mobile in the oxidized sexavalent state a similar migration of uranium into dilational zones is likely to have occurred. The presence of fluorite, microcline, carbonate and tourmaline suggest that such hydrothermal activity was indeed associated with the ore deposition. The viability of this mechanism as part of an ore-forming process is clearly demonstrated by minor remobilisation of uranium into small scale D_3 shear zones in the Kitts area.

The importance of the dilational environment created by shearing and faulting is illustrated by the association of many uranium deposits in Czechoslovakia with major faults, lineaments and shear zones (Ruzicka, 1974). An example on a regional scale is the Labe Lineament which contains six deposits and separates the Tepla-Moldanubian crystalline block from the main Variscan fold belt. A more isolated example is the Okroukla Radoun deposit that occurs in shear zones cutting a Variscan granite. The shear zones are strongly mylonitized and affected by chloritisation, graphitisation and carbonatisation; pitchblende is finely dispersed within the zones.

(iv) Relationship to sulphide and graphite-bearing lithologies

Uranium is readily precipitated from solution under reducing conditions; carbonaceous matter, coalified wood debris and hydrogen sulphide are the most effective reducing agents encountered in geological environments (Klepper and Wyat, 1959; Grutt, 1972). There is a common association of uranium with carbonaceous marine shale in which the uranium is coextensive with a particular bed and is regarded as syngenetic. Other elements are associated with uranium in such deposits, notably vanadium, molybdenum and copper. Coal, lignite and associated non-marine carbonaceous shale are also locally uraniferous, but the uranium in the shale is erratically distributed and appears to be epigenetic; the uraniferous examples are mostly associated with acidic tuffs.

The distribution of uranium in the graphite-sulphide bearing units in the Kitts-Post Hill belt is very erratic. This is especially true in the metasedimentary formation in which anomalous radioactivity is minimal even where graphite is abundant, as on Post Hill. This relationship suggests an epigenetic rather than syngenetic origin. On the other hand, the major concentrations of uranium occur where the carbonaceous beds have acted as shear zones - i.e., in the iron formation members. It is concluded that the reducing environment presented by the graphite and sulphide bearing rocks resulted in precipitation and sorption of uranium from mobile fluids channeled into the shear zones.

The carbonaceous rocks thus appear to have acted as "chemical traps" in zones where the mobility of fluids is enhanced. An example of the same basic process operating in a very different geological environment - that of a major unconformity - appears to be the Rum Jungle and South Alligator River deposits in north Australia (Dodson, 1972). These deposits are hosted by carbonaceous shale units in a folded early Proterozoic sequence. The mineralisation is localized where the carbonaceous units intersect an erosion surface on which the flat lying middle Proterozoic Carpentarian sediments were laid down. This and other unconformities appear to present an environment in which groundwater movement is facilitated, and dissolved uranium will precipitate and accumulate where reducing conditions are encountered.

(v) Relationship to acid volcanics

It is found that only certain of the zones identified as tectonic slides contain economically significant uranium mineralisation, even though all are associated to some extent with anomalous zones. The common feature of the mineralised slides is their association with the upper part of the inferred stratigraphic succession - the banded tuff and rhyolite formations. The source of the uranium therefore appears to be the acid volcanics, volcanogenic sediments and porphyries with their relatively high primary uranium content. This is supported by the clear association of low grade mineralisation with rhyolite flows in the Witch Lake Showing. Also examination of the Michelin Showing by the writer found that the mineralisation there is in quartz-feldspar porphyry and acid volcanogenic sediments, not quartzites as was generally believed (e.g., Stevenson, 1970).

The association of uranium deposits with acid volcanics is recognized in many parts of the world. For example, uranium-copper-molybdenum mineralisation is directly related to quartz porphyry, acidic tuffs and associated sediments of Permian age in Czechoslovakia (Ruzicka, 1971). The presence of acidic tuffs is recognized as an important parameter in peneconcordant sandstone-type deposits such as those of the Colorado Plateau region (Klepper and Wyat, 1957; Fisher, 1974).

CONCLUSIONS

The stratigraphic and structural relationships described above suggest that the primary source of the uranium was the acid volcanic rocks. The early deformation (D_1) of the Aillik Group created major dilational zones along developing tectonic slides and shear zones. Where these structures cut or bounded acid volcanic units, uranium appears to have been mobilized from the acidic volcanics into the dilational zones. Deposition of the uranium appears to have occurred by reduction and sorption in amphibolitic and graphite-sulphide bearing rocks. Limited remobilization of uranium occurred during the third deformation; this was again related to migration of uranium into the shear zones.

CHAPTER IX

CORRELATIONS AND REGIONAL SYNTHESIS

Introduction

In this chapter, correlations within the Aillik Group are first discussed, and the Aillik Group is then considered in relationship to the Central Mineral Belt. The geological setting of the Group is then evaluated within the broader framework of the early Proterozoic evolution of the northeastern Canadian Shield and Greenland. Despite limitations imposed by lack of data it can be concluded that the Aillik Group evolved on the continental side of an early Proterozoic Cordillerian-type plate margin that bounded the southeast side of the Laurentian Shield.

CORRELATION WITHIN THE AILLIK GROUP

(i) Stratigraphy

This study indicates that the Aillik Group consists of two major divisions - lower and upper. The lower Aillik Group consists of mafic pillow lavas and terrigenous metasediments, and is overlain by an upper division of conglomerates, acid volcanogenic sediments, rhyolite and minor mafic flows. The base of the upper division marks a major change in the tectonic framework and depositional environment, and has a disconformable or locally unconformable relationship to the underlying rocks.

The lower division comprising the Post Hill amphibolite, the metasedimentary formation and the Kitts pillow lava formation can be directly correlated with the English River Greenstones southwest and west of Kaipokok Bay (Sutton, 1972). The maps of Gandhi et al. (1969), Clark (1974) and unpublished BRINEX data suggest that the lower division does not occur to the east or south of the Kitts-Post Hill belt. It thus appears that lower structural and stratigraphic levels are represented along the boundary of the Archean Craton.

The conglomerate, banded tuff and rhyolite formations comprising the upper division in the Kitts-Post Hill belt are lithologically identical to map units in the Makkovic region described by Gandhi et al. (1969) and Clark (1974), and visited by the writer. However, there is no correlation of the stratigraphic order in which these units appear from place to place. Gandhi et al. (1969) and Clark (1974) found that although successions involving conglomerate, banded tuff and mafic lava units can locally be established, no sure correlations can be attempted across the regional strike, or even at one locality east of Long Island, from one limb of a fold to the other (Clark. 1971; Fig. 3). From the work of Clark (1974), it appears that the Aillik Group in the Makkovic region consists of arkose, conglomerate, tuff, rhyolite and mafic lava units alternating in varying order and showing numerous facies changes and diachronous relationships. Nevertheless, many of the map units show excellent continuity along strike.

(ii) Intrusive history

Despite the stratigraphic uncertainties, two of the major intrusive bodies in the Aillik Group can be correlated with a reasonable degree of certainty. The Quartz Monzonite is represented by three major syntectonic domes in the Makkovic Peninsula and by other major bodies found to the south as far as the Michelin area. These equivalents are named the "Granite Gneiss" or "Syenite" by Gandhi et al. (1969), or the Kennedy Cove Gneiss by Clark (1974), but all show a close lithological unity. The distinctive Long Island Gneiss is more limited in extent, but two small intrusions in the Michelin area have been correlated with it by Gandhi (unpublished compilation map) and there is indeed a remarkable similarity (writer's observations).

The Porphyritic Microgranite is interpreted in this study as a major hypabyssal syntectonic body with demonstrable intrusive contacts. It was mapped by previous workers as Feldspathic Quartzite (Variable Lithology) (Gandhi et al., 1969). This rock, and a similar massive type named the Feldspar Porphyroblastic Arkosic Quartzite forms very thick and extensive map units in the Makkovic region where they separate local successions of mafic lava, conglomerate and tuff (Gandhi et al., 1969). Clark (1974) interpreted these map units as rhyolite lavas, but where seen by the writer they appear to be too homogeneous over large areas to be of extrusive origin. If the writer's interpretation of the Porphyritic Microgranite is correct, it would suggest that the Aillik Group has been intruded by large sub-concordant hypabyssal bodies that have served to fragment the stratiform volcano-sedimentary succession. This may explain many of the apparent facies changes mentioned by Clark (1974).

STRATIGRAPHIC RELATIONSHIPS IN THE CENTRAL MINERAL BELT

The Central Mineral Belt is a belt of Proterozoic supracrustal rocks that flanks the northern margin of the Grenville Province for a distance of approximately 300 kms. (Fig. 132). The belt has been divided into three main groups of supracrustal rocks: the Aillik Group in the east, the Croteau Group in the middle (Fahrig, 1959) and the Seal Lake Group in the west (Brummer and Mann, 1961). Recently, the Croteau Group has been redefined into two new groups: the Moran Group, overlain by the Bruce River Group (Smyth et al., 1975). Two other sequences of relatively minor extent occur at the west end of the belt - the Letitia Lake Group (Brummer and Mann, 1961) and the Petscapiskau Group (Emslie, 1970).

The Aillik Group is effectively isolated from the nearest possible equivalents, the Moran and Bruce River Group, by an area underlain by very poorly exposed Archean rocks and granite intrusions. As a consequence very little is known about the western part of the Walker Lake - White Bear Mountain belt (Plate 1), hindering effective comparison of the supracrustal sequences.

(i) The redefined Croteau Group

The Croteau Group was defined by Fahrig (1959) as consisting of a lower sequence of pyritic black shales, minor quartzite, greywacke, dolomite and mafic flows, a middle sequence of conglomerate and arkose, and a thick upper sequence of rhyolitic to andesitic volcanics. Williams (1970), mapping in the eastern part of the Croteau Group regarded the lower sequence ("Lower Croteau") as Aphebian, and the middle and upper sequences as Helikian, but it is not clear if a stratigraphic break was recognized. However, Roy and Fahrig (1973) did recognize that the Lower Croteau is unconformably overlain by the Middle Croteau, and they stated the need for separate group names. Recent work by Smyth et al. (1975) has confirmed these relationships in the field, and they proposed replacing the Lower Croteau Group by the name Moran Group, and the middle and upper Croteau Group by the name Bruce River Group (Plate 1).

(a) Moran Group

The Moran Group comprises a succession of quartzite, iron formation, slate, mudstone and dolostone overlain by pillowed and massive basaltic flows. The sequence unconformably overlies Archean granite and gneiss and forms a narrow linear belt extending for some 75 kms. east north-eastwards to Kanairiktok Bay. The Moran Group is reported to have undergone two phases of moderate to penetrative deformation in the low greenschist facies of metamorphism prior to deposition of the overlying Bruce River Group (Smyth et al., 1975). The Bruce River Group has yielded a Rb/Sr isochron age of 1474 $\pm$ 42 m.y., reported as a "reasonable estimate" of the true age (Wanless and Loveridge, 1972). The Moran Group is thus bracketed by similar upper and lower age limits as the Aillik Group, though a break of approximately 1 b.y. is involved. Nevertheless, because of the geographical association and lithological affinities it appears reasonable to tentatively correlate the lower mafic volcanic sedimentary division of the Aillik Group with the Moran Group, as suggested by Sutton et al. (1972). Comparisons with Greenland discussed below support this correlation.

(b). Bruce River Group

There is an overall similarity between the Bruce River Group and the upper division of the Aillik Group; both consist essentially of a bimodal suite of volcanic rocks. In addition, the Bruce River Group is directly on strike of the Walker Lake - White Bear Mountain belt. As a consequence, there has been a tendency to regard the two groups as equivalent, at least in part (Beavan, 1958; Sutton et al., 1971). Nevertheless, there are important lithological differences.

The Bruce River Group comprises a basal polymictic conglomerate overlain by 1000 m. of acid tuffaceous sandstones, succeeded in turn by a thick sequence of alternating basalt and rhyolite (ignimbrite) subaerial flows (Smyth et al., 1975). The thick flow sequence includes minor tuff and sediment horizons but lacks the major units of banded tuff and conglomerate that are conspicuous in the Aillik Group. Quartz phenocrysts are abundant in the Aillik Group volcanics but are virtually absent in the Bruce River Group.

The apparent age of the Bruce River Group is 1474 $\pm$ 42 m.y. as noted above. This is considerably younger than the minimum K-Ar age of 1600 m.y. for the Aillik Group (Gandhi et al., 1969). Moreover, the Bruce River Group does not appear to have been extensively folded other than by tilting before the Grenville orogeny (Marten and Smyth, 1975). These relationships suggest conclusively that the Bruce River Group post-dates the Aillik Group as indicated by Greene (1972).

(ii) Letitia Lake Porphyry

A belt of quartz-feldspar porphyry flanks the south margin of the Seal Lake Group and was formerly named the Letitia Lake Group by Mann (1959). It was divided into a lower unit of quartz-feldspar porphyry and an upper unit of banded rhyolite, tuff and quartz sericite schist (Brummer and Mann, 1961). Correlation with the "Upper Croteau Group" (Bruce River Group) was proposed by Brummer and Mann (1961). However, Marten (1975) has interpreted the "lower unit" as the peripheral fine-grained phase of an epizonal granite pluton, and the "upper unit" as a thick regolith marking the old erosion surface beneath the Seal Lake Group. Group status for the porphyry was therefore abandoned and the name Letitia Lake Porphyry adopted; correlation with the Croteau Group can no longer be considered. The age of the Letitia Lake Porphyry is unknown but as it straddles the extrapolation of the Nain-Churchill boundary and is in turn unconformably overlain by the Helikian Seal Lake Group it is believed to be post-Hudsonian and pre-Helikian.

An adamellite pluton occurring northeast of the Harp Lake Anorthosite has been briefly described by Taylor (1972). Portions of this body consist of a quartz feldspar porphyry that appears to be identical to the Letitia Lake Porphyry and the two plutons appear to be related as part of the anorthosite-adamellite suite. Taylor (1972) describes an upward gradation into rhyolite at one locality, and though this was not observed in the Letitia Lake area, rhyolite clasts were observed in basal beds of the Seal Lake Group suggesting that the

Letitia Lake body may have had an eruptive phase also.

The Bruce River Group appears to be overlapped in time by emplacement of the anorthosite-suite plutons (K-Ar age 1400 m.y., Emslie, 1964; minimum age of cooling) and it may therefore represent the surface expression of the plutonism. There may therefore be an indirect relationship between the Letitia Lake Porphyry and the Bruce River Group.

(iii) Seal Lake Group

The Seal Lake Group is a sequence of quartzites, basalt flows, shales and diabase sills in the order of 20,000 feet total thickness (Brummer and Mann, 1961). The Seal Lake Group rests unconformably on the Letitia Lake Group or Porphyry (Brummer and Mann, 1961; Marten, 1975), on the Bruce River Group (Marten and Smyth, 1975) and on the Harp Lake Anorthosite. The Group has been folded into an arcuate overturned synclinorium with northward-directed thrusting by the Grenville Orogeny. The age of the Seal Lake Group is therefore Neohelikian, and Neohilikian K-Ar ages have been obtained (Wanless et al., 1965). A deep regolith (Marten, 1975) and weathering of bedrock (Marten and Smyth, 1975) is developed beneath the basal unconformity of the Seal Lake Group, in common with other Helikian sequences of the Canadian Shield (Fraser et al., 1970).

(iv) Petscapiskau Group

Rocks of the Petscapiskau Group and probable equivalents occur west of the Seal Lake Group and have a minimum age of 1520 m.y. (K-Ar biotite, Emslie, 1970). They are folded but not extensively metamorphosed, and are a sequence of pelitic and semi-pelitic sediments, tuffs and pyroclastics with some interbedded quartzite, amphibolite and carbonate (Emslie, 1970; Emslie et al., 1972). Emslie et al. (1972) favour a Petscapiskau-Croteau-Aillik correlation, which can now be modified to a Petscapiskau-Moran Group-lower Aillik Group correlation. This is a possibility, but little other comment can be made at the present state of knowledge. However, it should be pointed out that Emslie et al. (1972) consider that the Petscapiskau Group was "not severely folded" prior to intrusion of the Michikamau Anorthosite (K-Ar 1400 m.y. age). They suspect an unconformity separating the sediments from the underlying regional gneisses. Yet these gneisses are generally considered to have been intensely deformed during the Hudsonian orogeny (e.g., Greene, 1972). If this were so a post-Hudsonian age of the sediments is implied, rendering the suggested correlation suspect.

(v) Conclusions

Three major sedimentary-volcanic cycles separated by two episodes of folding and major magmatic activity are developed in the Central

Mineral Belt: the Aillik (east), Bruce River (middle) and Seal Lake Groups (west). The cycles show a progressive decrease in age westwards towards the position of the extrapolated Nain-Churchill boundary. The lower division of the Aillik Group is believed to be represented by the Moran Group which can be traced to the eastern edge of the Seal Lake Basin. However, no possible correlative of the upper Aillik Group appears to exist in the Central Mineral Belt. The limit of major Hudsonian effects in the Moran-Aillik Group appears to trend southwestwards between the Moran Group and Kaipokok Bay, to be truncated by the boundary of the Grenville Province.

THE AILLIK GROUP IN RELATIONSHIP TO APHEBIAN SEQUENCES OF THE EASTERN CANADIAN SHIELD

Aphebian supracrustal rocks are distributed in two major zones of the eastern Canadian Shield. One forms a continuous belt known as the Labrador Trough, and the other is represented by isolated remnants resting on the Archean craton of coastal Labrador (Fig. 133).

The Labrador Trough forms part of the circum-Ungava geosyncline bordering the Superior Province, and the sedimentary-volcanic fill of the trough is known as the Kaniapiskau Supergroup. The supergroup consists of shelf and miogeosynclinal rocks in the west, and eugeosynclinal facies in the east (Dimroth et al., 1970). The miogeosynclinal facies consists of cyclical sequences of quartzite and carbonate, banded iron formation, shale and greywacke. Basaltic volcanics form the distal eugeosynclinal facies.

In coastal Labrador, the isolated Aphebian sequences all rest unconformably on Archean basement and are, from north to south, the Ramah Group, Mugford Group, Snyder Group and Moran Group (already described above). The Ramah Group is an almost flat lying sequence of shelf quartzites overlain by a deep water basinal sequence (Knight, 1972). Though formerly regarded as Helikian in age, it is now recognized as Aphebian (Morgan, 1974). The Mugford Group consists of thin euxinic shale overlain with minor unconformity by a dominantly tholeiitic continental flood basalt sequence (Daly, 1902; Douglas, 1933; Barton, 1975). The Snyder Group is a thin sequence of conglomerate, quartzite, iron formation, carbonate and euxinic siltstone lying within the aureole of the Kiglapait anorthosite intrusion (Speer, 1973).

Knight (1974) proposed a correlation of the Ramah, Mugford and Snyder Groups. He also suggested that these sequences are equivalent to facies in the Labrador Trough, and that the trough may therefore be an advanced aulocogen. The Moran Group is also comparable to facies in both the Labrador Trough and the northern Labrador sequences. It appears that Knight's correlation can be extended to include the Moran Group.

Except for the lower Aillik-Moran group correlation, the Aillik

Group as a whole does not compare well with the Aphebian sequences described above. The unique feature of the Aillik Group is the upper, acid volcanic-dominated division which appears to have no equivalents in the eastern Canadian Shield. Consideration of this feature in relation to the proposed correlations in the Labrador coastal strip suggests that a facies change to a bimodal volcanic suite occurred in the middle part of the Aphebian sequence southeast of the present outcrop of the Moran Group.

Acid volcanics are reported to be virtually absent in the Labrador Trough (Dimroth et al., 1970). Very minor occurrences have been noted in one mafic volcanic formation of the eugeosynclinal sequence. One of these occurrences appears to be related to the Cambrian Lake graben in the central part of the Trough (Dimroth, personal communication), a structure that Burke and Dewey (1973) have interpreted as a failed arm. Nevertheless, Wynne-Edwards (1961) has mapped a considerable volume of acidic porphyries and volcanics at the extreme south end of the east margin of the trough, straddling the Grenville Front. The volcanics form a unit that attains a width of 7 kms. before being truncated against gneiss of the Grenville Province. The volcanics are associated with intraformational conglomerates of the type found within the Aillik Group. A southward facies change in the Kaniapiskau Supergroup towards an acid volcanic-dominated regime is indicated, as appears to be the case in coastal

Labrador. The acid volcanics may therefore be equivalent to the upper division of the Aillik Group, at least in terms of tectonic setting and significance.

COMPARISON OF WEST GREENLAND WITH THE NORTHEASTERN CANADIAN SHIELD AND LABRADOR

The Precambrian shield areas of the north Atlantic region show a clear structural unity when re-assembled into their pre-Phanerozoic continental drift positions (Fitch, 1965; Bullard et al., 1965). On the basis of this refit the present day coastlines of Labrador and Greenland are some 200 km. apart, and the major tectonic subdivisions can be clearly correlated (Allaart et al., 1969; Figure 2). West Greenland includes a central block of Archean gneisses and supracrustals that can be correlated with the Nain Province of Labrador, forming the main part of the North Atlantic craton (Bridgewater et al., 1973; Bridgewater, 1970; Bridgewater et al., 1975).

The Archean craton is bounded by Proterozoic mobile belts. On its west side in Labrador the craton is bounded by Hudsonian fold belt that clearly correlates with the Nagssugtoqidian mobile belt in Greenland (Figure 2; Bridgewater et al., 1973). On the south margin of the craton the "Hudsonian" fold belt of the Makkovic region and the Ketilidian mobile belt in Greenland have been compared and correlated in a general way by Allart et al. (1969), Bridgewater (1970) and Bridgewater et al. (1973). Bridgewater et al. (1973) have demonstrated that the Ketilidian mobile belt contrasts in tectonic and plutonic history with the Nagssugtoqidian mobile belt, and a similar contrast appears to exist in Labrador between the Makkovic-Hudsonian and the Churchill Province. This underlines the general equivalence, but detailed correlations are more difficult to make.

(i) Correlation of Aphebian Supracrustal Sequences

Early Proterozoic (Aphebian) sequences in west Greenland are confined to the Nagssugtoqidian and Ketilidian mobile belts. The Nagssugtoqidian supracrustals are known as the Karrat Group and have been compared with the basal quartzites and late greywackes of the Ramah Group. In the Ketilidian mobile belt, supracrustal rocks occur in two separate parts of the belt: in the north marginal zone, and in the south-central zone. The two sequences are separated by a large mass of variable granitic rocks called the Julienhaab Granite, and they cannot be correlated, nor their relationship established (Pulvertaft, 1968).

A thick gently dipping Proterozoic sequence rests unconformably on Archean gneiss and supracrustals in the north foreland zone of the Ketilidian mobile belt (Higgins and Bondesen, 1966). The succession is divided into two groups: the Vallen Group overlain by the Sortis Group. The Vallen Group consists of conglomerate, quartzite, dolomite, graphitic slate, shales and greywacke. The Sortis Group is composed dominantly of tholeiitic pillow basalts with some pyroclastics, minor greywackes and pelite, intruded by many thick mafic sills. Knight (1974) has pointed out that the Ramah and Mugford Groups resemble the Vallen and Sortis Groups respectively. A further correlation of the lower part of the Moran Group with the Vallen Group, and of the upper mafic flow part of the Moran Group with the Sortis Group can also be suggested. Jackson and Taylor (1972) has reviewed Aphebian successions of the circum-Ungava, Dorset, Foxe and Committee fold belts, embracing the whole of the northeastern Canadian Shield. They concluded that the successions are broadly equivalent in terms of facies and sequences of facies. All of these relationships underline a general similarity in Aphebian stratigraphy over a very large area, and suggest that shelf miogeosynclinal and marginal mio-eugeosynclinal strata covered the entire northeastern Canadian Shield-Greenland area (Jackson and Taylor, 1972; Knight, 1974).

(ii) The north margin of the Ketilidian Mobile Belt and its continuation in Labrador

The Vallen and Sortis Groups record a classic foreland-mobile belt transition in the Ivigtut area (Windley et al., 1966; Henriksen, 1969). The transition is marked by a southward increase in amount of deformation and metamorphic grade, and by progressive obliteration of the unconformity (Fig. 134). Two main phases of Ketilidian deformation are recognized. The first formed tight to isoclinal folds with flat lying axial planes, and was associated with horizontal thrusting; its effects are largely confined to certain stratigraphic boundaries and horizons. The second phase formed open to tight folds on subvertical north-east trending axial planes.

In the north where dips are gentle the unconformity is perfectly preserved. Deformation is limited to recumbent folding in certain horizons related to first-phase low angle thrusts; metamorphism was in the low greenschist facies. Southwards the unconformity becomes sheared and then obliterated as the sediments are thrust over the basement, and successively higher stratigraphic levels are brought into contact with Archean gneiss; metamorphic grade is in the epidote amphibolite facies. Still further south a "gneissic schist" transition zone up to 400 m. thick is developed at the basement-cover contact and foliation in the immediately underlying gneiss is conformable. Deformation throughout the supracrustal sequence becomes intense and pillow lavas are transformed to hornblende schist or are intensely flattened; the metasediments show amphibolite facies low pressure assemblages. The first phase foliation, concordant with the basement-cover contact, is folded.

by northeast trending F_2 folds which become dominant. In the extreme south, a "gneissified" zone up to 1 km. wide is reported at the basement-cover contact, and early Ketilidian autochthonous granites have been generated close to the basement-cover contact zone, locally obscuring it (Windley et al., 1966).

It has been suggested above that the Moran Group in Labrador is equivalent to the Vallen and Sortis Groups, and that the Moran Group is also equivalent to the lower divisions of the Aillik Group. These correlations are strengthened by comparing the Ketilidian foreland transition with the differences in structural and metamorphic style exhibited by the Moran and lower Aillik Group.

The Moran Group rests unconformably on basement, and is weakly deformed. The lower Aillik Group records early basement-cover transposition with strata-bound flat lying structures in the supra-crustals, refolded by regional north east-trending folds on sub-vertical axial planes. Absence of a sedimentary lower Moran Group equivalent beneath the metavolcanics in the Kaipokok Bay area can be accounted for by thrusting of a higher stratigraphic level directly onto basement. Metamorphism in the northwest (Moran Group) was of low greenschist facies, in the central zone was middle greenschist facies (English River belt, Sutton, 1972), and in the southeast (Kitts-Post Hill belt) was of the amphibolite facies. The suggested transition is compared with that in Greenland in Figure 135, and it is inferred that the northern margin of the Ketilidian mobile belt can be extrapolated to coastal Labrador where it lies between the Kanairiktok River and Kaipokok Bay.

(iii) Significance of the Aillik Group to Ketilidian Geology

From the foregoing it appears that Kaipokok-Ivigtut comparisons involving the lower Aillik Group are remarkably favourable for broad structural and stratigraphic correlations, despite the great distance involved. On the other hand, the acid volcanic-dominated upper division of the Aillik Group has no apparent equivalents in the Ivigtut area. However, Bridgewater (1970) has reinterpreted certain rocks in the Ketilidian supracrustals found south of the Julienhaab Granite as acid volcanics. Supracrustals in the Tasermuit Fjord area have been described as schists, quartzites, meta-arkoses, metaconglomerate and pillowed mafic flow units by Escher (1966) and Dawes (1970). No new descriptions of these rocks appear to have been published since Bridgewater's comments, but a recently published sketch map by Van Breeman et al. (1974) shows the "quartzites" as "feldspathic quartzite and acid volcanic rocks". The meta-arkoses and meta-conglomerates described and figured by Dawes (1970) appear to be identical to the banded tuff and conglomerate units in the upper Aillik Group.

It can be inferred that the Ketilidian sequences occurring between the Julianhaab Granite and Kap Farvel consist at least in part of a bimodal volcanic assemblage rather similar to the upper division of the Aillik Group; a very broad upper Aillik Group - central Ketilidian sequence correlation can be suggested. This in turn suggests that the Ketilidian acid volcanics bear a similar relationship to the Vallen and Sortis Groups as the Aillik acid volcanics bear to the lower Aillik Group and Moran Group.

(iv) Age of the Ketilidian Orogeny and deformation of the Aillik Group

The main period of Ketilidian deformation, metamorphism and formation of early granites was followed by a phase of intense magmatism known as the "Sanerutian" event. The Sanerutian event was responsible for several generations of late Ketilidian granites as well as widespread recrystallisation and anatexis.

K-Ar mineral dates from west Greenland range from 1640 to 1500 m.y. and cluster around 1600 m.y. (Bridgewater, 1965). These were interpreted as reflecting the late Sanerutian episode, and it was thought that the main Ketilidian event took place much earlier, around 1800 m.y. B.P. (Bridgewater, 1965). The latter assumption has been confirmed recently by a U-Pb discordia age of 1840 ± 25 m.y. and a whole rock isochron age of 1894 ± 1 m.y. from the early granites (Van Breeman et al., 1974). However Van Breeman et al. (1974) have dated the later widespread Sanerutian episode at 1780 ± 20 m.y.

(U-Pb zircon and Rb-Sr whole-rock isochron ages) i.e., about 180 m.y. older than previously recognised. Rb-Sr mineral ages agree with the cluster of K-Ar ages around 1600 m.y. and it is now thought that this age merely reflects very slow cooling of the mobile belt.

K-Ar ages from the Aillik Group and post-kinematic granites intruding the Aillik Group range from 1600-1500 m.y. These results were interpreted by Gandhi et al. (1969) as reflecting the Hudsonian orogeny at about 1600 m.y. B.P. This interpretation was abandoned by Clark (1974) who equated the deformation of the Aillik Group with the Sanerutian episode in Greenland on the basis of the 1600 m.y. peaks. However the results of Van Breeman et al. (1974) indicate that this is invalid. Correlations with Greenland suggest that a Hudsonian (Ketilidian) age for the deformation in Labrador can be safely assumed until evidence to the contrary is presented.

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THE RELATIONSHIP BETWEEN THE AILLIK GROUP AND THE HOPEDALE COMPLEX, KAIPOKOK BAY, LABRADOR

VOL. 2

BRIAN ERNEST MARTEN

THE RELATIONSHIP BETWEEN THE AILLIK GROUP AND THE HOPEDALE COMPLEX KAIPOKOK BAY, LABRADOR

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INTRODUCTORY NOTE

In all photographs of outcrops, the direction of true north is indicated by the head of the hammer, with the handle aligned in a north-south position. In some photographs, true north is indicated by the alignment of a pencil used as scale.

APPENDIX A

PETROGRAPHIC DESCRIPTIONS

HOPEDALE COMPLEX

Banded Gneiss

Plagioclase (An 32-38) and quartz occur in a mosaic of xenomorphic crystals 0.3 - 1.5 mm. in diameter. Grain boundaries vary from indented to curved and in places the mosaic is subpolygonal. Twinning in the plagioclase crystals is not prominent but that which is developed is on the Albite and Pericline laws. Glide twinning is common and is distinguished by narrow wedge-like twin lamellae that are often slightly curved, and undulose extinction is widespread. The quartz grains are strained and show slight preferred dimensional orientation.

Rare K-feldspar crystals are commonly untwinned and are slightly perthitic. In some bands of granite gneiss K-feldspar is the dominant feldspar. It may occur in relict porphyroblasts or phenocrysts broken down to a xenomorphic aggregate of untwinned K-feldspar and cross hatched microcline. Myrmekite is common in the granite gneiss along microcline/microcline grain boundaries and as wart-like overgrowths on plagioclase protruding into the micro-cline.

Irregular lenses of myrmekite are common in the banded gneiss in places. Worm-like quartz blebs form a typical myrmekite pattern and extinguish simultaneously, but unlike normal myrmekite, they are included in a fine-grained mosaic of three or four plagioclase grains that are frequently twinned. It is suggested that the plaio-clase host of a normal myrmekite was broken down to a mosaic during the last pre-Hudsonian deformation represented by the biotite fabric.

The biotite is pleochroic most commonly in olive green, but also in brown and red brown. It is the dominant and usually the only mafic mineral, and occurs in flakes 0.2 - 1.5 mm. long with a preferred orientation sub-parallel to the banding. It shows no evidence of any earlier growth stages, but a later growth stage is seen where the Hudsonian S_3 is developed.

The hornblende is pleochroic in: X, yellow; Y, olive green; Z, blue-green, and occurs in prisms 0.3 - 1.5 cms. long that are somewhat irregular as the prism faces are not well formed when in contact with feldspar. There is no evidence of replacement of hornblende by biotite where the two minerals are juxtaposed.

Apatite is the most common accessory and occurs in scattered xenomorphic grains and occasional prisms up to 0,3 cm. long. Subidiomorphic and xenomorphic grains of orthite rimmed by epidote are associated with the mafic-rich bands, and the epidote shows idiomorphic form when included in or in contact with biotite. Sphene occurs in small droplets and rare idiomorphic crystals, and together with very minor opaques is associated with the mafic-rich bands.

Amphibolite

Both the concordant amphibolites and complex boudins are texturally similar and consist of 40% - 80% hornblende in subidiomorphic prisms 0.3 - 1 mm. long showing a weak to good preferred orientation, with calcic oligoclase in xenomorphic crystals up to 1 mm. in diameter showing curved grain boundaries. Minor amounts of quartz occur in xenomorphic grains 0.1 - 3 mm. in diameter.

The hornblende shows the same pleochroic scheme as in the gneisses. The plagioclase shows the same type of twinning as in the gneisses and normal zoning is well developed in the boudins. Sphene is the most common accessory and occurs as rounded grains 0.1 mm. in diameter that may be evenly scattered or in trains parallel to the fabric. It is frequently associated with xenomorphic grains of magnetite or ilmenite up to 0.3 mm. in size.

Early Migmatite

The major constituent minerals of both phases of the granodiorite calcic oligoclase, quartz and biotite; apatite, orthite, epidote and magnetite are present in accessory amounts. The crude gneissic aspect often apparent in outcrop appears to result from the breakdown and flattening of larger plagioclase phenocrysts of porphyroblasts. Plagioclase and quartz occur in xenomorphic crystals up to 2.5 mm. in diameter and have indented or curved grain boundaries. The quartz crystals are strained and commonly elongate with a dimensional orientation parallel to the biotite fabric. The plagioclase shows glide twins, but twinning is not common. Reverse zoning is developed and a type of oscillating zoning is also seen with cores and rims of An 28 and a median more sodic zone about An 24 in composition.

AILLIK GROUP

MAFIC VOLCANIC FORMATIONS

The undeformed, foliated and hornblende schist facies are all composed dominantly of amphibole (70%) and plagioclase (20%, An 40) with minor quartz and accessory magnetite, epidote and sphene.

Two varieties of amphibole occur: a pale green type in the undeformed pillow lavas, and a green more strongly pleochroic amphibole in the foliated pillow lavas and hornblende schists. The former is pleochroic in: x = colourless or pale yellow; y and z = pale green; it is optically negative and resembles actinolite, but has an extinction angle z:c of 24°, slightly higher than that expected for a member of the tremolite-actinolite series (maximum z:c = 20°); it is probably an actinolite with some hornblende in solid solution. The green amphibole is pleochroic in x, pale yellow; y, olive green; z, blue green or green; and is optically negative; it is probably a common hornblende.

(i) Undeformed pillow lavas

The undeformed pillows have an isotropic fabric of felted pale green pleochroic actinolitic amphibole with interstitial zoned and untwinned plagioclase, and scattered subidiomorphic pale green amphibole porphyroblasts (0.1 mm.) overgrowing the fibrous amphibole of the groundmass (Fig. 136). Scattered blebs up to 1 mm. in diameter composed of a subpolygonal mosaic of twinned and untwinned plagioclase (An 40) and quartz appear to represent relict glomero-phenocrysts. The chilled margins of the pillows are composed almost exclusively of radiating clusters of fibrous amphibole rimmed by discontinuous trains of finely divided epidote and sphene, and overgrown by randomly oriented idiomorphic amphibole porphyroblasts. Material interstitial to pillows is represented by a coarser grained (0.2 - 0.5 mm.) xenomorphic to subpolygonal mosaic of plagioclase

(An 40) and quartz with unoriented actinolitic amphibole prisms up to 5 mm. long. The relatively coarse texture of this encrusting material is probably due to greater availability of volatiles in the pillow intersteces during metamorphism.

(ii) Foliated pillow lavas

The hornblende is subidiomorphic, 0.1 - 0.3 mm. in grain size and shows a weakly to strongly developed preferred orientation that defines the L-S tectonite fabric. The plagioclase (An 40) is generally zoned and shows a subpolygonal disequilibrium fabric with curved and indefinite grain boundaries. About 20% of the plagioclase grains are twinned on the albite and albite-pericline lows, and there is partial sericitisation in places.

The chilled margins of pillows are sharply defined zones 3 - 5 mm. thick composed almost entirely of subidiomorphic hornblende crystals slightly coarser that those within the pillows. A coarse aggregate of epidote and minor diopside occupying pillow intersteces was noted south of Inda Lake. The epidote is in granular and prismatic form with crystals up to 1 cm. in diameter, and it shows undulose extinction indicating straining. The diopside intermittently rims the pillow margins in rough prisms oriented perpendicular to the margins and is broken down marginally to the hornblende defining S_3.

An S_3 biotite-sericite foliation 1 - 2 mm. wide occurs in places. The biotite post-dates and replaces the hornblende and sericite is interleaved with the biotite. Rusty weathering chloritised biotite schist zones of D_3 age are also common northeast of Nash Lake and are up to 5 cms. wide. Relicts of biotite and saggenitic webes of rutile included in the chlorite show that the chlorite is diaphthoretic after biotite (Tilley, 1925). In these zones, xenomorphic microcline crystals up to 1 mm. in diameter occur and may form up to 25% of the rock. They include fine "droplets" of epidote and minute rods of amphibole, and also occasional curved Si trails of pyrite and magnetite that may represent S_2. S_3 forms slight augen around the microcline grains.

Local plagioclase veinlets up to 2 mm. thick have been boudinised by D_3. S_3 forms augen around the microboudins and pyrite and epidote occupy boudin necks. The plagioclase has been largely replaced by a felted aggregate of prehnite and sericite.

Post-D_3 prehnite and prehnite-scapolite veinlets 1 - 3 mm. thick are widespread; the scapolite generally lines the vein walls and the prehnite occupies the centres.

(iii) Hornblende schist

The amphiboles (0.1 mm.) are prismatic with a high degree of preferred orientation; occasional porphyroblastic amphiboles (1 mm.) of MP_2 age lie athwart this fabric. The amphibole-rich bands in the Post Hill Amphibolite that may represent chilled pillow margins consist of hornblende with approximately 5% pyrite. The hornblende varies from 0.3 - 1 mm. in grain size; the smaller prisms are aligned in S_2 and the larger ones tend to post-date these and to be randomly oriented (Fig. 89). Hornblende prisms (0.2 mm.) also occur aligned in the axial planes of S_3 kinks, truncating the amphiboles related to S_2.

The plagioclase together with minor quartz has subpolygonal grain boundaries with other plagioclase grains but has straight boundaries developed against amphibole facies. It occurs in evenly distributed grains and also in aggregates in thin hair line streaks 1 - 4 mm. long parallel to S; the latter gives the fabric its laminar aspect in hand specimen and may represent flattened phenocrysts or incipient metamorphic segregation.

Magnetite occurs as minute rods (0.05 mm.) aligned in S_2 and usually included within the amphiboles. Pyrite forms scattered xenomorphic grains up to 0.5 mm. in diameter that are most abundant in the amphibole rich bands. The pyrite is in places mobilised into the axial planes of S_3 kinks.

(iv) Iron formation members

(a) Cherty iron formations

The quartzite bands consist of an annealed fine-grained (0.1 mm.) sub-polygonal quartz mosaic showing triple junctions. Magnetite (5 - 15%) occurs in scattered grains up to 0.1 mm. in size and in aggregates associated with blue-green amphibole (5%) and stilpnomelane (3%). These three minerals occur in intersecting fine hair-line trails apparently outlining early healed fractures in the rock. The stilpnomelane occurs as minute (0.05 mm.) radiating sheaves nucleated on quartz grain boundaries. In the Inda Lake member, psammitic bands appear in a transition zone between iron formation and amphibolitic sediments. Here the bands are composed of a mosaic of quartz (60%), turbid sericitised plagioclase (25%), chloritised biotite flakes aligned subparallel to SS (10%), minute subidioblastic garnet (.05 mm.; 3%) and accessory epidote (2%). The garnets in places occur in aggregates (0.25 mm.) of coalescing grains, around which S_2 forms a slight augen.

The mafic bands consist of tremolite-actinolite, magnetite (0 - 90%); garnet and finely divided opaque material (probably graphite). The tremolite-actinolite (generally the major constituent) is colourless, non-pleochroic and occurs in sheaves and rosettes of radiating needles .5 to 10 mm. in size. Fine-grained opaque particles, probably mainly graphite, are included within or localised along grain boundaries of the tremolite-actinolite crystals, and in places define fine laminae (S_1 or S_2) overgrown by the tremolite-actinolite. The garnet occurs as xenomorphic, ovoid or subidioblastic crystals 0.1 to 1 mm. (though rarely up to 2.5 mm.) in diameter and contains inclusions which in some crystals are in a crude sectored arrangement. The garnets are rimmed by graphite, presumably expelled from the crystal while growing, and relic graphitic laminae (S_2) form augen around the crystals. In places, the crystals are cut by quartz-filled fractures oriented at right angles to the relic S_2. Pyrite occurs as disseminated fine grains and also as occasional idiomorphic porphyroblasts up to 3 mm. in diameter which in places are nucleated on small scale D_2 slides.

Locally a zone of inclusion-free tremolite-actinolite 0.5 to 1 mm. thick occurs at the contacts between quartzitic and mafic bands. The amphibole occurs in radiating acicular form and appears to have nucleated on the sharply defined border of the mafic material, and has grown into the quartzite.

(b) Pelitic and semi-pelitic rocks

The graphitic pelite is composed of 30% biotite, 25% quartz-feldspathic matieral, 15% opaques, 5% andalusite, 5% garnet and 5% muscovite. Staurolite, chloritoid and tourmaline are occasionally present. The biotite occurs in oriented flakes 0.2 - 0.5 mm. long, is pleochroic from almost colourless to pale orange brown and shows two growth stages related to D_2 and D_3. It contains extremely fine graphite inclusions which are occasionally abundant enough to render some grains nearly opaque. The quartz and plagioclase is in an extremely fine-grained mosaic obscured by abundant scattered graphite particles. The plagioclase is zoned and untwinned. Opaque material including pyrite and magnetite also occurs in lenses aligned in S_3 and which overgrow the S_2 biotite.

The andalusite occurs in unoriented prisms up to 2.5 cm.s long containing dendritically arranged inclusions, and also forms xenoblastic poikiloblasts preferentially replacing bedding laminae.

The garnet forms idioblastic crystals (1 - 4 mm.) the faces of which generally sharply truncate S_2 and S_3, though S_2 forms an augen around some of the crystals. Poikiloblastic garnets in places contain inclusion trails that are straight in the centre of the grains but curve sharply into S_2 at the rims which are clear of inclusions and idioblastic. In the South Showing zone a biotite-poor lithology with 15% epidote and sphene contains idioblastic garnets 1 mm. in diameter with tubular inclusions arranged in sectors. The cubic outline of some of the crystals with indented corners and the suggestion of graphite inclusion arranged along the diagonals of the cubes suggests that the sectored arrangement reflects initial rapid dendritic growth followed by more complete layeritic growth infilling between the dendrites (cf. Rast, 1966).

Muscovite occurs as randomly oriented, often poikiloblastic flakes up to 2 mm. long that overgrow both S_2 and S_3, and in places include S_2 as a trail of fine graphite particles. The muscovite also occurs in mimetic flakes parallel to S_2, and as folia inter-leaved along the cleavage of both S_2 and S_3 biotite crystals. Muscovite porphyroblasts and irregular masses of sericite replace the andalusite locally.

Unoriented prisms of partly chloritised chloritoid up to 2 mm. long were noted locally in the South Showing Zone. They show a faint pleochroism from nearly colourless to a yellowish tinge, and polysynthetic twinning masked by chloritisation. Staurolite occurring in radioactive semipelite at the South Showing is xenomorphic and contains inclusion trails of graphite particles defining S_2. Up to 70 cms. of tourmaline schist occurs between iron formation and quartz porphyry at the south end of the South Showing. Tourmaline rich laminations alternate with quartz rich laminations. The tourmaline is pleochroic from pale olive brown to olive brown and occurs in stubly prisms 0.1 mm. long aligned parallel to the laminations and defining S_2.

