High grade metamorphic rocks of northwestern Melville Peninsula, District of Franklin

Project 840013

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Abstract

High grade metamorphic rocks are exposed in the Encampment Bay area. Preliminary results indicate that a tonalitic-granodioritic plutonic suite was intruded by granite and mafic dykes and later unconformably(?) overlain by sediments correlated with the 2.9 Ga Prince Albert Group. Shallow dipping slabs of dry basement and wet supracrustals were tectonically stacked and transported to deep levels within the crust where they were metamorphosed and partially melted under granulite and upper amphibolite conditions, probably during late Archean time. They were then uplifted possibly along the previous shallow dipping discontinuities. Northwest trending mafic dykes cut the rising mass and were metamorphosed to varying amphibolite facies grades probably conjointly with emplacement of a late pegmatite swarm in early Proterozoic time. Steep, east-west faults of Proterozoic age cut the region and late Proterozoic clastic sediments were deposited onto the basement after which faults, reactivated and new, cut the area. The region was peneplaned by early Ordovician time before the mid-Devonian uplift of the Melville Peninsula horst.

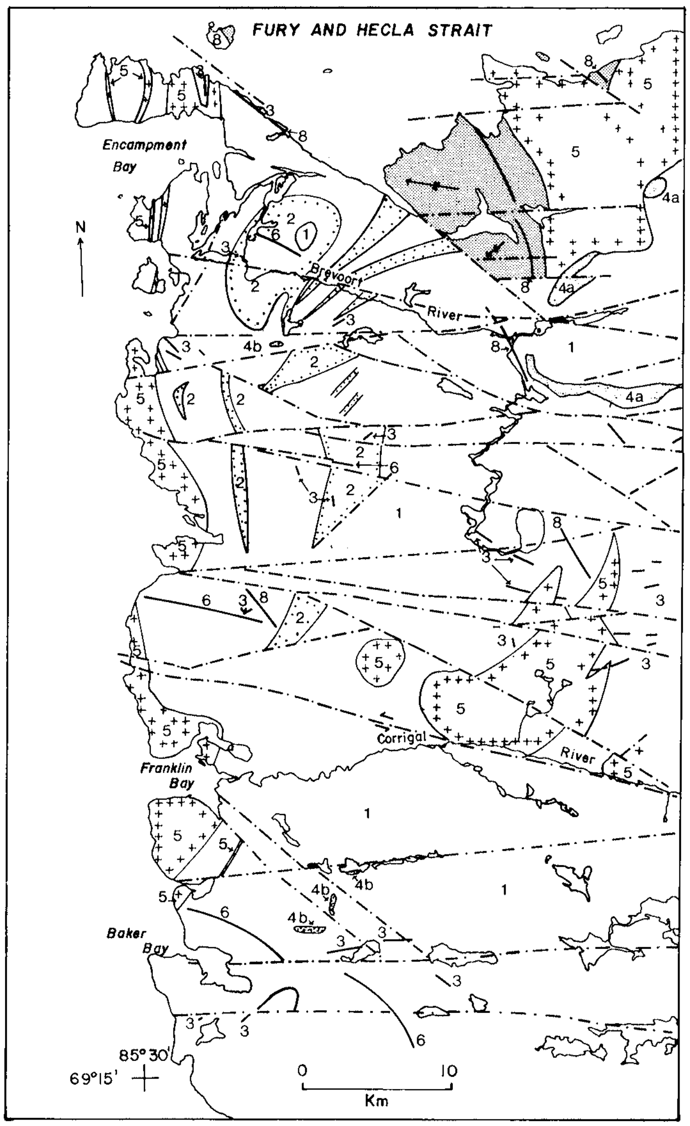
Résumé

Des roches fortement métamorphiques affleurent dans la région de la baie Encampment. Des résultats préliminaires indiquent qu'une série plutonique de tonalite et de granodiorite a été pénétrée par un granite et par des dykes mafiques et recouverte plus tard, en discordance (?) par des sédiments correlés au groupe de Prince-Albert de 2,9 Ga. Des plaques de socle sec à faible pendage, et des roches supracrustales humides ont été empilées tectoniquement et transportées en profondeur dans la croûte, où elles ont été métamorphisées et partiellement fondues dans des conditions de granulites et d'amphibolites supérieures, probablement à la fin de l'Archéen. Ces plaques auraient été ensuite soulevées suivant les anciennes discordances à faible pendage. Des dykes mafiques de direction nord-ouest coupent le massif ascendant et ont été métamorphisés en divers faciès d'amphibolite, probablement au cours de la mise en place d'une nuée de pegmatite tardive au début du Protérozoïque. Des failles abruptes de direction est-ouest, du Protérozoïque, traversent la région; des sédiments clastiques du Protérozoïque supérieur se sont déposés sur le socle, après quoi des failles tant réactivées que nouvelles ont traversé la région. Cette dernière a été pénéplanée au début de l'Ordovicien avant le soulèvement du môle de la presqu'île de Melville au milieu du Dévonien.

