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BULLETIN 385

GEOLOGY OF THE ARCHEAN PRINCE ALBERT GROUP IN THE RICHARDS BAY AREA, NORTHEASTERN MELVILLE PENINSULA, DISTRICT OF FRANKLIN, NORTHWEST TERRITORIES

M. Schau

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A view of folded calcareous arenitic metasediments on the Coxe Islands.

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Preface

Reconnaissance geological mapping in the District of Franklin was initiated more than thirty five years ago with the Geological Survey's first helicopter-supported operation. This identified many of the broad aspects of the geology of the region and enabled mapping of more complex areas at the appropriate scale. The Prince Albert Group, which is greenstone suite widely exposed in northeastern mainland Arctic Canada, is particularly well exposed in the Richards Bay area of northern Melville Peninsula. These exposures provided an opportunity to study the relatively simple structural deformation, significant stratigraphic section, and, most importantly, the economically interesting lithologies.

In this report the author describes three volcanogenic formations of the Prince Albert Group as well as later crosscutting plutons that here constitute the crystalline basement of the peninsula. He concludes that the "inverted" volcanic stratigraphy displayed here, i.e. intermediate volcanics overlain by increasingly mafic volcanic units, is indicative of deposition in a continental rift environment.

This report adds considerably to our understanding of the Prince Albert Group, and the relationship of iron-formations, ultramafic units, quartzites, and acid volcanics. Because this area lies within the land claimed under the landclaim treaties, the report forms one basis for the evaluation of prospecting potential in these selected Nunavut regions.

M.D. Everell
Assistant Deputy Minister
Geological Survey of Canada

Préface

Dans le District de Franklin, la cartographie géologique de reconnaissance a commencé il y a plus de 35 ans avec la première opération héliportée de la CGC. Ces travaux ont permis de reconnaître de nombreux aspects généraux de la géologie de la région et de cartographier des régions plus complexes à une échelle convenable. Le Groupe de Prince Albert, suite de roches vertes exposée sur une grande étendue dans le nord-est de l'Arctique continental canadien, affleure particulièrement bien dans la région de la baie Richards, dans le nord de la presqu'île Melville. On a utilisé ces affleurements pour étudier la déformation structurale relativement simple, une coupe stratigraphique significative et, le plus important, les lithologies qui présentent un intérêt économique.

Dans le présent bulletin, l'auteur décrit trois formations volcanogéniques du Groupe de Prince Albert ainsi que des plutons croisés plus jeunes qui, à cet endroit, constituent le socle cristallin de la presqu'île. Il conclut que la stratigraphie volcanique «inversée» que l'on voit à cet endroit, soit des volcanites intermédiaires sous-jacentes à des unités volcaniques de plus en plus mafiques, est caractéristique d'une mise en place dans un milieu de rift continental.

Le bulletin élargit considérablement nos connaissances du Groupe de Prince Albert et des liens qui existent entre les formations ferrifères, les unités ultramafiques, les quartzites et les volcanites acides. Puisque la région fait partie des terres visées par les traités portant sur les revendications territoriales, le bulletin constitue une base pour l'évaluation du potentiel économique de cette partie du Nunavut.

M.D. Everell
Sous-ministres adjoint
Commission géologique du Canada

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GEOLOGY OF THE ARCHEAN PRINCE ALBERT GROUP IN THE RICHARDS BAY AREA, NORTHEASTERN MELVILLE PENINSULA, DISTRICT OF FRANKLIN, NORTHWEST TERRITORIES

Abstract

A well preserved, greenschist grade, 5 km thick, incomplete section of the Archean Prince Albert Group, showing primary textures and structures, is exposed in the Richards Bay region. There the group has been divided into three formations separated from each other by prominent iron-formations. The oldest and lowermost Adge-go Formation is 2.2 km thick and consists of intermediate volcanics and metasedimentary rocks topped by banded iron-formation and cut by acid, basic, and ultramafic dykes. The intermediate, 1.0 km thick, Richards Bay Formation has an upper sequence of metasediments and pillowed calc-alkaline basalt topped by a banded iron-formation cut by ultramafic dykes, and a lower clastic unit of basal quartzite with an overlying polymictic breccia. The Mount Sabine Formation is the youngest and consists of 1.8 km of mainly metasedimentary rocks in which two large mafic members occur; an upper cherty, pillowed, variolitic, magnesian basalt to ultramafic, flow, dyke, and sill complex, and a lower, calcareous, pillowed, feldspar-phyric metabasalt sequence.