(c) Psammite

The psammitic unit in the South Showing Zone shows a mosaic of quartz and plagioclase with many curved and lobate grain boundaries, but some triple point junctions are developed. The plagioclase is zoned and untwinned (2V 90°). The tremolite-actinolite needles are colourless and partly chloritised in places. The biotite is in unoriented flakes up to 0.5 mm. long.

(d) Amphibolitic sediments

The amphibolitic sediments consist of approximately 30% biotite, 25-40% quartz and plagioclase, up to 35% amphibole, 18% garnet and 7% opaques. The biotite is pleochroic from pale straw to reddish brown and occurs as 0.2 mm. flakes oriented to define the fabric. The quartz and untwinned zoned plagioclase form a fine grained mosaic texturally similar to that in the semipelitic rocks described above.

The amphibole in the more biotite rich types is pleochroic from very pale green to green and occurs in sub-idioblastic porphyroblasts mostly aligned parallel to L_1. The crystals are marginally recrystallised to finer grained but similar type amphibole related to S_2. Some of the porphyroblasts lie across the L-S fabric which forms augen around them. Amphibole porphyroblasts pre-dating S_2 from the North Showing zone include an early fabric defined by minute opaque rods (Fig. 15). In more psammitic types the amphibole is colourless and often acicular, and appears to be of tremolitic composition.

The garnet occurs as idioblastic crystals up to 5 mm. in diameter which contain a fairly straight Si of small opaque rods that curves into Se at the margins of the crystals. The garnets also include unoriented prisms of colourless amphibole up to 0.7 mm. long that include an Si of opaque rocs continuous with the Si in the garnet (Fig. 16). Thus the amphibole in the garnet appears to be of the same generation as the green amphibole in the matrix, and to have been overgrown by the garnet. The difference in colour suggests that ionic diffusion of Fe took place from the included amphibole into the garnet; in some of the included crystals the colourless amphibole merges into pleochroic green cores.

Undetermined radioactive mineral(s) occur in minute particles up to 0.001 mm. in diameter included in the amphibole and biotite and are surrounded by dark brown pleochroic haloes. The radioactive particles tend to be concentrated along discrete S planes, and where numerous, amphibole appears to be metamict and shows brown pleochroism, and the biotite is pleochroic from pale brown to black.

(e) Pyroxene-bearing boudins

The boudinised mafic horizons in the semipelites in the Kitts

"Main Zone" consist of a generally very fine-grained indefinite mosaic of epidote, sphene, zoisite and quartzo-feldspathic material, with bands 1 - 33 mm. thick that contain an extremely fine streaky fabric defined by finely comminuted opaque material. This fabric, S_1, is included as Si in relatively coarse (2 mm.) unoriented porphyroblastic amphibole and diopside. The amphibole and diopside appear to be of the same age; the former is in places idioblastic, uniformly pleochroic from pale green to olive green, and shows no relic cores of pyroxene. However, there is some alteration of pyroxene to amphibole which is probably related to D_2, as some porphyroblasts have inclusion-free overgrowths indicating a period of minor secondary growth. MP_1 metamorphic diopside also occurs in a boudin in the North Showing Zone; it replaces lithologic bands and encroaches as an optically continuous film along grain boundaries of probably MP_1 quartz-plagioclase mosaic.

Diopside also occurs in thin veinlets with quartz, and quartz and microcline. These veinlets truncate S_1, and have been boudinised by D_2. Diopside-microcline veinlets in the Inda Lake Member have been streaked out on S_2, but the microcline has subsequently recrystallised into a limpid unstrained optically continuous form. Boudins of relatively coarse grained mosaic of diopside (up to 66 mm.) occur in the Main Zone and Gear Showing Member (Fig. 17) and may represent boudinised larger-scale veins. They show only minor marginal alteration to amphibole, although the crystals have been strained.

METASEDIMENTARY FORMATION

(i) Psammites

The less recrystallised psammites in the Post Hill Fold consist of a subpolygonal mosaic of quartz and plagioclase (c. An 28) grains 0.5 mm. in diameter with minute flakes of biotite and minor muscovite 0.2 mm. in size showing a weakly to well developed preferred orientation (Figs. 24, 27 and 28). The quartz grains are strained, show internal sub-boundaries and occasionally have decussate grain boundaries. The plagioclase is largely untwinned but the extinction indicates many grains to be strongly zoned. The mica flakes generally occur along or astride quartz-feldspar grain boundaries, and show two stages of growth related to S_2 and S_3. Biotite is partially retrogressed to chlorite. The shapes of original detrital grains are approximately outlined by biotite flakes indicating a pelitic content in the original matrix. Relics of authigenic overgrowths on detrital quartz grains are in places picked out by inclusions of minute biotite flakes near the margins of the grains, or more clearly by a rim of fine graphite dust (Fig. 24). These rims show that the grains were subrounded. The authigenic overgrowths have been obscured by deformation but optical continuity with the parent grains can often be seen. Accessory magnetite occurs in subidiomorphic grains 0.1 mm. in diameter, and pyrite occurs in xenomorphic grains of approximately the same size. Epidote, tourmaline and apatite also occur in minor amounts.

The more highly recrystallised psammites are mineralogically similar but show a coarser and better developed sub-polygonal quartz-plagioclase fabric. Consequently a detrital texture is no longer apparent in thin section, but vestiges of detrital grains are occasionally seen as clear areas up to 0.5 mm. in diameter of quartz mosaic free of biotite flakes (Fig. 137). The plagioclase (An 28-40) is frequently untwinned and occurs in xenomorphic crystals which in places contain very fine-grained dust-like inclusions, probably of epidote. The biotite is pleochroic in either brown or green, and muscovite may form up to 20 per cent of the total micas.

(ii) Semipelites

The less recrystallised semipelites in the Post Hill Fold consist of fine-grained biotite flakes 0.1 mm. long with interstitial quartz and indeterminate plagioclase. The biotite, as in the psammites, is pleochroic in brown. The quartz and plagioclase occurs as extremely fine grains showing uneven extinction, and they have straight grain boundaries with the biotite flakes. Accessory magnetite occurs in minute rods and subidiomorphic grains 0.1 mm. in diameter. Pyrite occurs in occasional xenomorphic grains 0.1 mm. in diameter. Tourmaline pleochroic in blue-green, occurs in stubby idiomorphic prisms up to 0.2 mm. long. Apatite, epidote and sphene are also present in accessory amounts.

Porphyroblasts of plagioclase, chloritoid, garnet and muscovite were noted at several localities close to the contact with the Post Hill Amphibolite. The plagioclase (C. An 28) porphyroblasts are roughly ovoid, up to 0.8 mm. in diameter and contain straight inclusion trails of biotite, chlorite after biotite, epidote and magnetite. The chloritoid occurs in randomly oriented prisms up to 0.8 mm. long that show simple and polysynthetic twinning; they include rods of magnetite and xenomorphic quartz blebs. The garnet is in subidiomorphic crystals up to 3 mm. in diameter that show straight inclusion trails of quartz and magnetite. The muscovite is in randomly oriented flakes up to 1 mm. long that grow across the biotite flakes.

The more recrystallised semipelitic schists consist of biotite and muscovite flakes 0.5 - 2 mm. long, quartz, plagioclase and accessory apatite, tourmaline, opaques and sphene (Figs. 30 and 31). The micas tend to be segregated into folia alternating with quartzo-feldspathic folia 0.5 mm. thick. Quartz and feldspar form a xenomorphic mosaic showing curved and indented grain boundaries. In places the grains show a dimensional orientation parallel to the schistosity. Quartz and plagioclase are also elongate where sandwiched between mica flakes. The plagioclase is frequently untwinned. Where late crenulations are strong, glide twins are common. The plagioclase shows curved inclusion trails of thin rod-like grains that represent relics of included micas. Garnet occurs locally in subidiomorphic crystals that occasionally show a two-stage growth history. The accessory minerals are as described for the psammites.

(iii) Graphitic Member

The graphitic slate consists of black opaque matrix containing very fine quartz grains and minor flakes of biotite up to 0.05 mm. long. The opaque material appears to be composed of an amorphous aggregate of extremely fine graphite particles. The quartz grains are lens shaped and show a preferred orientation that together with the biotite flakes define the fabric of the rock. The quartz contains graphite incusions and has diffuse boundaries with the opaque material. Pyrite occurs in xenomorphic lenses oriented parallel to the fabric, and occasionally in cubes up to 2 mm. across.

The graphitic metasiltstones in the core of the Post Hill fold are similar to the non-graphitic lithologies described above, except that the quartz-feldspar mosaic is obscured by fine graphitic particles that tend to be concentrated along grain boundaries.

The more recrystallised schistose semipelite and psammites are petrographically similar to their equivalents outside the member as their graphite and pyrite content is small. The graphite tends to be dispersed in fine-grained particles throughout the quartz and feldspar grains. Garnet is common as subidiomorphic porphyroblasts up to 4 mm. in diameter; some are poikiloblastic and show straight inclusion trails of quartz biotite and magnetite.

CONGLOMERATE FORMATION

In thin section, the psammite clasts are frequently difficult to distinguish from the matrix which is of similar composition. All psammitic and volcanic lithologies forming the cobbles are petrographically similar to their equivalents in the Aillik Group formations; except for the amphibolitic clasts in the Turnip Lake-Gear Lake belt. These consist of an aggregate of xenomorphic epidote, sub-prismatic pale green actinolite, quartz and albite. Pale yellow isotropic metamict orthite is commonly associated with the epidote. Some mafic pebbles are partly recrystallised to an aggregate of coarse (5 mm.) epidote.

The granodiorite cobbles are composed of a leucocratic and xenomorphic aggregate of plagioclase 40%, microcline 30%, quartz and accessories 5%. The plagioclase is frequently untwinned and commonly zoned, ranging in composition from partly saussuritised oligoclase in the cores of grains to narrow rims of clear albite. In many grains the plagioclase includes rectilinear shaped inclusions of microcline in optical continuity with a rim of clear microcline suggesting replacement of plagioclase by microcline. Microcline also occurs in discrete grains and intergranular patches. Quartz grains are strained and generally partly broken down to a fine-grained mortar texture.

The matrix of the conglomerate consists of a fine-grained xenomorphic mosaic of quartz, plagioclase and microcline. Within the Turnip Lake-Gear Lake belt, mafic minerals are represented by scattered xenomorphic and subidiomorphic grains of epidote, many of which have reddish brown cores of orthite, and scattered ragged prisms of actinolite. In the conglomerates of the Duck Pond-Limestone Lake belt the mafic minerals are represented chiefly by biotite (pleochroic in green), epidote and hornblende.

BANDED TUFF FORMATION

Plagioclase, K-feldspar and quartz occur in an aggregate of xenomorphic grains with subidiomorphic crystals of amphibole, diopside, epidote, muscovite, biotite and accessories. The relative proportions of minerals vary widely from bed to bed. The quartz and feldspar grains in places show a weak dimensional preferred orientation. Their grain boundaries are commonly curved and lobate with local suturing. Straight grain boundaries with triple points are locally developed notably in the Limestone Lake slice. The plagioclase is calcic oligoclase; it may show alibte and pericline twinning but is commonly untwinned. The K-feldspar consists of microcline and untwinned orthoclase, some of which is perthitic (string type, Alling, 1938). Locally subrounded, detrital quartz, plagioclase and microcline grains up to 1 mm. in diameter occur in a fine-grained matrix. Some of the quartz grains contain fine biotite inclusions that define the shape of the original detrital grains and their authigenic overgrowths (Fig. 138). The plagioclase grains contain many minute quartz blebs elongated parallel to albite and pericline twin directions (former dominant) and also larger irregular inclusions of microcline. These textures are similar to thoes noted in plagioclase phenocrysts in the rhyolites.

The amphibole is sub-prismatic (up to 1.5 mm. long) and is commonly hornblende with a pleochroic scheme similar to that in the mafic volcanics. Some grains are mottled with pale green actinolite parts; this may indicate a miscibility gap between actinolite and hornblende; tremolite occurs instead of hornblende in some beds. The amphiboles show a weak to good preferred orientation.

The diopside is in subidiomorphic equant grains 0.1 - 1.0 mm.

in diameter and may exceed, equal or be subordinate to amphibole in the green beds; in places it may be the only mafic mineral present (Fig. 139). Epidote occurs in subprismatic and xenomorphic grains up to 0.2 mm. in diameter that frequently contains cores of orthite. The orthite has given rise to pleochroic haloes where epidote grains abut against, and are included in hornblende.

Muscovite and minor biotite is common in the banded tuffs just south of Kiwi Lake in flakes up to 1.5 mm. that belong to two growth stages defining S_2 and S_3 (Fig. 37). Accessory minerals include widely scattered subrounded droplets of sphene and xenomorphic grains of apatite generally less than 0.1 mm. but sometimes up to 0.2 mm. in size. Locally restricted minerals include garnet, in granules (0.2 mm.) forming 10% of fine-grained streakily laminated pale green tuff east of Witch Lake. Piedmontite occurs in a band of fine-grained red cherty sediments that crops out on the southwest shore of Limestone Lake. Rare fluorite was noted in a few specimens.

The rhyolitic tuff just northeast of Fiace Lake consists of lensoid clasts (flattened in the plane of S_3) of grey rhyolite containing quartz and feldspar phenocrysts, with pale quartzofeldspathic interstitial material. The rhyolite groundmass is a very fine-grained mosaic of xenomorphic quartz-plagioclase-K-feldspar grains with scattered minute opaque rods and flakes of biotite oriented in S_3. Staining shows that K-feldspar and plagioclase alternate as the dominant feldspar in streaky bands 0.1 - 0.5 mm. thick; this differentiation may result from devitrification.

The marble consists of a mosaic of xenomorphic to subpolygonal grains of calcite 0.1 - 0.5 mm. in diameter. The calcite crystals often show a dimensional orientation parallel to S_4. Scattered subidiomorphic grains of diopside tremolite and tremolite-actinolite are common and also occur in trains with xenomorphic grains of quartz feldspars. Poikiloblastic diopside crystals up to 5 mm. long by 1 mm. wide orientated in these bands were noted. Diopside in tuff interbanded with the marble is in places included within microcline porphyroblasts that also have peripheral inclusion trails of quartz and biotite. The calcareous bands in the banded tuffs consist of calcite grains varying in size from 0.2 mm. to less than 0.02 mm. scattered among the normal constituent minerals of the banded tuffs; they show subpolygonal calcite-calcite boundaries, but grain boundaries with quartz and feldspar are often indented and serated.

RHYOLITE FORMATION

The groundmass of the flow banded rhyolites consists of an ultrafine cherty-type mosaic of quartz, plagioclase and K-feldspar with scattered fine xenomorphic grains of opaques, calcite and biotite flakes with extremely fine grained almost submicroscopic dust-like particles distributed throughout and probably responsible for the pink colouration of the rock. Calcite, opaques (chiefly pyrite) and the fine particulate matter tend to be concentrated in trains and zones that define the laminations. Apatite is present in accessory amounts. The lithic fragments in the streaky rhyolites are texturally identical to the groundmass material of the flow banded-rhyolites, but are distinguished by slightly varying proportions of the fine opaque "dust". The groundmass in the massive rhyolite of the Turnip Lake-Gear Lake is similar but it tends to be coarser grained and it also contains scattered clusters of ragged tremolite-actinolite prisms (0.2 mm.) associated with xenomorphic magnetite and sphene. Some of the tremolite-actinolite prisms are partly rimmed by riebeckite.

The quartz phenocrysts are partly or wholly broken down to a fine-grained xenomorphic mosaic; remaining parts of the original phenocrysts are highly strained. In places the subgrains also show strain-shadowing and have indentate or sutured grain boundaries; this is probably related to D_4-D_5 cold working. Quartz also occurs in places in thin lenticular stringlets of grains aligned parallel to S_3. Two types of plagioclase phenocrysts occur; one show normal albite twinning and has composition of An 28-32. The crystals are subhedral to ovoid in shape and tend to be strained with local replacement by quartz in trains parallel to S_3. The other type consists of albite and shows indistinct lamellar twinning that appears to be of albite type vaguely combined with pericline type; it locally shows a tendency to form more sharply defined chequer-albite twinning. In one instance the two types were noted in a single phenocryst with the albite appearing to replace the An 30. A process of sodafication on conversion of the more calcic plagioclase to albite is suggested. Soda-metasomatism need not be involved.

The plagioclase phenocrysts in the andesitic horizons are subhedral and show albite twinning; in places they are strongly strained and fractured showing undulose extinction and bent or microfaulted lamellae. Minor microcline crystals are present locally, but are not fractured like the plagioclase. The groundmass is a xenomorphic quartz-plag mosaic with interspersed biotite flakes that may form up to 38% of the groundmass. The biotite is pleochroic in brown or pale olive and is commonly partly or totally retrogressed to chlorite. Variable amounts of carbonate (up to 60%) in crystals up to 0.2 mm. replace the groundmass and also penetrates feldspars along fractures. The biotite or chlorite flakes show a moderate to strong preferred orientation defining S_3 and tend to form augen around the phenocrysts. Magnetite occurs in xenomorphic grains, and sphene in scattered droplets of lensoid aggregates up to 0.3 mm. long aligned in S_3. The black material outlining the clasts is similar to the groundmass material except for greater abundance of biotite and magnetite and the presence of extremely finely divided opaque particles, possibly of haematite as they appear to be responsible for a local pinkish tinge in hand specimen.

REMOBILISED HOPEDALE COMPLEX

i) Refoliated Gneiss

The constituent minerals have been noted in Chapter IV. The texture of the gneiss depends on whether the dominant fabric is S_2, as in the envelope of Post Hill, or S_3 as in the zone east of Brumwater Lake. Quartz, sodic andesine and minor microcline in xenomorphic grains averaging 0.1 mm. in diameter, with curved and indented grain boundaries form the main part of the rock. Where S_2 is dominant, e.g., Fig. 50, quartz occurs in trains of grains that form narrow lenticles 2 - 10 mm. long in the direction of the lineation, but that are seen as stout lenses 0.2 mm. long in the plane perpendicular to this direction. Xenomorphic grains of epidote associated with granles of sphene tend to occur in trains that emphasise the fine stripey texture produced by the quartz lenticles. Biotite is pleochroic in olive green and occurs in flakes 0.1 mm.

that are moderately orientated in S_2. Scattered flakes show a preferred orientation lying across the main fabric and define S_3. Scattered microcline lenses up to 2 mm. thick are partially broken down to a fine microcline mosaic, and the remaining portions are intergrown with optically continuous andesine that appears to replace the K-feldspar. These augen are also seen in leucocratic lenses 1.5 mm. thick of quartz-microcline-plagioclase mosaic that appear to represent relic leucosome veins.

Where S_3 is dominant the streaky S_2 fabric has been recrystallised and the gneiss consists of an even-textured disequilibrium mosaic of xenomorphic quartz and andesine crystals 0.1 - 0.2 mm. in diameter with scattered biotite flakes 0.2 mm. long showing a moderate degree of preferred orientation (Fig. 52). The plagioclase shows normal and reverse zoning in the range An 38-26. Apatite typically occurs in rounded or sub-prismatic crystals 0.2 mm. in diamater regardless of the intensity of the fabric whether S_2 or S_3.

ii) Foliated granitic rocks

The grey granodiorite consists of xenomorphic crystals of: sodic andesine and less abundant microcline that are marginally broken down to fine-grained aggregates; irregular patches of xenomorphic quartz crystals 1 - 2 mm. in diameter that appear to represent the original quartz grains, all in a matrix of xenomorphic quartz, andesine and minor K-feldspar crystals 0.3 - 0.1 mm. in diameter. Scattered fine flakes of biotite are pleochroic in olive green and tend to vaguely outline patches of mosaic c. 2 mm. in diameter that appear to represent the outlines of original feldspar crystals. In the darker granodiorite biotite occurs in elongate lensoid clots of fine flakes. Muscovite occurs in relatively coarse flakes up to 0.5 mm. long that tend to be in lensoid aggregates. The biotite and muscovite flakes shows a preferred orientation defining S_2 with a later growth stage defining S_3 axial planar to crenulations in S_2.

In the porphyritic granite the phenocrysts are of microcline and show relic carlsbad twins in hand specimen but patchy microcline cross hatched twinning in thin section indicating that primary orthoclase has inverted to microcline. The microcline shows undulose extinction and is marginally broken down to a fine aggregate of xenomorphic microcline, quartz and plagioclase crystals. The phenocrysts are also traversed by seams of granular quartz, oligoclase and microcline and calcite replaces microcline along sub-boundaries. The pale lenses in the groundmass are composed of aggregates of xenomorphic quartz crystals and appears to represent stretched and broken down original quartz grains. The grey groundmass consists of a mosaic of xenomorphic quartz, oligoclase-andesine and microcline crystals 0.1 mm. in diameter with fine biotite flakes showing a preferred orientation. The biotite tends to be differentially concentrated to define darker streaks. There is also a tendency for microcline-rich and plagioclase-rich streaks to alternate at about 0.4 intervals; the plagioclase-rich streaks are distinguished by the slightly turbid nature of the plagioclase due to incipient alteration. The streaky fabric of the groundmass is believed to result from the breaking down and flattening of a coarse K-feldspar-plagioclase-quartz-biotite aggregate. Prismatic orthite rimmed with epidote, sphene and apatite are accessories.

The essential petrographic feature of the intensely deformed granites, the break down and flattening of K-feldspar crystals into fine lenticular laminae has been described above (Figs. 42 and 43). The intervening grey laminae consist of a very fine mosaic of xenomorphic quartz and feldspar crystals 0.1 mm. in diamter, with interstitial fine-grained sutured quartzo-feldspathic material including oriented green biotite flakes up to 0.1 mm. long.

iii) Quartzitic mylonite

The quartzite consists of elongate strained quartz grains up to 0.5 mm. long with sutured grain boundaries separated by irregular zones of sutured quartz mosaic (Fig. 51). Muscovite flakes up to 0.2 mm. long with a moderate degree of preferred orientation occur distributed evenly in the interstitial quartz mosaic and also are concentrated on discrete regular planes that form partings. Epidote occurs in scattered elongate and subprismatic crystals strongly oriented in S_3 and show two growth stages, the later of which produced idiomorphic overgrowths. Occasionally epidote crystals include bent fibrolite. Minor amounts of tourmaline and chlorite after biotite also occur.

The typical quartz-muscovite schist marginal to the quartzitic mylonite consists of lenticles up to 2 mm. thick and 1 - 3 cm. long composed alternately of muscovite and quartz with minor oligoclase, biotite and accessory tourmaline, apatite, epidote and opaques. The quartz lenticles consist of strained xenomorphic quartz crystals up to 0.5 mm. in diamter with indented grain boundaries. They include small flakes of muscovite and biotite oriented parallel to the lenticles and also ocoid crystals of untwinned oligoclase up to 1 mm. in diameter sieved with minute quartz blebs. Some of the oligoclase crystals contain patches of albite-quartz myrmekite and small irregular fins of microcline, and other plagioclase crystals are composed solely of an aggregate of myrmekite. The schistosity forms augen around the plagioclase crystals, some of which contain a sigmoidal included fabric of muscovite flakes. The muscovite lenticles consist of oriented muscovite flakes up to 1.5 mm. long with occasional green biotite selvages. In places the schistosity includes lenses containing an early generation of oriented muscovite flakes. Ragged oligoclase porphyroblasts up to 1 mm. in size occur in places within the muscovite lenticles, and overgrow the schistosity and trains of opaques and tourmaline lying in the plane of the schistosity. Tourmaline is a conspicuous accessory occurring in prisms up to 0.4 mm. long aligned in L_2-L_3; it is strongly pleochroic from colourless to green, and in basal sections is seen to be zoned with blue-green cores and olive green rims.

Where the schist grades into refoliated gneiss the quartz lenticles are not well developed but the rock contains the characteristic lenticles of muscovite. It consists of roughly ovoid andesine, microcline and intergrown andesine and microcline crystals 1 mm. in diameter that are broken down to sub-grains separated by zones of fine mortar texture, with many showing nearly total breakdown to very fine quartz and feldspar mosaic. The original outlines of the parent grains can be seen in plane polarised light picked out by biotite flakes. The biotite flakes and muscovite lenticles are aligned in a fabric that forms augen around the relic feldspar crystals. Quartz occurs in irregular patches and lenses of mosaic. Biotite also occurs in a later generation of flakes aligned in the axial planes of crenulations in the main fabric.

iv) Contact Zone

The refoliated gneiss in the bands in the contact zone is petrographically similar to the gneiss in the main part of the refoliated zone. The amphibolite bands in the contact zone east of Brumwater Lake are petrographically identical to the hornblende schist along the Fiace Lake Slide. However, in the contact with the Post Hill Amphibolite they may contain up to 25% biotite, pleochroic in brown and in flakes up to 0.5 mm. long. Both biotite and hornblende occur in two generations related to S_2 and S_3 but the biotite is recrystallised in S_3 to a greater extent than hornblende.

UNLUCKY HEAD MIGMATITE

The neosome is composed of about 30% quartz, 30% perthitic microcline, 20% oligoclase (An 20), 5% biotite and minor myrmekite with accessory apatite, magnetite, sphene, epidote, chlorite and muscovite. The grain size averages 2 mm. and the texture is hypidiomorphic granular though the idiomorphism of the plagioclase is not nearly as marked as Mehnert (1968) suggests is characteristic of plutonic migmatites.

The perthitic microcline (string type) is in xenomorphic crystals generally 1 - 6 mm. in diameter though scattered crystals up to 1 cm. or more in diameter occur. About half of the crystals show cross hatched twinning (often patchy), and the rest are untwinned.

The plagioclase occurs in subidiomorphic to xenomorphic crystals 1 - 3 mm., and occasionally up to 6 mm., in diameter. Some grains show albite twinning, but most are untwinned; all show incipient sericitisation. The quartz is in irregular-shaped aggregates up to 3 mm. in size, interstitial to and moulded around the feldspars. The quartz grains are strained with irregular curved and indented grain boundaries, and the aggregates as a whole show a very weak dimensional preferred orientation. Biotite, strongly pleochroic in greenish brown, occurs in scattered flakes that show a very weak preferred orientation. It is locally interbanded with fine muscovite, and in places is chloritised.

Quartz, plagioclase and microcline also occur in irregular interstitial aggregates up to 2 mm. across in which the grain size is 0.2 mm. The plagioclase is in places myrmekitic and the aggregates include partially chloritised biotite flakes up to 0.5 mm. long. Myrmekite also protrudes from the borders of these aggregates into adjacent microcline crystals. These aggregates may represent relics of palaeosome as the amount of deformation suffered by the rock is too weak for them to represent breakdown textures.

In the biotite selvages of the amphibolite pods the replacement of hornblende by biotite takes place in a zone about 8 mm. wide (Fig. 64). Between this zone and the contact with the neosome the biotite shows a variation in texture and colour indicating a compositional change. In the zone of replacement is it moderately pleochroic in green and contains a fine myrmekite-like vermicular quartz intergrowth. The resemblance to myrmekitic texture is particularly striking in some examples in which very fine quartz vermicules are arranged at right angles to grain boundaries with hornblende (Fig. 140). This fine vermicular type merges in places into a coarser graphic textured intergrowth (Fig. 141). About 5 - 10 mm. from the replacement zone the biotite becomes strongly pleochroic from pale straw to dark green brown, and the quartz intergrowths disappear. Further towards the neosome contact the pleochroism becomes less intense.

The similarity of the vermicular quartz-biotite intergrowth to myrmekite suggests that it is also of exsolution origin (cf. Hubbard, 1968).

The fabric of the biotite in the selvages is problematical; in outcrop it is seen that the biotite flakes are arranged parallel to the contacts, regardless of the orientation of the contacts, and complex strain-slip fabrics are developed where the selvages are pinched in between convex lobes of neosome. In thin section at least two stages of biotite growth are apparent.

THE BRUMWATER GRANITE

The model composition is approximately 35% quartz, 35% microcline, 25% plagioclase (An 20) and 5% biotite with accessory myrmekite, muscovite, magnetite and epidote. Where S_3 is weak the texture is hypidiomorphic granular and very similar to that in the neosome of the Unlucky Head Migmatite. The plagioclase is subidiomorphic and show albite and combined albite-pericline twinning, and the microcline is in xenomorphic form. Where S_3 is well developed the plagioclase crystals are partly broken down to xenomorphic grains about 0.2 mm. in diameter, and the subidiomorphic outline of the parent grains is lost as they become drawn out in the plane of S_3. Microcline shows a similar effect but to a lesser degree, and the quartz forms lenticles of xenomorphic crystals. In places close to the Refoliated Zone where S_3 is locally intense the original coarse texture is completely broken down to an aggregate of xenomorphic crystals 0.4 mm. in diameter in which the only relics of the origial grains are trains of microcline crytals and thin quartz streaks.

MIGMATITIC QUARTZ MONZONITE

The K-feldspar is microcline, usually with well developed cross-hatched twinning; relic carlsbad twinning indicates inversion from primary orthoclase. The crystals are anhedral to subhedral, and where S_3 is weak they are traversed by intersecting bands of a fine granular aggregateof quartz, K-feldspar and plagioclase (Fig. 80). The bands broaden as S_3 becomes more intense until they engulf most of the original crystals leaving small islands of microcline that extinguish in unison.

The plagioclase (An 28) is subhedral and shows poorly developed albite, combined albite pericline, and some carlsbad twinning. It shows normal zoning and the cores of the crystals tend to be preferentially saussuritised. The plagioclase is also partially or totally broken down to a fine-grained aggregate. The breakdown appears to be initiated by development of irregular sub-boundaries, rather than by discrete bands of granulation as in the microcline.

The biotite is pleochroic in olive green and occurs interstitially in 0.05 mm. flakes that usually form irregular aggregates up to 2 mm. in diameter. The flakes show a weak to good degree of preferred orientation and are locally retrogressed to chlorite. Quartz occurs in interstitial lenses and is moulded around idiomorphic feldspar crystals. The lenses consist of a xenomorphic mosaic of quartz crystals 0.2 mm. in diameter with indented grain boundaries. Sphene occurs in the intersteces in euhedra up to 1 mm. long and also in anhedral grains, some of which mantle ilmenite. The sphene is usually associated with the biotite aggregates as is epidote which occurs in subidiomorphic to xenomorphic crystals. Occasional prisms of metamict orthite occur and are often mantled with epidote.

The mylonite is composed of fine-grained quartz, feldspar and biotite with accessory sphene epidote and orthite, and shows alternating pale grey and dark grey streaky laminations 1 - 3 mm. thick. The pale grey laminae consist of xenomorphic quartz and feldspar grains 0.02 mm. in diameter with occasional wisps of biotite flakes, and the darky grey laminae contain about 15% biotite (Fig. 83). The biotite flakes are 0.2 mm. long and show a strong preferred orientation parallel to the laminations. The biotite forms augen around scattered lenses of quartz mosaic up to 2 mm. long and 0.5 mm. thick.

KITTS METAGABBRO

Tremolite-actinolite (50-65%) occurs in two optically identical habits that pseudomorph subhedral pyroxene forms averaging 2 mm. in diameter (Fig. 86); large poikilitic crystals envelope and appear to be replacing irregular patches of felted radiating acicular prisms. The amphibole is nearly colourless but is faintly pleochroic in pale green; green pleochroic amphibole occurs adjacent to the quartz porphyry dyke southwest of the adit.

Plagioclase occurs interstitially and is generally obscured by heavy saussuritisation; no euhedral forms appear to have been developed and relic sub-ophitic texture was not recognised. Where the plagioclase has survived it is seen to be oligoclase, partly broken down to a very fine subpolygonal mosaic. Sphene and biotite are accessories and the saussurite is composed of epidote, carbonate and sericite. Prehnite veinlets 0.2 mm. thick are common.

Diopside occurs wihtin 1 mm. of the contact of a quartz porphyry dyke south of the main zone, and the amphibole close to the contact is greener and more strongly pleochroic.

INDA METTAGABBRO

The hornblende occurs in lensoid aggregates about 8 mm. long and 1 - 2 mm. thick consisting of aligned prismatic crystals about 1 m. long. The andesine occurs in similar aggregates of fine polygonal crystals that are largely untwinned. These aggregates are relics of the primary coarse gabbroic texture, and together with oriented hornblende crystals serve to define S_2. Accessory epidote occurs in scattered xenomorphic grains 0.2 mm. in diameter, and in idiomorphic crystals associated with hornblendé. Aggregates of fine-grained sphene up to 0.5 mm. in diameter are associated with the hornblende aggregates, and in places poikilitically enclose small hornblende prisms.

The fine-grained rock on the contact with the iron formation is composed of a subpolygonal andesine-quartz mosaic with scattered hornblende ilmenite pyrite and epidote crystals, and irregular streaks containing fine-grained oriented hornblende prisms. Sphene occurs in lensoid aggregates 1 mm. in diameter that mantle xenomorphic ilmenite crystals. The hornblende veinlets consist of hornblende prisms up to 0.5 mm. long aligned in S_2, with scattered xenomorphic pyrite grains. The hornblende includes many radioactive specks surrounded by brown pleochroic haloes. Scattered crystals of metamict orthite are associated with these 'veinlets'. The diopside in boudin-like pods pre-dates the hornblende fabric, and is largely altered to tremolite-actinolite. This alteration post-dated the hornblende fabric.

The amphibole schist southwest of Knife Lake is composed of prisms of tremolite-actinolite 1 mm. long showing a strong preferred orientation, with interstitial polygonal albite, quartz and carbonate grains, and in places oriented sericite flakes. Pale yellow to orange metamict orthite and epidote forms 15-20% of the rock and occurs in scattered subidiomorphic crystals 0.1 - 0.5 mm. in diameter.

QUARTZ PORPHYRY

The major mineral constituents have been noted above, and pyrite, tourmaline rarely orthite and zircon are present in accessory amounts. The quartz grains are strained and are usually broken down to about 6. - 10 subgrains with irregular indented grain boundaries (Fig. 87). However, where the rock is strongly deformed they have recrystallised to a fine polygonal mosaic of quartz grains (Fig. 142).

The plagioclse phenocrysts show albite twinning and in places are recrystallised to subgrains. The K-feldspar phenocrysts are perthitic and are also broken down to subgrains 0.3 mm. in diameter that show patchy cross-hatched twinning. The quartzo-feldspathic groundmass shows a fine-grained xenomorphic mosaic in which the quartz grains are usually lensoid with a preferred dimensional orientation. In places subpolygonal grain boundaries are developed.

The biotite, pleochroic in greens and browns, and muscovite occur in oriented flakes 0.05 - 0.1 mm. in diameter. Radial sheaves of biotite (pleochroic in brownish green) in clusters 0.1 mm. in diameter were noted in one of the dykes in the Kitts Metagabbro; the sheaves post-date the biotite flakes oriented in S_3. The pyrite occurs in scattered xenomorphic grains 0.2 - 0.5 mm. in diameter that partly enclose polygonal grains of the groundmass mosaic. It is most abundant in the zones of S_2 and S_3 schistosity and is responsible for their rustiness in outcrop.

The garnet porphyroblasts are xenomorphic and vary from poikiloblastic to skeletal, being crowded with inclusions of quartz and feldspar (Fig. 88). Some have incomplete overgrowths which are clear of inclusions and have idiomorphic outlines developed.

GRANODIORITE

The granodiorite shows a xenomorphic granular texture of quartz and oligoclase and andesine with biotite flakes and in places hornblende prisms up to 1 mm. in size aligned in S_3. The biotite is pleochroic in brown. Sphene in scattered idiomorphic crystals up to 1 mm. in diameter is a prominent accessory constituent and minor amounts of apatite also occur.

PITRE LAKE GRANITE

The major mineral components have been noted in Chapter V, and fluorite is the only notable accessory. The grain size of the rock averages 2 mm., and the texture varies from hypidiomorphic granular to xenomorphic granular. Grain boundaries are typically irregularly curved and indented. The microcline is perthitic and the andesine is twinned on the albite law. The mica flakes are up to 2 mm. in diameter, and in hand specimen tabular crystals with hexagonal outlines can be distinguished. The fluorite occurs in xenomorphic grains up to 0.3 mm. in diameter, and a few scattered grains of zircon were also noted.

METAGABBRO DYKES

The major petrographic features of the dykes have already been outlined in Chapter V. The amphibole in the unfoliated and weakly foliated parts is commonly pleochroic in pale green and is probably actinolite. The undeformed dykes in the northwest, however, contain amphibole showing the stronger pleochroism of common hornblende. The amphibole in the fine-grained aggregates is subidiomorphic while the larger poikilitic crystals vary from ragged xenomorphic to subidiomorphic form. Towards the foliated margins the colour of the amphibole deepends and in the hornblende schist appears to be a common hornblende. The biotite is pleochroic in brown and occurs in flakes up to 0.1 mm. long intergrown with the amphibole which locally, it appears to replace. Epidote, most abundant in the northwest, occurs in idiomorphic prisms up to 0.4 mm. long. Ilmenite is in scattered xenomorphic and skeletal crystals rimmed with sphene, and isolated sphene granules are also common. The ilmenite is progressively replaced by sphene towards the schistose margins of the dykes.

The textural changes of the plagioclase have been noted above. The laths in the cores show albite and combined albite-pericline twinning, and also strong normal zoning. Normally they have suffered little alteration apart from minor sericitization. The subgrains that develop in the foliated margins are untwinned and have polygonal outlines; they are composed of andesine.

PLAGIOCLASE PORPHYRY

The plagioclase phenocrysts are heavily altered to an ultra-fine aggregate chiefly composed of sericite in approximate optical continuity with other indeterminate very fine-grained mineral grains, probably epidote and calcite; scattered xenomorphic and subidiomorphic crystals of epidote up to 0.5 mm. in diameter and irregular ovoid grains of sphene are also included. Xenomorphic patches 1 mm. across of prehnite locally replace the plagioclase. Narrow rims of incipiently altered plagioclase mantle the altered cores and are of albitic composition. Microcline in xenomorphic crystals is locally associated with these rims.

The hornblende in the groundmass occurs in subidiomorphic prisms generally up to 0.5 mm. long; where S_3 is strong they are up to 2 mm. in length. S_3 where developed is defined by a preferred orientation of the hornblende prisms and also chlorite after biotite in flakes up to 1 mm. long. The oligoclase in the groundmass occurs in untwinned, sometimes weakly zoned subpolygonal grains 0.2 mm. in diameter that usually show saussuritisation. Fine-grained ilmenite crystals and round droplets of sphene are scattered throughout the groundmass, and the apatite occurs in aggregates (up to 0.5 mm. in diameter) of subpolygonal grains.

LONG ISLAND GNEISS

The plagioclase phenocrysts show normal zoning from andesine cores to albite rims, but generally the cores are saussuritised and indeterminate. In most cases optically continuous microcline forms a narrow partial or complete mantle around the phenocrysts (Figs. 98 and 99). Some phenocrysts have been albitised throughout giving rise to a mottled zonal extinction pattern.

The mafic eyes are composed of subidiomorphic and xenomorphic hornblende crystals up to 1 mm. in diameter, and biotite flakes 0.1 - 0.5 mm. long; they are associated with grains of sphene, and ilmenite mantled by sphene. The hornblende is characteristically poikilitic, with many irregular quartz inclusions; it has a low 2V (20°) and is pleochroic in X = yellow green, Y = olive green, Z = blue green or dark green. The biotite is pleochroic in brownish green.

The plagioclase, microcline and quartz of the groundmass occurs in xenomorphic grains with irregular curved grain boundaries. Hornblende crystals and biotite flakes 0.1 mm. long are scattered throughout the groundmass, and show a preferred orientation where S_3 is developed. Some sphene, apatite and epidote occur in the groundmass but are chiefly associated with the mafic eyes.

PORPHYRITIC MICROGRANITE

Despite the variations in fabric that are visible in outcrop, the microgranite is petrographically simple and monotonous. The approximate modal composition is plagioclase 41%, microcline 32%, quartz 25% and accessories 8%. The accessories are chiefly biotite and ilmenite with minor apatite, and epidote and orthite are locally important. Much of the plagioclase content is in the phenocrysts so that when they are lacking the K-feldspar is dominant. The plagioclase phenocrysts are petrographically identical to those in the Long Island Gneiss but they lack the mantle of microcline; their cores tend to be saussuritised (Fig. 103). Grain boundaries in the groundmass are irregular and curved; the microcline is perthitic. The biotite and ilmenite (0.1 mm. in diameter) occur in sparsely scattered flakes and grains respecitvely. The ilmenite is usually thinly mantled by sphene and is associated with apatite. Chlorite commonly replces the biotite.

MONZONITE

The plagioclase prisms (3 - 8 mm. long) are stubby and unoriented; commonly they are incipiently saussuritised and of albitic composition. West of Swell Lake they are unaltered and have a composition of An 28. The prism form is best developed where the composition is dioritic; microcline occupes the spaces between the prisms and is moulded against them (Fig. 105). As the proportion of microcline increases, the prisms are more irregular and are mantled completely by optically continuous xenomorphic perthitic microcline. The quartz occupies interstices between the composite feldspar crystals.

Biotite and hornblende are subidiomorphic and occur in irregular aggregates with interspersed minor microcline and quartz grains. The biotite is strongly pleochroic in X = yellow, Y = very dark green, Z = deep blue green, and it has a low 2V (less than 20°) indicating that it may be ferrohastingsite. The mafic aggregates are associated with prominent grains of sphene that often include cores of ilmenite, and apatite. Except immediately west of Swell Lake the biotite and hornblende are partly chloritised and are associated with epidote.

Where S_3 is developed the biotite and hornblende show a preferred orientation, the plagioclase and microcline crystals are locally broken down to a fine xenomorphic mosaic and the quartz grains form elongate aggregates of xenomorphic grains.

NET-VEINED DIORITE

The plagioclase occurs in laths from 0.2 to 1 mm. in length depending on the overall grain size of the dyke, and shows strong normal zoning from andesine cores (An 48) to oligoclase rims. The laths are randomly oriented and felted, with oligoclase overgrowths filling the interstices. The hornblende occurs in euhedral prisms 1 - 2 mm. long, and in quantitatively less important fine anhedral grains occupying the interstices between plagioclase laths. Biotite flakes, pleochroic in green, are associated with and appear to replace the hornblende. The accessory quartz occupes interstices between the plagioclase laths, and often accessory constituents are evenly scattered throughout.

APPENDIX B

MAP UNITS CORRELATED WITH THE KITTS PILLOW LAVA FORMATION

Introduction

There are two groups of map units in this category: Group (a) - map units that appear to form a structurally attenuated southwesterly continuation of the formation, but are separated from it and from one another by D_3 slides; this group comprises two map units in the Watts Lake Fold. Group (b) - spatially separated map units chiefly of pillow lava that appear to be correlateable on the basis of contact relationships; this group includes pillow lavas south of Inda Lake, between Henry and Gear Lake and on Anderson Ridge.

Group (a)

(i) Map unit in core of Watts Lake Fold

The hornblende schist zone along the contact of the pillow lavas with the Metasedimentary Formation widens progressively southwestwards until truncated by the Watts Lake Slide. Hornblende schist occupying the core of the Watts Lake Fold to the west of this slide has identical contact relationships with the

Metasedimentary Formation, and shows the same lithology and tectonite fabrics. It is therefore correlated with the Kitts-Nash Lake pillow lavas and owes its facies to the southwesterly increasing D_2 effects related to the Witch Lake slide zone.

The contact with the Metasedimentary Formation is gradational over about 3 m. with interbanding of amphibolite and psammite on a 0.2 - 3 cm. scale. The contact with the banded tuffs is very sharp, S_2 is the dominant fabric and it isoclinally folds the banding at the contact. S_3 is a locally developed crenulation cleavage that does not transpose S_2 even in the hinge of the major F_3 fold.

(ii) Map unit on west limb of Watts Lake Fold

This unit is separated from hornblende schist in the core of the fold by a slide. Although much thinner, it shows the same contact and structural relationships. This unit is therefore believed to be the structurally thinned continuation of the Kitts-Nash Lake belt of volcanics and itself shows a progressive thinning southwestwards; it finally pinches out northwest of Watts Lake.

Group (b)

(i) South of Inda Lake

This unit of pillow lavas appears to be stratigraphically conformable with conglomerate to the north, and is bounded on the south by an intrusive contact. Mafic detritus in the conglomerate suggests that the pillow lavas face north and underlie the conglomerate and banded tuffs, as in the Kitts-Nash Lake belt. Although exposure is poor, the lithology appears to be identical to that of the Kitts-Nash Lake belt. Fabrics are zonally developed and undeformed pillows up to 1 m. in diameter lacking a tectonite fabric were noted. S_3 is a weak penetrative L > S tectonite fabric. In the south, a few outcrops were noted with a strong penetrative L-S schistosity, the age of this fabric is not clear as it resembles S_1 in hornblende schist outcrops about 1 km. to the south, discussed in (ii) below.