Introduction

Mapping in the Encampment Bay map area (47C) in the 1985 season focused on problems in high grade terranes outlined in 1984 (Schau and Ashton, 1985) and extended to areas to the south and northwest (Fig. 80.1) but was limited by paucity of landing spots for a wheeled Twin Otter. Mapping was by foot traverse originating from main camps and backpack sites. A helicopter was available for two days in late June. The region is close to the magnetic north pole and sun compasses were used when possible. Brunton compasses were calibrated against true north daily to provide a means of measuring orientations during cloudy periods. Daily drift in magnetic declination was usually only a few degrees but on July 22, 1985 the azimuth of the magnetic pole, at one location, varied from 75°W to 41°W during the day.

The map area contains many glacial features which in part obscure the bedrock geology. Amphibolite grade rocks occur at higher elevations but are largely covered by felsenmeer, till, and other glacial debris. Granulites occur at lower elevations and are better exposed and present a more rugged topography since dykes, joints, and minor fractures have been preferentially excavated whereas granite, more easily eroded, forms lowlands.



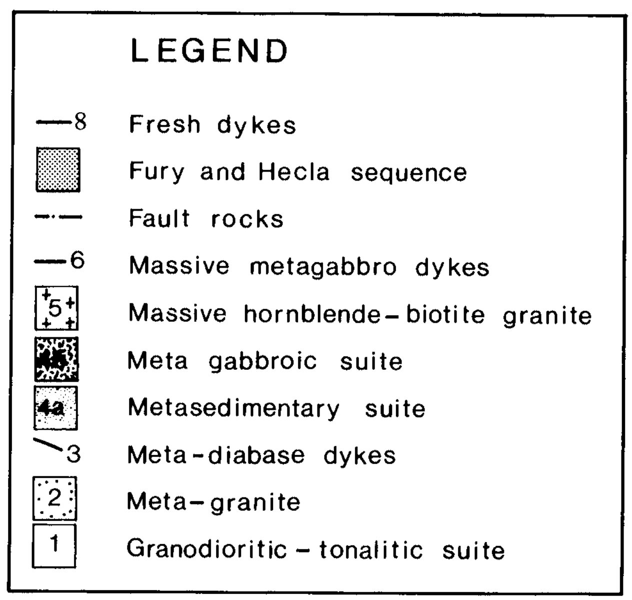


Figure 80.1. Geological sketch map of parts of NTS 47C.

The area is within the barren lands and there is only a sparse vegetational cover. Large lakes were ice covered until mid-July. Pack ice stayed in Committee Bay throughout the field season. Inclement weather in June was followed by good weather in July but extensive sweeping fog banks covered the area in August.

Description of lithological units

Tonalite-granodiorite orthogneiss suite (unit 1)

Unit 1, which underlies most of the area, consists of high grade orthogneisses formed from tonalitic to granodioritic intrusive rocks. Granulite grade orthogneiss comprises beige to olive weathering, grey to greenish blue coloured, quartzofeldspathic rocks with biotite, small amounts of orthopyroxene, and variable amounts of hornblende and/or clinopyroxene. The predominant rock is fine grained, foliated and lineated and is composed of quartz, feldspar, biotite, hornblende, pyroxenes and opaques. Textural variants include a "coarse-grained" type, in which centimetre-sized feldspar shapes are now composed of polygonitized feldspars and hornblende is more abundant than biotite; a streaky type, in which the relict fabric is medium grained and biotite is approximately equal to hornblende; a fine grained biotite variety in which a few relict feldspars persist giving a local seriate fabric; and a quartzose type in which the quartz is abundant and biotite is not. The granulites are generally homogeneous, but layered varieties with biotite-rich layers on the order of a centimetre in thickness, interlayered with leucocratic layers, do occur locally. In a few outcrops the typical fine grained gneiss has been intruded by the coarse type.

Similar rock types are encountered at amphibolite grade; these lack orthopyroxene, are grey in colour, and weather white or pink to red. Two localities at amphibolite grade studied in detail (Prevec, 1985) were found to be largely of granodioritic composition with hornblende, biotite, and opaques varying from 17 to 39 per cent and quartz ranging between 18 and 34 per cent. The alkali feldspar varies between 3 and 17 per cent and is largely untwinned perthitic orthoclase although most thin sections have small amounts of grid twinned potash feldspar as well. The plagioclase is calcic oligoclase to andesine. These variations are representative and although rocks poor in alkali feldspar are known, the relative proportions of each type await the completion of mapping.