Deformation of the Prince Albert Group was compressive and is postulated to have cast the rocks into a large antiformal syncline imposing a foliation with flatter dip on shallow southeast dipping beds north of Richards Bay. A later flexural fold bent the somewhat higher grade (garnet zone)rocks near a western granite pluton at the west edge of the map area into a steeply dipping western limb of an open south plunging synform. On the two Coxe Islands, south of the bay and within the map area, the more tightly folded, recrystallized, higher metamorphic grade rocks are considered to be a facies equivalent of the Adge-go Formation. The area lies within the Ossory fault zone and is cut by splays with steep reverse as well as transverse movement.

The volcanic sequence presented in the section is "inverted", compared to usual Archean sequences, in that more mafic volcanic rocks overlie less mafic units. Partial analogues of the sequence are found in modern marginal seas.

Whatever the tectonic significance of the deposition of the group in a shallow unstable tensional environment, it was one in which banded iron-formations formed readily. The prospect for massive sulphide deposits in the area is judged to be low, but the possibility of small vein deposits is not discounted since appropriate host rocks are present, although assays on vein materials have been discouraging.

Résumé

Une coupe incomplète bien conservée de 5 km d'épaisseur de roches du faciès des schistes verts, dans laquelle on reconnaît des textures et des structures primaires, affleure dans la région de la baie Richards. Ces roches appartiennent au Groupe de Prince Albert de l'Archéen. À cet endroit, le groupe est divisé en trois formations séparées par d'importantes formations ferrifères. La formation basale, celle d'Adge-go, qui est la plus ancienne, a 2,2 km d'épaisseur et se compose de roches métasédimentaires et de volcanites intermédiaires recouvertes de formation ferrifère rubanée et recoupées par des dykes acides, basiques et ultramafiques. La formation intermédiaire, celle de Richards Bay, qui a 1,0 m d'épaisseur, comporte une séquence supérieure de métasédiments et de basalte calco-alcalin en coussins surmontée de formation ferrifère rubanée que recoupent des dykes ultramafiques, et une unité inférieure clastique de quartzite basal recouvert d'une brèche polygénique. La Formation de Mount Sabine, la plus récente, se compose de 1,8 km de roches principalement métasédimentaires dans lesquelles se rencontrent deux grands membres mafiques, soit un complexe supérieur de coulées, de dykes et de filons-couches basaltiques magnésiens à ultramafiques, variolitiques, cherteux et en coussins, et une séquence inférieure de métabasalte carbonaté en coussins, à phénocristaux de feldspath.

Le Groupe de Prince Albert a été déformé par compression, et cette déformation aurait créé un vaste synclinal antiforme et produit une foliation à pendage moins raide dans les lits peu profonds à pendage sud-est au nord de la baie Richards. Près d'un pluton granitique occidental sur la bordure ouest de la région cartographique, la formation subséquente d'un pli par flexion a déformé les roches légèrement plus métamorphisées (zone à grenats) pour former le flanc ouest fortement incliné d'une synforme ouverte à

plongement vers le sud. Dans les deux îles Coxe au sud de la baie et dans la région cartographique, les roches recristallisées, plus fortement métamorphisées et plus serrées, sont considérées comme un faciès équivalent à la Formation d'Adge-go. La région se situe dans la zone de failles d'Ossory et est recoupée par des failles subsidiaires, comportant un mouvement transversal et un mouvement inverse fortement incliné.

La séquence volcanique présentée dans la coupe est «inversée» par rapport aux séquences archéennes habituelles, car des volcanites plus mafiques sont sus-jacentes à des unités moins mafiques. Des séquences en partie comparables se rencontrent dans les mers bordières actuelles.

SUMMARY

Original textures and structures of a volcanogenic portion of the Archean Prince Albert Group, are exposed in the Richards Bay region at the northeastern end of Melville Peninsula. Although strained, incomplete, and metamorphosed to greenschist grade, the section shows at least a 5 km thickness on the largest of the Bouverie Islands north of the bay. There, the Prince Albert Group is divided into three formations from oldest to youngest: Adge-go, Richards Bay, and Mount Sabine formations.