(ii) Map units southeast of Nash Lake

Two units of hornblende schist are in contact with phyllonitic Hopedale Complex gneiss southeast of Nash Lake. Lithologically they are identical to the hornblende schist facies of the mafic volcanics elsewhere in the area, but since they occur on the edge of the area mapped and are poorly exposed, their boundaries and general relationships are not clearly established.

The northern unit has a gradational interbanded contact with the Hopedale Complex similar to that of the Post Hill Amphibolite described below; the contact is inferred to be of D_1 age. It shows a penetrative L-S tectonite fabric parallel to the contact and to the phyllonitic schistosity in the Hopedale Complex. This fabric is inferred to be S_2 and has been involved in large scale folding, probably of D_3 age though a related fabric was not observed. The southern unit shows similar relationships except that S_2 becomes weaker towards the west end of the unit.

Both of these map units can be tentatively correlated with the pillow lava unit south of Inda Lake as they are only separated from the latter by a belt of intrusive rocks. As already noted, the pillow lavas become locally schistose in the south, possibly indicating a transition to the hornblende schist facies across the Monzonite intrusion. Also, the southern unit in common with the pillow lavas has conglomerate on its northern contact, though only in a small wedge. The conglomerate is cut out by an apparently structurally transgressive contact suggesting that a wedge of the Hopedale Complex was tectonically emplaced into the cover rocks producing D_1/D_2 fabrics adjacent to the wedge.

(iii) Map unit between Gear Lake and Henry Lake

This outcrop between Gear Lake and Henry Lake is separated from the Hopedale Complex by a D_1 slide. The contact with the banded tuffs is not seen, but as it appears to be folded and is truncated by the D_1 slide it is inferred to be a stratigraphic boundary. Stratigraphic tops are lacking but it is thought that pillow lavas underlie the

Banded Tuffs and are correlateable with the Kitts-Nash Lake belt since nowhere in the area are mafic lavas seen within or overlying the Banded Tuffs, and further southwest the Banded Tuffs appear to occupy a syncline.

(iv) Anderson Ridge

Anderson Ridge is underlain by pillow lavas with horizons up to 15 m. thick of fine-grained quartzite (metachert), iron formation and rusty weathering metasiltstones. Lithologies and fabric are similar to those in the Kitts Pillow Lava Formation. Anderson Ridge was not mapped in detail and the contacts of the pillow lavas with the surrounding rocks were not seen. The western contact is probably a continuation of the D_1 slide bounding the Hopedale Gneiss north of Gear Lake. The Anderson Ridge volcanics may therefore be correlateable with the wedge of pillow lavas between Gear Lake and Henry Lake, and consequently also with the Kitts Pillow Lava Formation.

TABLE I. Table of Formations

AGE/EVENT	GROUP	FORMATION	LITHOLOGY
	POSTKINEMATIC INTRUSIVE ROCKS	Gently dipping net-veined diorite dykes; minor felsite dykes	
		INTRUSIVE CONTACT	
HUDSONIAN OROGENY	SYNKINEMATIC INTRUSIVE ROCKS	Monzonite	Coarse-grained, leucodiorite to monzonite in composition
		INTRUSIVE CONTACT	
		Porphyritic Microgranite	Leucocratic fine-grained porphyritic adamellite
		INTRUSIVE CONTACT	
		Long Island Gneiss	Medium grained porphyritic quartz monzonite with ubiquitous mafic xenoliths
		Minor bodies of granodiorite, Pitre Lake Granite and mafic rocks (includes gabbro dyke swarm on Post Hill)	
	REMOBILISED HOPEDALE COMPLEX	Leucogranite	Massive leucogranite
		Migmatitic Quartz Monzonite	Xenolithic migmatite with an homogeneous quartz monzonite phase
		Brumwater Granite	Homogeneous to migmatitic biotite granite
		Unlucky Head Migmatite	Xenoliths of Hopedale Complex in gneissic to homogeneous granitic neosome
		INTRUSIVE CONTACT	
		Refoliated Gneiss Zone	Fine-grained, thin-banded and flaggy biotite gneiss
	STRUCTURAL CONTACT		
APHEBIAN	PREKINEMATIC INTRUSIVE ROCKS	Quartz Porphyry dykes	Metarhyolite, with quartz and feldspar phenocrysts
		Metagabbro sills	Massive to foliated medium to coarse-grained metagabbro
	INTRUSIVE CONTACT		
	AILLIK GROUP (Upper)	Banded Tuff Formation (300 m.)	Waterlain, thin-bedded reworked acid tuff (feldspathic psammite)
		Rhyolite Formation (300 m.)	Massive and ignimbritic-textured rhyolite with quartz and feldspar phenocrysts
		Conglomerate Formation (260 m.)	Massive, with subrounded granite, acid porphyry and acid volcanic clasts
		Disconformity	
	AILLIK GROUP (Lower)	Kitts Pillow Lava Formation (910 m.)	Pillowed and massive metabasalt, passing into hornblende schist; includes banded chert-magnetite iron formation members
		Metasedimentary Formation (820 m.)	Thinly interbedded psammite, biotite-muscovite semi-pelite and biotite-muscovite pelitic schist; includes a graphitic-sulphide-bearing member
		Post Hill Amphibolite (1000 m.)	Fine-grained hornblende schist
	UNCONFORMITY		
ARCHEAN	HOPEDALE COMPLEX	Biotite and biotite-hornblende gneiss amphibolite, migmatite, granodiorite and granite	

TABLE II. Metamorphic mineral growth history of the iron formation members of the Kitts Pillow Lava Formation

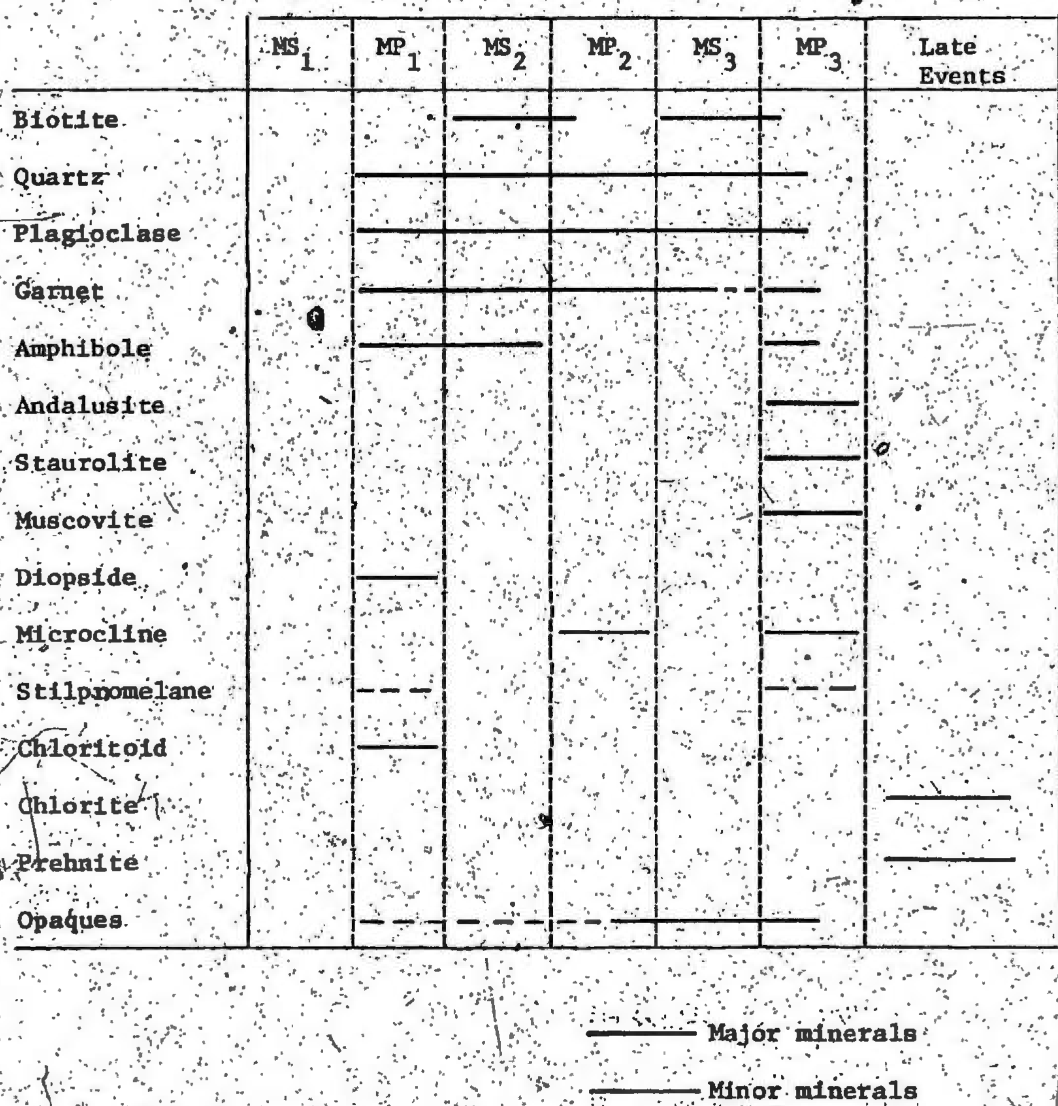


TABLE III. Metamorphic mineral growth history of the Kitts Pillow Lava and Post Hill Amphibolite Formations, exclusive of the iron formation members.

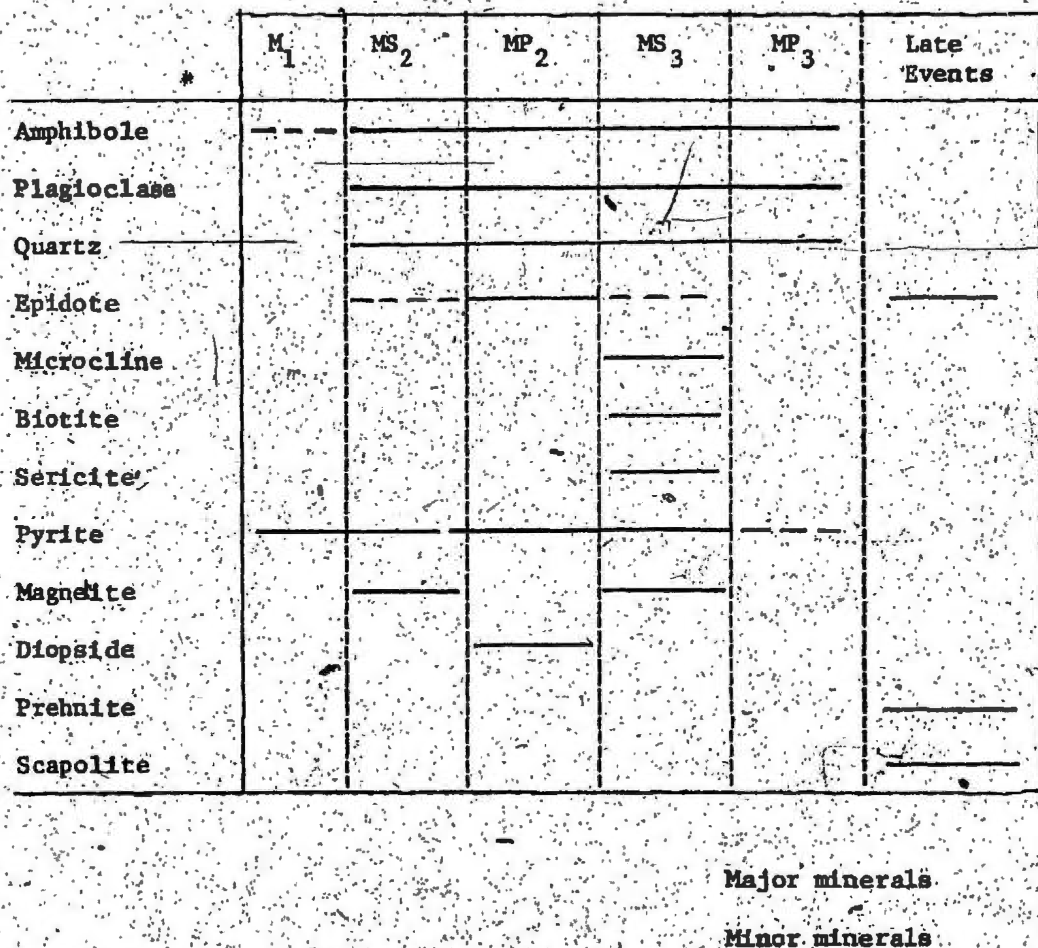


TABLE IV. Metamorphic mineral growth history of the Metasedimentary Formation.

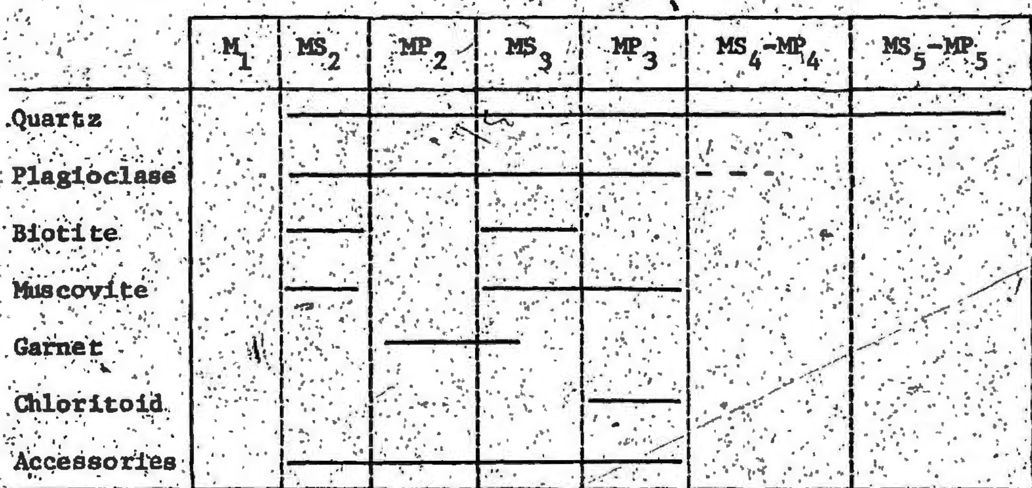


TABLE V. Metamorphic mineral growth history of the Conglomerate, Rhyolite and Banded Tuff Formations.

	MS_1	MP_1	MS_2	MP_2	MS_3	MP_3	MS_4-MP_4	MS_5-MP_5
Quartz			- - -	- - -	———	———	—— - -	- - -
Plagioclase			- - -	- -	———	- - -		
K-feldspar			- - -	- -	———	- - -		
Hornblende			- -		———	- - -		
Diopside					———	———		
Calcite					———	———	———	—— - -
Biotite			———		———			
Muscovite			———		———			
Garnet					———			
Accessories					———	———		

TABLE VI. Metamorphic mineral growth history of the Refoliated Gneiss Zone.

	MS_1	MP_1	MS_2	MP_2	MS_3	MP_3	Later Effects
Biotite	- - -		——		——		
Muscovite	——						
Plagioclase		——	——	——	——		
K-feldspar		——	——		——	- - -	- - -
Hornblende	——		——		- - -		
Epidote		- - -					- - -
Fibrolite	- - -						
Tourmaline			——		- - -		
Sphene, Opaques			——		——		
Chlorite							——

TABLE VII. Metamorphic history of the Unlucky Head Migmatite, Brumwater Granite and Migmatitic Quartz Monzonite.

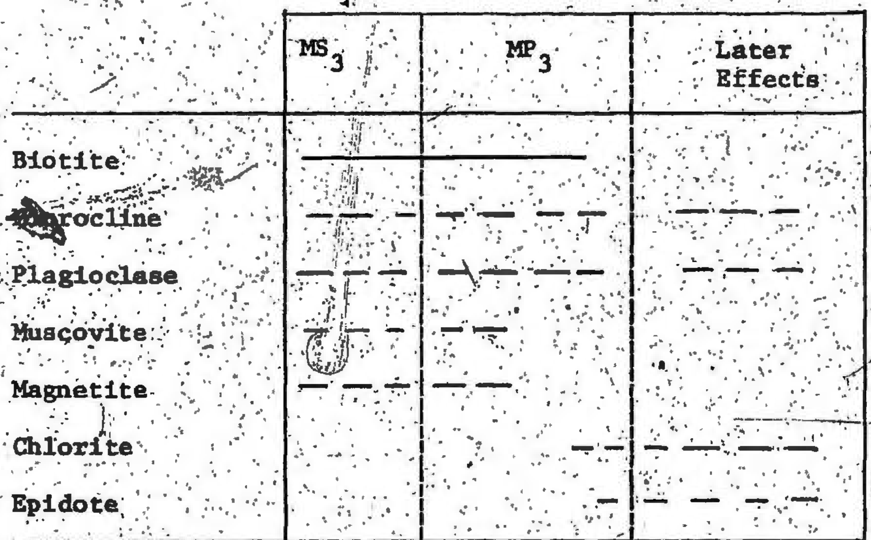


TABLE VIII. Metamorphic mineral growth history of the prekinematic intrusive igneous rocks.

		MS_1-MP_1	MS_2	MP_2	MS_3	MP_3	Later Effects
Quartz Porphyry	Quartz	?	———	- - -	———	- - -	
	Feldspar		———	- -	———	- - -	
	Biotite		———		———		
	Muscovite		———		———	- - -	
	Garnet	?				———	
	Pyrite			- - -	———	- -	
Metagabbro	Tremolite-Actinolite	- - -	- - -		- - -	- - -	
	Hornblende		———	- - -	- - -	- - -	
	Plagioclase	- - -	———	- - -	- - -	- -	- -
	Diopside	———					
	Prehnite						———

TABLE IX. Metamorphic mineral growth history of the synkinematic, post-D_2 igneous rocks.

		MS_3	MP_3	Later Effects
Long Island Gneiss Porphyritic Microgranite Monzonite	Quartz	– – – –	– –	
	Plagioclase	– – – –	– –	
	Microcline	– – – –	———	
	Biotite	———		
	Hornblende	———	– –	
	Chlorite		– – –	– – –
Mafic dykes	Hornblende	———	– –	
	Biotite	———		
	Plagioclase	———		
	Chlorite		– – –	– – –

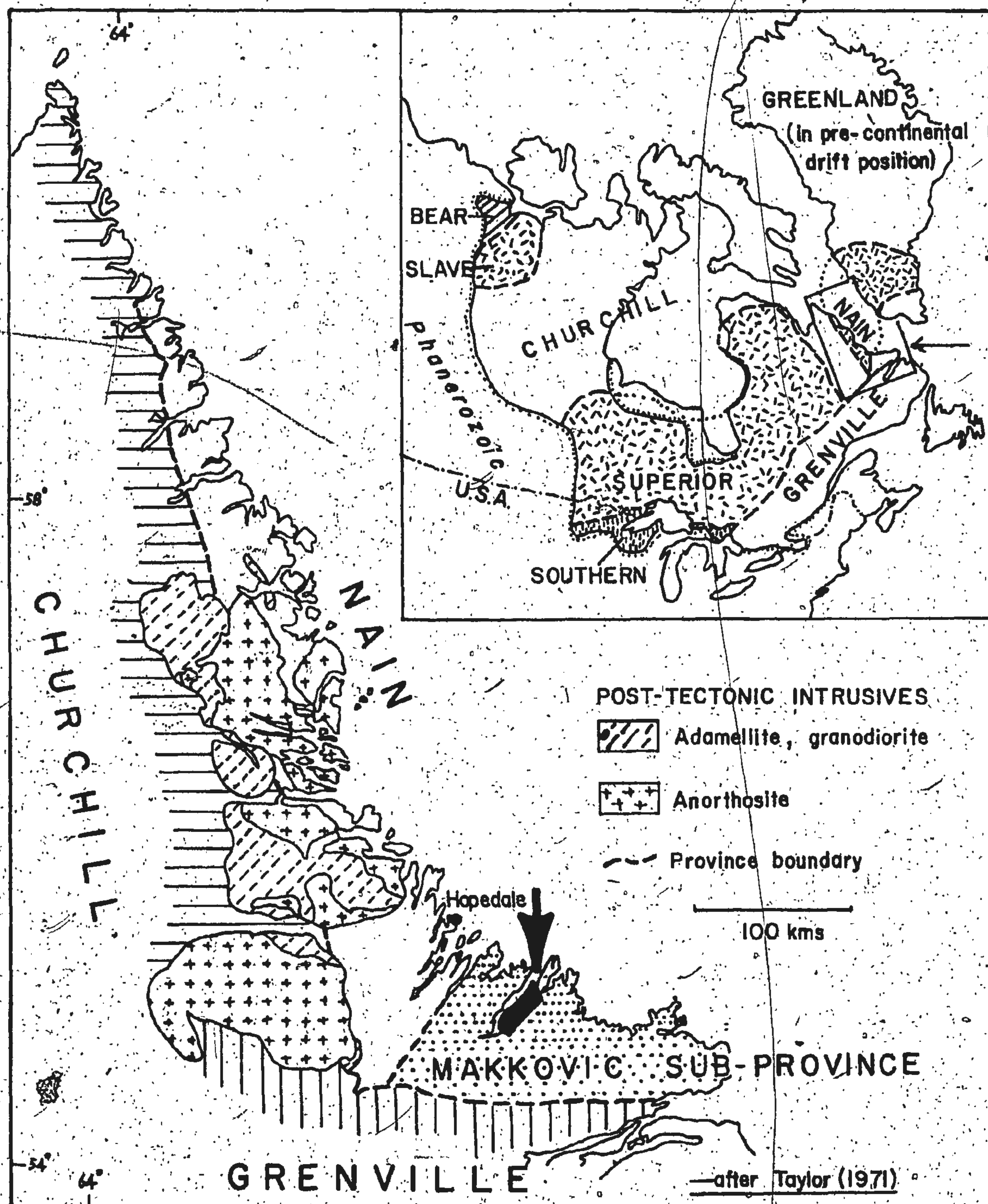


Fig. 1. Location of the area in relationship to Structural Provinces of the Canadian Shield.

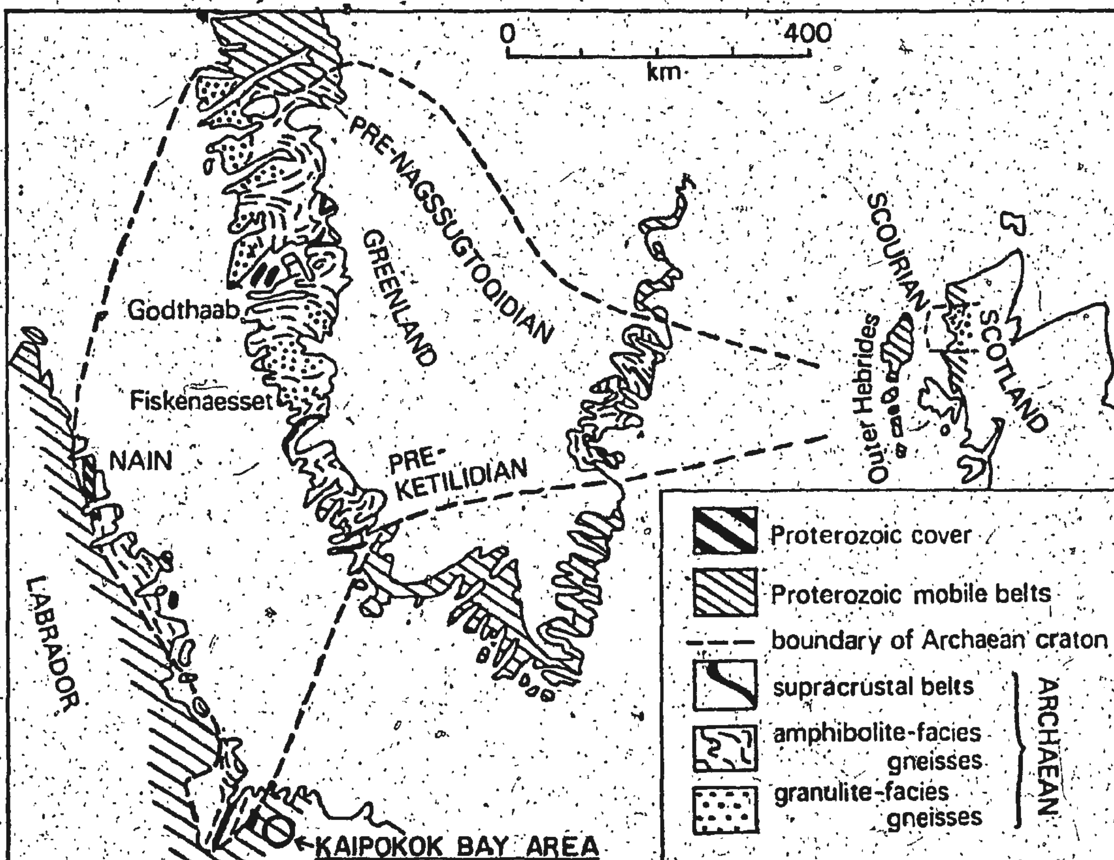


Fig. 2. Pre-Mesozoic continental drift reconstruction of the Archean North Atlantic Craton. From Bridgewater et al. (1973a).

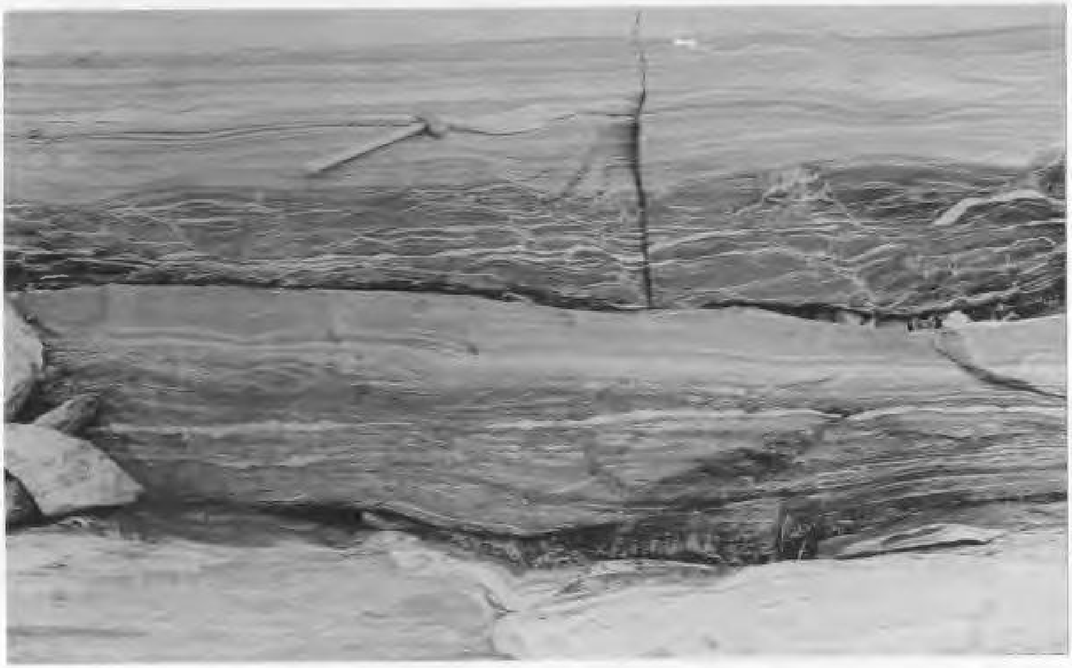


Fig. 3. Banded gneiss of the Hopedale Complex. Note incipient boudinage in band of amphibolite beneath hammer. Southwest of Unlucky Head.

Fig. 4. Early migmatite (pale grey with leucocratic patches) in contact with biotite gneiss, both cut by Unlucky Head Migmatite on right. Note truncation of a penetrative fabric in the early migmatite by the Unlucky Head Migmatite. At Unlucky Head.

Fig. 5. Foliated early migmatite in the Hopedale Complex. Note the two phases of granodiorite (pale and darker grey), cut by a vein of granite related to the Unlucky Head Migmatite. Southwest of Unlucky Head.

Fig. 6. Isoclinal folds in leucocratic bands and segregations refolded by folds related to a penetrative D-1, pre-Aillik Group fabric in the Hopedale Complex. Note the strong mineral and stretching lineation parallel to fold axes on the lower right.

Fig. 7. Lens-shaped pod of gneiss within banded gneiss of the Hopedale Compl
The foliation in the pod is oblique to the gneissic banding. In a
raft of Hopedale Complex at Unlucky Head.

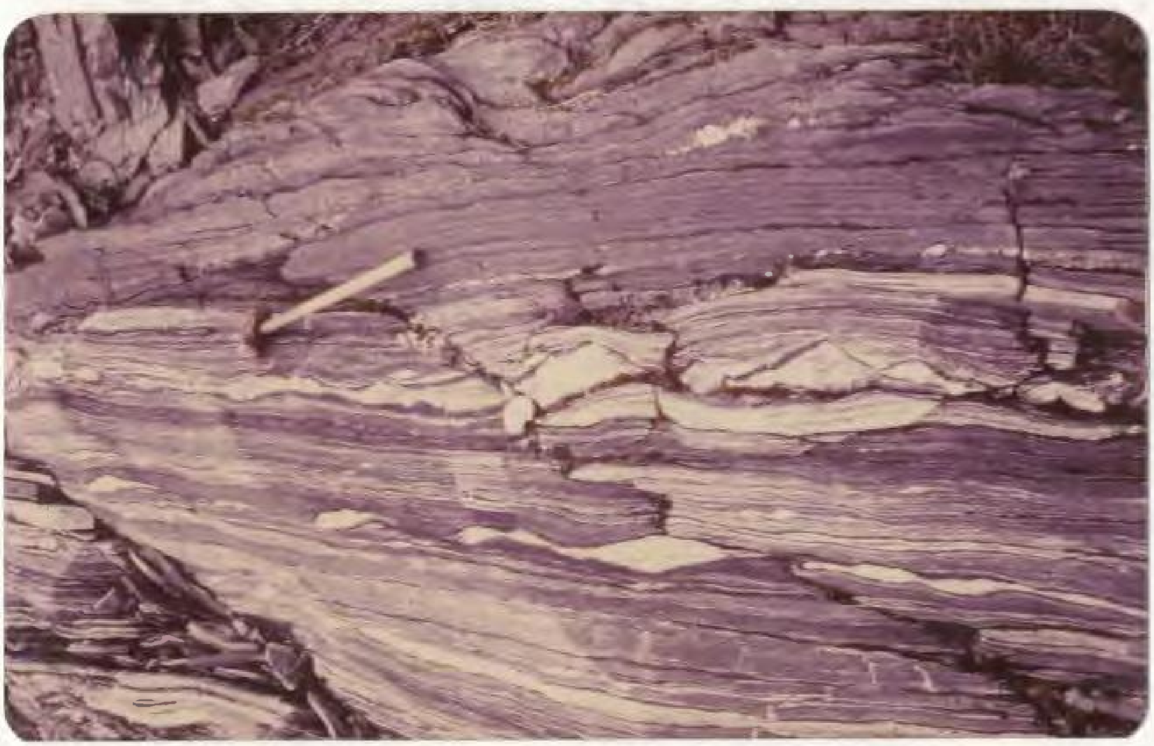


Fig. 8. Boudinage of gneiss bands in the Post Hill Slide. This is believed
to represent an early stage in the formation of pods such as that
in Fig. 7. Shore of Kaipokok Bay, west flank of Post Hill.

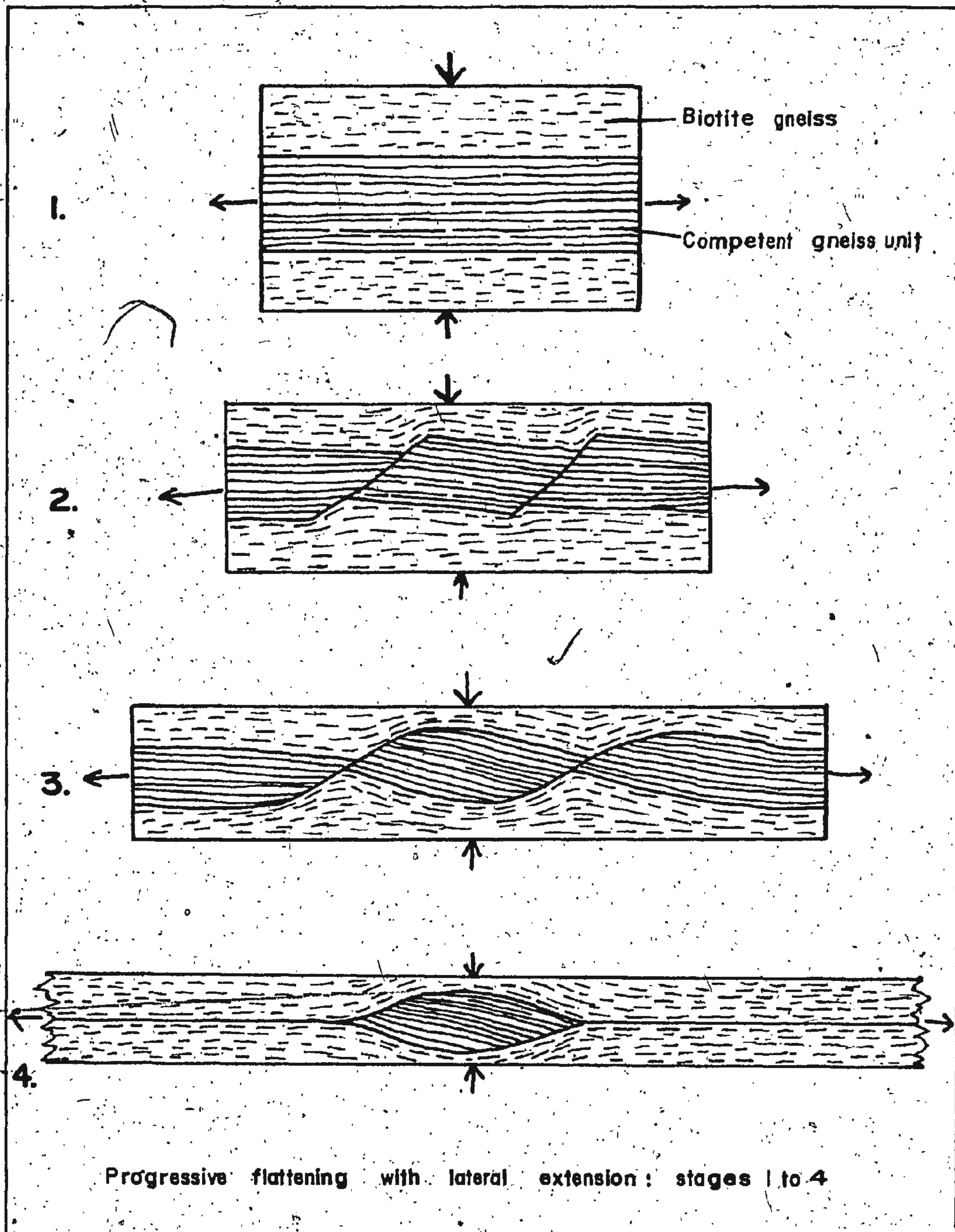


Fig. 9. Diagram illustrating postulated mechanism of formation of gneiss pods in the Hopedale Complex.

Fig. 10. Undeformed pillows in the Kitts Pillow Lava Formation. This outcrop occurs 50 m. east of the Limestone Lake Slide, illustrating the extremely inhomogeneous nature of the deformation. East of Kiwi Lake.

Fig. 11. Pillows showing northwest facing tops, close to the northwest contact of the Kitts Pillow Lava Formation. Northwest of Knife Lake.

Fig. 12. Zone of D_2 tectonic banding and schistosity in Kitts Pillow Lava Formation. S_3 is axial planar to open F_3 folds in S_2. 200 m. north of Nash Lake.

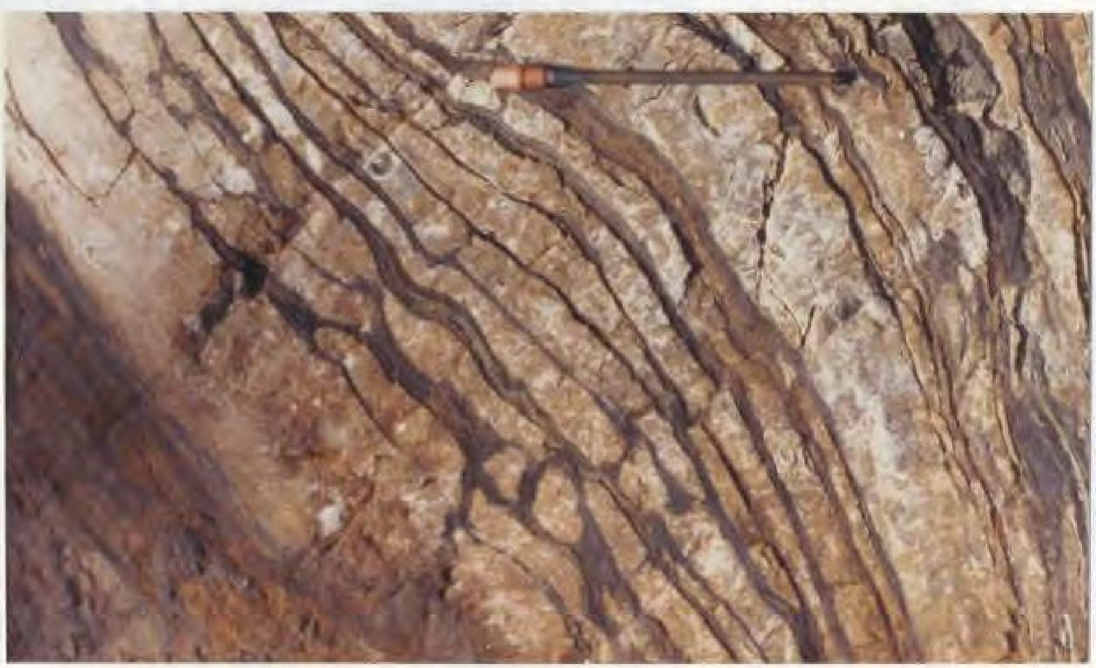


Fig. 13. Iron formation, consisting of thinly interbedded fine grained quart (metachert) and black magnetite-amphibole rock. Note evidence of penecontemporaneous disruption of beds. Kitts Pillow Lava Formatio Inda Lake member; 300 m. northeast of Knife Lake.

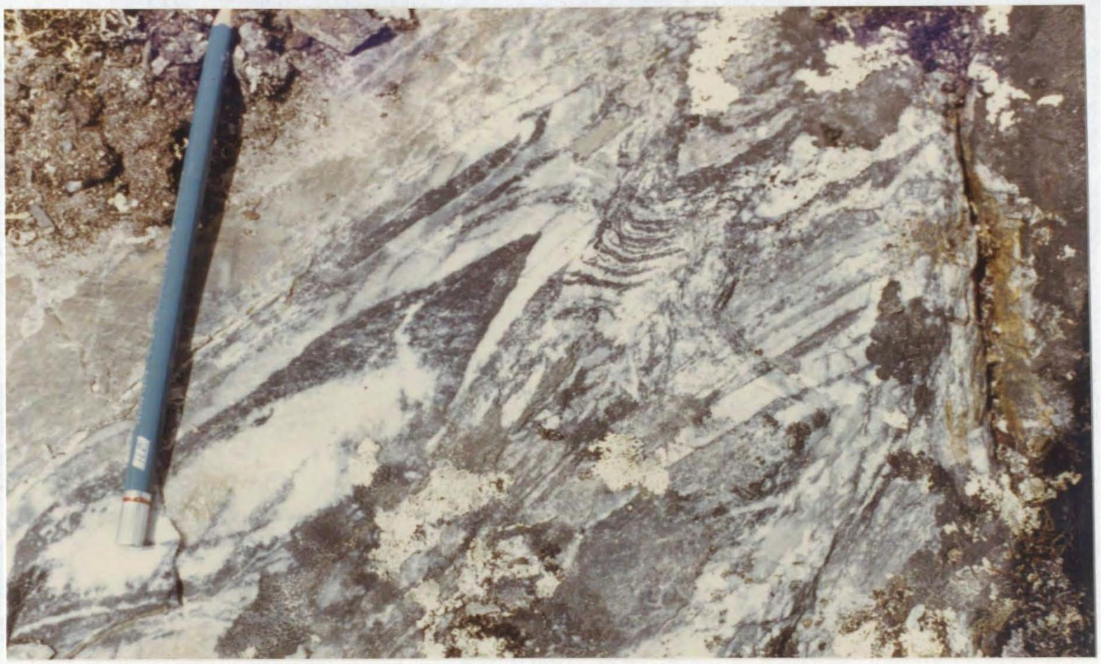
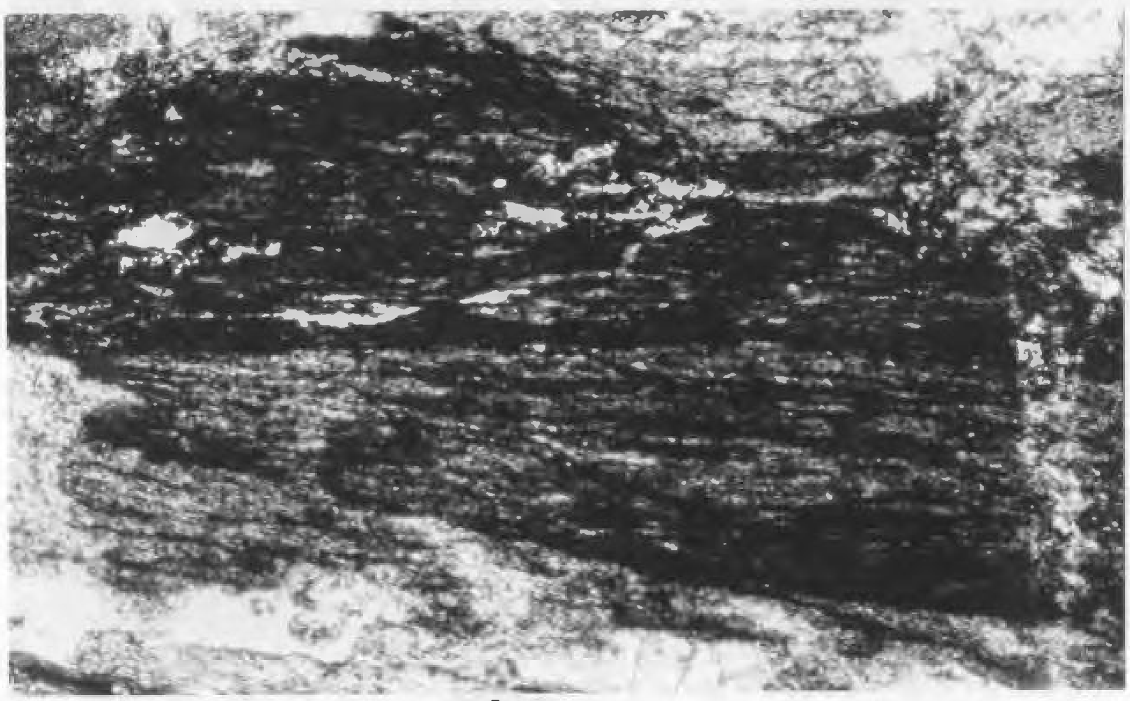


Fig. 14. Metachert consisting of pure white fine-grained quartzite and grey magnetite quartzite, showing penecontemporaneous soft-sediment disruption. S_2 is defined by faint dark streaks of magnetite (on a mm. scale, center of photograph) axial planar to open F_2 folds. Kitts Pillow Lava Formation, Kitts iron formation member; southwest of Luncheon Lake.



0·2 mm

Fig. 15. Amphibole porphyroblast containing abundant minute opaque inclusions defining S_1; S_2 forms augen around the porphyroblast outside the fie[l]d of view. Kitts Main Zone, at the Kitts Prospect. Plane polarised light.

0·2 mm

Fig. 16. S_1 defined by minute opaque rods included in MP_1 amphibole porphyroblasts around which S_2 (defined by hornblende and biotite) forms augen. North Showing, Kidney Pond. Plane polarised light.

0·2 mm

Fig. 17. S_1 defined by minute opaque rods included in a small MP_1 amphibole porphyroblast that in turn has been overgrown by MP_1 garnet. Kitts Main Zone, at the Kitts Prospect. Plane polarised light.