Foliations are generally shallow dipping and cast into local folds. At Baker Bay, for example, the foliation is folded into a broad open fold about a shallow northwest plunging axis. For other examples see Schau and Ashton, 1985. Only in localities such as south of Baker Bay where unit 3 dykes occur as passive markers can the foliation be shown to be axial planar to a previous relatively tight fold set. At Baker Bay early lineations are dispersed about a later shallow, northwest plunging lineation which is probably associated with the fold axis of a fold that affects the foliation. Lineations are not everywhere equally developed and several periods of lineation development are possible, but not proven, throughout the mapped region. Locally, poorly defined layers and aggregates of mafic minerals are tightly folded about horizontal axial planes defined by mafic clots and flattened quartz. Two poorly defined sets of subhorizontal foliations that intersect at small angles were noted in several localities. One outcrop mapped in detail as typical of unit 1 near Baker Bay shows many minor structures and variable leucosome development. North of Corrigal River contacts between coarse- and fine-grained types in the form of planar 0.5 to 5.0 m thick alternating lithologies are transitional over a few tens of metres suggesting tectonic interleaving of the two units. Although foliations are generally subparallel, in a number of localities layering or gneissosity is intersected by a later foliation. If this foliation is associated with a fold set, then, since the layering is either steeper or shallower than the shallow to moderately dipping foliation it follows that some layers are overturned. On the other hand some layers are leucosome formed during deformation so they need not show a relative position of a fold limb (Fig. 80.2). On the whole the minor structures and the layering relations do suggest that, as yet unmapped, large, tight, overturned folds are present in the rocks of unit 1.

High grade metamorphism has affected the rocks of unit 1 as shown by regional development of orthopyroxene, over an area 10 to 20 km wide and in excess of 80 km long (Fig. 80.3). As detailed petrology is required before the reactions by which the orthopyroxenes formed can be identified the region shown as orthopyroxene zone is not bounded by isograds. To the west, near the Committee Bay coast amphibolite grade orthogneisses and migmatites grade eastward into granulite grade rocks. Figure 80.4 shows migmatite from this area. Near Brevoort Lake and Grinnel Lake amphibolite grade rocks predominate, although small patches of pyroxene-bearing orthogneisses occur locally. The age of this suite is unknown but they are considered the oldest rocks in the area.

Lineated granite (unit 2)

Unit 2 is a metagranite suite which occurs in stocks, sheets, and dykes of unit 2 cutting the granulite grade country rock in the western part of the region. Large bodies are slightly less resistant to erosion than the granulite host. The sheets have a shallow dip and are interleaved with the host in an intricate manner. Some of the smaller sheets have been omitted from Figure 80.1 for clarity.

Unit 2 consists of orange to pink weathering, pink to white, coarse to medium textured granite with characteristic flattened or lineated smoky quartz and polygonitized to sugary feldspar growth pseudomorphing coarse feldspar shapes. The colour index is about 5, mafic minerals consist of biotite and an opaque, generally magnetite. A thin section of the rock is seen to be a perthite rich granite with a trace of biotite partly altered to chlorite and a trace of magnetite. Variants include polygonitized, almost completely recrystallized and finer grained types. At contacts with unit 1 small granite dykes are particularly abundant , locally generating injection type gneisses, although local passive dykes and narrow gradational contact zones are found at contacts of many of the sills.

Foliation and local lineation in the metagranite is shown by quartz plates accentuated by small, irregularly oriented biotite flakes that cluster near the quartz. In less

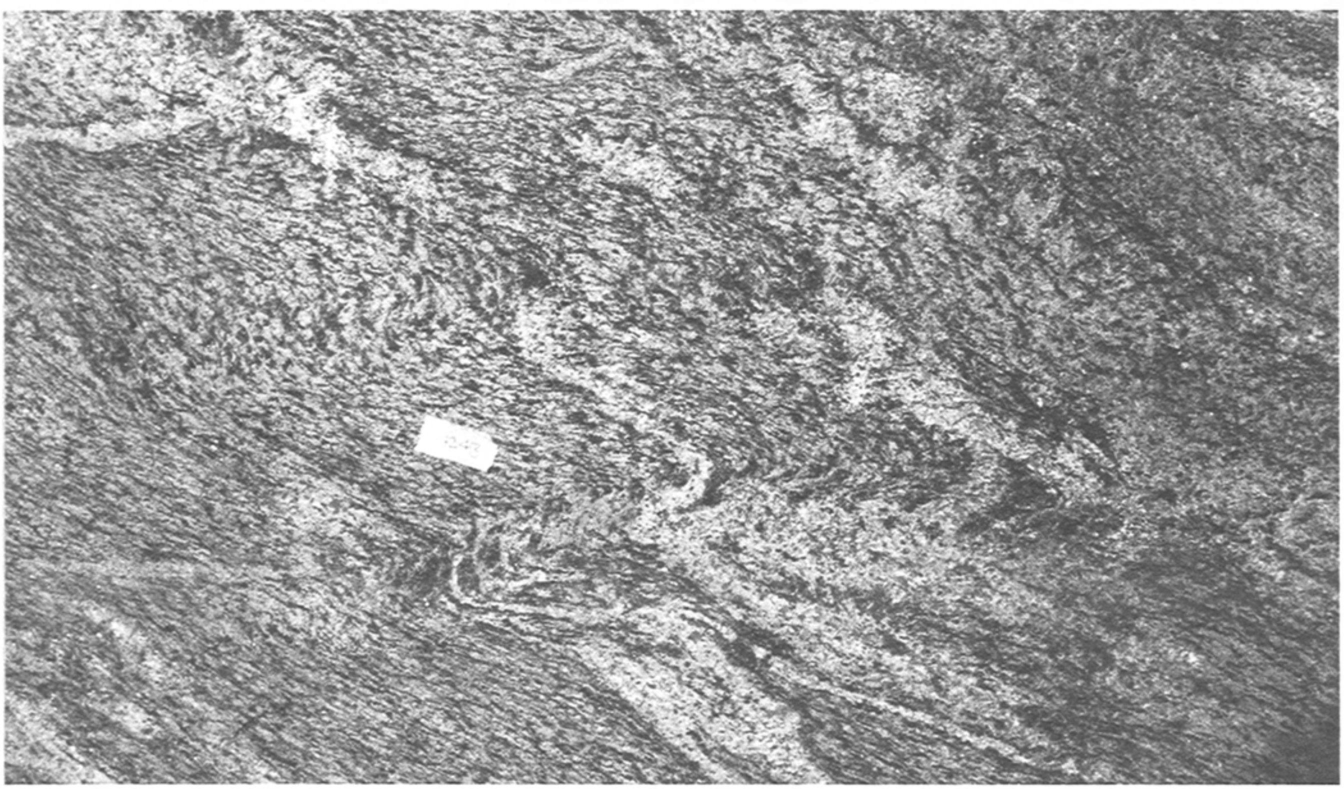


Figure 80.2. Photograph of unit 1 migmatite. Shows deformed unit 1 and development of unit 5 granite along axial plane. Tape is two cm across.

severely deformed rocks, in sections normal to foliation and the direction of lineation of the quartz grains, two intersecting foliations are distinguishable, and at two localities, relict feldspars show that they have been rotated in a dextral sense. These structures, although not common enough to characterize the deformation do indicate that shear was instrumental in producing the fabric. Thus, since grain size is demonstrably reduced by shear much of this unit can be considered as protomylonitic. The foliations so produced are generally shallow dipping and locally folded.

The mineral assemblage quartz, alkali feldspar, biotite, opaque with rare garnet and/or orthopyroxene is stable at high grades under moderately dry conditions. Dykes of unit 3 cut unit 2 and since unit 3 is locally metamorphosed to granulite grade the granite is likewise interpreted to have been affected by granulite metamorphism even though, as yet, only a few grains of orthopyroxene have been identified from the granite. The age of the granite is pre-unit 3, 5, and 6 and post-unit 1 and correlatives are not currently known.

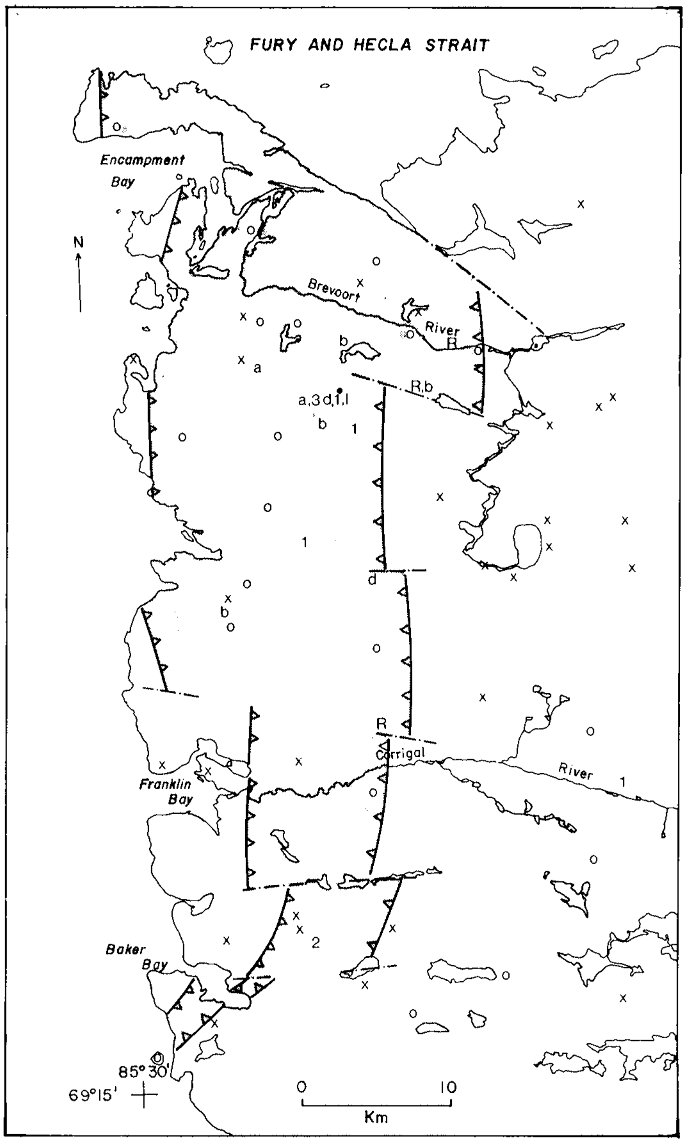


Figure 80.3. Sketch map of distribution of orthopyroxene zone. Note thin section distribution and assemblages reported therefrom. Letters and numbers correspond to those in Figure 80.5.