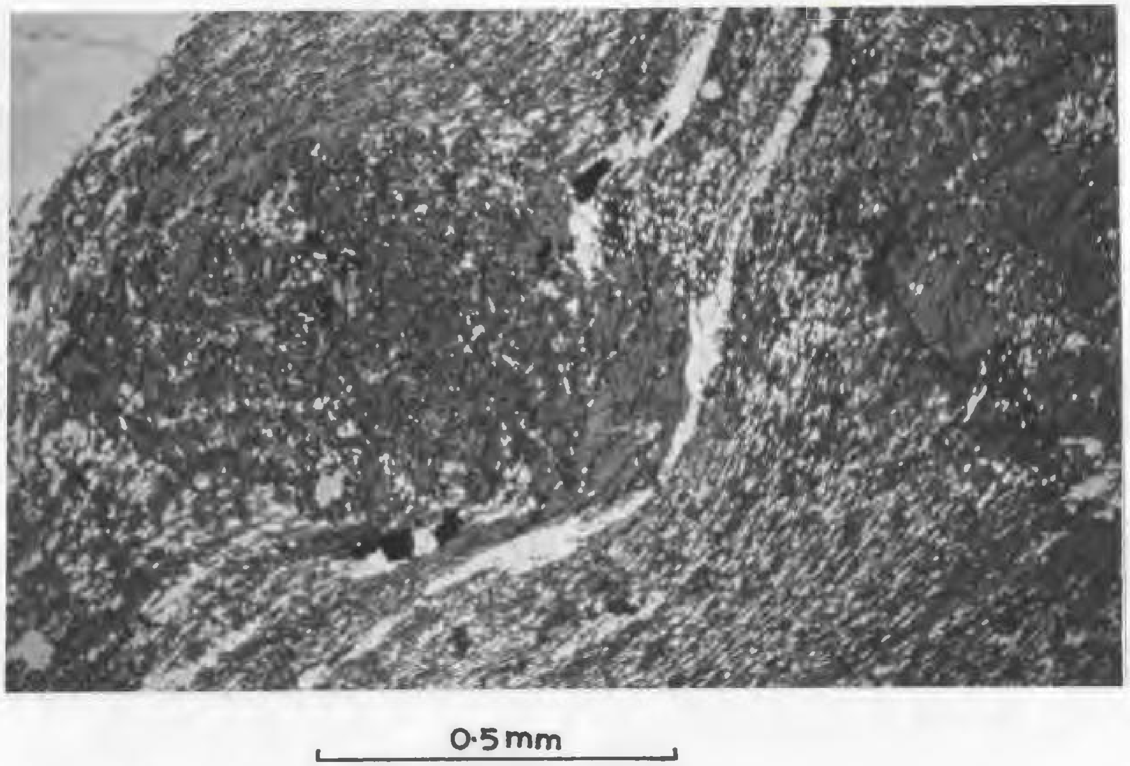


Fig. 18. Narrow MS_2 overgrowth on an MP_1 garnet porphyroblast. A straight S_1 in the MP_1 core (just visible, aligned NNW-SSE) is continuous with curved Si trails in the overgrowth. The external schistosity is S_2. Semipelitic schist, Kitts Main Zone, at the Kitts Prospect. Plane polarised light.

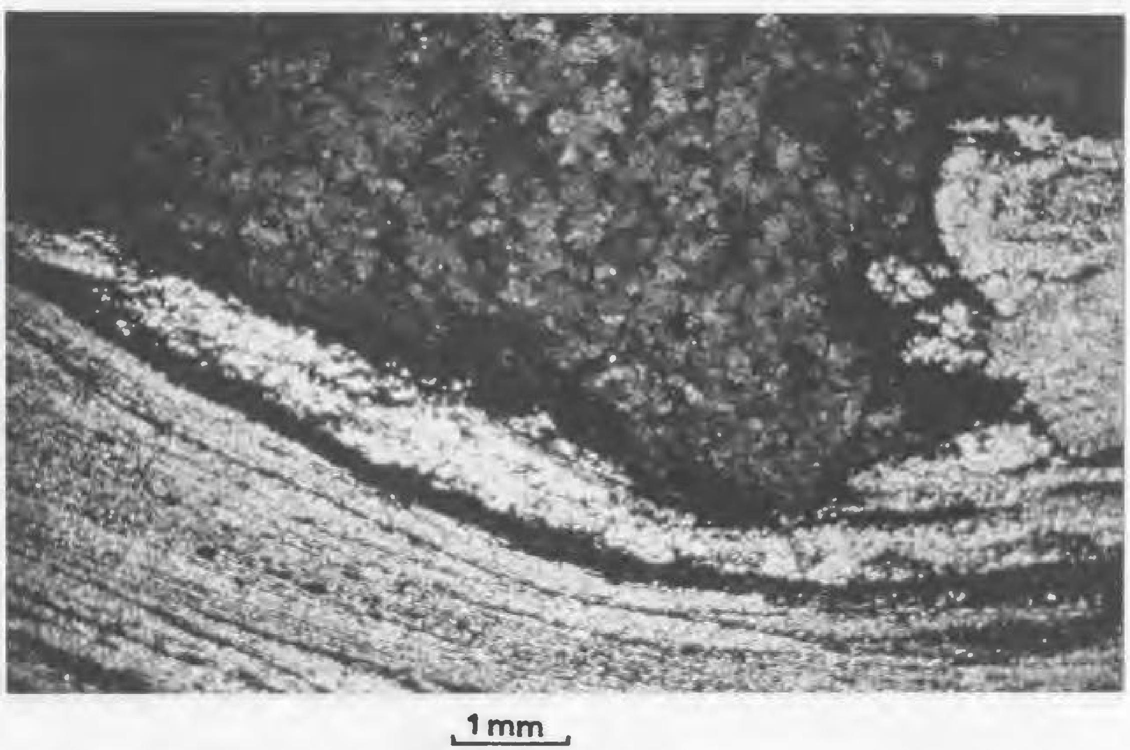
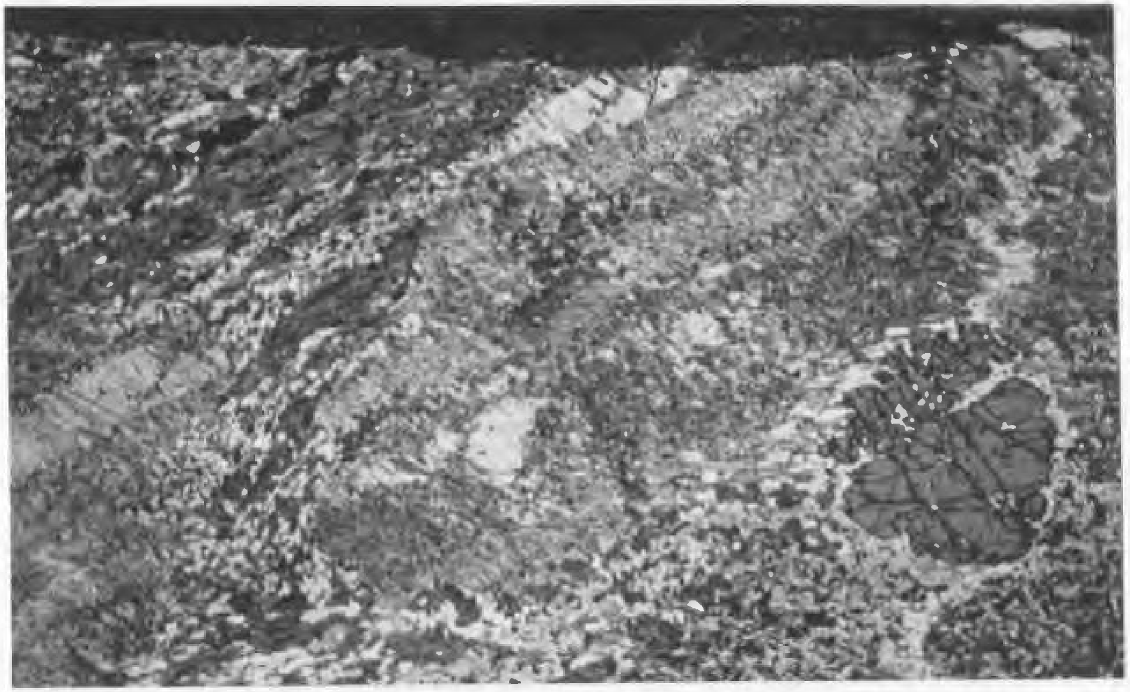
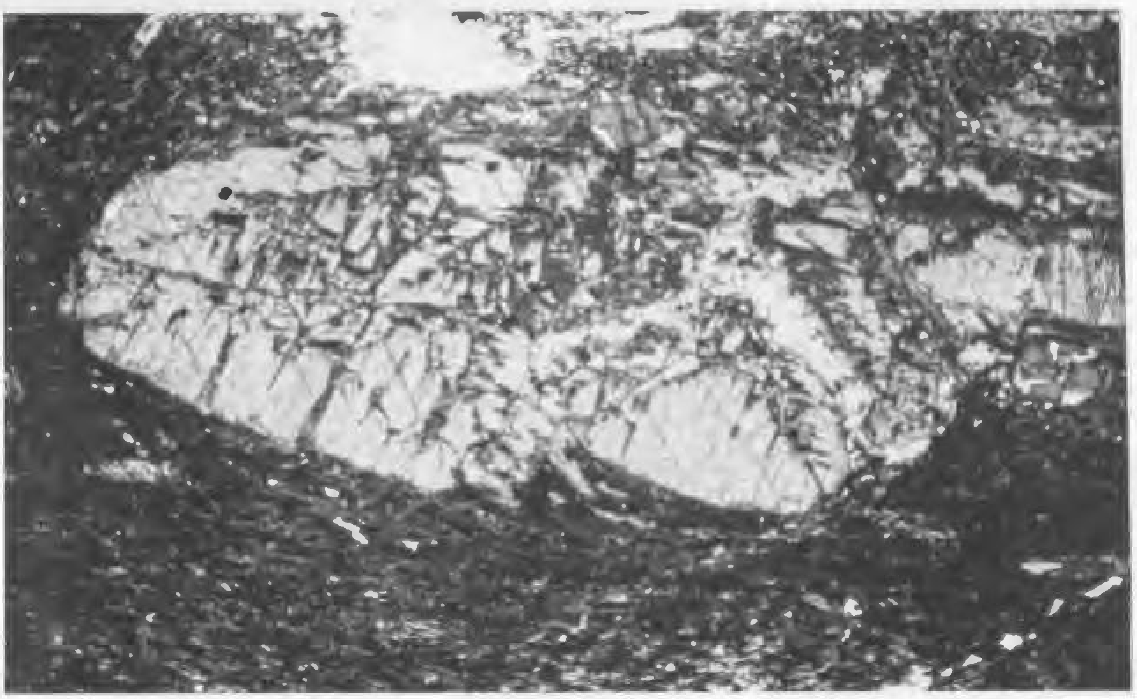


Fig. 19. D_2 boudin of coarse-grained, strained diopside crystals. The dark r represents marginal alteration of the diopside to amphibole. The la inar foliation forming an augen around the boudin is S_2; the dark laminae are composed of amphibole and the light ones of fine-grained epidote, quartz, feldspar and sphene. Gear Showing; partially cross



0·5mm

Fig. 20. Laminar S_2 (NE-SW) cut by S_3 (NW-SE) with both overgrown by MP_3 anda lusite porphyroblasts. An MP_3 garnet occurs in the top left corner. Semipelitic schist. South Showing zone; just south of Limestone Lake Partially crossed nicols.



1mm

Fig. 21. Idiomorphic MP_3 andalusite porphyroblast post-dating S_2. Semipelit schist, South Showing zone; just south of Limestone Lake. Partiall crossed nicols.

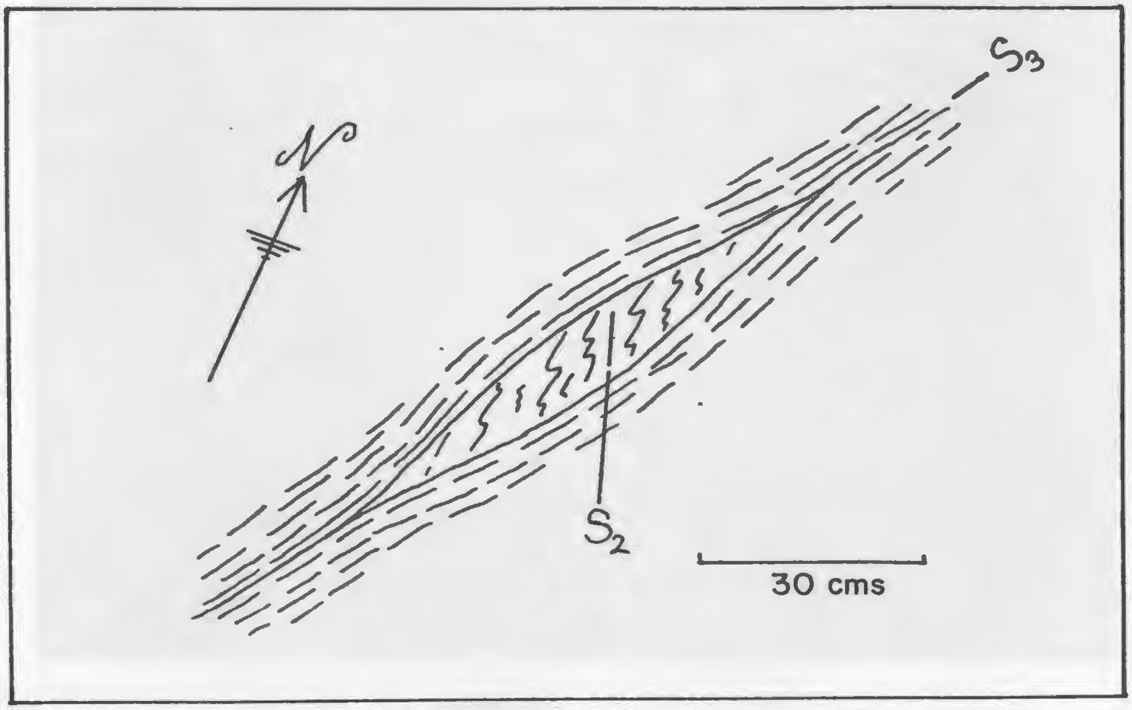


Fig. 22. Augen in S_3 containing S_2, in amphibolite of the Post Hill Slide. Field sketch; 600 m. west of Kiwi Lake.

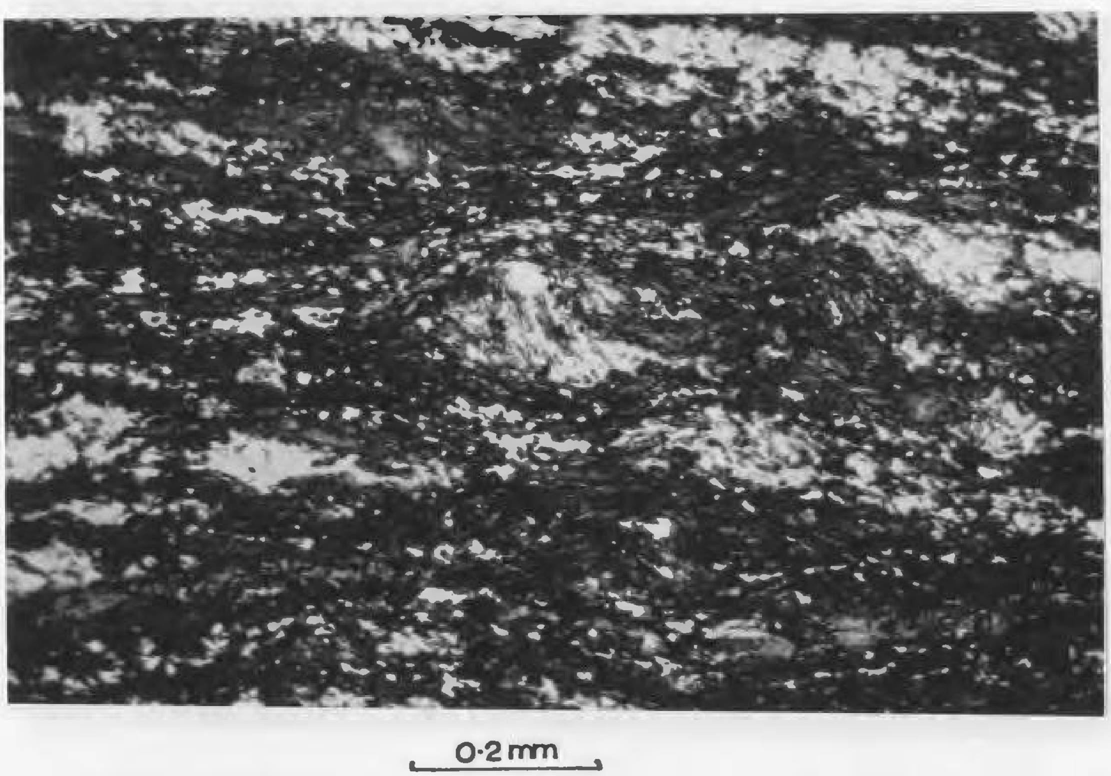


Fig. 23. S_2 included in an MP_2 plagioclase porphyroblast, around which S_3 forms an augen. Post Hill Amphibolite in the Witch Lake Slide; west of Watts Lake. Plane polarised light.

Fig. 24. Detrital quartz grain with an authigenic overgrowth outlined by particles of graphite. Metasedimentary Formation; Post Hill. Plane polarised light.

Fig. 25. Interbedded psammite and semipelitic schist (dark units). The folds are F_5 structures. Metasedimentary Formation; shore, west of Kitts Pond.

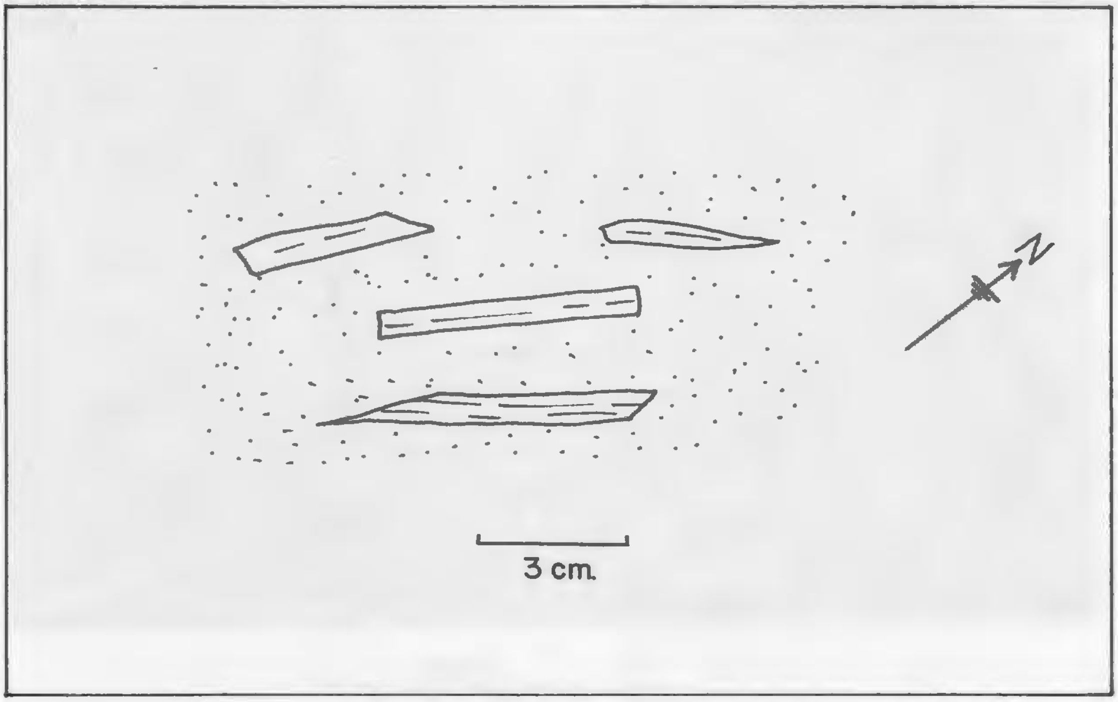


Fig. 26. Sketch of tabular siltstone clasts in the graphitic member of the Metasedimentary Formation. The flat ends of the clasts indicate that their shape is primary, and indicates contemporaneous rip-up. Post Hill.

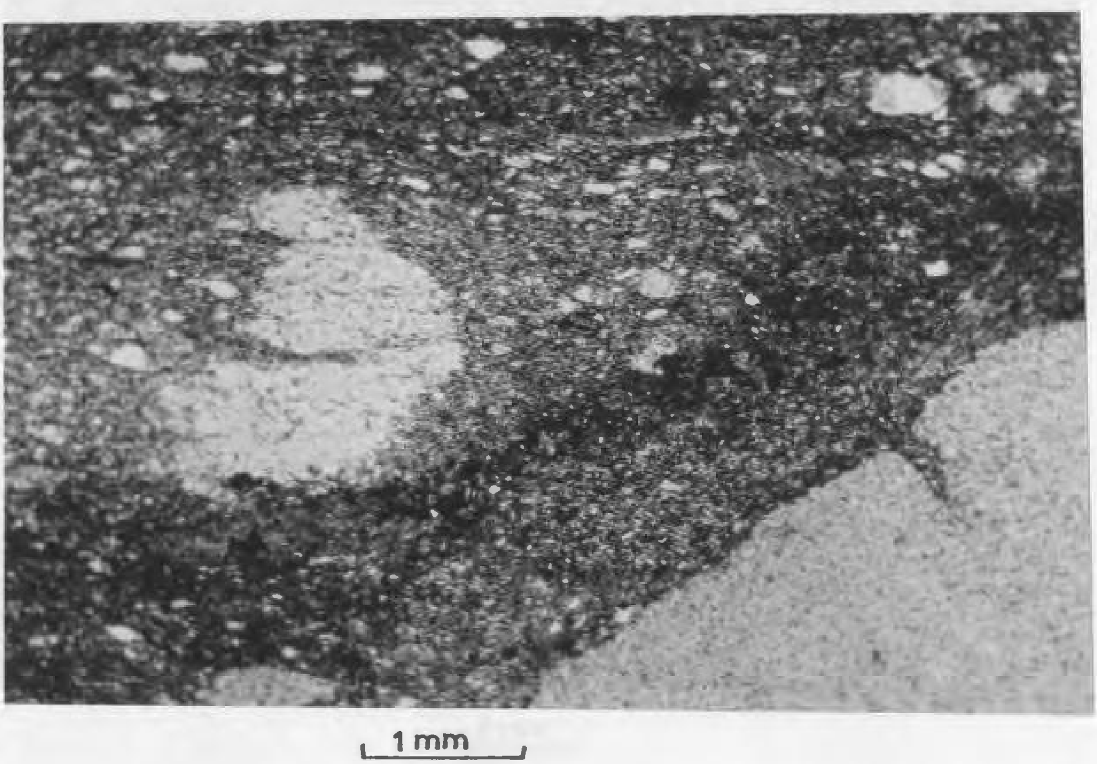


Fig. 27. Siltstone clasts in the Metasedimentary Formation showing evidence of soft sediment deformation. Post Hill. Plane polarised light.

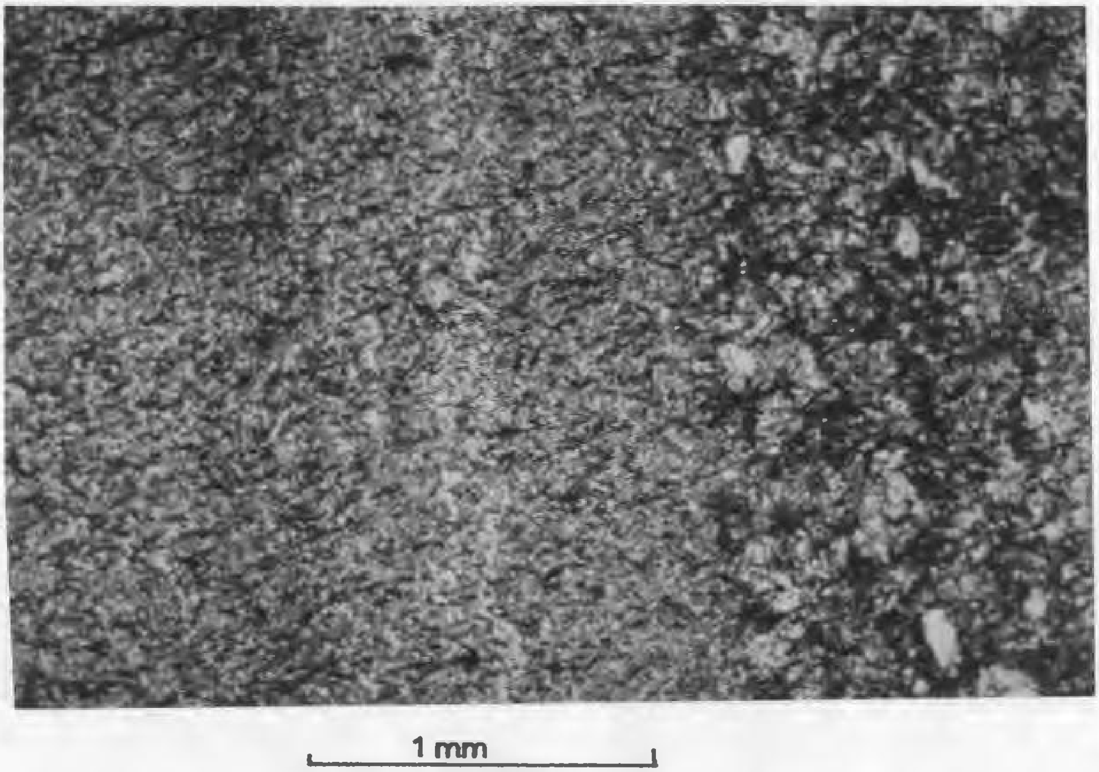


Fig. 28. Metasiltstone of the Metasedimentary Formation. S_2 is the penetrative sericite fabric parallel to bedding, cut by a fine strain-slip cleavag S_3 (E-W). Post Hill. Plane polarised light.

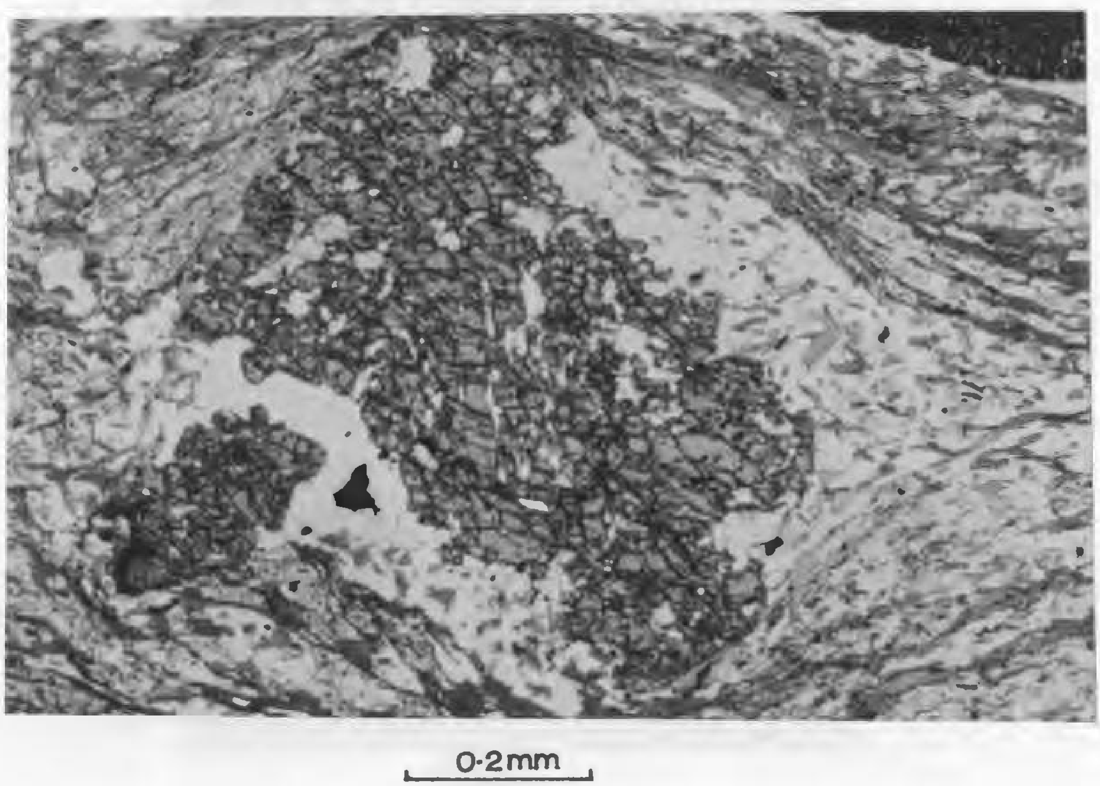
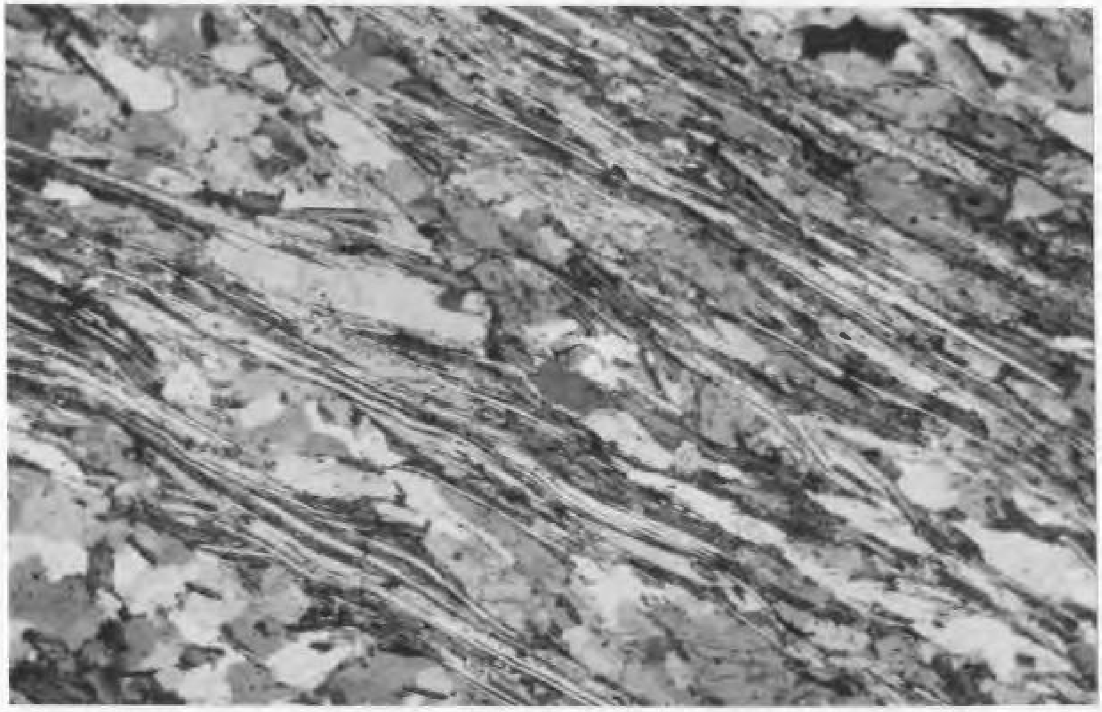
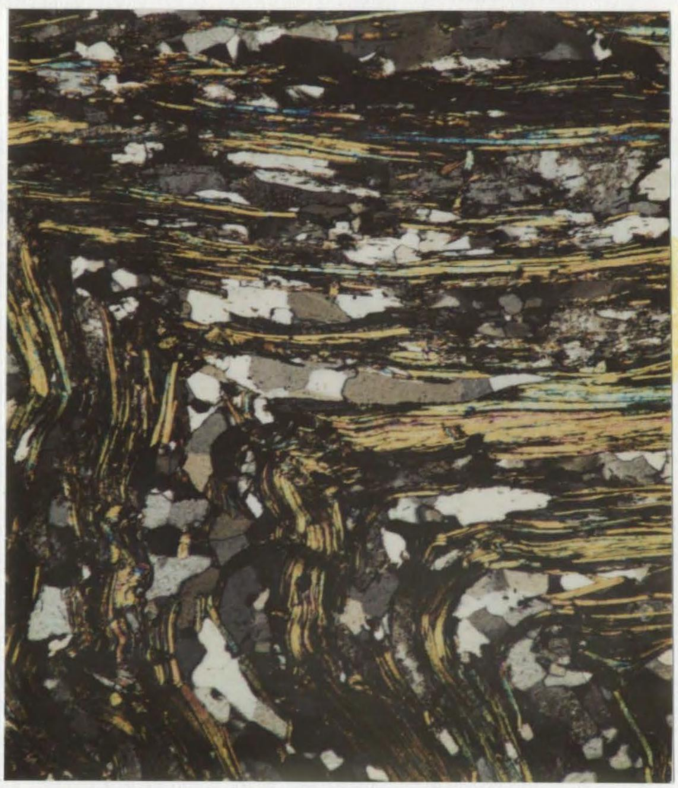


Fig. 29. S_2 preserved as an included fabric in an MP_2 garnet. The top left part of the garnet porphyroblast is an MS_3 overgrowth, and the schistosity forming the augen is S_3. Metasedimentary Formation; shoreline northwest of Kitts Pond. Plane polarised light.



0·2 mm

Fig. 30. Transpositional-type S_3 fabric in which relics of S_2 are preserved between the micaceous folia. Metasedimentary Formation. Shoreline, northwest of Kitts Pond. Partially crossed nicols.



0·2 mm

Fig. 31. Transpositional-type S_3, kinked by S_5. Metasedimentary Formation. Shoreline, northwest of Kitts Pond. Crossed nicols.

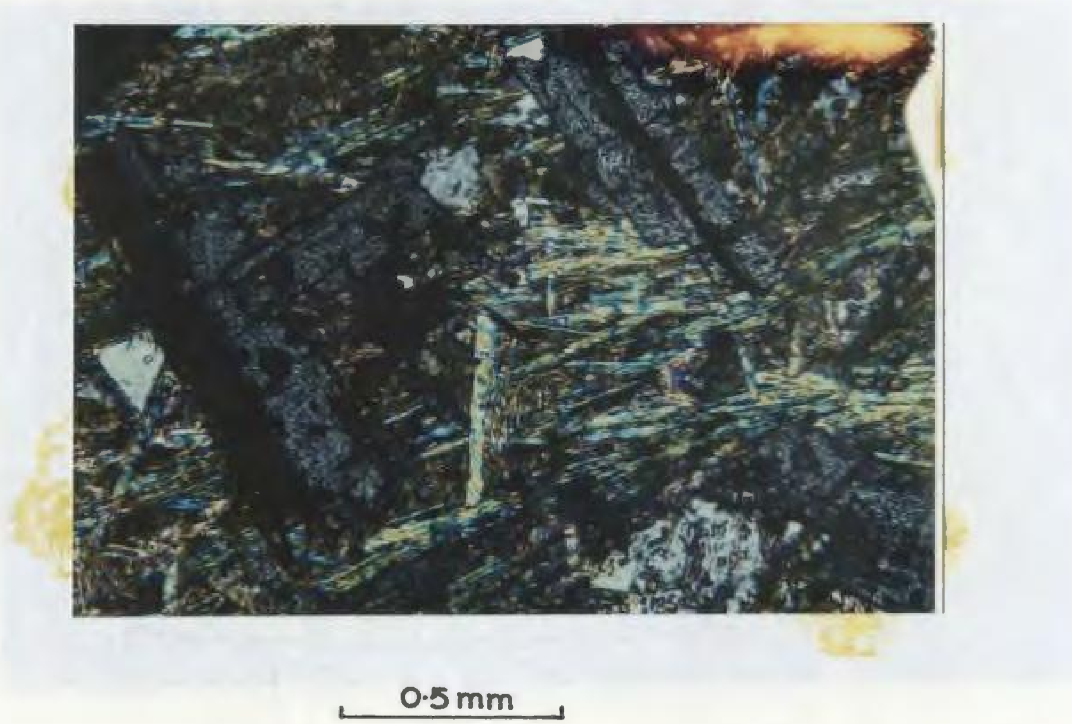


Fig. 32. Twinned MP_3 chloritoid porphyroblasts, and MP_3 muscovite flakes. Metasedimentary Formation. Post Hill. Partially crossed nicols.

Fig. 33. Conglomerate, with subrounded granite boulders and smaller clasts of pale quartz porphyry, grey felsic, acid volcanogenic psammite, and one dark clast of metabasalt. Note the weak flattening, probably related to D_2. Conglomerate Formation, northeast of Turnip Lake.

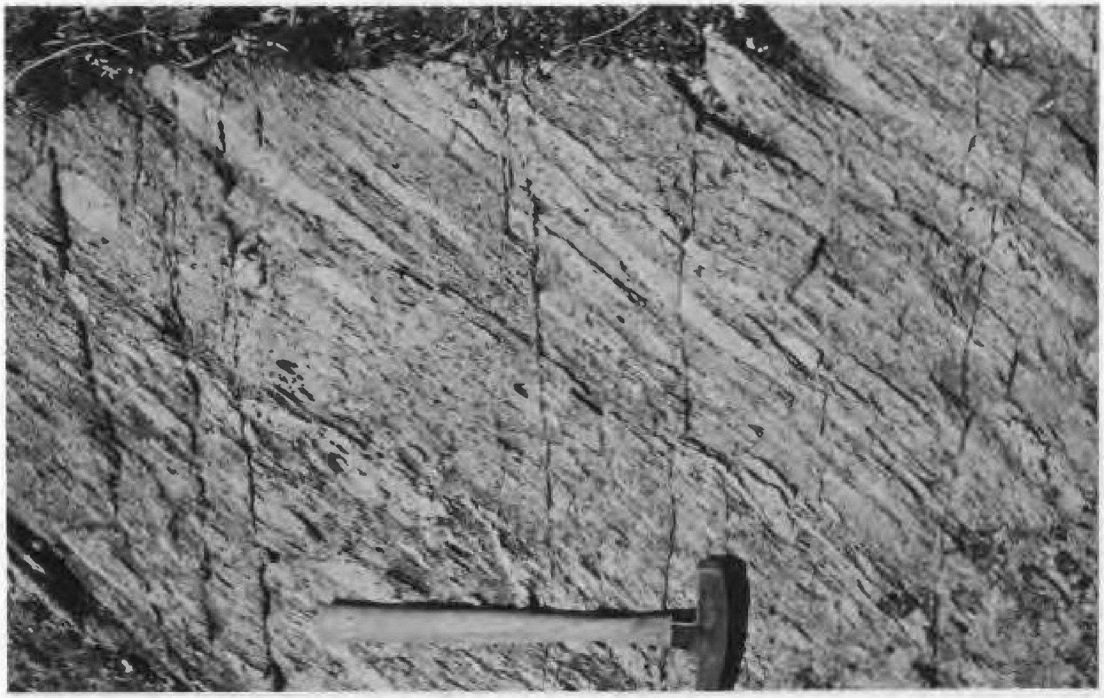


Fig. 34. Intensely flattened conglomerate; the plane of flattening is S_3. Conglomerate Formation; Limestone Lake.

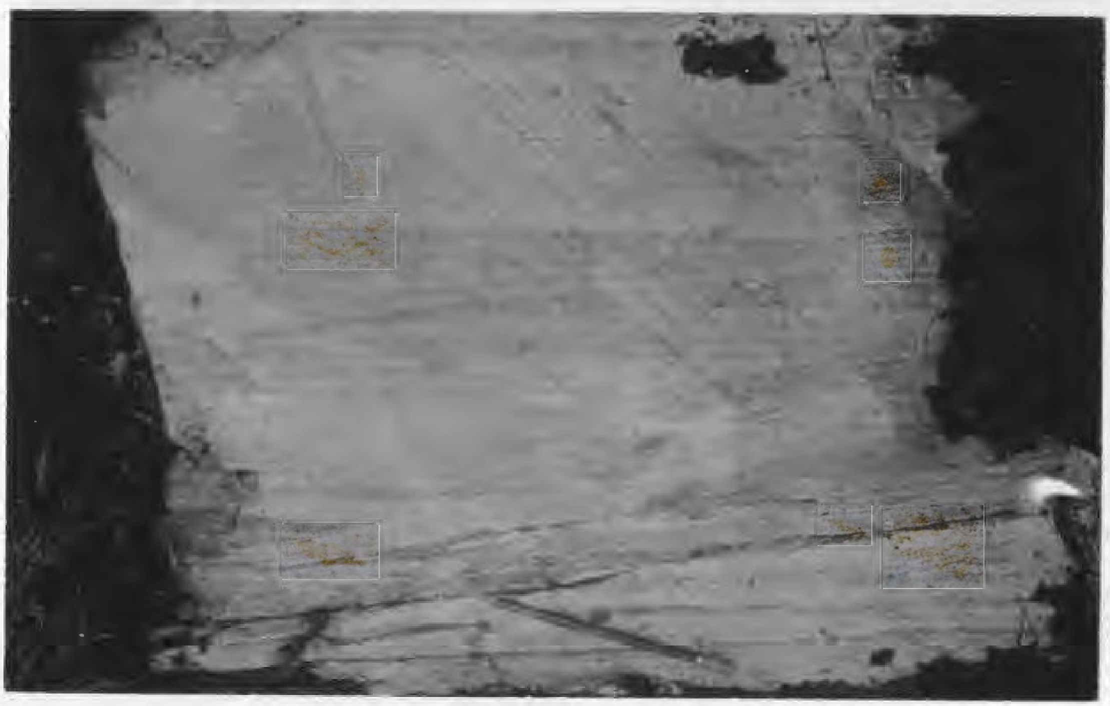


Fig. 35. Cross-lamination in banded tuff, showing tops to west. Banded Tuff Formation; 150 m. south of Kiwi Lake.

Fig. 36. Pebble bands in banded tuff; S_3 is faintly visible as a flattening of small clasts, dipping more steeply than bedding. Banded Tuff Formation; 500 m. northeast of Fiace Lake.

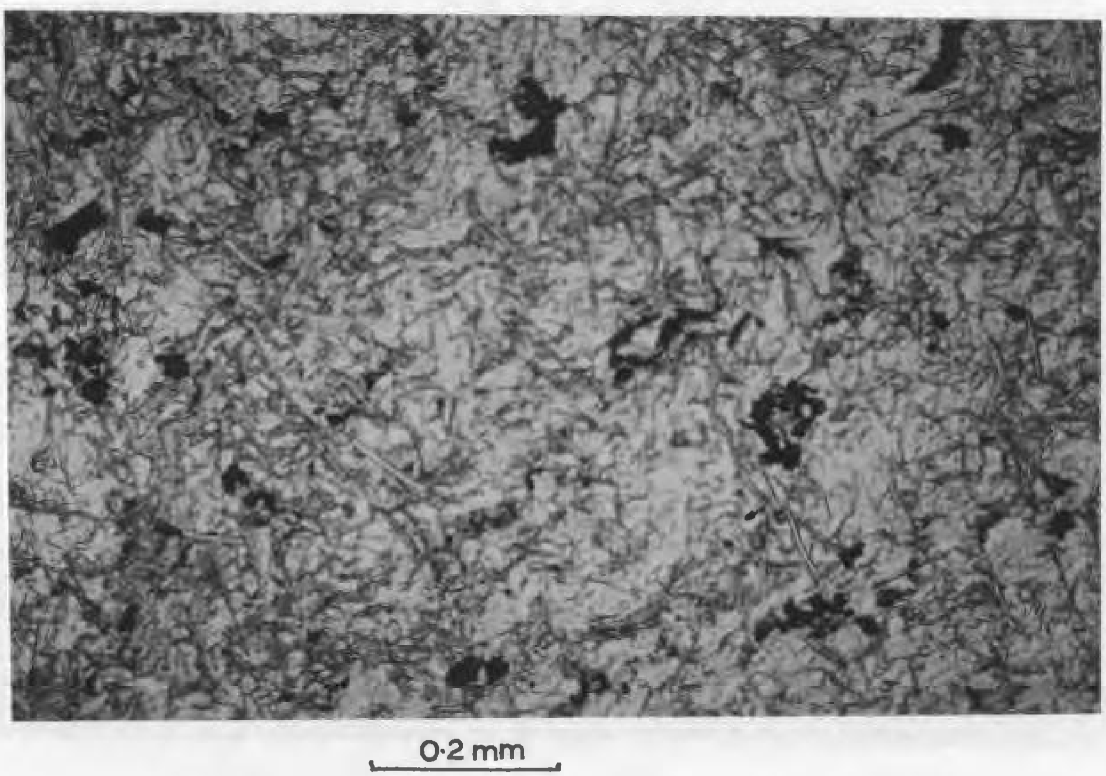


Fig. 37. S_2 in banded tuff defined by muscovite and minor biotite (NE-SW) cut by weak S_3 strain-slip with MS_3 muscovite flakes (NW-SE). Banded Tuff Formation; 150 m. south of Kiwi Lake.

Fig. 38. Thinly banded refoliated gneiss, showing detail of a minor D_2 tectonic slide. Refoliated Gneiss Zone; shore northeast of Julies Harbour.

Fig. 39. Banded gneiss of the Refoliated Gneiss Zone. Lenticular nature of the banding suggests flattening of early structures; D_3 effects are negligible in this outcrop. Shoreline north of Post Hill.

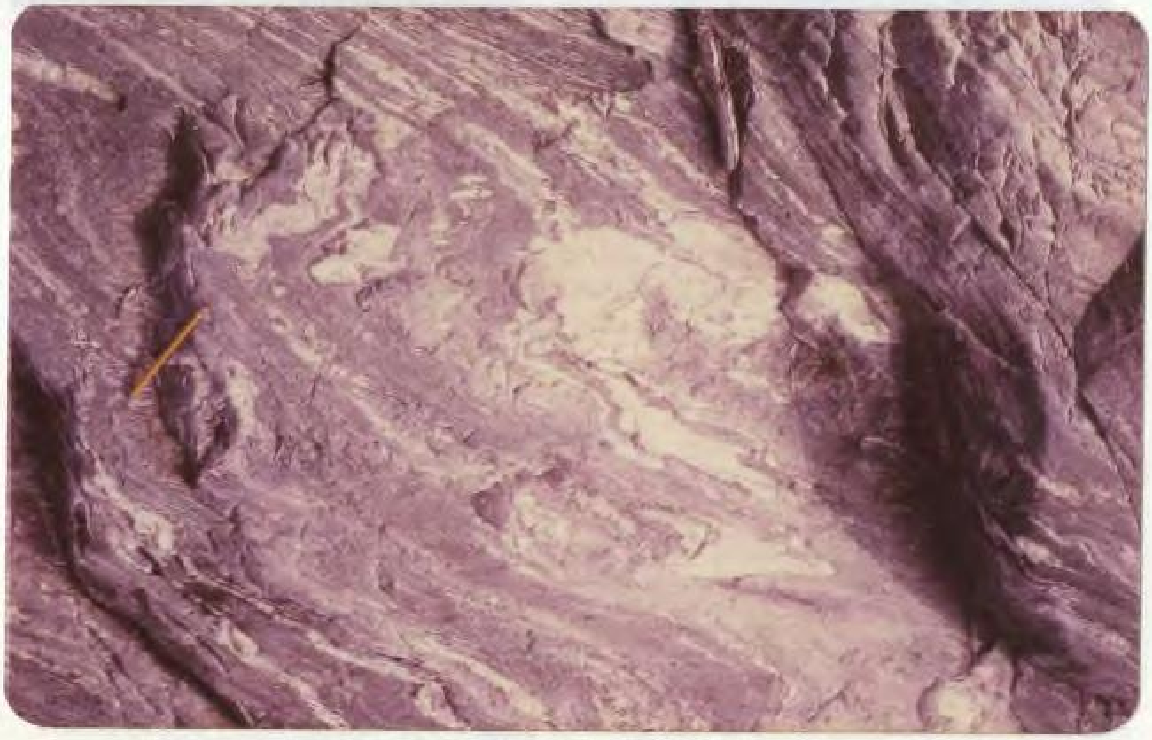


Fig. 40. Relic flattened pegmatites in gneiss of the Refoliated Gneiss Zone. D_3 effects in this outcrop are negligible; the flattening is of D_1 and D_2 age. Shoreline, north of Post Hill.

Fig. 41 Grey homogeneous granite with pre-S_1-S_2 isoclinally folded pegmatite bands. Refoliated Gneiss Zone. Shoreline north of Post Hill.

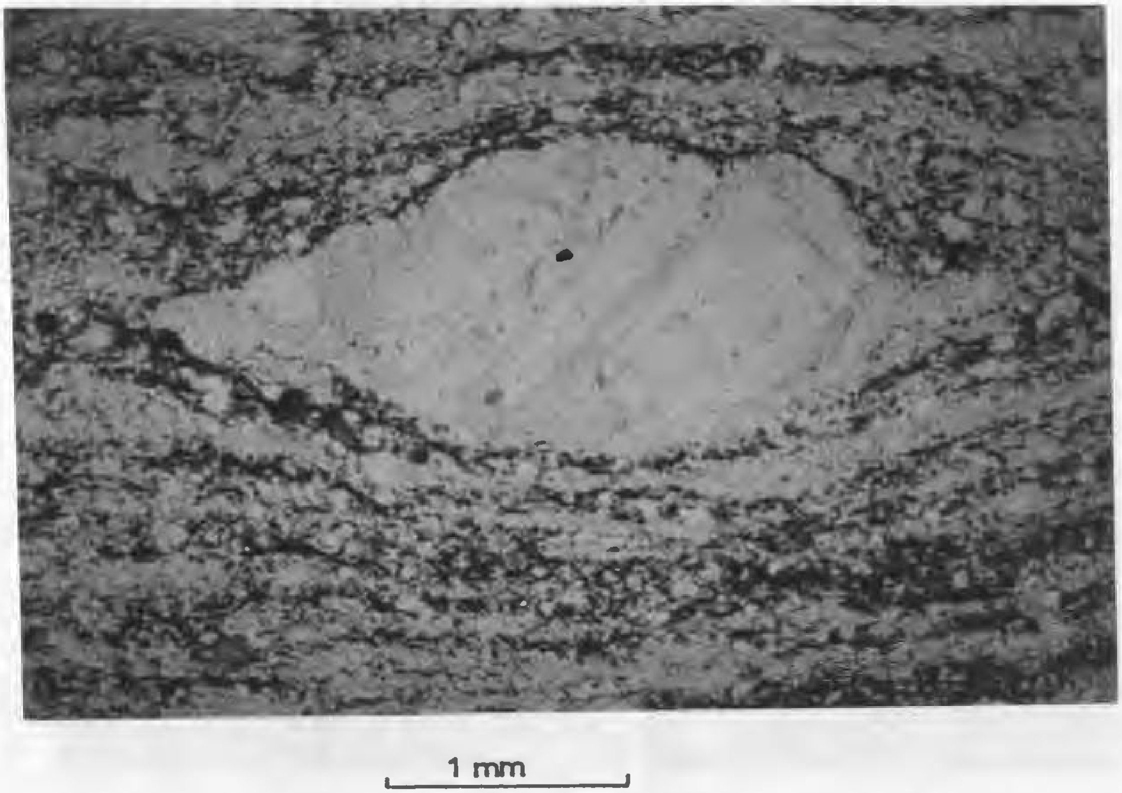


Fig. 42. Augen of microcline in intensely deformed Hopedale Complex porphyritic granite within the Refoliated Gneiss Zone. The fabric represents S_1, or S_1 transposed into S_2. Shoreline near Three Rapids Camp. Plane polarised light.

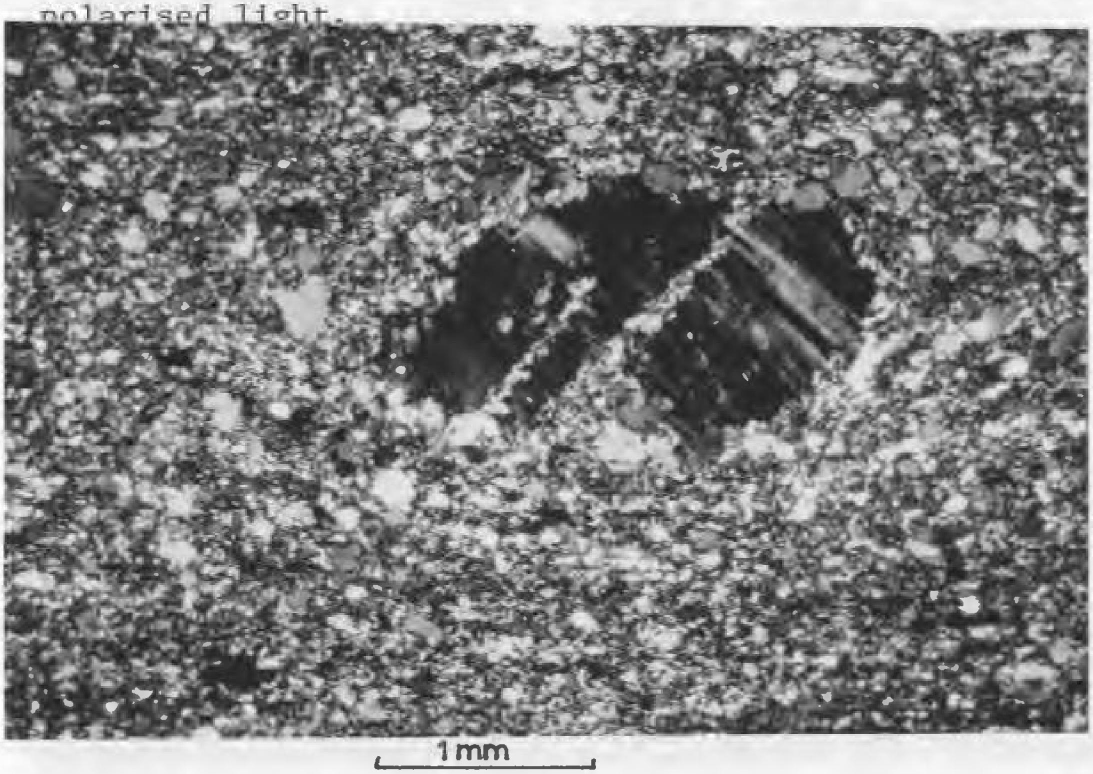


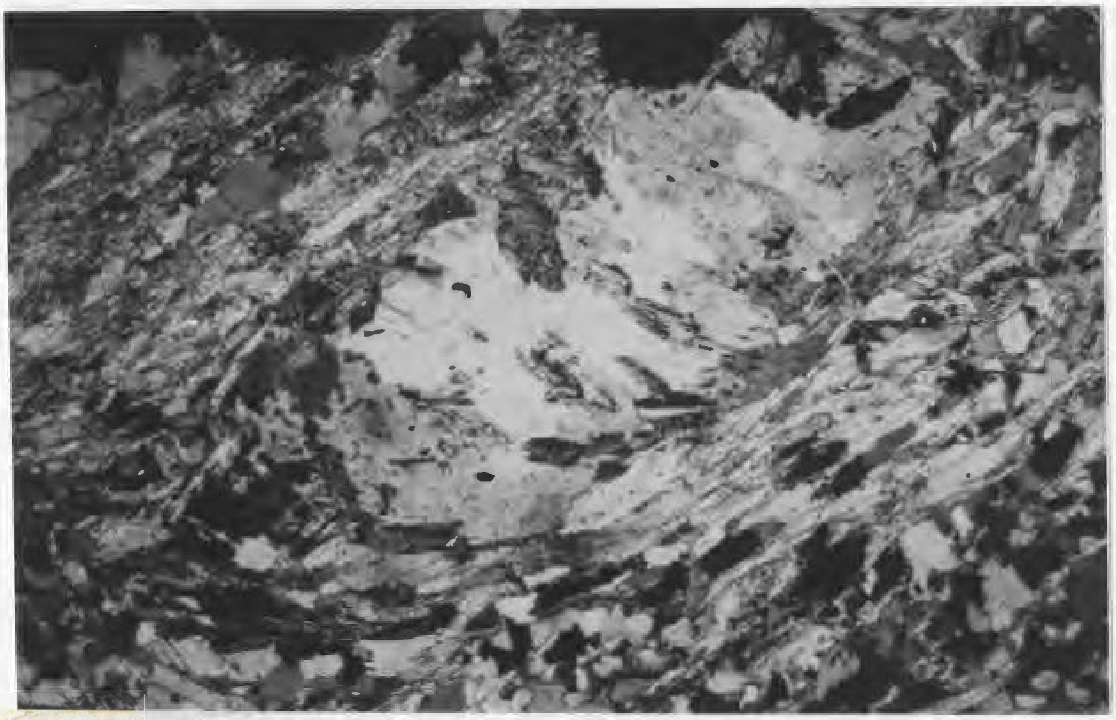
Fig. 43. The same as Fig. 42, with nicols crossed to show the extent of breakdown of the microcline augen.

Fig. 44. Quartzitic Mylonite unit in the Refoliated Gneiss Zone, showing the nature of the banding. North flank of Post Hill.

Fig. 45. Contact between white Quartzitic Mylonite and quartz-muscovite-feldspar schist. The fold axis is F_2, gently warped by F_3. Shoreline, northwest of Post Hill.

Fig. 46. Tectonic intercalation of Post Hill Amphibolite and Refoliated Gneiss in the Post Hill Slide. The intensely flattened folds are F_2, indicatin that the intercalation is of D_1 age. D_3 effects in this are insignificant. Shoreline, west side of Post Hill.

Fig. 47. Tectonic intercalation of Post Hill Amphibolite and Refoliated Gneiss in the Post Hill Slide. In this outcrop intense D_3 flattening of the essentially D_1-D_2 structure has occurred. Shorelines, northeast of Julies Harbour.



1 mm

Fig. 48. S_1 included in an MP_1 plagioclase porphyroblast, passing into S_2 in the schist. S_3 is a local crenulation at this locality, and is not represented in this thin section. Schist, Refoliated Gneiss Zone; north flank of Post Hill.

1mm

Fig. 49. S_1 included in an MP_1 plagioclase porphyroblast in the Post Hill Slide. S_2 is the dominant fabric. Shoreline, northwest side of Post Hill. Plane polarised light.

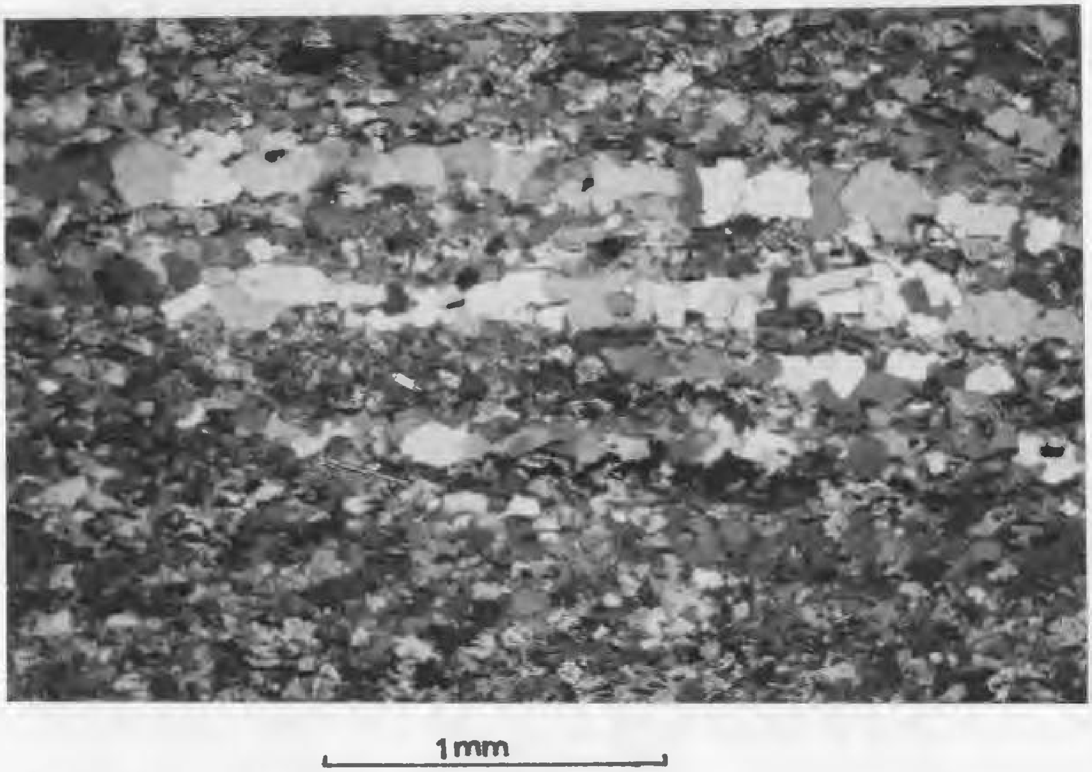


Fig. 50. Refoliated gneiss showing S_2 defined by aligned biotite flakes and laminae of quartz and feldspar mosaic. This type of fabric gives rise to the intense laminar aspect of the Refoliated Gneiss Zone. Refoliat Gneiss Zone; shoreline, east of Three Rapids Camp. Partly crossed nicols.

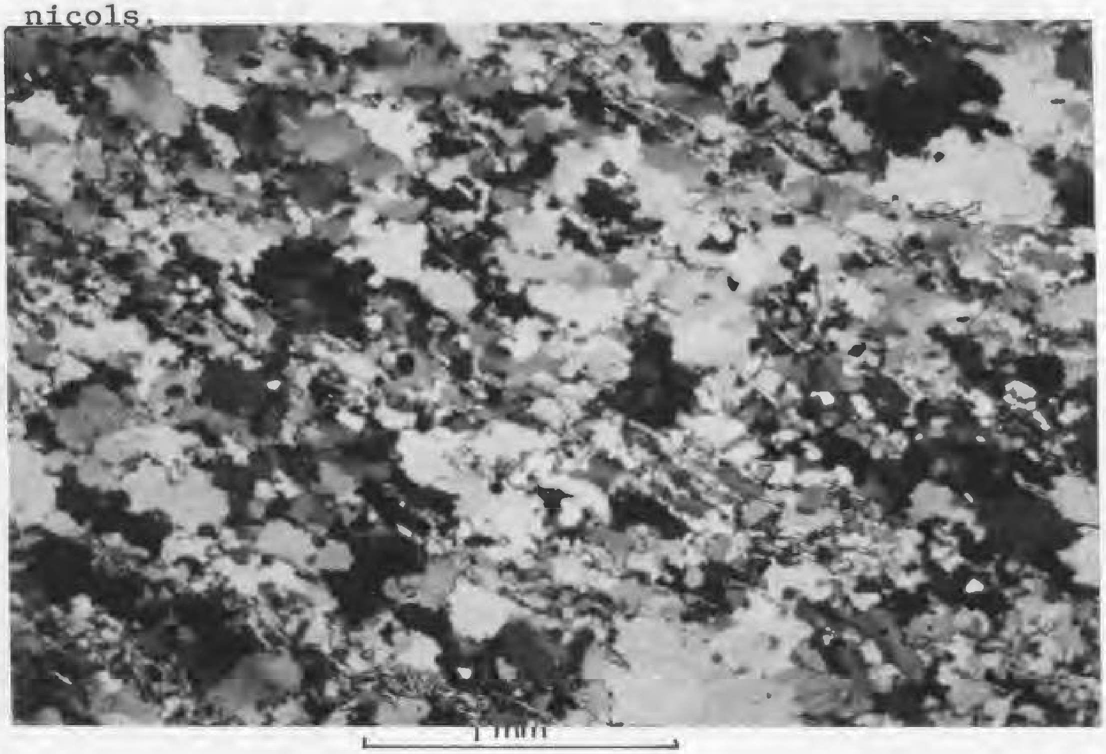


Fig. 51. Fine-grained sutured quartz mosaic with minor muscovite aligned in S_2. Quartzitic Mylonite; north flank of Post Hill. Crossed nicols.

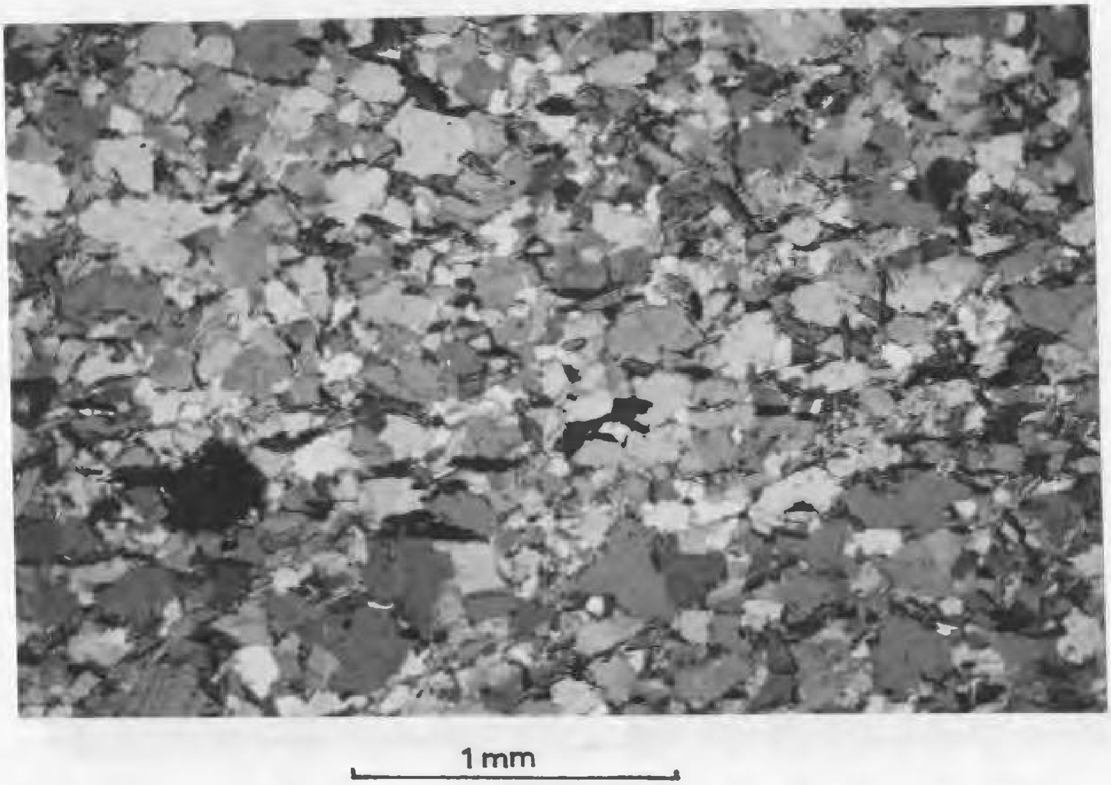


Fig. 52. Refoliated gneiss with S_3 dominant and defined by biotite; the quartz and feldspar shows MP_3 recrystallisation. Refoliated Gneiss Zone; Inda Brook. Partly crossed nicols.

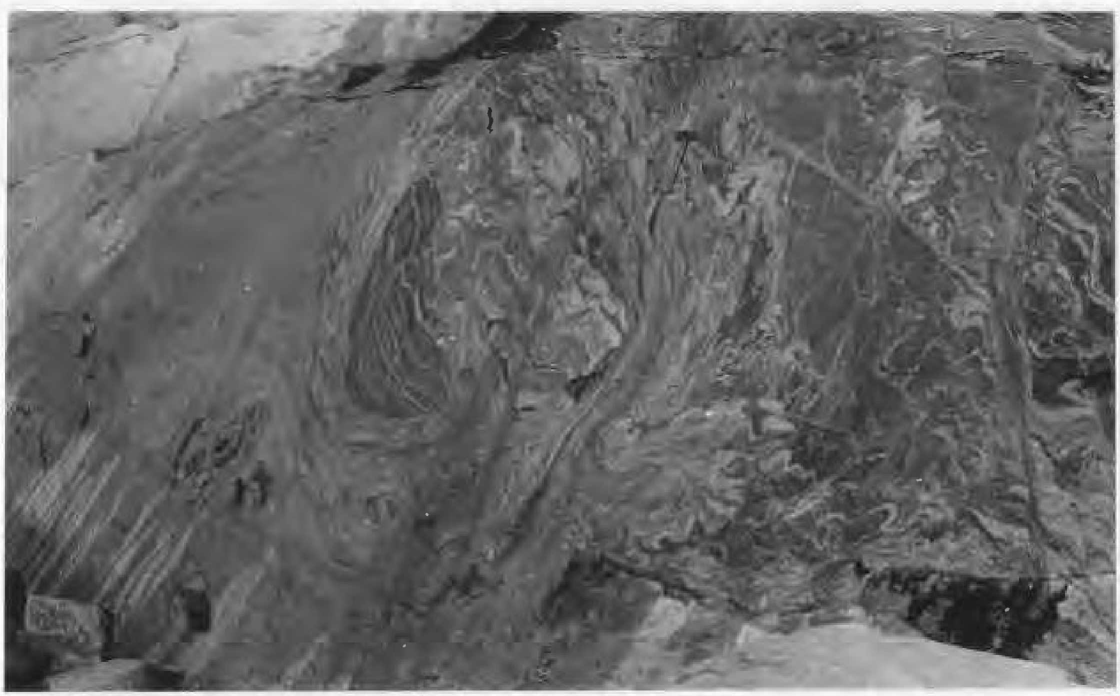


Fig. 53. Unlucky Head Migmatite. An ovoid raft of Hopedale Complex gneiss in a neosome that varies from nebulitic (left) to schlieric granite (right). Part of another raft is seen on the right edge of the photograph; note that the orientation of the Hopedale Complex banding is the same in both. Unlucky Head.

Fig. 54. Unlucky Head Migmatite, consisting here of irregular rafts of grey gneiss and minor amphibolite in a schlieric granite neosome. West of Unlucky Head.

Fig. 55. Unlucky Head Migmatite: here the rafts are more angular and agmatitic-like, and the neosome is fairly homogeneous. West of Unlucky Head.

Fig. 56. Raft of gneiss in the Unlucky Head Migmatite showing diktyonitic structure. Note that the banding in the raft strikes east-west, and the banding in the neosome strikes north-south; this is a common relationship in the Unlucky Head area. Unlucky Head.

Fig. 57. Diktyonitic structure in Hopedale Complex Gneiss, in the Unlucky Head Migmatite. Note: diffuse granite along the kink planes; the sinistral style; concentric-style folding in places between the kink planes. Some small-scale shear zones can be seen. Unlucky Head.

Fig. 58. A raft of early migmatite of the Hopedale Complex showing diktyonitic structure that developed at an early stage, as it is truncated by the neosome. Unlucky Head Migmatite; at Unlucky Head.

Fig. 59. Detail of a contact between a gneiss raft and the neosome. Note granitic material on the kink planes merging with the neosome. Unlucky Head Migmatite; at Unlucky Head.

Fig. 60. Small pod of gneiss showing sinistral kinking of the internal foliation at its margins, a common feature of the rafts. Even in this small pod the Archean foliation strikes east-west, at right angles to the banding in the neosome. Unlucky Head Migmatite, at Unlucky Head.

Fig. 61. A poorly defined raft of gneiss in very gneissic neosome. This illustrates the relationship between the ubiquitous sinistral kinking in the rafts and the transposition of the Hopedale Complex banding into the schlieric gneissosity of the neosome. Unlucky Head Migmatite; at Unlucky Head.

Fig. 62. Disrupted amphibolite units "floating" in nebulitic neosome. Note how some of the original continuity is preserved. The cuspate contacts typical of the amphibolite rafts can also be seen. Unlucky Head Migmatite; west of Unlucky Head.

Fig. 63. A cluster of amphibolite rafts in the Unlucky Head Migmatite. The large raft under the hammer consists of agmatitic or boudinised amphibolite, veined with pale granodiorite; this complex is thought to be of Archean age. The granodioritic material appears to have been remobilised, causing the agmatite to fall apart into separate rafts in the neosome. At Unlucky Head.

Fig. 64. Amphibolite raft showing typical cuspate margins. The narrow dark selvage is due to marginal alteration of hornblende to biotite. S_3 is seen as a cross-cutting crenulation cleavage (dark bands). West of Unlucky Head.

Fig. 65. Large scale D_3 kink folds in banded gneiss, with kink planes occupied by granitic neosome. From a large body of Hopedale Complex in the Unlucky Head Migmatite; southwest of Julies Harbour.

Fig. 66. Tight F_3 folds in gneiss, folding Archean-age structures in leucocratic bands. Granitic neosome veins (extreme right) intrude the limbs of these folds parallel to the axial planes and to S_3, here an axial planar fabric. Unlucky Head Migmatite, southwest of Julies Harbour.

Fig. 67. F_3 fold in gneiss with dyke (right) of granitic neosome with concordant faint nebulitic banding, intruded along the limb sub-parallel to the axial plane. Unlucky Head Migmatite; southwest of Julies Harbour.

Fig. 68. Complex outcrop pattern produced by interference of gently plunging F_3 folds with early folds in banded gneiss, outcropping on irregular surfaces. Granitic neosome is seen at the top of the photograph. In large body of Hopedale Complex; southwest of Julies Harbour.

Fig. 69. Complex fold geometry in migmatised gneiss. A north-south flattening parallel to a weak S_3 is apparent, but in detail the fold patterns cannot be explained by superimposition of several fold phases during homogeneous deformation. Great inhomogeneities in deformation are apparent. Large body of Hopedale Complex; southwest of Julies Harbour.

Fig. 70. Chaotic structure in raft of gneiss in the Unlucky Head Migmatite. Extremely inhomogeneous deformation is indicated. Note the homogeneous neosome. Northeast of Unlucky Head.

Fig. 71. Grey nebulitic granite forming the neosome of the Unlucky Head Migmatite. The ghost banding is subparallel to a weak S_3 biotite fabric, striking approximately north-south. Northeast of Unlucky Head.

Fig. 72. Grey nebulitic granite, with faint regular banding sweeping around a raft of amphibolite. Unlucky Head Migmatite; west of Unlucky Head.

Fig. 73. Homogeneous neosome showing a sharp agmatitic contact with Hopedale Complex gneiss. The gneiss does not show diktyonitic structure. Unlucky Head Migmatite; at Unluckly Head.

Fig. 74. Early migmatite of Archean age on left, cut by the Unlucky Head Migmatite on right. The "early" migmatite (under hammer) has a generally paler neosome that has a strong penetrative fabric truncated by the neosome of the Unlucky Head Migmatite. West of Unlucky Head.

Fig. 75. Homogeneous Brumwater Granite. The dark band is a minor S_4 zone of granulation. Shore northeast of Julies Harbour.

Fig. 76. Brumwater Granite cutting D_1-D_2 banding in refoliated gneiss. At this contact the granite is migmatitic; note the similarity to the Unlucky Head Migmatite. Contact of Refoliated Gneiss Zone; northeast of Julies Harbour.

Fig. 77. Xenolith of amphibolite and gneiss in strongly foliated (S_3) quartz monzonite. Hornblende in the amphibolite shows marginal alteration to biotite, forming the 3 cm.-wide selvage just visible in the photograph. The fold is an F_3 fold, formed by flattening of an irregular apophysis of the xenolith. Migmatitic Quartz Monzonite; west of Watts Lake.

Fig. 78. Laminar S_2 is the Post Hill Amphibolite truncated by a homogeneous quartz monzonite phase of the Migmatitic Quartz Monzonite. East side of Post Hill.

Fig. 79. Xenoliths of Post Hill Amphibolite in a homogeneous phase of the Migmatitic Quartz Monzonite. Note the sharp contacts, and truncation of S_2 in the amphibolite. East side of Post Hill.

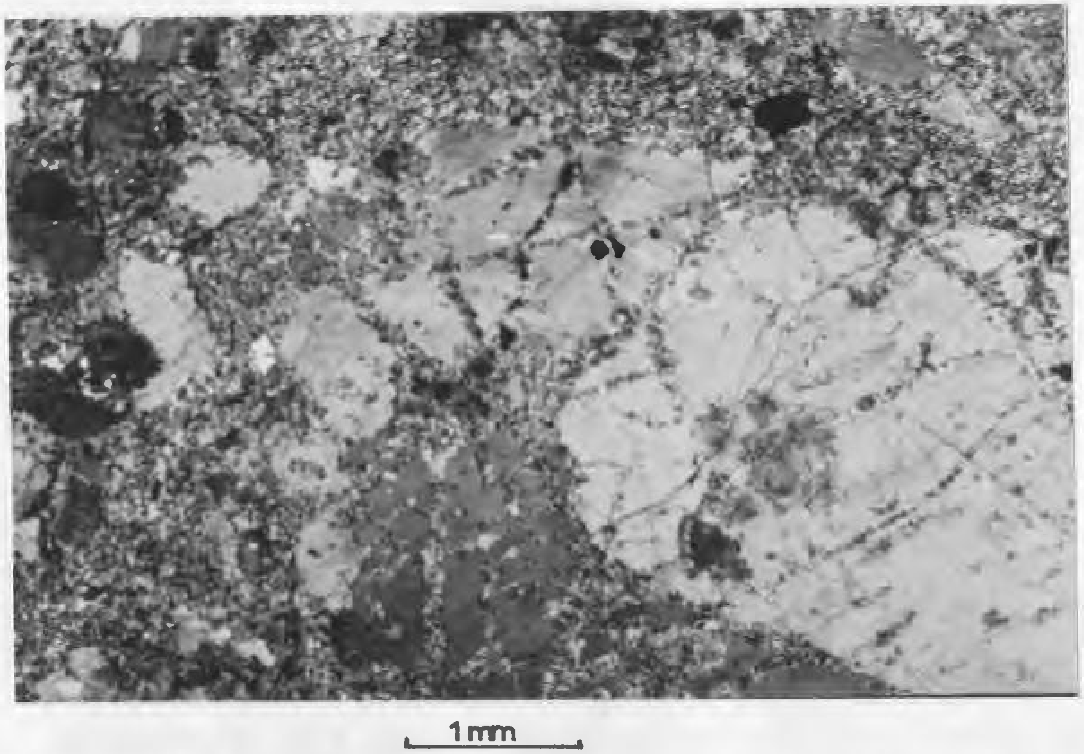


Fig. 80. Microcline megacryst in the Migmatitic Quartz Monzonite. The microcline is traversed by bands of granular feldspar, representing an early stage in the breakdown of the megacrysts. West of Watts Lake. Partially crossed nicols.

Fig. 81. Wispy rafts of fine-grained gneiss in the Migmatitic Quartz Monzonite. The very intense foliation, S_3, indicates proximity to the Witch Lake Slide, some 40 m. to the east of this outcrop. West of Watts Lake.

Fig. 82. Mylonitised (S_3) quartz monzonite on left, in contact with hornblende schist of the Witch Lake Slide zone. The contact is below the head of the hammer. The hornblende schist is extremely attenuated Post Hill Amphibolite, here only 30 m. thick, showing a laminar S_3 with relics of a transposed laminar S_2. Southwest of Witch Lake the quartz monzonite is progressively transferred to mylonite of the type seen here. Southwest of Watts Lake.

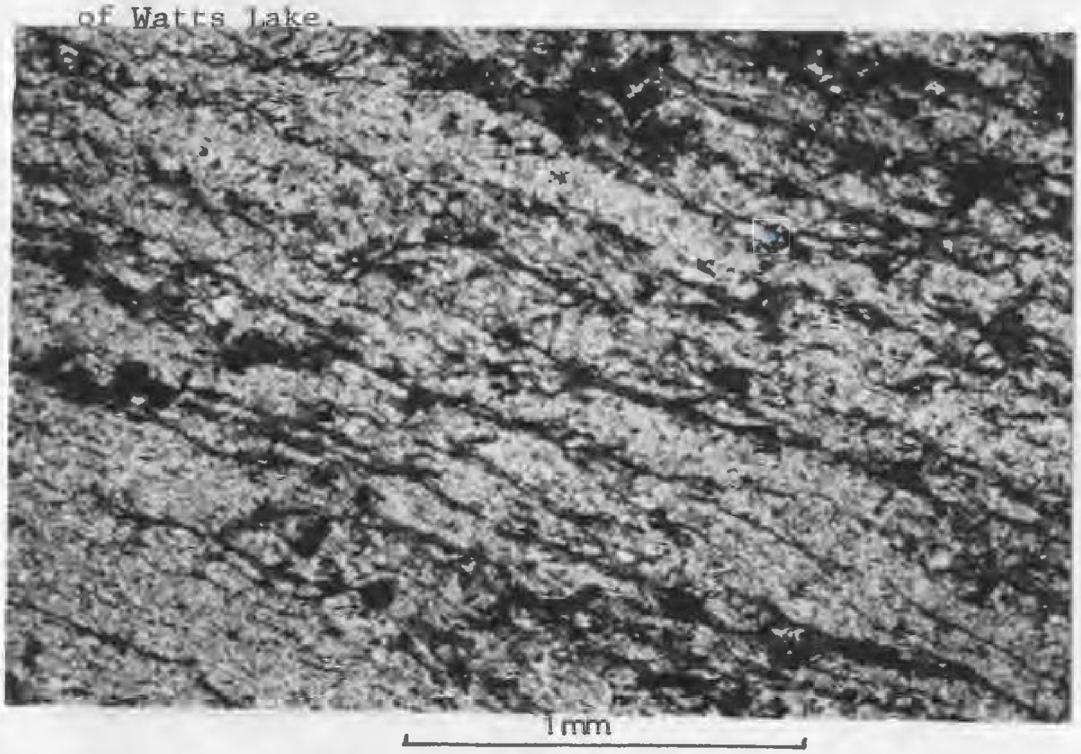


Fig. 83. Mylonitised quartz monzonite from a mylonitised zone close to the Witch Lake Slide. The very fine-grained quartzo-feldspathic mosaic shows some sutured grain boundaries; fine biotite flakes from the dark folia that define S_3. Migmatitic Quartz Monzonite; northeast corner of Witch Lake.

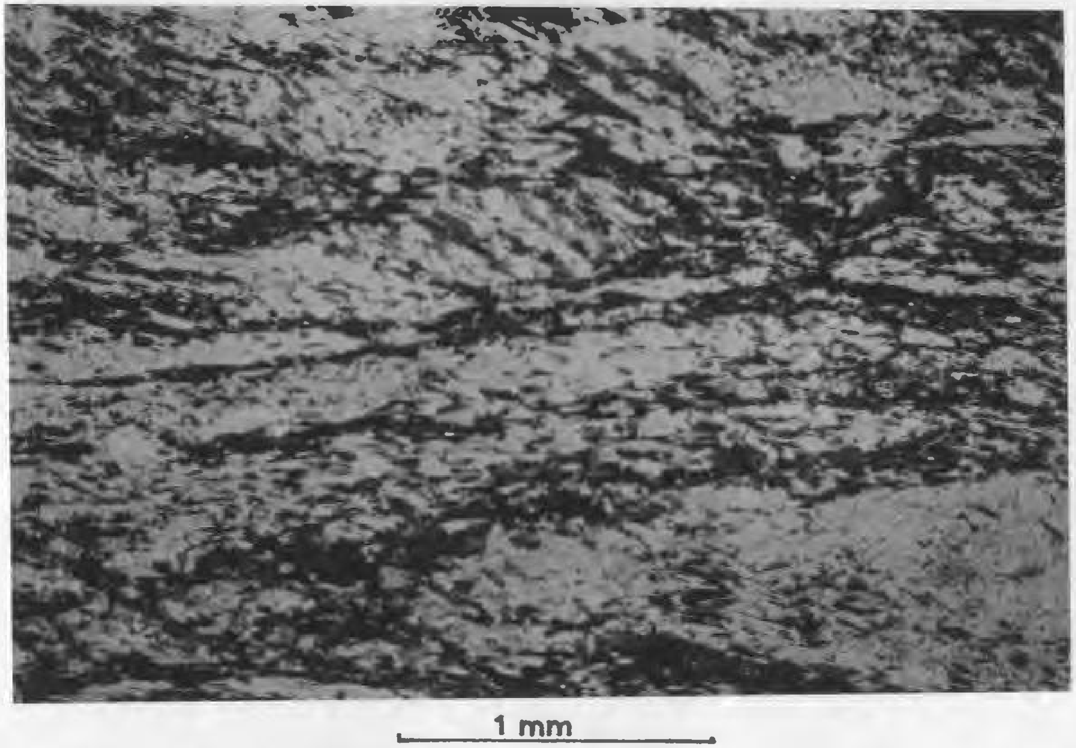
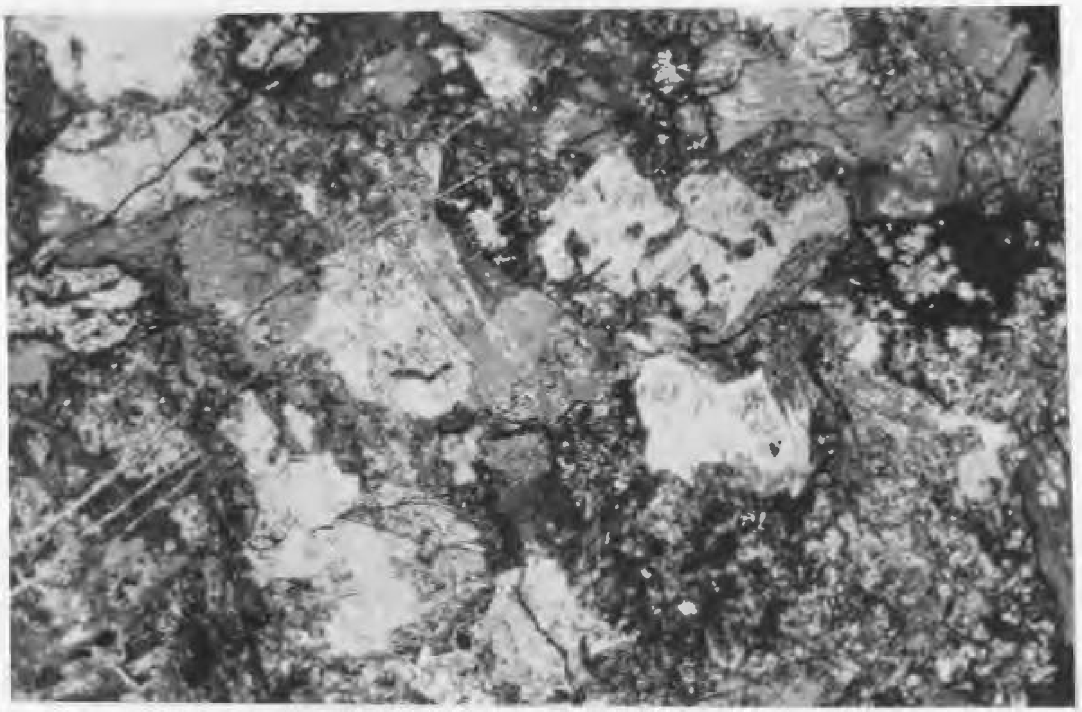


Fig. 84. Mylonitised quartz monzonite from the contact with the Witch Lake Slide. Note that S_3 is locally a strain-slip cleavage, indicating composite development. Contact of the Migmatitic Quartz Monzonite; southwest of Watts Lake.

Fig. 85. Anastomosing mylonitic D_4 shear zones cutting quartz monzonite that shows a weak penetrative S_3. Migmatitic Quartz Monzonite; Witch Lake.



1mm

Fig. 86. Kitts Metagabbro, showing poikiloblastic tremolite-actinolite crystals and heavily saussuritised plagioclase. Southwest of Kitts Prospect. Crossed nicols.

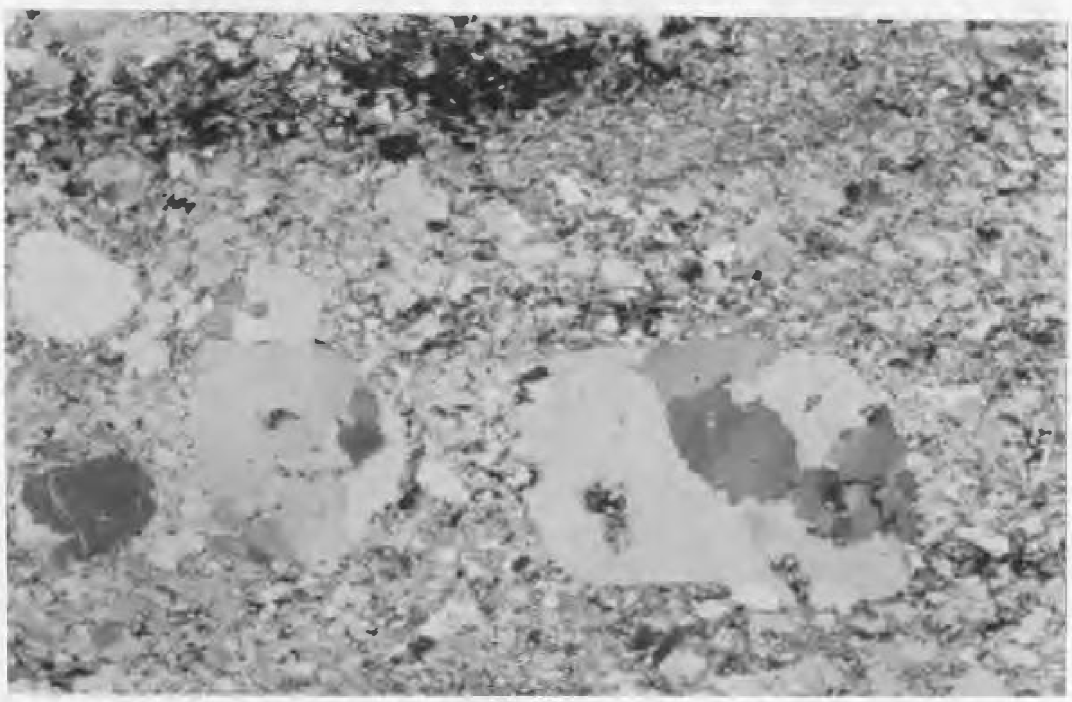


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Fig. 87. Corroded quartz phenocrysts in a quartz porphyry dyke. North of Kitts Prospect. Partly crossed nicols.