Lineated metabasic dykes (unit 3)

Foliated, lineated metadiabase dykes are well exposed in the cleared area southeast of the lake at the head of Brevoort River and are found in unit 1, and less abundantly in unit 2, throughout the area.

The dykes are 10 cm to 30 m wide and extend along strike for up to 6 km, but poor exposure and tectonic disruption combine to make most mapped dyke segments short.

In the amphibolite grade terrane the dykes are dark weathering, dark, fine- to medium-grained and consist of lineated hornblende and minor plagioclase whereas in the granulite terrane they are brown weathering, medium grained and contain pyroxenes and biotite as well as leucosome pods. Thinner dykes are fine grained and occur as satellites to nearby thicker medium grained dykes. The latter generally contain fist sized medium- to coarse-grained, feldspar-rich, pyroxene- and hornblende-bearing leucosomes. In the amphibolite grade region, the dykes are folded into upright, open, moderately northeast plunging structures with an internal lineation defined by elongate hornblendes. Dykes from the hypersthene zone lie along or at small angles to the foliation; at Baker Bay a large fold nose is fortuitously exposed and serves as an important marker in the sequence of geologic events. The fold is tight, has a steep plunge to the north-northeast and a moderately northwest dipping axial plane.

Dykes from the west consist of hornblende, orthopyroxene, clinopyroxene, plagioclase, quartz, biotite, and opaques which is consistent with granulite grade. In contrast, dykes from amphibolite grade country rocks are lineated, medium grained and contain sweats which, on the basis of one thin section consist of hornblende, clinopyroxene, plagioclase, quartz, biotite, opaque, and alkali feldspar, an assemblage consistent with the amphibolite grade of the country rock. We conclude that the dykes were emplaced prior to the high grade metamorphism that has affected the region.

The dykes cut units 1 and 2 and are cut by unit 5. The contact relations between units 3 and 4 have not been seen. There are three sets of deformed Archean dykes exposed to the southeast (GSC Open File 1046); the correlation of unit 3 with one of these three sets may be possible with further knowledge of field relationships and geochronological results.

LEGEND

Field data

orthopyroxene zone

Thinsection data

l,1,2,3,a,b,d diagnostic assemblages see figure 5

o orthopyroxene bearing locality

x amphibolite grade assemblage

R retrograded opx? present in thinsection

Figure 80.4. Photograph of unit 5 migmatite. Shows fragment of unit 1 set in massive unit 5 granite. Photos (Fig. 80.2 and 80.4) were taken a few metres from each other.

Metasedimentary suite (unit 4)

Small areas in the northern part of the map area are underlain by metasedimentary gneiss. Resistant units such as metaquartzite characteristically form hills whereas units such as sillimanite schist are recessive.

Rock types of the suite include gneiss, amphibolite, quartzites, sillimanite schist, and metapyroxenite. Hornblende- and biotite-bearing quartzofeldspathic gneisses grade into biotite-bearing quartzofeldspathic gneisses. The amphibolites are thin layers composed of hornblende and plagioclase and are locally garnetiferous. The quartzites are generally white but are locally red or green. They contain scattered muscovite and locally, chromiferous muscovite. They are fine- to medium-grained with abundant quartz veins and thin interbeds of mica- and sillimanite-bearing layers. Near the base, thin layers of strongly foliated quartzite pebble conglomerate and biotite, muscovite, and feldspar-bearing quartzite are interbedded with relatively pure quartzite and sillimanite schist. The schists generally contain muscovite, biotite, sillimanite and on occasion garnet and/or cordierite. Metre thick metapyroxenite dykes cut quartzites.

The unit outcrops in a crude U-shape, with the open end pointing to the east. In general, the foliations are shallow dipping and lineations have shallow plunges. The relationships of unit 4 with structurally underlying units is locally gradational, although pods of massive unit 5 granite occur throughout the contact region complicating relationships. The metasediments in contact with unit 1 are aluminous and grade into unit 1 with decreasing sillimanite and increasing hornblende contents. Nowhere is an intrusive relationship recognized between units 1 and 4. Instead we postulate that the aluminous metasediments are pelites and that the gradational part constitutes a metaregolith formed over an unconformity between units 1 and 4.

The metamorphic grade of the metasediment is upper amphibolite based on the coexistence of garnet and hornblende in the amphibolites and quartz and muscovite in the schist. An occurrence of garnet, cordierite, biotite, sillimanite schist suggests that metamorphic conditions were near highest amphibolite grade (cf. Froese, 1978). Metasedimentary rocks of unit 4 sit unconformably(?) on granodiorite of unit 1 and are cut by granite of unit 5. The association of chromiferous quartzites and iron rich (= garnetiferous) sediments is similar in lithology to the Prince Albert Group as described in adjacent areas (Frisch, 1982; Schau, 1977). We postulate that unit 4 can be correlated with the 2.9 Ga old Prince Albert Group.

Anorthositic metagabbro

Metamorphosed, small, layered sills of anorthositic gabbro are emplaced in the foliation of unit 1 northeast of Baker Bay. The metamorphism is characterized by grossularite, plagioclase and hornblende. These sills are not foliated although their layering is subparallel to the foliation. They are correlated with metagabbroic bodies of Archean age to the southeast (GSC Open File 1046). Metagabbroic stocks are irregularly distributed in the region and have been assigned to this unit.

Massive hornblende-biotite granite (unit 5)

Irregular stocks of fresh granite and dykes of pegmatite and aplite occur in areas underlain by amphibolite grade country rock. A large body underlies the north-central portion of the map area, smaller sheets are found along the west coast, and the small stock, outlined in 1984, is found in the central part of the map area. The granite is pink weathering, white to grey, medium grained, massive hornblende biotite granite. The aplites are pink and white with only a small amount of biotite. A large proportion of the area marked unit 1, especially the region at amphibolite grade, contains about 15 per cent leucosome fraction of granite veins or pods. Gneissic rocks occur locally where sheets of granite intrude lit-par-lit fashion into tonalite gneiss of unit 1. Elsewhere, decimetre long, massive, unconnected pods of granite are set in tonalite and granodiorite. The composition of this leucosome is similar to larger bodies of granite. Migmatite with small blocks of unit 1 set in granite are locally well developed. Figure 80.4 is an example of this type. A working hypothesis is that the granite is the result of partial melting of tonalite granodiorite suite and, locally, of unit 2 granite, which occurred at deeper levels and possibly at presently exposed structural levels. Perhaps partial melting and the high grade metamorphism are coeval and/or cogenetic. The location of granite bodies in the amphibolite grade part of unit 1 may indicate the extent of higher partial pressures of water in the amphibolite grade rocks.

The granite cuts units 1, 2, 3, and 4 and is cut by fresh dykes and faults. The granite was exposed to erosion by time of deposition of Fury and Hecla sequence. Although the age of the granite is uncertain, and massive granites of both early to middle Proterozoic and late Archean age occur on Melville Peninsula to the south (GSC Open File 1046), a working hypothesis is that the granite and the high grade metamorphism are coeval and part of the Archean metamorphic event that affected the Prince Albert Group elsewhere on the peninsula.

Massive metagabbro dykes (unit 6)

West-trending, steeply dipping dykes of black weathering, fine- to medium-grained metagabbro cut granulite terrane. The dykes are less resistant to erosion than the country rock and are poorly exposed at edges of canyons or as small knobs on the canyon floor. Nevertheless they have been followed for many tens of kilometres along strike in several locations.

The dykes are hornblende-plagioclase rocks with white plagioclase phenocrysts locally rimmed by garnet suggesting that the dykes are metamorphosed. In thin section the rock is seen to be composed of hornblende, plagioclase, and opaques widely replaced by actinolite, chlorite, albite, and clinozoisite.

The dykes are cast into mesoscopic folds with shallow northwest plunges. The age and assignment of the dykes is not known. Other dyke swarms of similar appearance to the south on Melville Peninsula are Proterozoic in age.

Pegmatites (not on map)

Biotite bearing pegmatites cut unit 6. There are several sets of pegmatite which may be of differing ages, some containing hornblende others allanite?.

Fault rocks

Late faults are marked by linear zones of intensely altered rocks. The alteration is commonly quartz and hematite impregnation but epidosites are also common. Rusty patches are found as well. Where rare fabrics were observed, slickensides are nearly horizontal. The faults contain disrupted veins and have several episodes of movement and hence the fault rocks were probably formed at different times after the metamorphism. The east west faults and included fault rocks are part of a peninsula wide fault set of middle Proterozoic age (GSC Open File 1046).

Fury and Hecla sequence

Within the map area, this sequence outcrops along the south shore of Fury and Hecla Strait. A wedge mapped this year underlies 35 km^2 and is bounded to the west by a northwest striking, steeply dipping fault, to the south by an east-striking fault and to the east by an unconformity.

The sequence is 5 km thick as estimated from map pattern and measured dips. It consists of thick sequences of bedded quartzites and thinner interbeds of red siltstones.

Sedimentary structures include crossbeds which indicate current travelled from east to west and only rarely from south to north. Diagenetic discoloration have added fine purple patterns to the essentially white to tan quartzites. These patterns suggest massive water flow through the sediments probably precipitating newly oxidized iron hydroxides. The discoloration and local hematite veins indicate that oxidizing solutions which can transport uranium were active in this area during late Proterozoic time. Anomalous concentrations of uranium have been associated with this unit north of the strait (Chandler et al., 1980).

Secondary structures include fracture cleavage parallel to steep east-west faults that are apparently north side down. Two open synclines, a northern one with a shallow northwest plunge and a southern one with a southwest plunge also affect the sequence. The age of the sequence is late Proterozoic.