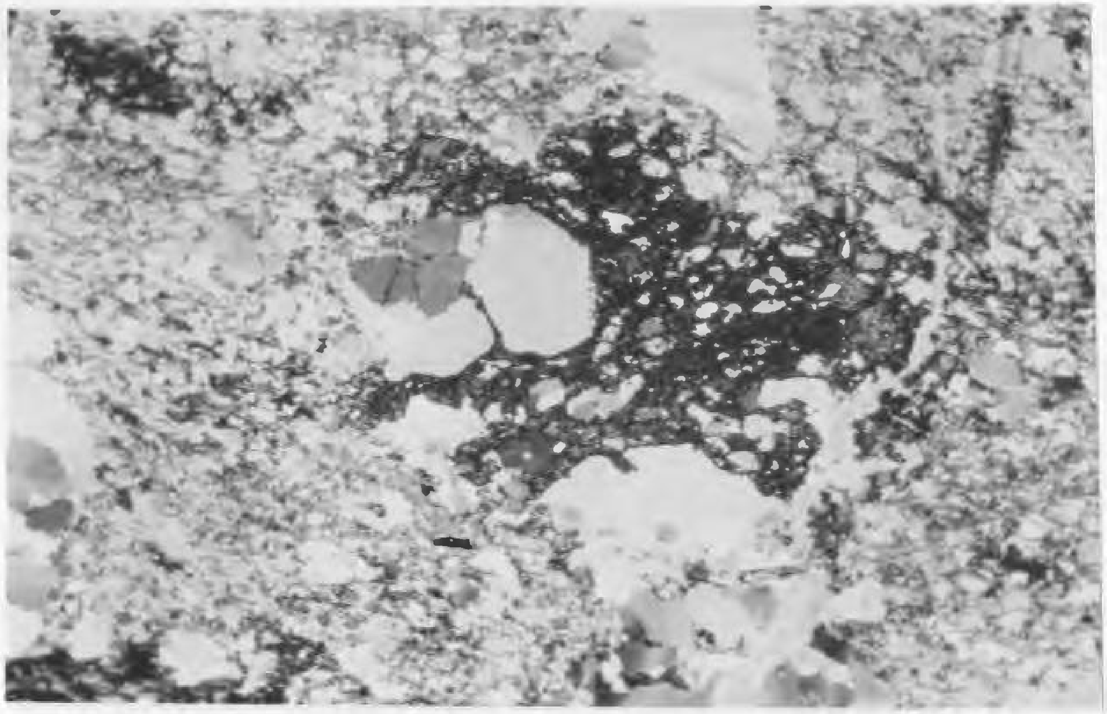


Fig. 88. Amoeboidal garnet porphyroblast (dark) overgrowing corroded quartz phenocrysts in a quartz porphyry dyke. Northeast of Kidney Pond. Partly crossed nicols.

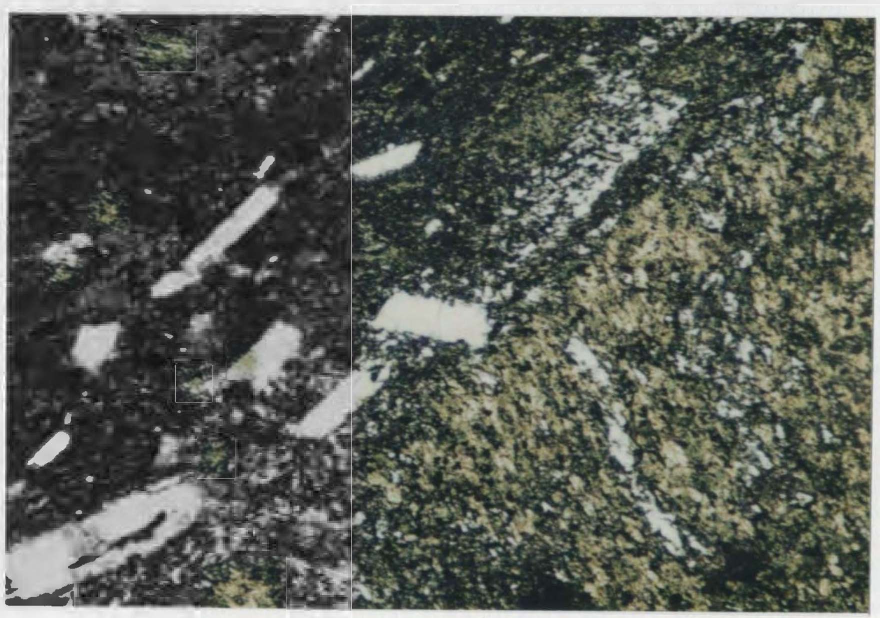


Fig. 89. Chilled contact of a syn-D_3 gabbro dyke with plagioclase phenocrysts, sharply truncating S_2 in the Post Hill Amphibolite. D_3 strain is negligible at this locality. Southwest of Post Hill summit.

Fig. 90. Relic ophitic texture in the core of a gabbro dyke that is marginally foliated by S_3. Pyroxene is pseudomorphed by amphibole. Witch Lake.

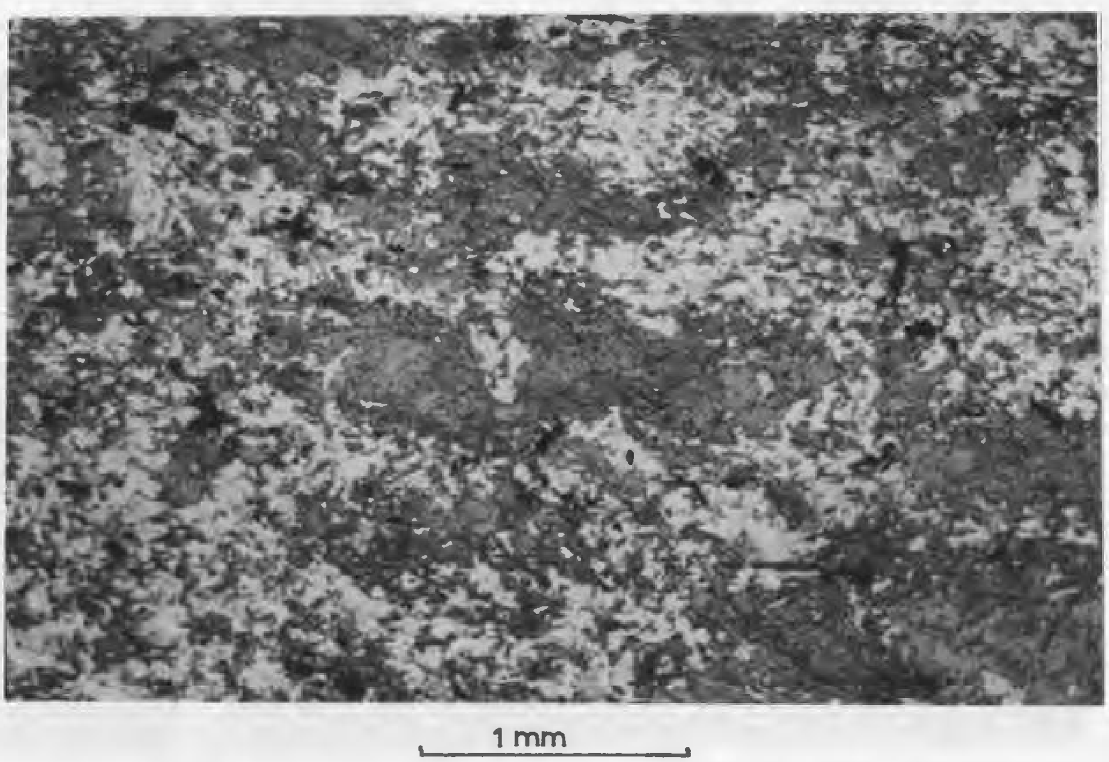


Fig. 91. Flattened relic igneous texture in the weakly foliated margin of a syn-D_3 gabbro dyke. The lensoid feldspathic aggregates represent broken-down plagioclase laths. Lensoid hornblende aggregates represent deformed pyroxene crystals. South of Post Hill Summit.

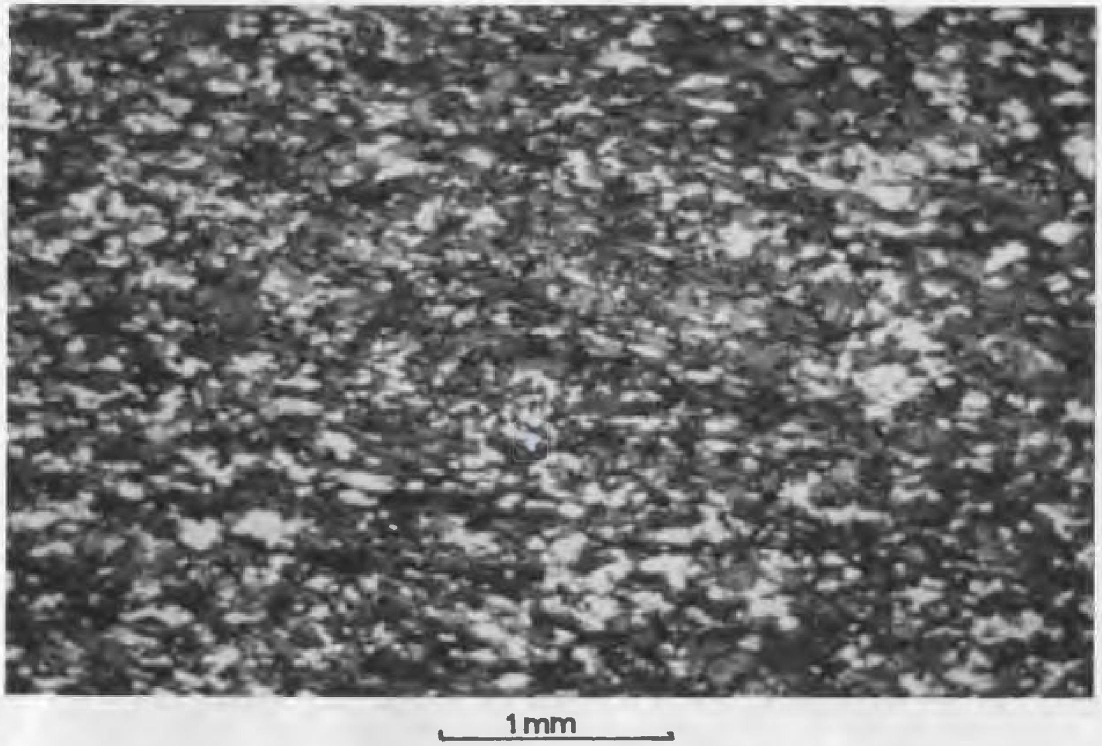
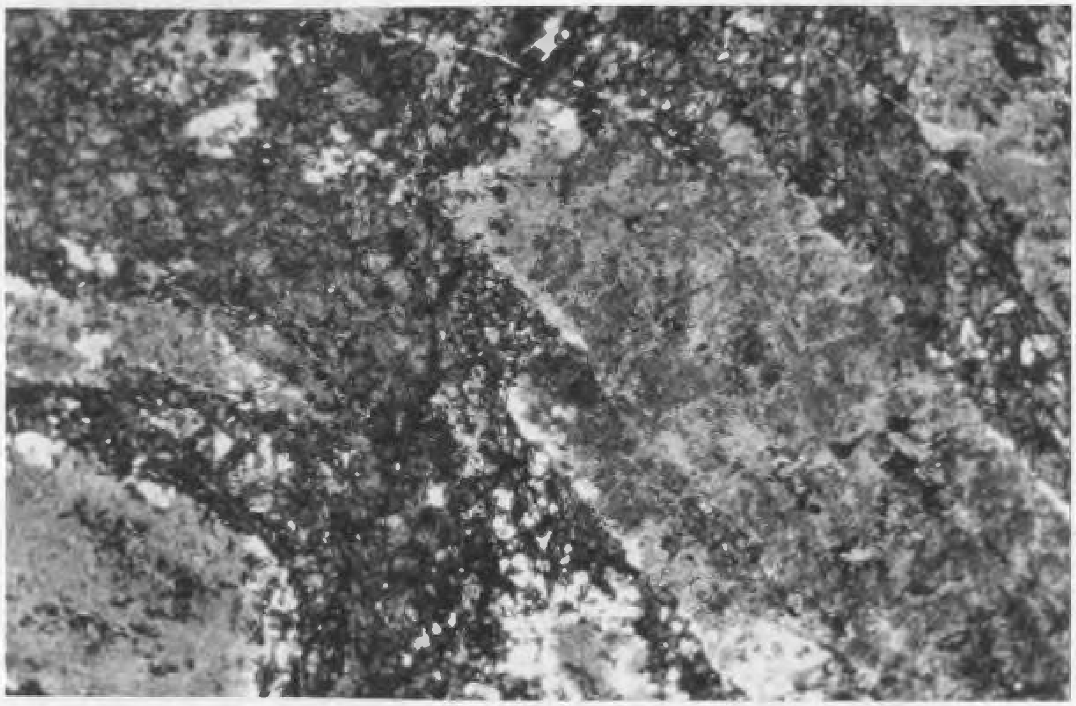


Fig. 92. Hornblende schist in the margin of a deformed syn-D_3 gabbro dyke. The schistosity is S_3. West of Witch Lake.

Fig. 93. Plagioclase Porphyry intruded by the Long Island Gneiss. Plagioclase phenocrysts are not abundant here, but they crowd the rock about 5 m. to the northeast. South of Turnip Lake.



2 mm

Fig. 94. Euhedral saussuritised plagioclase phenocrysts in a hornblende-oligoclase (-minor biotite) groundmass. Plagioclase Porphyry. South of Turnip Lake. Plane polarised light.

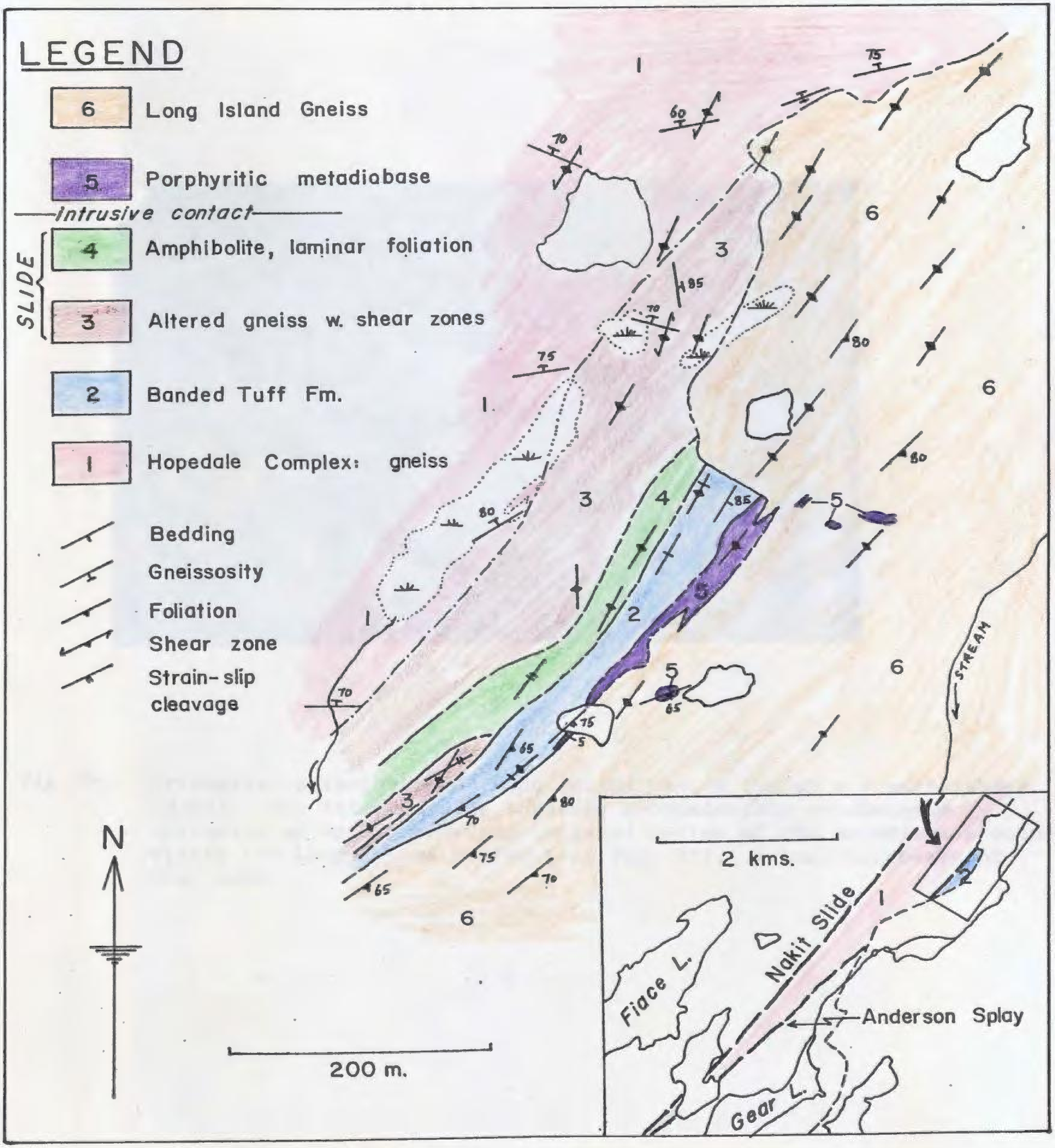


Fig. 95. Detailed geology of an area northeast of Gear Lake, showing the intrusive relationship of the Long Island Gneiss to the D_1-D_2 tectonic slide (Anderson Splay).

Fig. 96. Irregular contact between Long Island Gneiss (pale) and metadiabase (dark). The intertonguing suggests approximately synchronous intrusion of both phases, as isolated bodies of the metadiabase occur within the Long Island Gneiss (see Fig. 95). 2 kms. northeast of Gear Lake.

Fig. 97. Sharp intrusive contact of Long Island Gneiss against fine-grained white psammite of the Banded Tuff Formation. The penetrative fabric is S_3; note dark lensoid xenoliths in the Long Island Gneiss. 2 kms. northeast of Gear Lake.

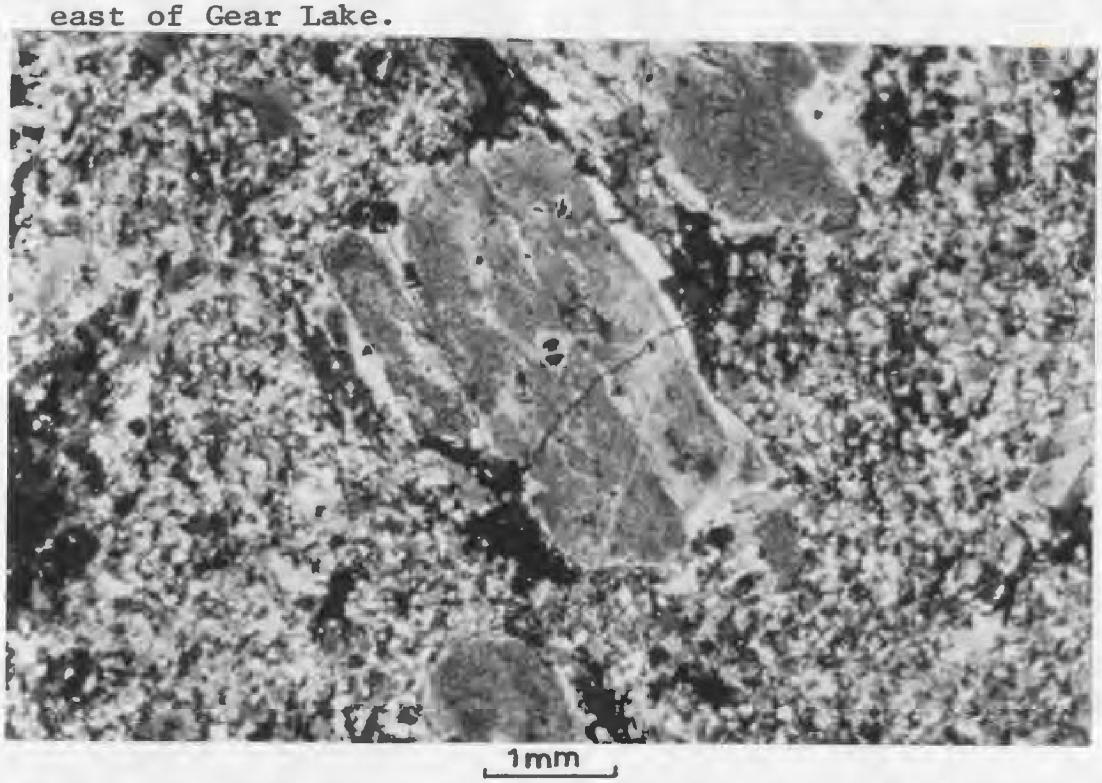


Fig. 98. Thin section of Long Island Gneiss showing saussuritised plagioclase phenocrysts mantled by microcline. The dark areas are hornblende-biotite aggregates. West of Marks Bight. Crossed nicols.

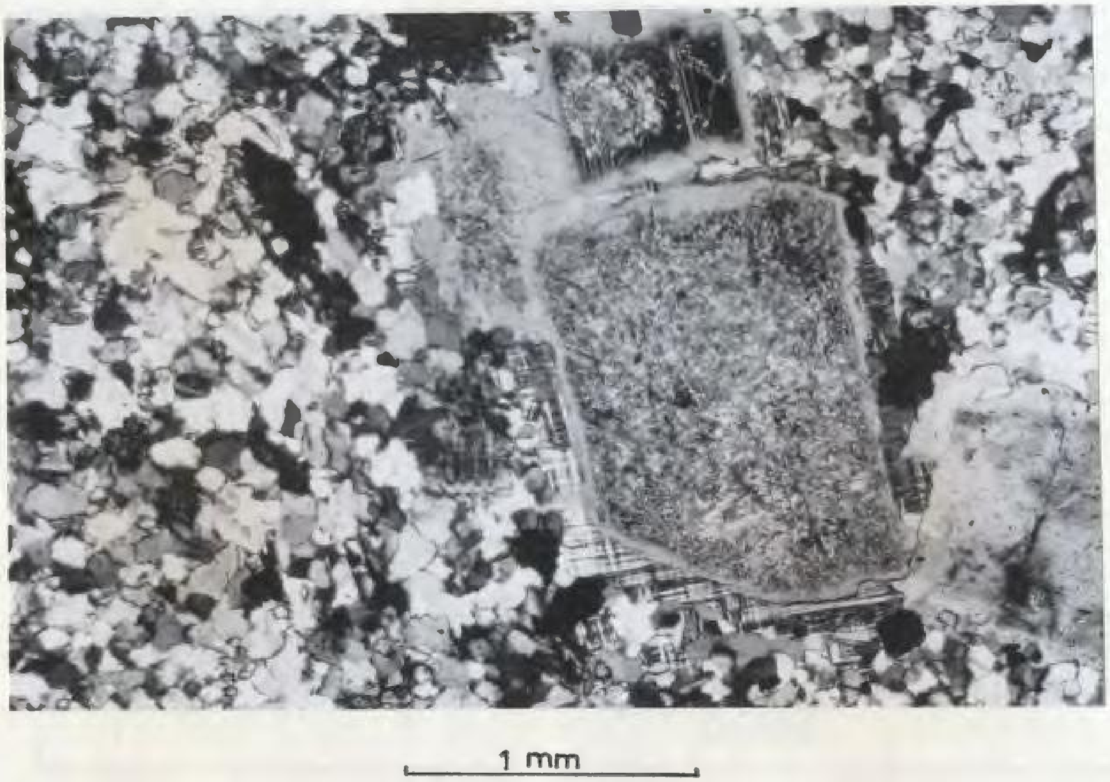


Fig. 99. Microcline rimming a saussuritised plagioclase phenocryst in the Long Island Gneiss. East of Kitts Pond. Crossed nicols.

Fig. 100. Long Island Gneiss, showing typical mottled aspect caused by feldspar phenocrysts and mafic eyes. The even penetrative fabric is S_3. In this outcrop an early pegmatite vein oriented perpendicular to the plan of flattening has been buckle-folded. Homogeneous deformation of the Long Island Gneiss around it is shown by the curve in S_3. Shore of Marks Bight.

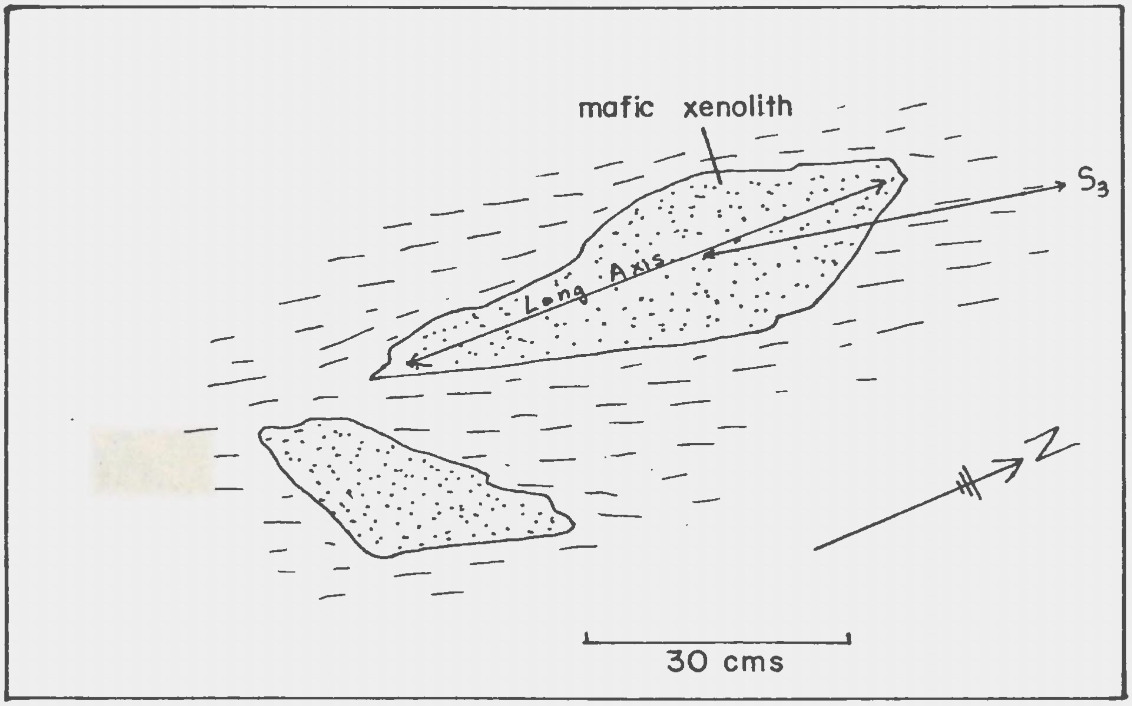


Fig. 101. Sketch showing that the elongate shape of xenoliths in the Long Islan Gneiss is partly primary. The long axis of the clast is at an angle to S_3. West shore of Marks Bight.

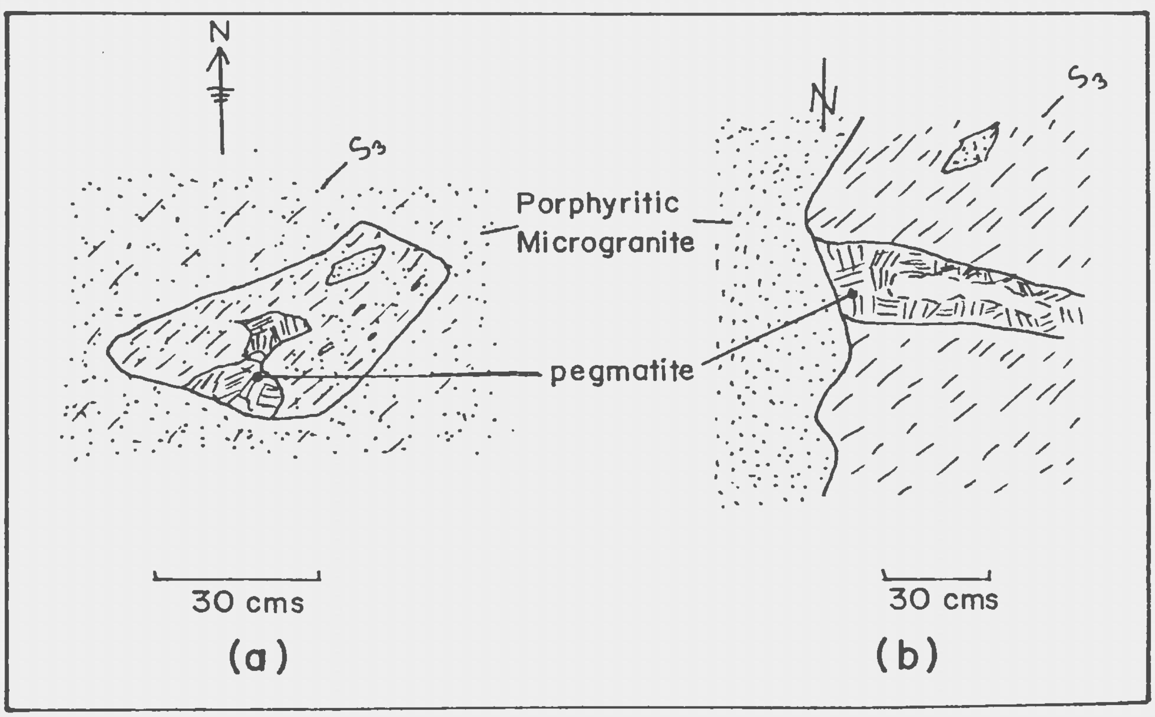


Fig. 102. Field sketches showing (a) a xenolith of Long Island Gneiss in Porphyritic Microgranite and (b) a pegmatite dyke in the Long Island Gneiss truncated by the Porphyritic Microgranite. West of Swell Lake.

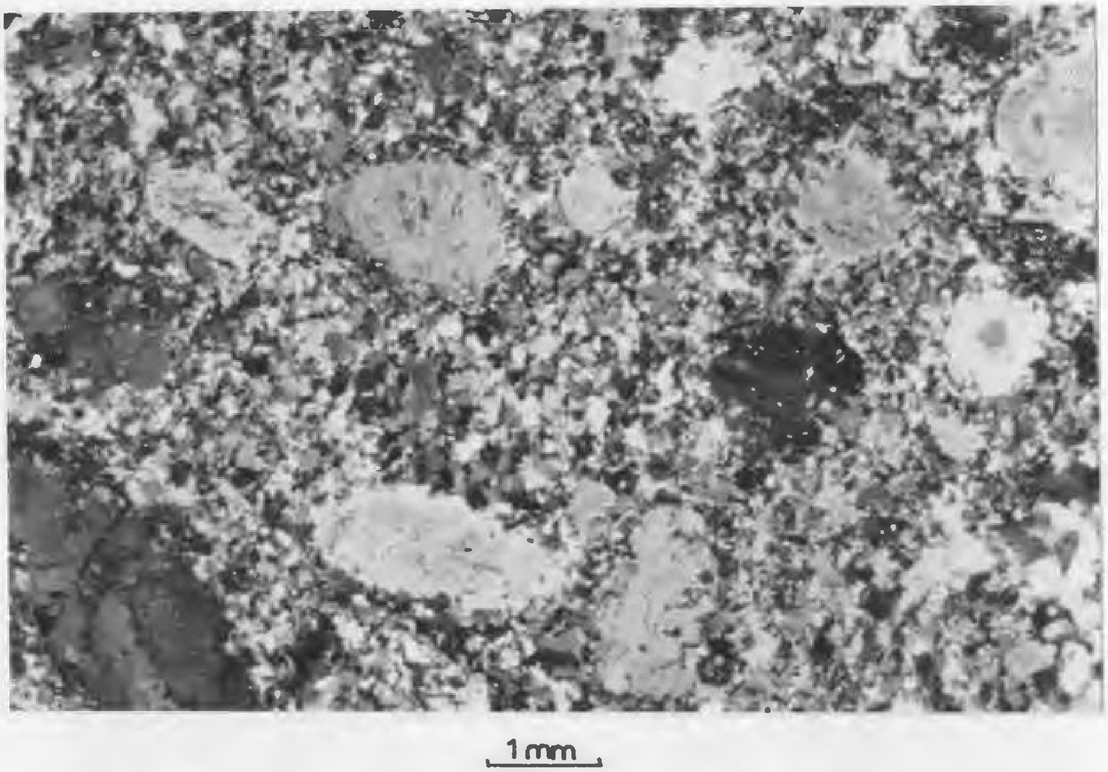


Fig. 103. Porphyritic Microgranite containing subhedral, somewhat ovoid plagioclase phenocrysts in a xenomorphic microcline-plagioclase-quartz groundmass. North of Swell Lake.

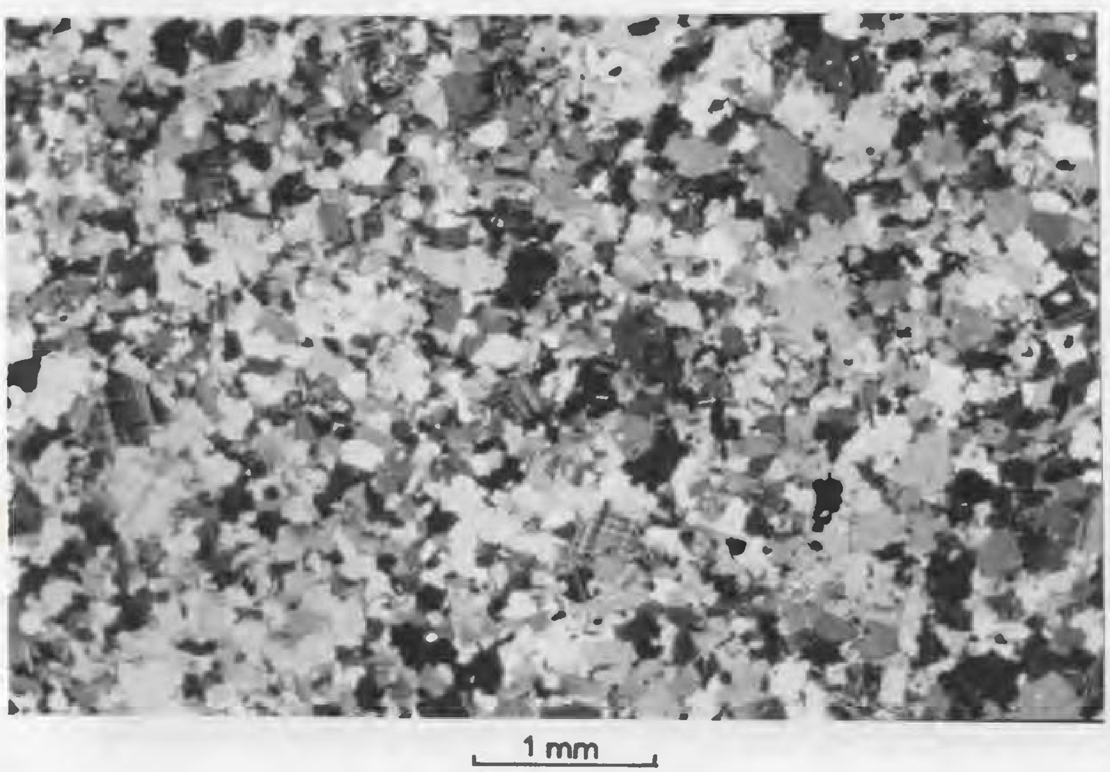


Fig. 104. Local non-porphyritic part of the Porphyritic Microgranite. It consists of a xenomorphic mosaic of microcline, plagioclase and quartz with minor biotite. South of Nash Lake. Crossed nicols.

1mm

Fig. 105. The Monzonite. Note euhedral form of the plagioclase which is mantled by K-feldspar. Microcline fomrs xenomorphic perthitic crystals. The dark aggregate is hornblende and minor biotite. South of Nash Lake.

Fig. 106. Flat-lying net-veined diorite dyke, showing marginal flow-banded zone and central net-veined portion. Unlucky Head.

Fig. 107. Composite diorite-granodiorite body. Diorite has been intruded by adamellite. A xenolith of metasediment occurs above the pack-sack. 2 km. north of Kitts Brook.

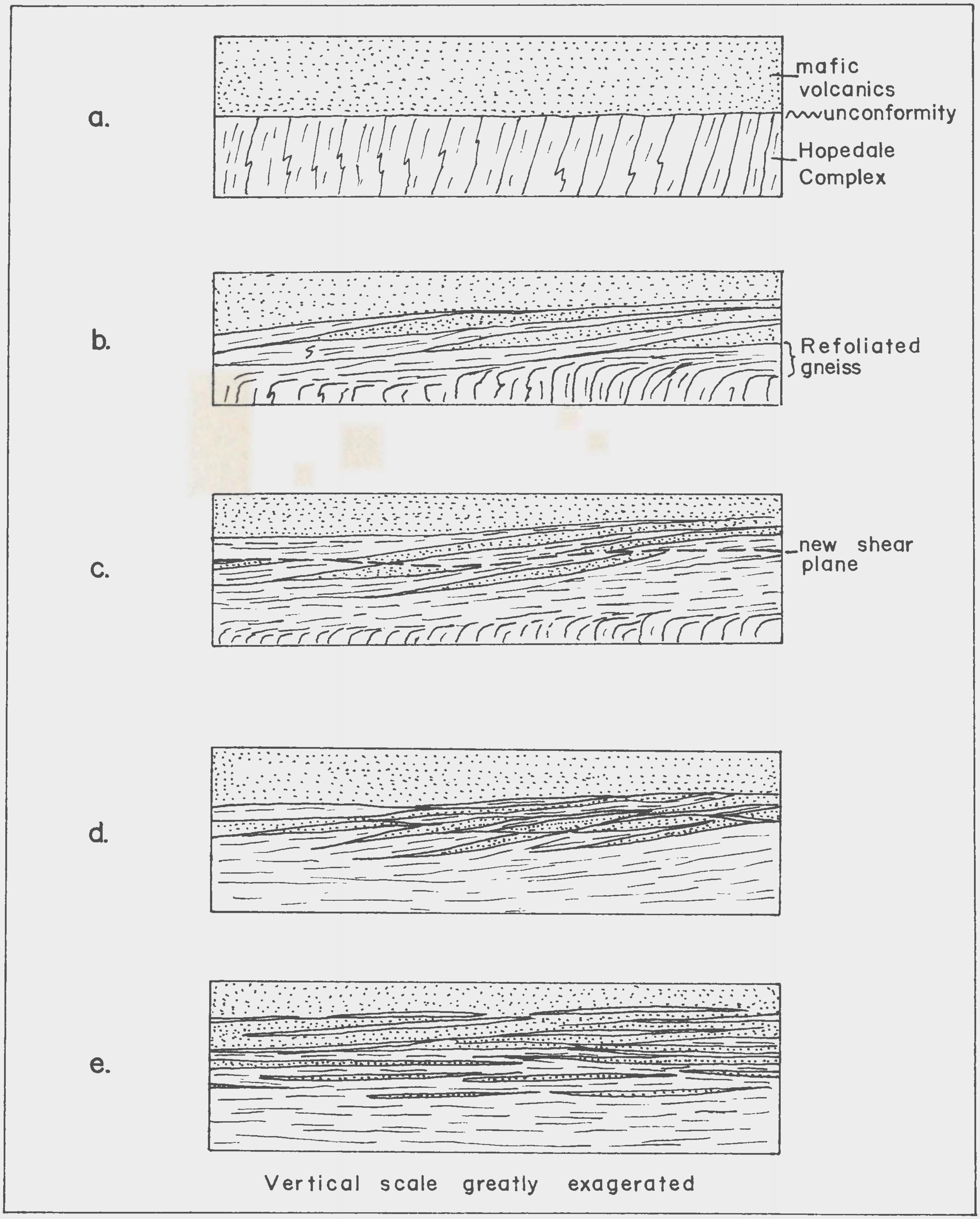


Fig. 108. Postulated mechanism of formation of the interbanded gneiss-amphibolite transition zone in the Post Hill Slide. (a) original unconformable relatioship; (b) shear-planes carry slices of gneiss into the volcanics; (c) new shear plane forms in axial zone and slices the early slices; (d) the process repeats; (e) the final product is thinly intersliced amphibolite and gneiss.

Fig. 109. The D_1-D_2 Nakit Slide forming contact between the Kitts Pillow Lava Formation and Banded Tuff Formation. Amphibolite is streakily interbanded with pink and grey calcareous psammite showing tight F_2 folds, locally refolded by F_3. West side of Inda Lake.

Fig. 110. The "Anderson Splay" of the Nakit Slide. Banded hornblende schist on left is in contact with intensely deformed banded tuffs on right. The contact is truncated by a chilled intrusive contact of the Long Island Gneiss 100 m. to the northeast (Figs. 95 and 97). 1.5 km. northeast of Gear Lake.

Fig. 111. D_1-D_2 shear zones disrupting banding in amphibolitic gneiss of the Hopedale Complex within 60 m. of the "Anderson Splay" of the Nakit Slide. 1.5 km. northeast of Gear Lake.

Fig. 112. Coarse muscovite schist in the Witch Lake Slide zone. The schistosity is S_3 that has transposed S_2 during D_3 rejuvenation of the slide. This is the only example of what could be called "slide facies" (Rast, 1958). Northeast of Watts Lake. Partly crossed nicols.

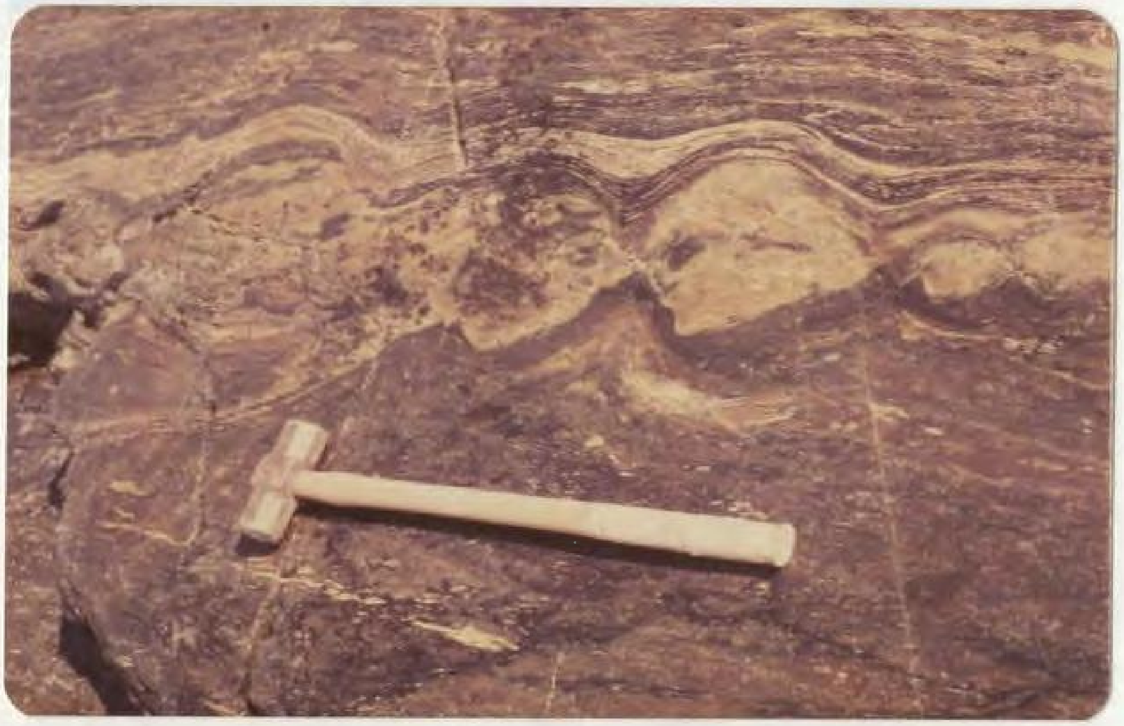


Fig. 113. D_3 epidotic boudins in the Limestone Lake Slide. 3 kms. north of Kitts Pond.