Fresh diabase dykes and sills (unit 8)

Brown weathering, black to greenish brown, very fine- to medium-grained diabase dykes with steep dips, a northwesterly trend, and widths of 5 cm to 45 m cut all units. The dykes are more resistant to weathering than the country rock but are more poorly exposed in the felsenmeer-covered amphibolite grade country rock. Linear magnetic anomalies (taken from GSC Geophysical Map Series 8304g) with similar trends and marked by diabase boulder trains probably indicate additional diabase dykes to those located in outcrop.

Although the dykes are linear on a map scale, in detail the contacts are irregular and metre-long blocks of country rock have been spalled from the walls of the dykes. The thinner dykes have irregular and angular shapes. At one locality an east-west trending steeply dipping fault offsets a fresh dyke with an apparent dextral offset of a few metres. The question of whether the fresh dykes belong to either of the major late Proterozoic northwest trending dyke swarms (i.e. the Franklin or Mackenzie sets), must await further work.

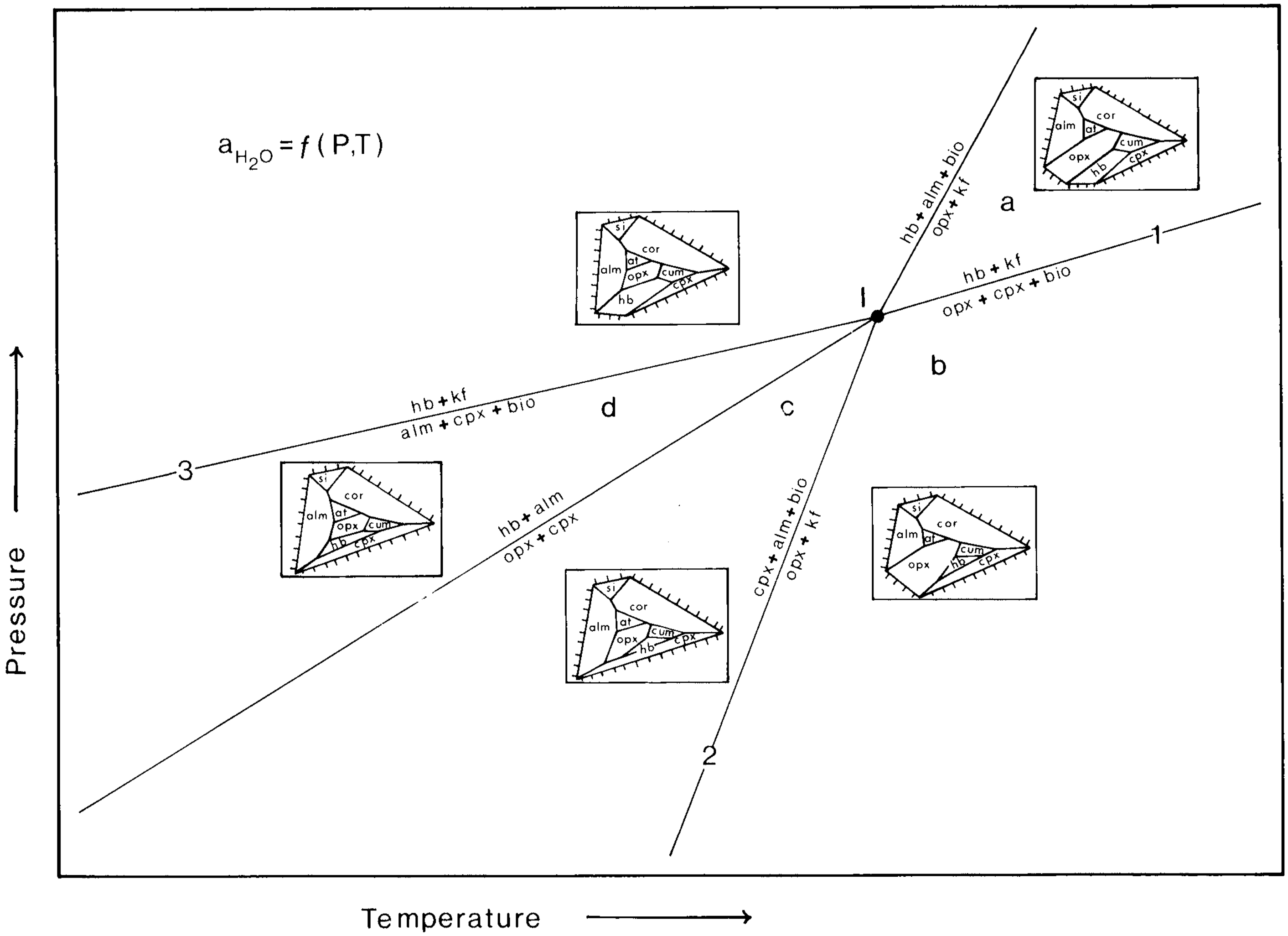
Sills in the Fury and Hecla sequence are up to 50 m thick and extend along strike for tens of kilometres. The sills are medium grained olivine-bearing gabbro, which locally along strike has been affected by deuteric alteration. The sills have been affected by some east-west faults. The age of the sills may be similar to the dykes.

Later events

Although no direct evidence of later depositional events is preserved in the region it is known that faulting affected the clastic rocks and the mafic dykes and sills. The region was then apparently peneplaned by early Ordovician time (Sanford, 1977). The uplift of Melville Peninsula in mid-Devonian time is the last structural event, save the isostatic adjustments to Pleistocene ice sheets.

Economic minerals

No interesting showings were located this year. Grab samples of rusty material with sulphides collected in previous seasons were assayed for Au, Ag, and As and returned values



LEGEND

Abbreviations

si sillimanite
cor cordierite
alm almandine
at anthophyllite
cum cummingtonite
hb hornblende
opx orthopyroxene
cpx clinopyroxene
bio biotite
kf K feldspar

I invariant point
tie lines to K feldspar
1,2,3 univariant reactions
a,b,c,d divariant fields

Figure 80.5. *Sketch showing granulite invariant point taken from Froese and Sen (1979). Numbers and letters correspond to those used on Figure 80.3. The compatible assemblages are shown on the biotite surface (Froese, 1978).*

at or near detection limit. Although granites contain radioactive accessories no concentrations nor complex pegmatites were located.

Special problems

Metamorphosed fault zones by virtue of their strained nature and reduced grain size are recrystallized and hence difficult to identify in high grade metamorphic terranes. At one locality near Brevoort River a narrow shear zone is seen to have formed along a pegmatite dyke cutting unit 2 granite. Evidence that the zone is a fault zone is shown by relict amazonite crystals which have been rotated and reduced in size, z-shaped folds, and rare doubly plunging folds (sheath folds?) which only occur along the length of this 50 m by 0.5 m zone. The zone consists of quartzofeldspathic fine grained matrix interlayered with fine grained garnet-rich layers whereas the country rock is typical unit 2 granite. A longer zone, some 30 km long, and which traverses the deformed rocks of unit 1 being deflected only by the latest faults, is similarly composed of garnet, quartz, feldspar with local development of biotite and sillimanite. A third occurrence thought to be a fault zone is an aplite. In the Baker Bay area a thin unit of leucocratic, very fine grained granite can be traced across the area. The zone is subparallel to the foliation and is affected by the latest open northwest plunging fold but not by the earlier northeast plunging folding. Locally near the edge of the aplite the country rock becomes more foliated and biotitic. Country rock on either side is unit 1 so offset is difficult to demonstrate. We believe this unit to be a shallow dipping fault possibly active in the later stages of the metamorphism and that the recrystallization took place when unit 6 was metamorphosed.

Another problem to be addressed is the extent of large fold structures. There is local evidence of folding on a sizable scale from minor structures and outcrop patterns from units 1 to 4 inclusive. The sparsity of marker horizons and the nature of the folded material (essentially homogeneous irregular masses of quartzofeldspathic rock) combined with the high grade of metamorphism which has partially melted or recystallized the rocks so as to remove the evidence, militate against proper definition of the folds. Nevertheless the possibility that slabs of basement and infolds of supracrustal units have been stacked in such a manner that the supracrustals have been lowered some five times their original thickness into the crust seems likely.

Schau and Ashton (1985) posed the question of whether granulites developed in unit 1 are "higher" grade than the surrounding amphibolite. The extent of the orthopyroxene zone as determined in the field is shown on Figure 80.3. Also shown are some locations of different mineral assemblages. These are keyed to the excerpt from Froese and Sen (1979) P-T diagram derived for biotite bearing mafic granulites (Fig 80.5). On the map the metamorphic conditions as deduced from the P-T diagram are not regular. Explanations for this irregularity include structural modification subsequent to peak metamorphism, variable extent of back reactions so that different quenching assemblages are preserved, or variable activity of water during metamorphism. There is local evidence supporting all three hypotheses, however the argument for the latter hypothesis is amplified below. Powell (1983) proposed phase relations for a model metabasic rock under high grade conditions. Powell (ibid.) shows the mineralogical evolution of a garnet, plagioclase, hornblende, and quartz assemblage under external buffering of water activity and contrasts it with the evolution of a similar assemblage under internal buffering. The sporadic occurrence of orthopyroxene with hornblende in the partial melts that constitute unit 5 supports the model of internal buffering of water activity. The occasional leucosome in which clinopyroxene is well developed would support externally imposed water activity. The relative importance of each of the processes is not known since the required mineral assemblages are not known to be widely distributed. Perhaps a competing reaction is more important. Percival (1983) suggested that biotite and hornblende react to form orthopyroxene, clinopyroxene, potash feldspar, and water. This assemblage is sporadically present and may have fixed the water activity instead of the Powell reactions. We conclude that water activity probably varied irregularly during metamorphism but that the processes responsible are not yet identified.

The proposal that hornblende bearing granite results from partial melting of crustal, albeit plutonic materials, recieves theoretical support from Powell (1985), and is analogous to that made by Kenah and Hollister (1983), as their explanation for high grade rocks in northwestern British Columbia.

Future work will focus on determining large scale structures and relating them to regions of higher and lower water activity. The processes whereby the high grade rocks reappear at the surface will be pursued.

Acknowledgments

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