Fig. 114. Transposition of Hopedale Complex into streakily banded rock in contact with hornblende schist in the Limestone Lake Slide. A post-D_2 metadiabase dyke is visible in the top right corner; it is intensely foliated close to the slide. Shore, 3 kms. north of Kitts Pond.

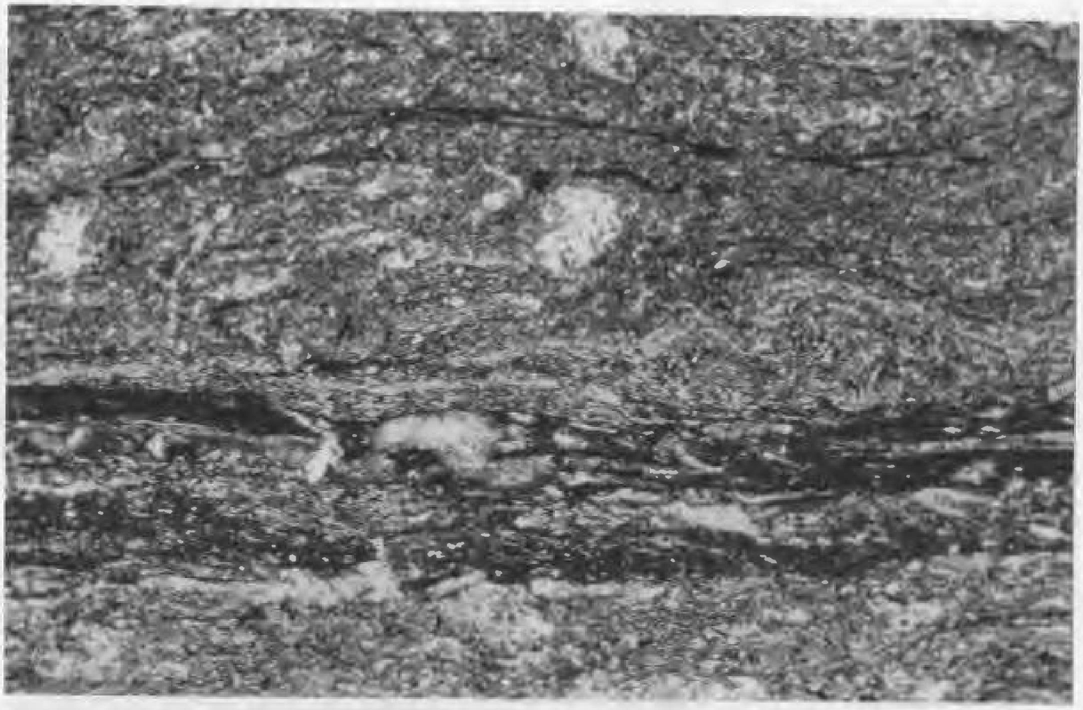


Fig. 115. Thin section of splay of the Limestone Lake Slide showing sillimanite (fibrolite; dark streaks) concentrated on micro-scale D_3 slide. Actinolite-biotite schist with a composite S_2-S_3 fabric. Shore, north of Kitts Brook.

Fig. 116. Isoclinal F_3 microfolds in tourmaline-rich bands showing S_2. Limestone Lake Slide; west of Limestone Lake.

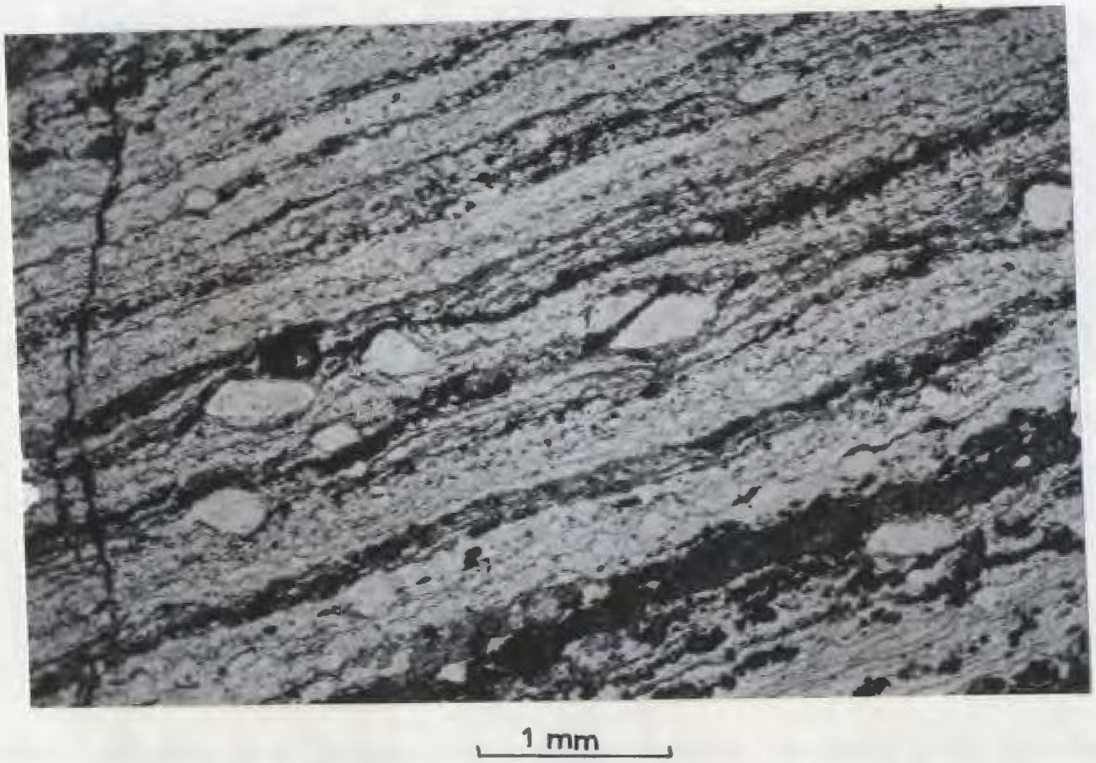


Fig. 117. Quartz-feldspar-epidote mylonite in a splay of the Limestone Lake Slide cutting conglomerate at Kiwi Lake. The mylonitic fabric represents S_3. Kiwi Lake; plane polarised light.

Fig. 118. Intensely flattened Long Island Gneiss on the edge of the Watts Lake Slide. The dark lenticles represent flattened xenoliths; this outcrop is 70 m. from the slide plane. South of Watts Lake.

Fig. 119. Boudinaged pegmatite bodies in the Metasedimentary Formation along the contact with the Post Hill Slide (dark outcrops on the shore are hornblende schist). The pegmatites show F_3 folding of tight F_2 folds and D_2 boudins. Quartz-lenticle schist also characterises this contact. These features indicate dilational openings during formation of the Post Hill Slide. Looking east from helicopter. Shore west of Kitts Pond.

Fig. 120. D_2 pegmatite boudins and isoclinal F_2 folds that have been refolded by F_3 folds, producing Type III interference patterns. Tectonised Metasedimentary Formation in the Witch Lake Slide. West side of nose of Watts Lake Fold.

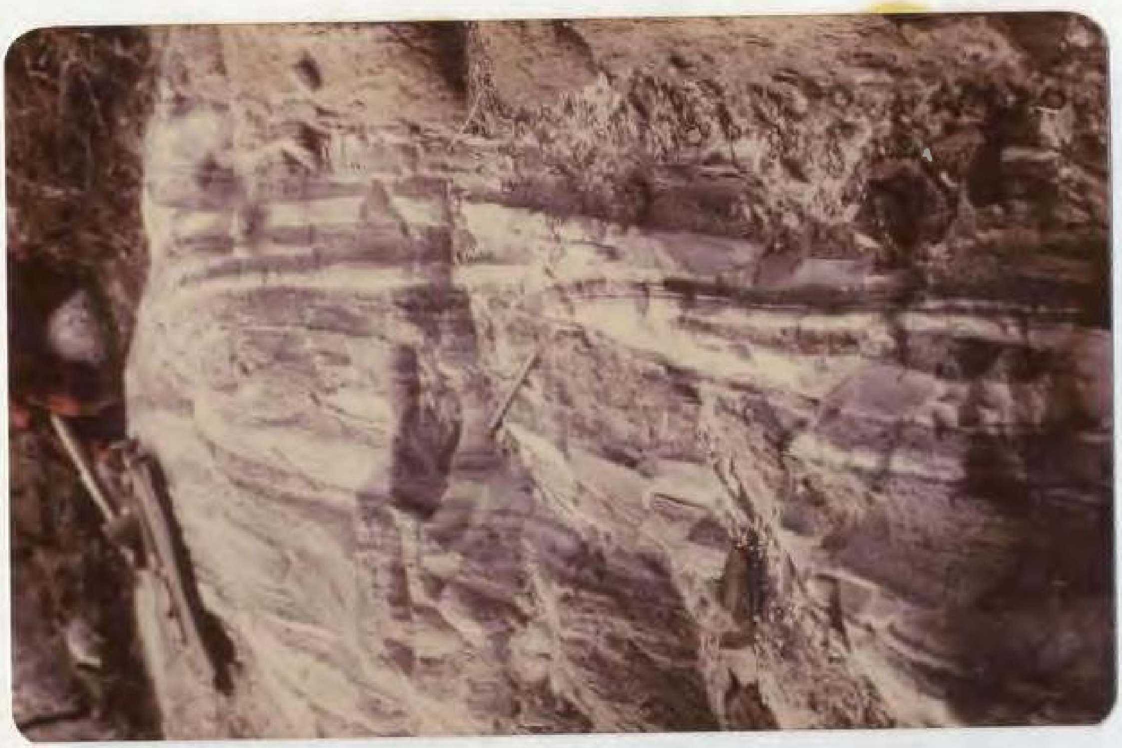


Fig. 121. Isoclinal F_2 folds in banded tuff adjacent to the Nakit Slide. The brown-weathering rock on the right (west) is a hornblende-diopside-epidote-carbonate zone of the Nakit Slide containing uranium mineralisation; it forms part of the Nash Showing, West Extension. West of Nash Lake. Looking southwest.

Fig. 122. Banded tuff adjacent to the Nakit Slide showing a late D_2 slide that post-dates F_2 isoclinal folds. The folds illustrated in Fig. 121 occur on a steep face just beyond the hammer.

Fig. 123. Tight F_3 folds in the Metasedimentary Formation. The attenuated aspect is caused partly by the shallow plunge (about 25° southwest). Shore, west of Kitts Pond.

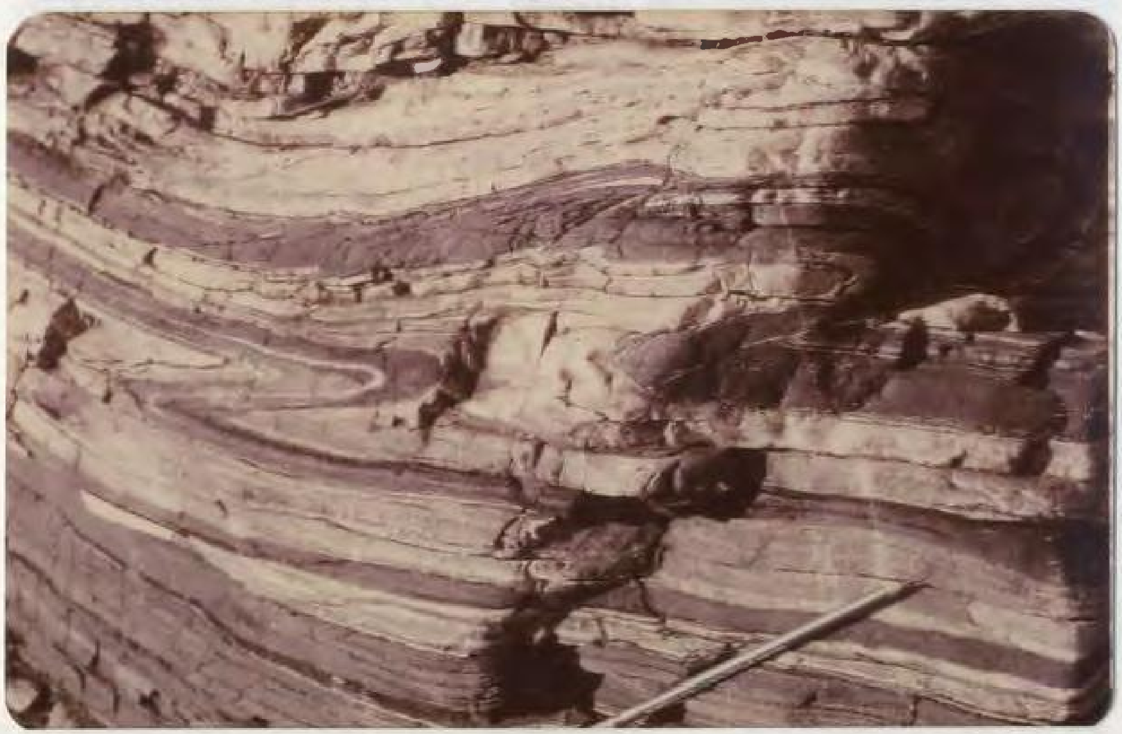


Fig. 124. Tight F_3 fold in interbanded gneiss and amphibolite of the Post Hill Slide. The left limb passes into a small-scale slide at the top of the photograph. A complex interference pattern is apparent indicating that an F_2 structure has been refolded. Shore, west of Kitts Pond.

Fig. 125. Intrafolial F_3 folds in rusty weathering thin bedded psammite of the Metasedimentary Formation. Below the hammer a pod-shaped stack of the folds can be seen. Shore, north of Kitts Pond.

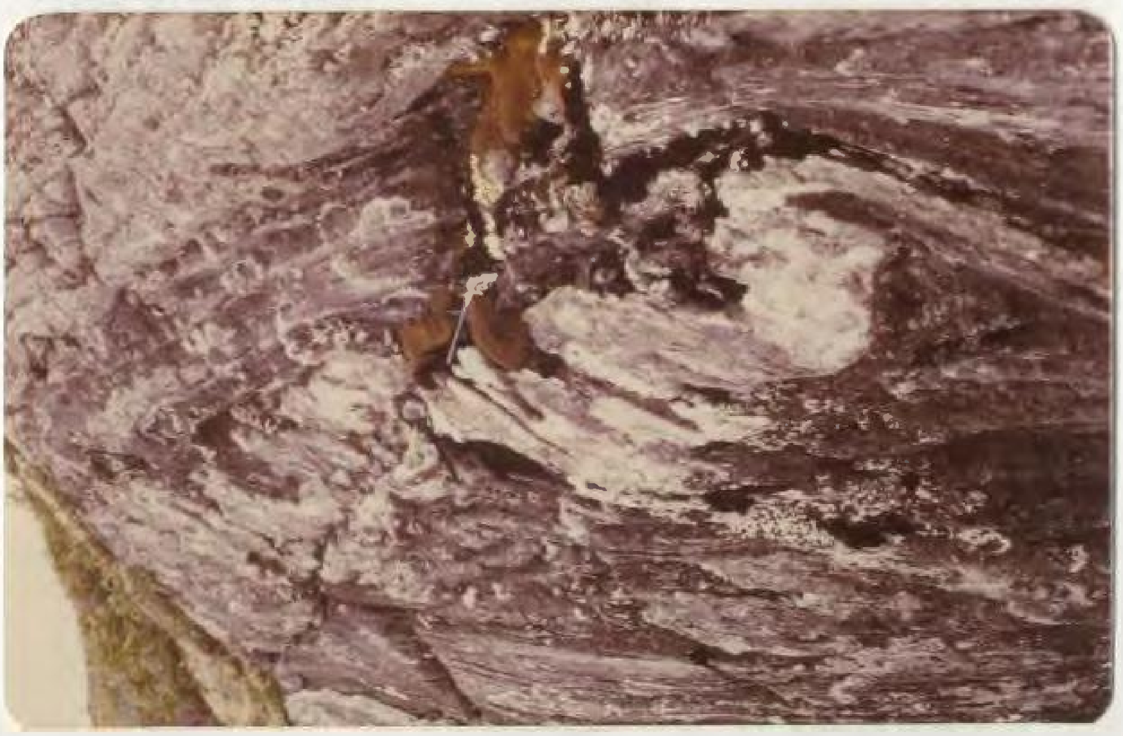


Fig. 126. Intrafolial F_3 folds in interbanded psammite and calcareous psammite of the Banded Tuff Formation, adjacent to the Limestone Lake Slide. S_3 is parallel to bedding outside the pod of folds; note how the axial planes of the folds are sigmoidal in cross-section, curving into S at the margins of the pod. West side of Limestone Lake.

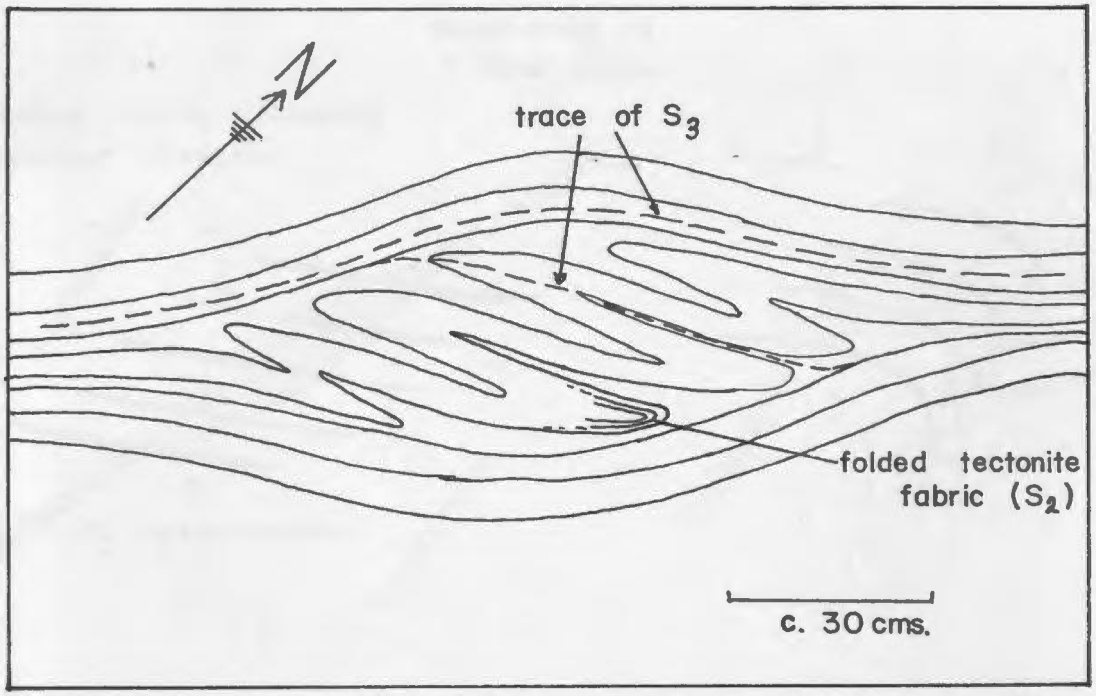


Fig. 127. Diagram summarising relationships seen in the F_3 intrafolial folds. Their origin is obscure; it is thought that buckle-folds formed initially and were then rotated out of the field of shortening, causing them to unfold. However, inhomogeneities in the initial buckling may have caused some sectors of buckle-folded beds to remain in the field of shortening, allowing the folds in these sectors to tighten up (see Flinn, 1962).

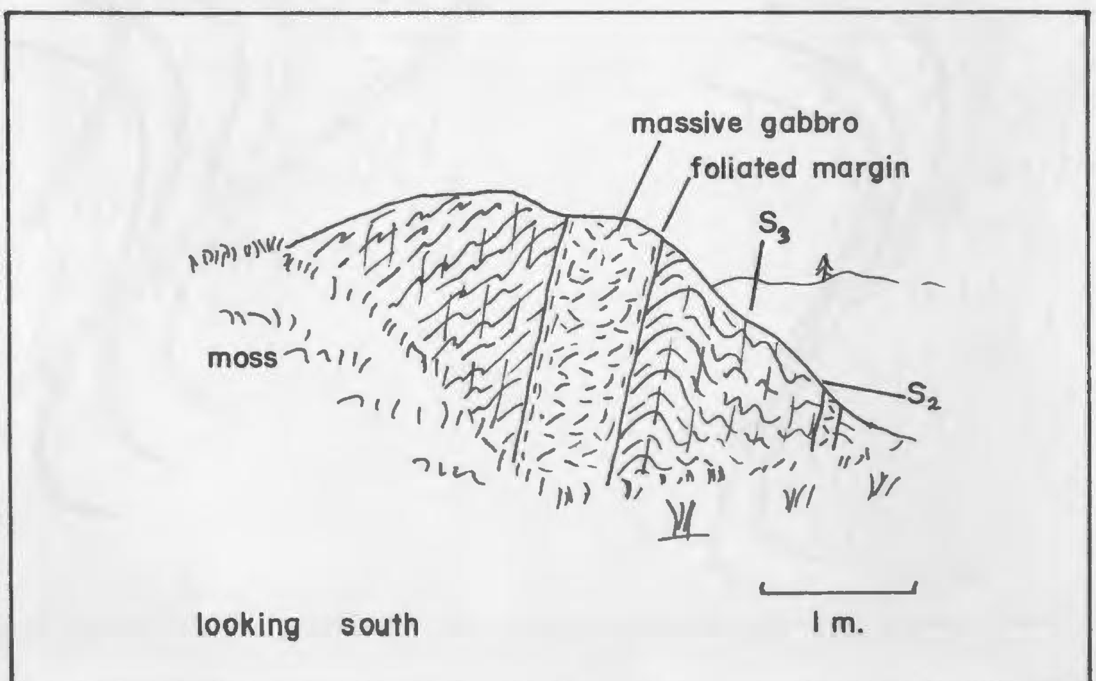


Fig. 128. Field sketch of gabbro dykes truncating S_2 and occupying the axial planes of F_3 folds in S_2. The gabbro dykes are marginally foliated. Post Hill Amphibolite. West of Witch Lake.

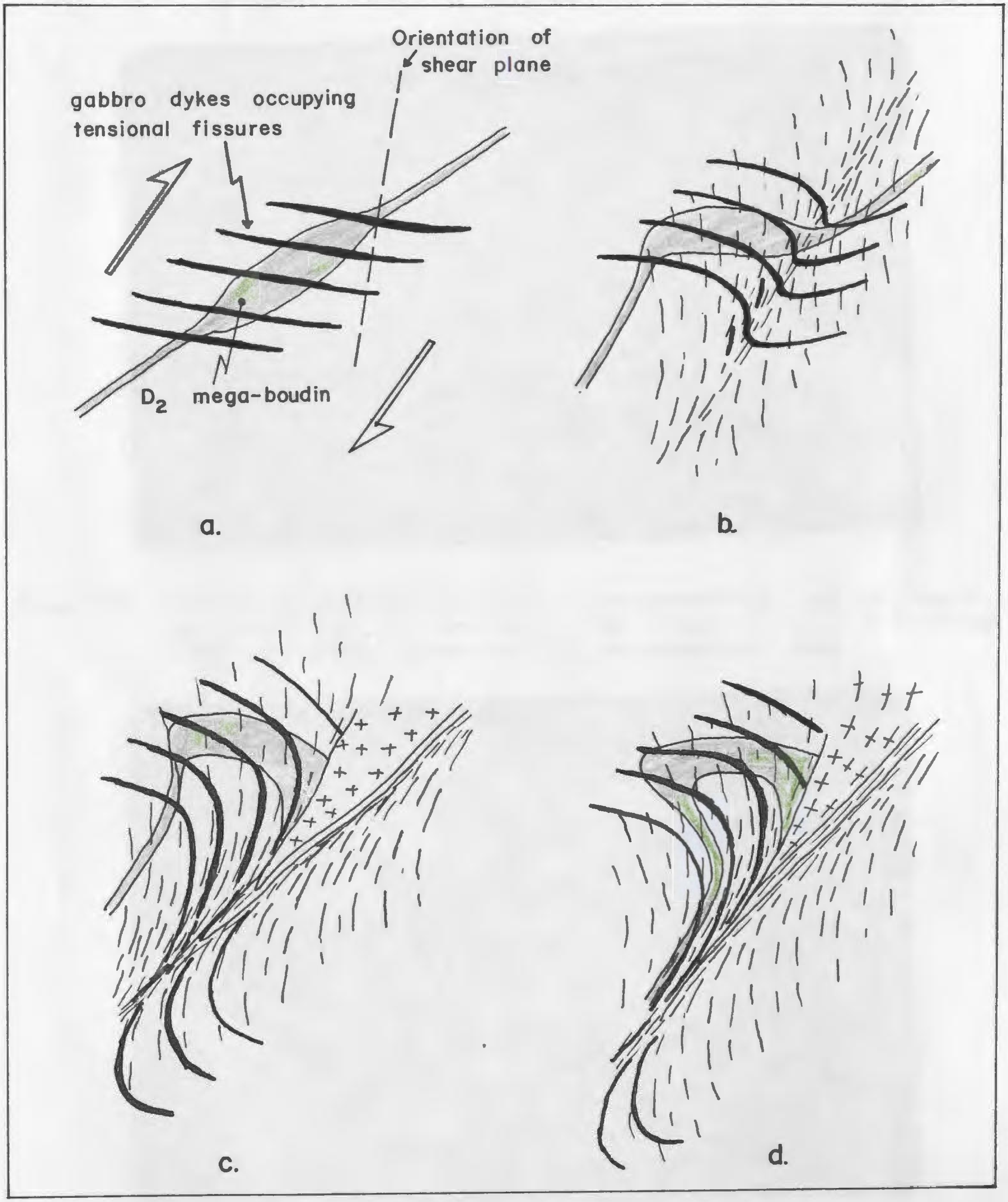
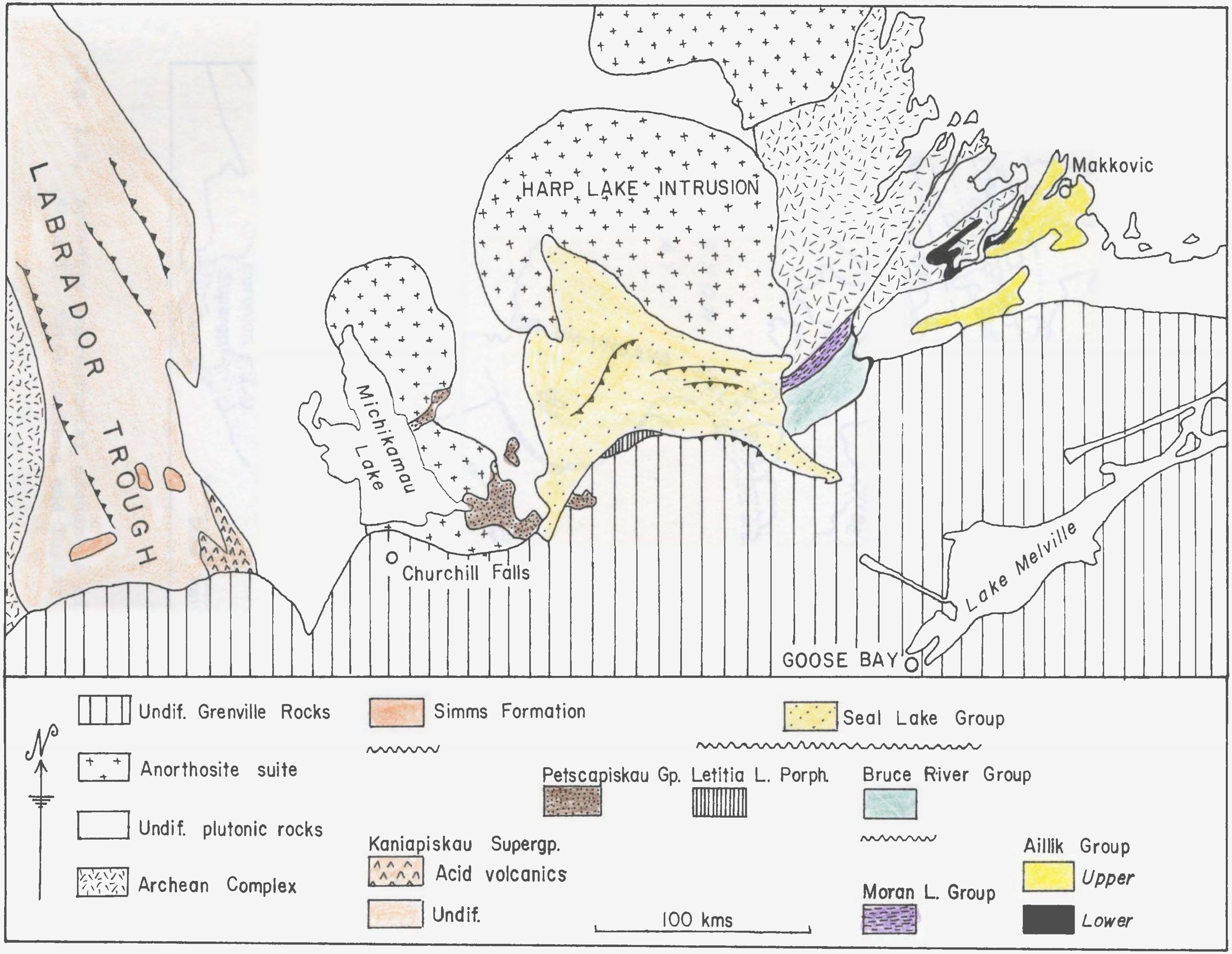


Fig. 129. Postulated origin of the Post Hill Fold. (a) Gabbro dyke swarm intrudes tension gashes formed under influence of a shear couple. (b) Shear belt with related S_3 develops and folding commences. (c) Migmatitic Quartz Monzonite intrudes along shear belt. (d) Continued developement with formation of S_3 and marginal mylonitisation

Fig. 130. Intense S_4 developed as a fine transpositional laminar fabric, cutting an F_3 fold at a shallow angle. The cross-cutting relationship is difficult to see due to the late F_5 monoclinal warp.

Fig. 131. A tourmaline-bearing pegmatite dyke that truncates tight F_3 folds. The boudins are of D_4 age. A late kink-style S_5 cleavage is axial planar to monoclinal warps and kink-folds. Metasedimentary Formation; west of Kitts Pond.



of the Central Mineral Belt, Labrador

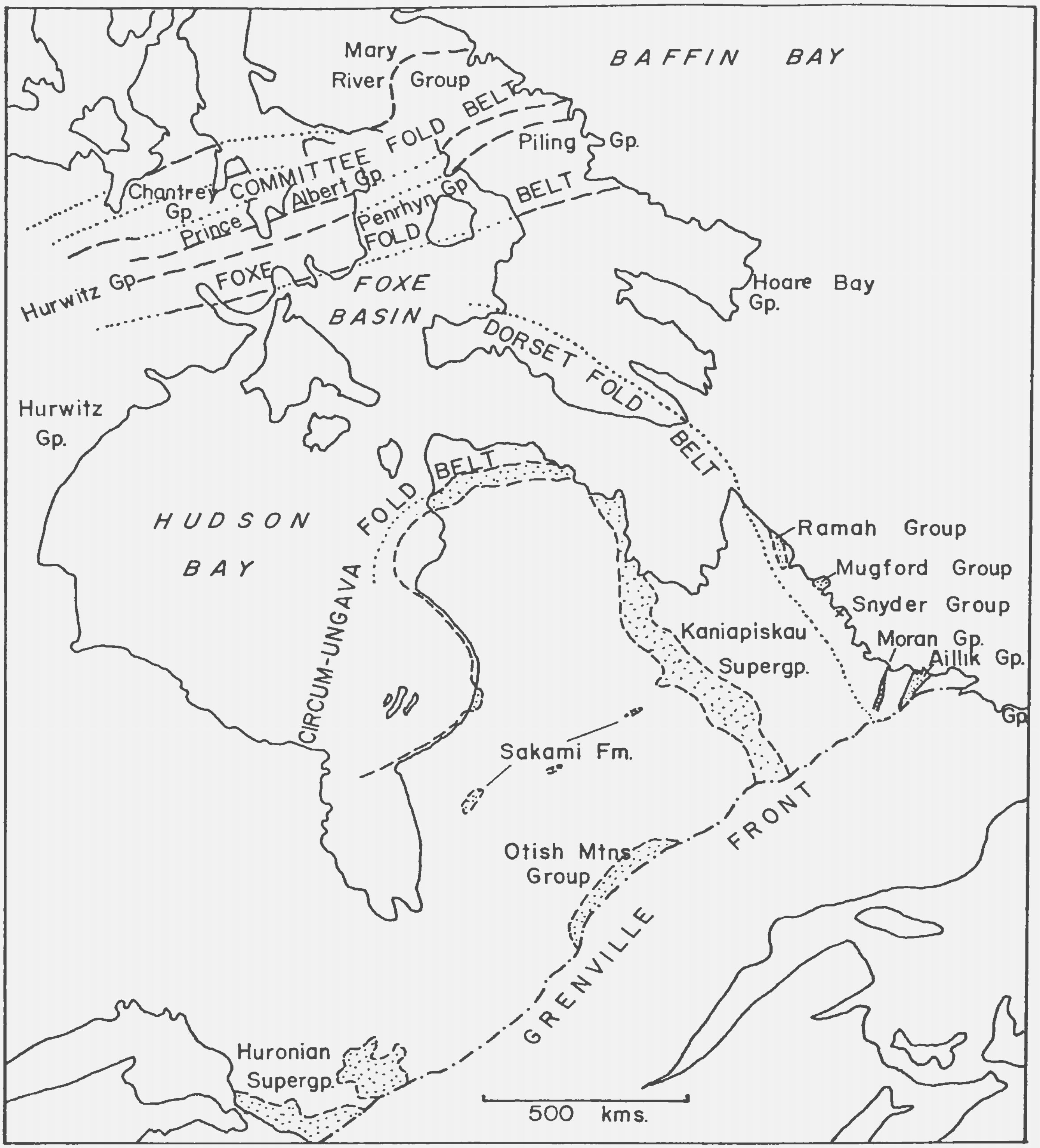


Fig. 133. Aphebian supracrustal sequences of the eastern Canadian Shield. After Jackson and Taylor (1972).

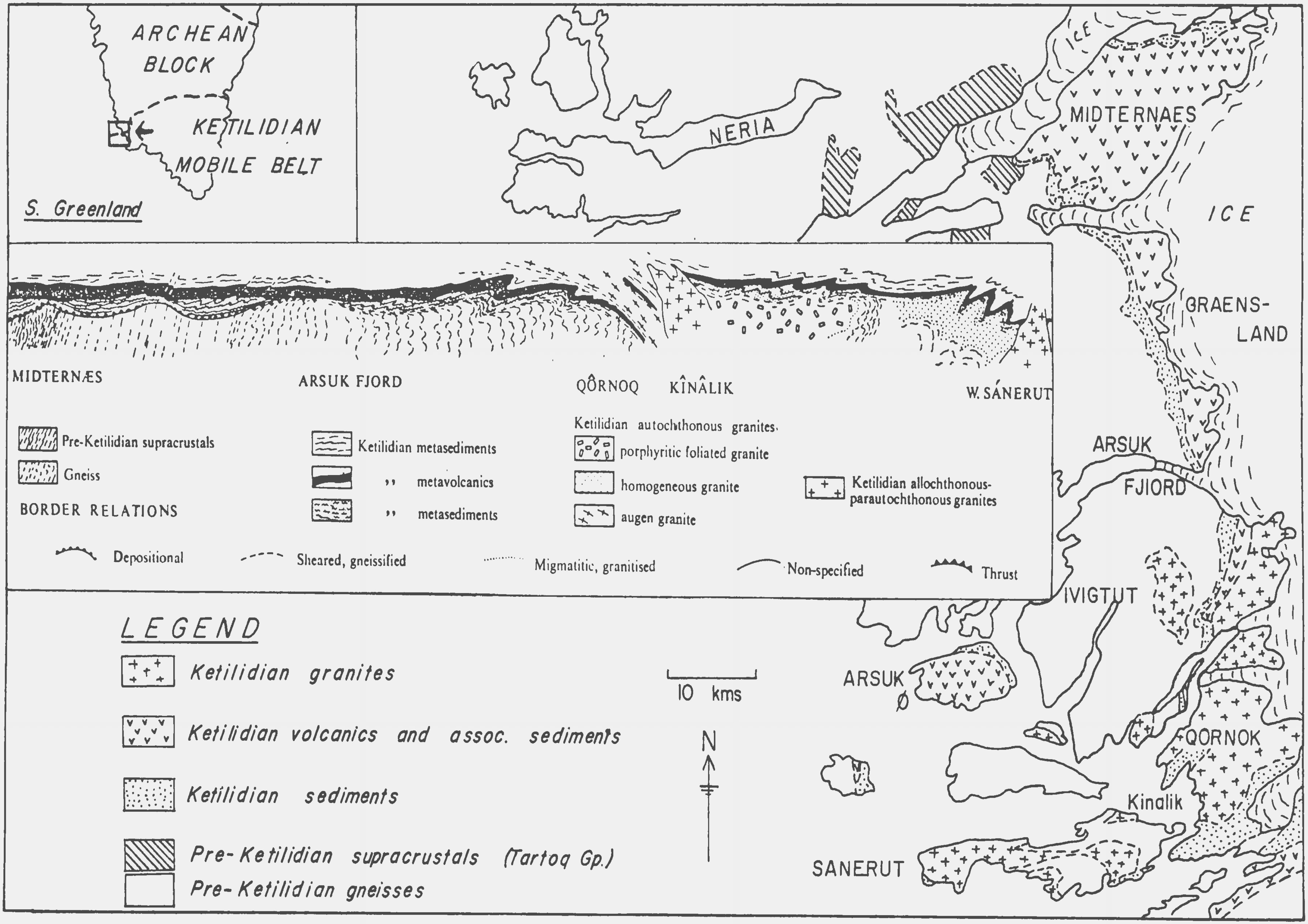


Fig. 134. The foreland of the Ketilidian Mobile Belt in southwest Greenland. After Henrikson (1969).

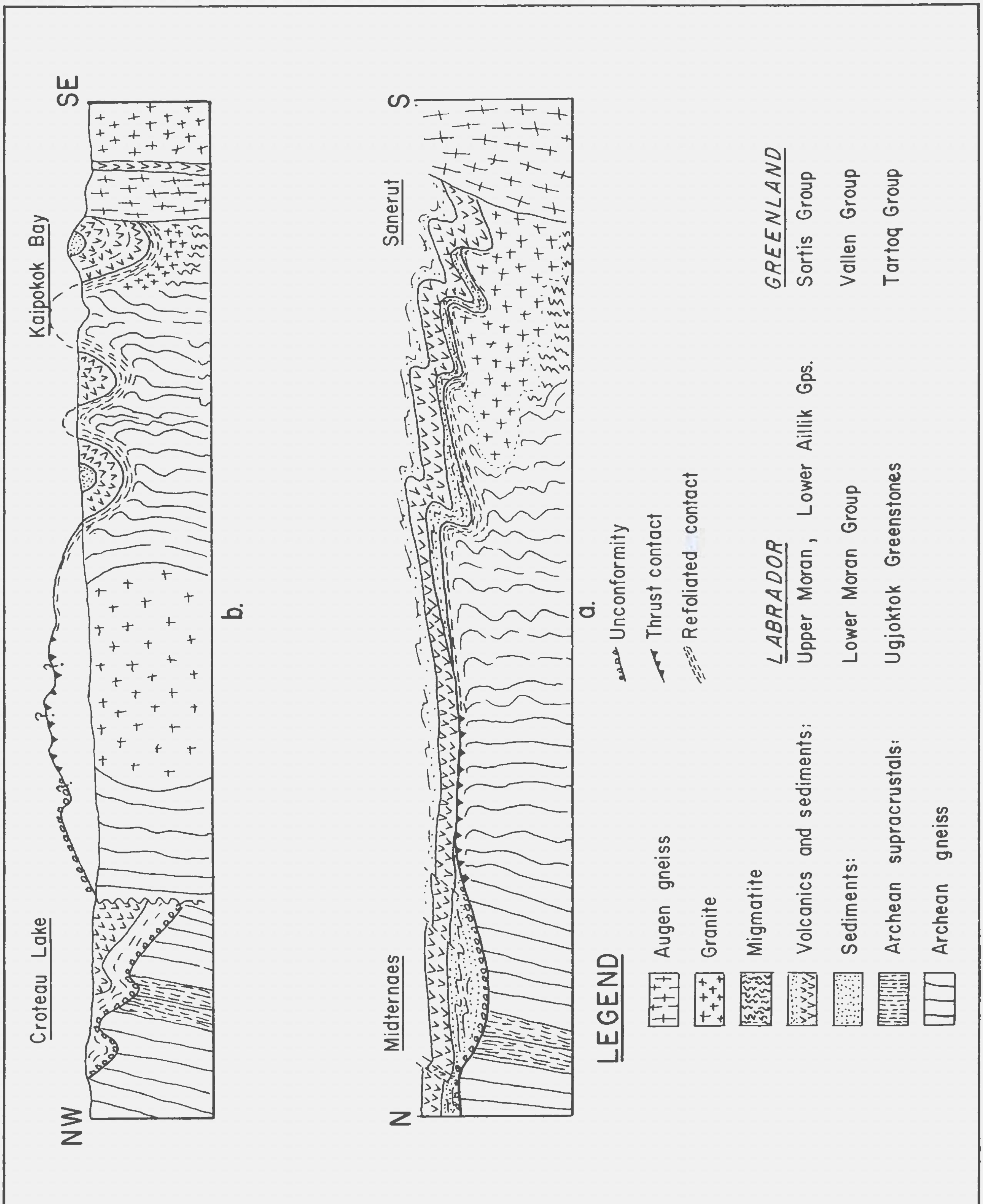


Fig. 135. Comparison of the Hudsonian and Ketilidian foreland transitions in Labrador and Greenland respectively. Schematic cross-section (a) after Windley et al. (1966). Section (a) and (b) represent approximately 75 and 50 kms. respectively.

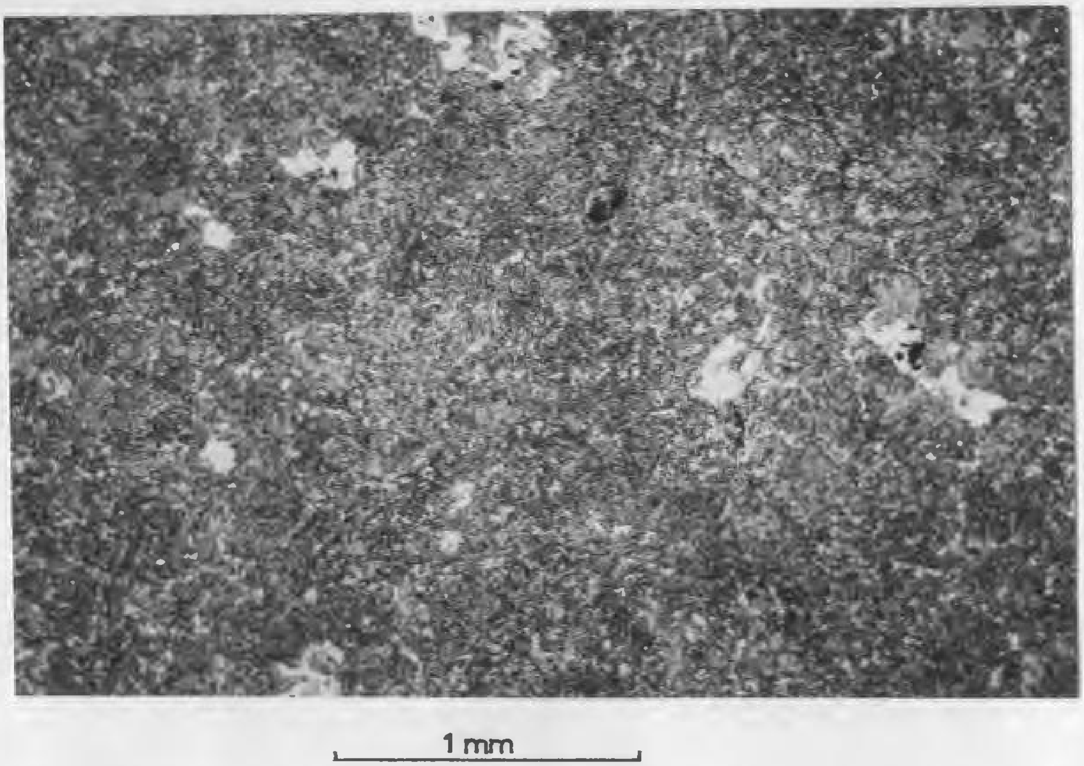


Fig. 136. Texture of the undeformed pillows in the Kitts Pillow Lava Formation. The fabric is isotropic, consisting dominantly of felted tremolite-actinolite. The pale areas represent recrystallised plagioclase (glomer-phenocrysts ?). Southeast of Kiwi Lake. Plane polarised light.

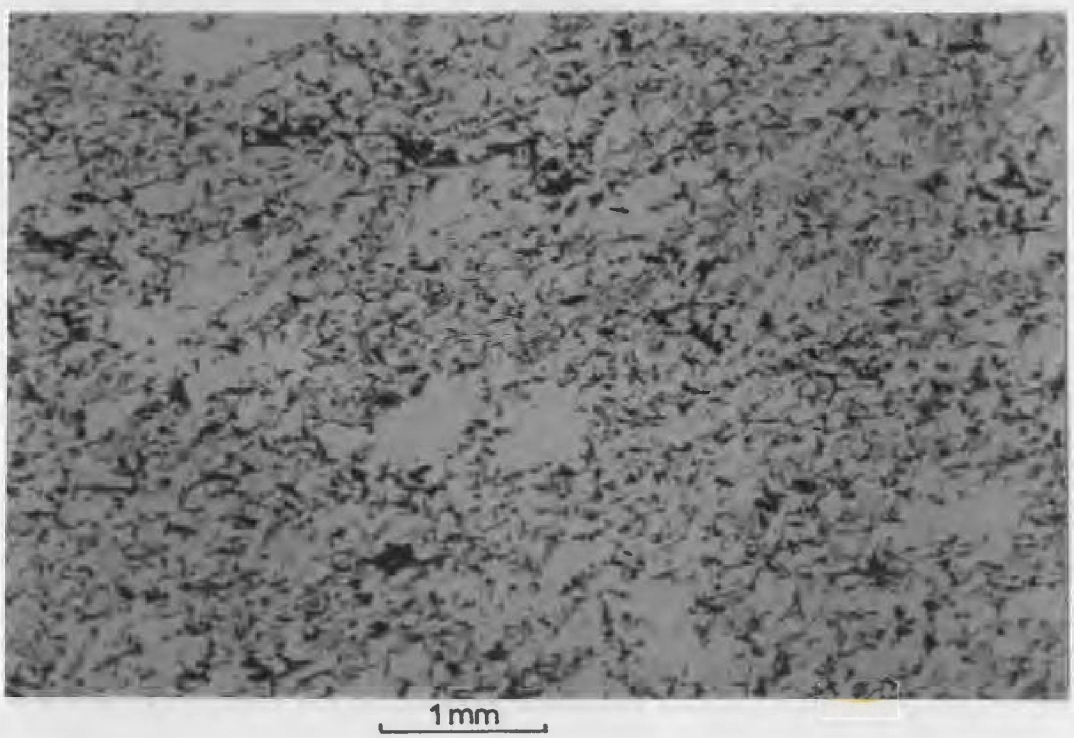


Fig. 137. Relict clastic texture preserved in impure psammite. Metasedimentary Formation; west of Fiace Lake. Plane polarised light.

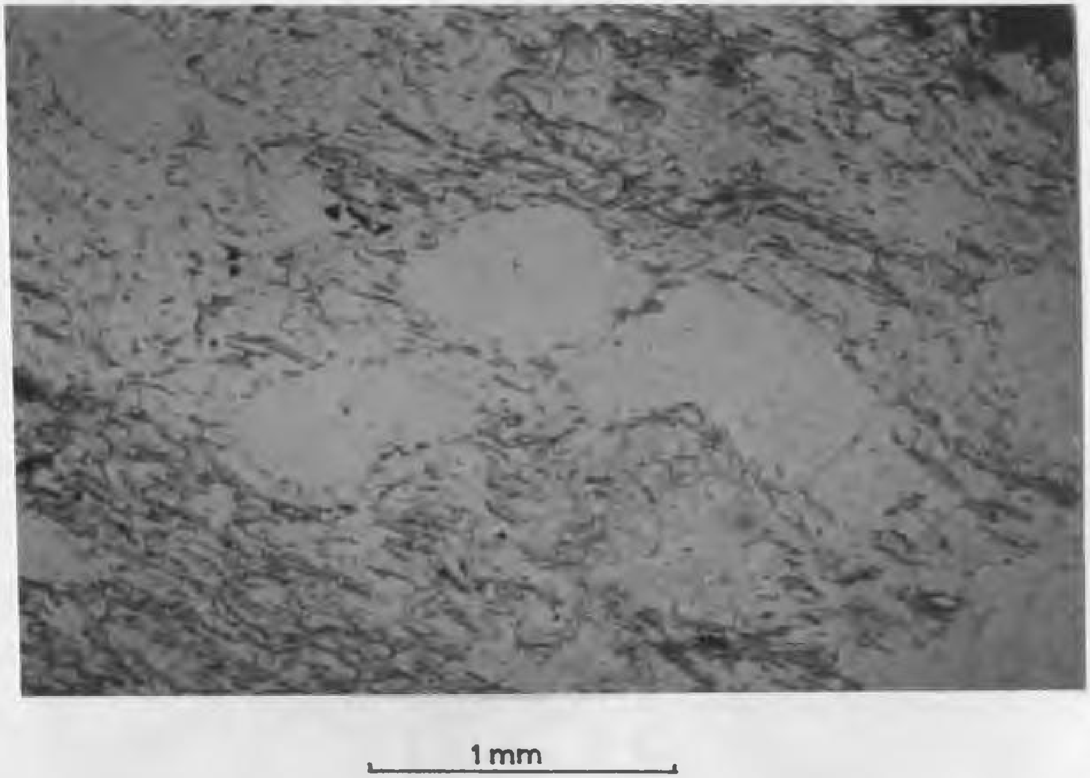


Fig. 138. Relict clastic texture with authigenic overgrowths on quartz grains outlined in places by minute inclusions of biotite. Banded Tuff Formation; south of Kiwi Lake. Plane polarised light.

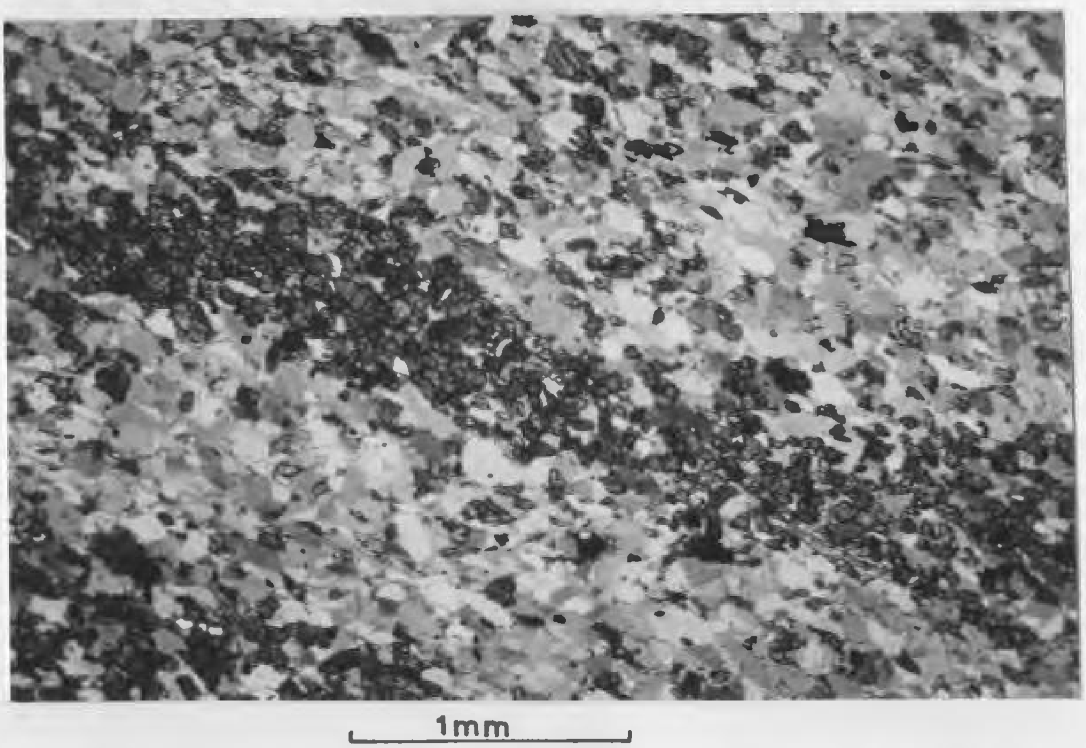
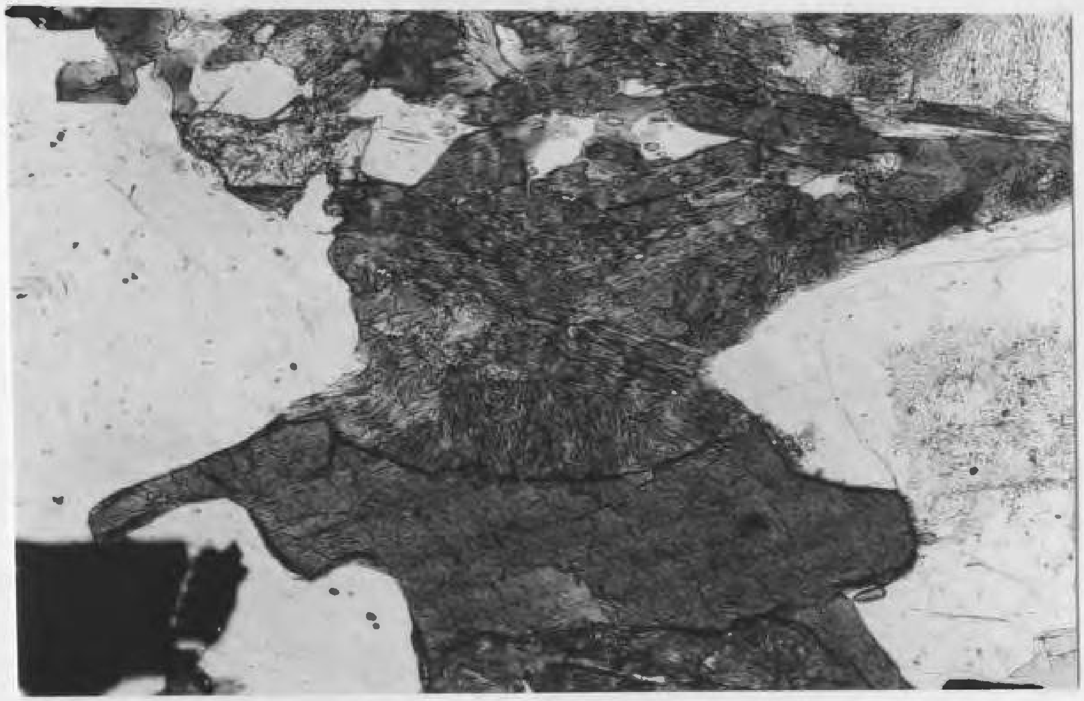


Fig. 139. Subidiomorphic grains of diopside forming a green lamination in banded tuff. The weak dimensional orientation is S_3. Banded Tuff Formation; south of Inda Lake.



0·5 mm

Fig. 140. Myrmekite-like intergrowth on a hornblende-biotite grain boundary at the edge of the biotitic selvage of an amphibolite raft. Part of the biotitic selvage occupies the lower half of the photo. Unlucky Head Migmatite; at Unlucky Head. Plane polarised light.

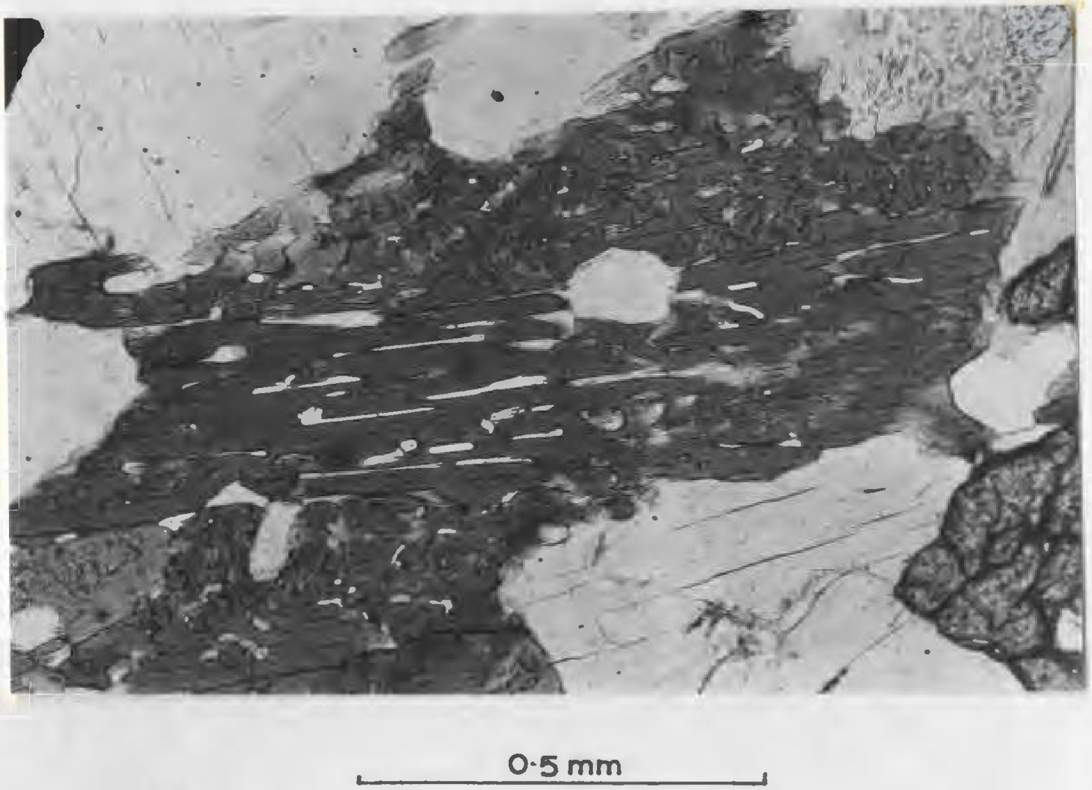


Fig. 141. Graphic intergrowth of biotite and quartz in the biotitic selvage of an amphibolite raft. The quartz blebs are in optical continuity with one another. Unlucky Head Migmatite; at Unlucky Head. Plane polarised light.

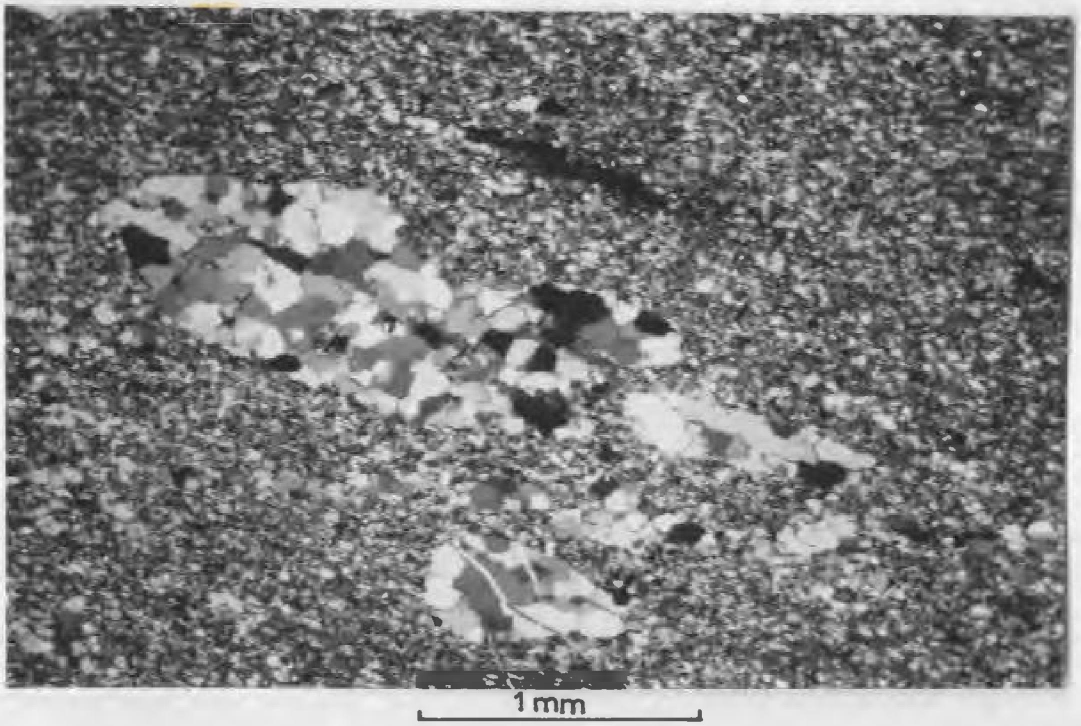


Fig. 142. Flattened quartz phenocryst in quartz porphyry. The phenocryst has recrystallised to an MP_3 polygonal mosaic. From an S_3 schist zone, northeast of Kidney Pond. Crossed nicols.

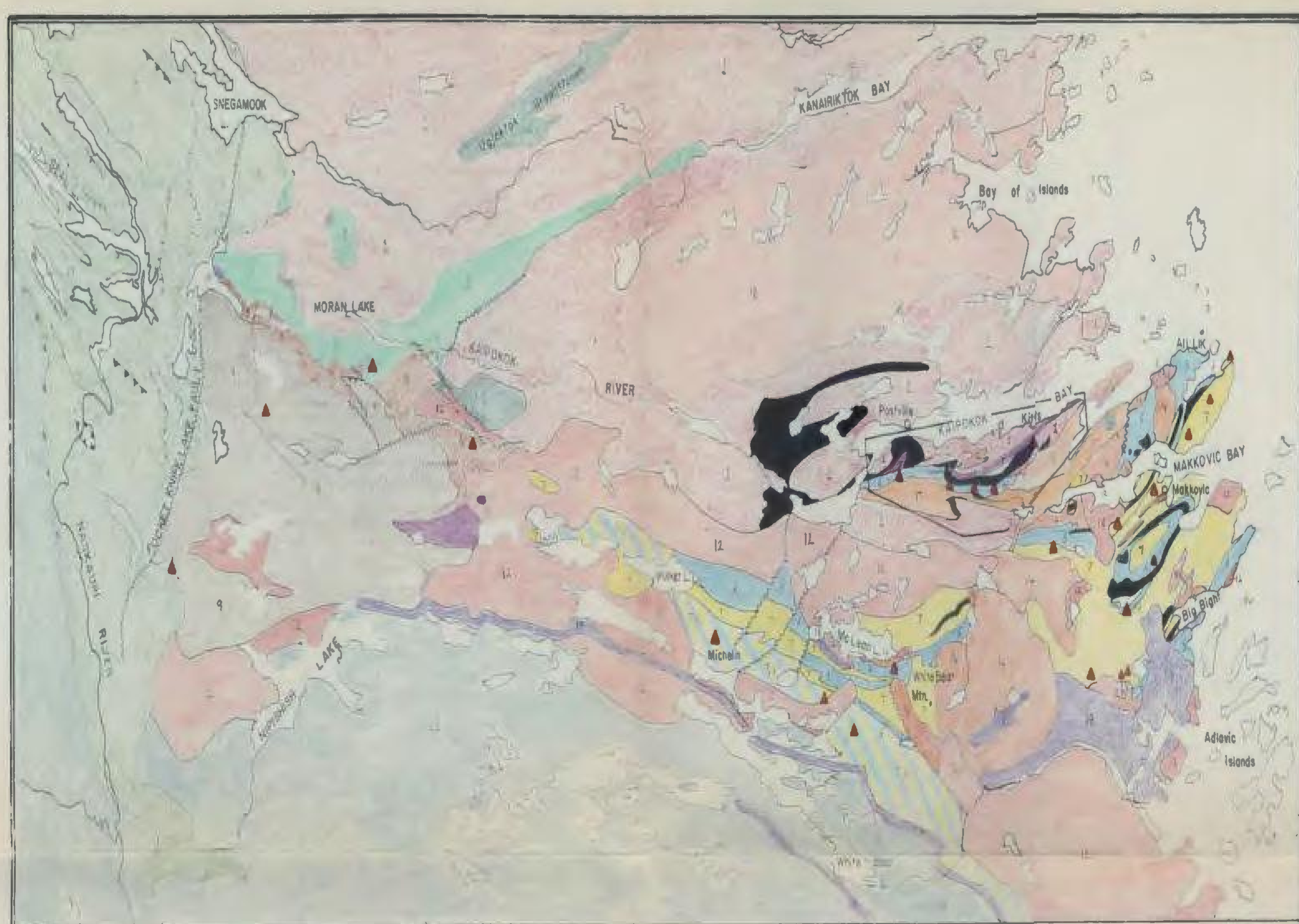


PLATE I

REGIONAL SETTING OF THE KITTS-POST HILL AREA

LEGEND

INTRUSIVE IGNEOUS ROCKS

- 18 Gabbro
- 17 Feldspar porphyry porphyritic microgranite
- 16 Quartz porphyry, in part extrusive
- 15 Long Island Gneiss
- 14 Syenite, quartz monzonite
- 13 Granite gneiss
- 12 Granite
- 11 Undifferentiated Grenville gneiss

HELIKIAN

SEAL LAKE GROUP

- 10 Arkose, shales, slate, quartzite, mafic flows

PALEO-HELIKIAN

BRUCE RIVER GROUP

- 9 Mafic & acid (ignimbrite) flows
- 8 Conglomerate, sandstone

APHEBIAN

AILLIK GROUP

- 7 Massive quartzo-feldspathic "sediment" and rhyolite: same as unit 17 ?
- 6 Banded tuff, acid volcanogenic sediments, conglomerate
- 5 Terrigenous metasediment
- Mafic volcanics: pillow lava, amphibolite

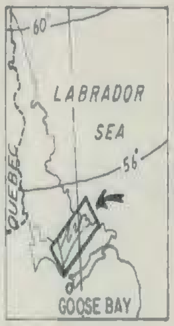
MORAN GROUP

- 3 Mafic pillow lava, argillite, siltstone

ARCHEAN

- 2 Greenstone
- 1 Gneiss, migmatite, granite

▲ Uranium showing or deposit



N

10 0 20 40 60

KILOMETRES

—Compiled from sources cited in text

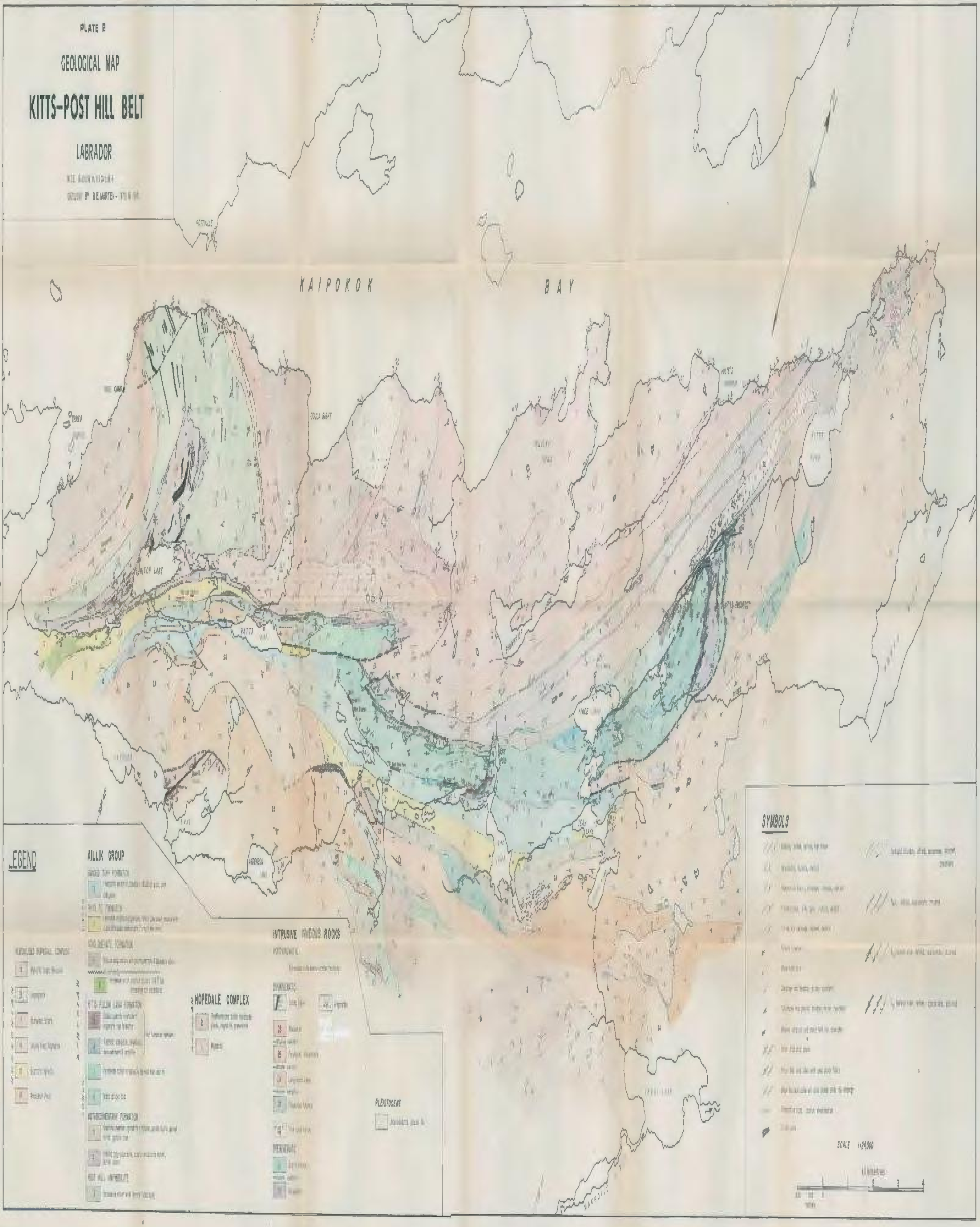
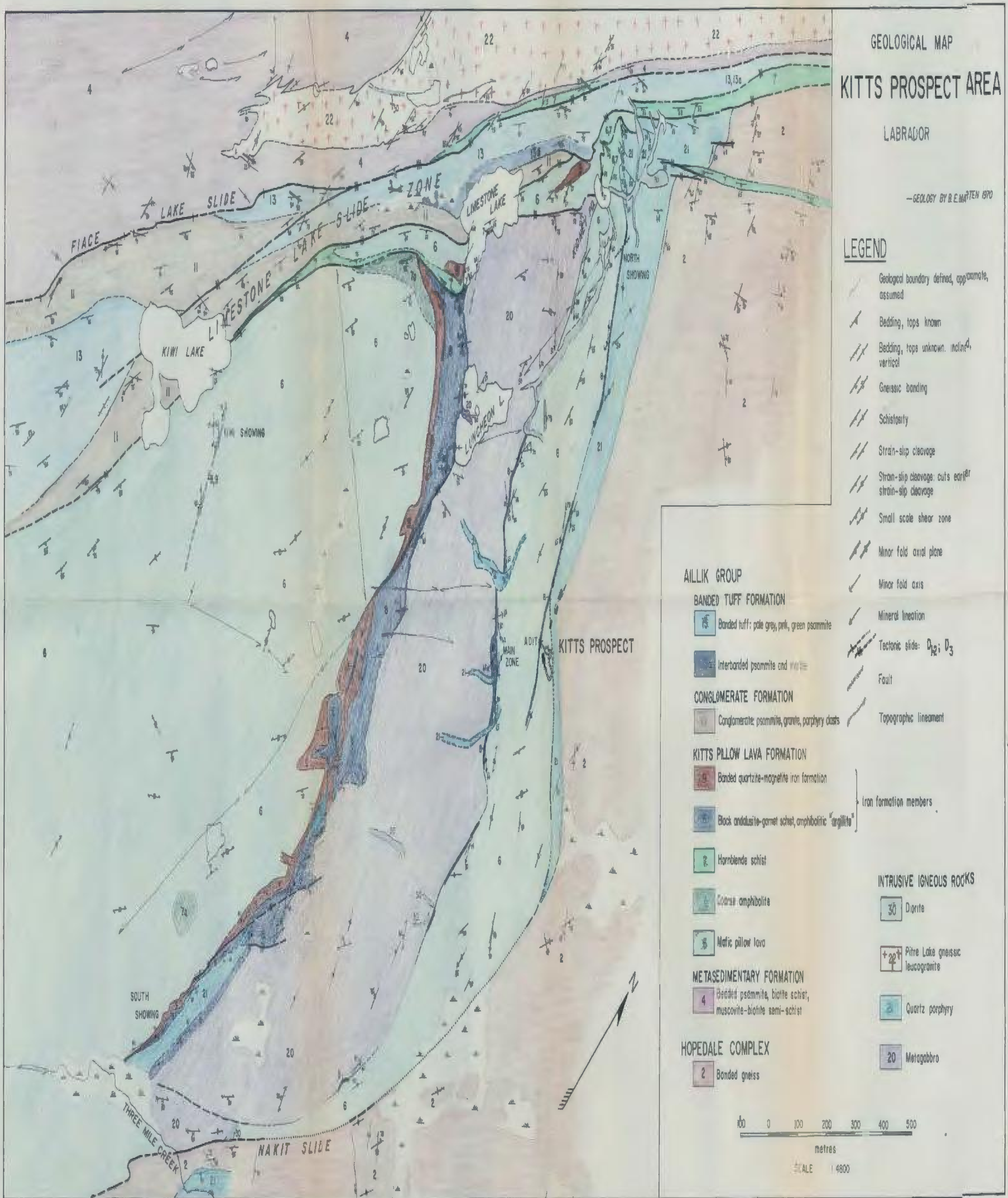


PLATE B
GEOLOGICAL MAP
KITTS-POST HILL BELT
LABRADOR
KAIPOKOK
BAY
LEGEND
AILLIK GROUP
HOPEDALE COMPLEX
INTRUSIVE IGNEOUS ROCKS
PLEISTOCENE
SYMBOLS
SCALE 1:24,000

PLATE 3



GEOLOGICAL MAP
KITTS PROSPECT AREA
LABRADOR
—GEOLOGY BY B.E.MARTEN 1970
LEGEND
Geological boundary defined, approximate, assumed
Bedding, tops known
Bedding, tops unknown. inclined, vertical
Gneissic banding
Schistosity
Strain-slip cleavage
Strain-slip cleavage: cuts earlier strain-slip cleavage
Small scale shear zone
Minor fold axial plane
Minor fold axis
Mineral lineation
Tectonic slide: D1,2; D3
Fault
Topographic lineament
AILLIK GROUP
BANDED TUFF FORMATION
Banded tuff: pale grey, pink, green psammite
Interbanded psammite and
CONGLOMERATE FORMATION
Conglomerate: psammite, granite, porphyry clasts
KITTS PILLOW LAVA FORMATION
Banded quartzite-magnetite iron formation
Black andalusite-garnet schist, amphibolitic "argillite"
Iron formation members
Hornblende schist
Coarse amphibolite
Mafic pillow lava
METASEDIMENTARY FORMATION
4 Banded psammite, biotite schist, muscovite-biotite semi-schist
HOPEDALE COMPLEX
2 Banded gneiss
INTRUSIVE IGNEOUS ROCKS
30 Diorite
22 Pitre Lake gneissic leucogranite
Quartz porphyry
20 Metagabbro
100 0 100 200 300 400 500
metres
SCALE 1:4800
FIACE LAKE SLIDE
LIMESTONE LAKE SLIDE ZONE
LIMESTONE LAKE
KIWI LAKE
KIWI SHOWING
LUNCHEON L.
NORTH SHOWING
MAIN ZONE
ADIT
KITTS PROSPECT
SOUTH SHOWING
THREE MILE CREEK
NAKIT SLIDE
N

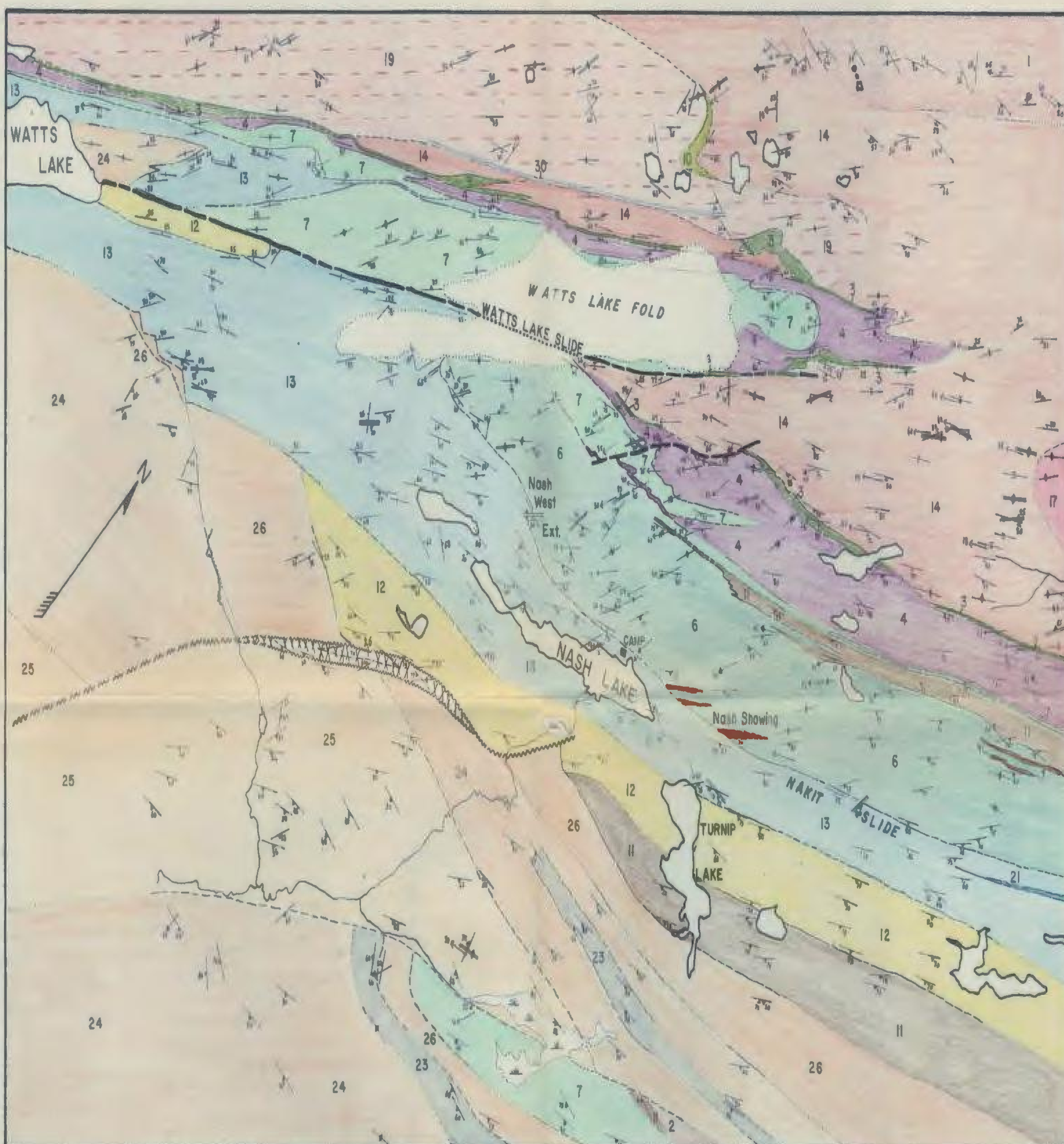


PLATE 4

GEOLOGICAL MAP, WATTS LAKE - NASH LAKE AREA

FOR LEGEND, SEE PLATE 2

500 0 1
m km

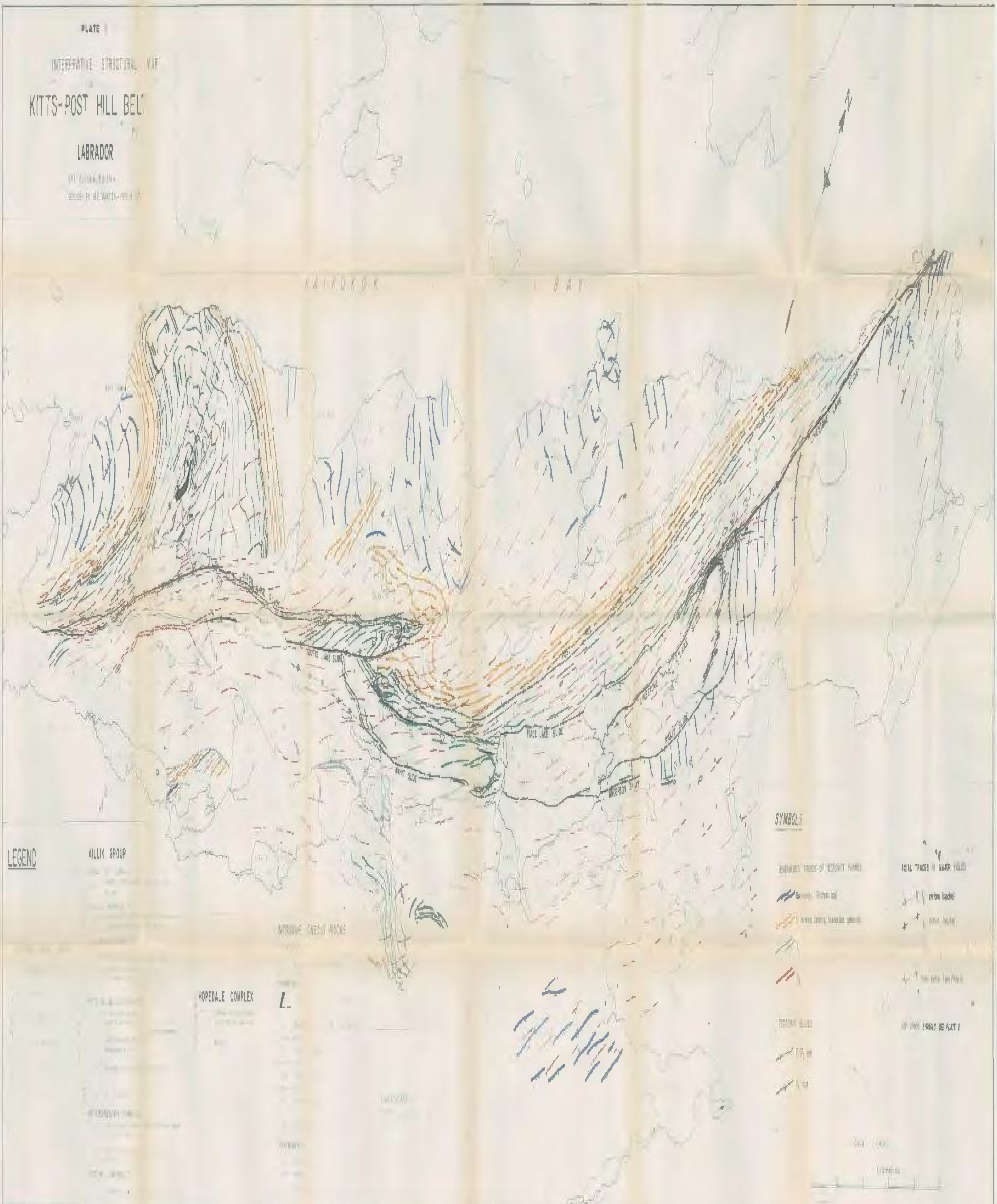
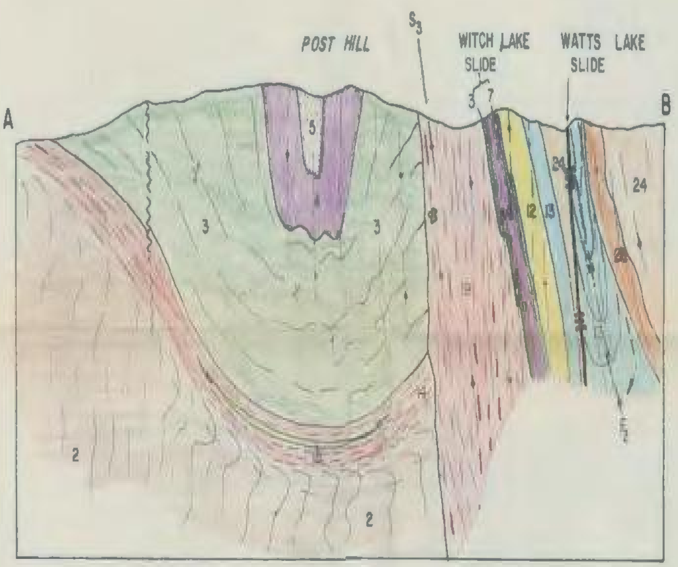
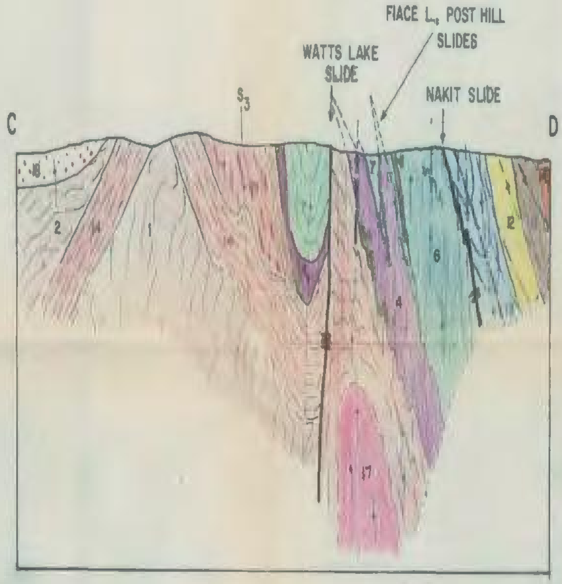


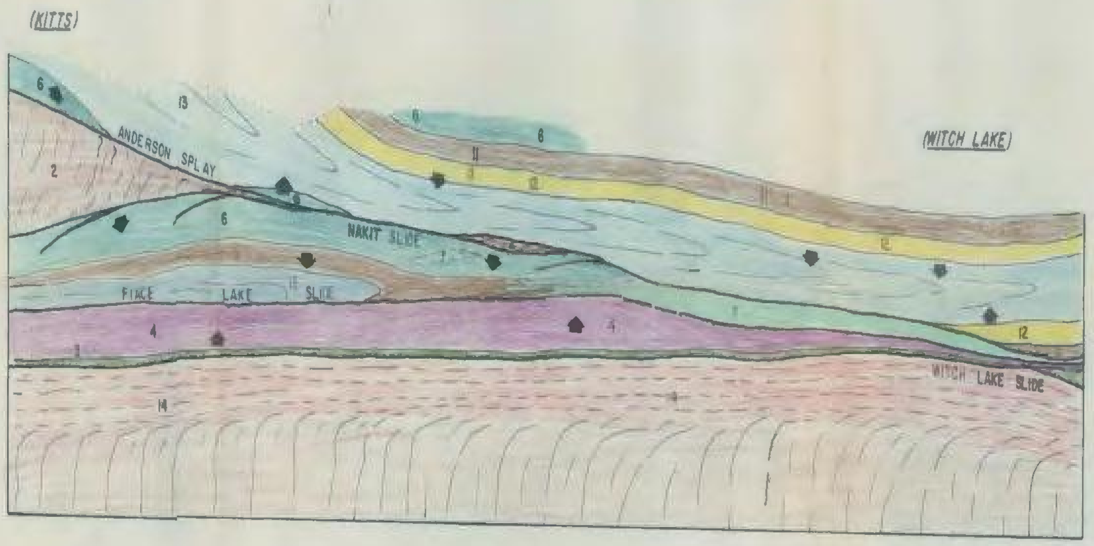
PLATE
KITTS-POST HILL BEL
LABRADOR
KITTS LAKE SLIDE
PACE LAKE SLIDE
LEGEND
AILLIK GROUP
HOPEDALE COMPLEX
SYMBOL
AXIAL TRACES



a. POST HILL SYNFORM Scale: as on Plate 5



b. WATTS LAKE SYNFORM



c. SCHEMATIC CROSS-SECTION: summarises tentatively inferred pre-D_3 structural relationships. D_1-D_2 thrust sheets and nappes are suggested. The direction of tectonic transport is not known. Not to scale. ⬟ = facing direction.

PLATE 6

SYNOPTIC STRUCTURAL CROSS-SECTIONS

Location of sections a & b on Plate 5