0 m The base of the section is taken at the western edge of the island, at the narrow isthmus which is below water at high tide. On the mainland, a locally agmatitic granite pluton carries fragments of the Prince Albert Group, indicating that the depositional base of the group has not been located.

0-1000 m from the base. This basal sequence of the Adge-go Formation consists of recrystallized andesite flows and breccias cut by calcalkaline basalt dykes. Layering and clast outlines are obscure but locally relics are preserved. Small granite dykes from the pluton to the west cut the section. Near the base the rocks are well layered on a 1-5 cm scale, biotite-rich, locally epidotized gneisses which are cut by 15 cm thick biotite amphibolite dykes. These have a biotite foliation at a small angle to the layering, and are cut by thin granite dykes and sills. Low in the section and nearer the granite contact the rocks are gneissose. Alternating amphibole-rich and quartzofeldspathic layers have variable grain size and some layers are mixtures of larger, commonly felsic clasts set in a finer grained chiefly mafic matrix. In some beds a subparallel but crosscutting compositional layering is marked by amphiboles. Small quartz veins are folded and if the folding is due to compression the beds containing the veins have been shortened by 25%. Near the centre of the section, several sets of 40-50 m thick units of alternating darker gneiss and lighter gneiss with intercalations of darker and lighter coloured sequences of flattened, brecciated metavolcaniclastic units, with a foliation at a small angle to the layering and cut by red granite dykes, are abundant. Near the top of this part of the section, massive thick units with moderate colour index (felsic metatuff?) are interbedded with

SOMMAIRE

Les textures et structures d'origine d'une portion volcanogénique du Groupe de Prince Albert de l'Archéen affleurent dans la région de la baie Richards, à l'extrémité nord-est de la presqu'île Melville. Bien que la coupe soit déformée, incomplète et métamorphisée au faciès des schistes verts, elle a au moins 5 km d'épaisseur sur la plus grande des îles Bouverie au nord de la baie. À cet endroit, le Groupe de Prince Albert est divisé en trois formations, données ici de la plus vieille à la plus jeune : Adge-go, Richards Bay et Mount Sabine.

La base de la coupe est prise sur le rivage ouest de l'île, à l'isthme étroit qui est immergé à la marée haute. Sur le continent, un pluton granitique localement agmatitique contient des fragments du Groupe de Prince Albert, ce qui indique que l'on n'a pas encore trouvé la base du groupe.

De 0 à 1 000 m de la base. Cette séquence basale de la Formation d'Adge-go se compose de brèches et de coulées andésitiques recristallisées que recoupent des dykes de basalte calco-alcalin. Le caractère stratiforme et les contours des clastes sont mal définis, mais des reliques sont conservées par endroits. De petits dykes granitiques provenant du pluton à l'ouest traversent la coupe. Près de la base, les roches sont des gneiss nettement stratiformes sur une échelle de 1 à 5 cm, riches en biotite et localement épidotisés, que recoupent des dykes d'amphibolite à biotite de 15 cm d'épaisseur. Ces dykes présentent une foliation qui est due à la biotite et qui est légèrement oblique par rapport à la stratification; ils sont recoupés par des dykes et des filons-couches peu épais de granite. Près de la base de la coupe et plus près du contact granitique, les roches sont gneissiques. Des couches amphiboliques et quartzofeldspathiques alternantes ont une granulométrie variable, et certaines couches sont des mélanges de clastes plus gros, fréquemment felsiques, fixés dans une matrice plus fine, principalement felsique. Certaines couches présentent une différenciation pétrographique subparallèle et croisée, marquée par des amphiboles. On y trouve de petits filons de quartz plissés et, lorsque les plis sont dûs à la compression, les lits contenant les filons sont raccourcis de 25 %. Près du centre de la coupe, il y a plusieurs ensembles d'unités de 40 à 50 m d'épaisseur où alternent des gneiss sombres et des gneiss clairs avec des intercalations de séquences claires et sombres d'unités métavolcanoclastiques bréchifiées et aplaties, qui présentent une foliation légèrement oblique par

darker amphibolites of calc-alkaline basalt (metatuff?) and cut by subparallel but locally crosscutting amphibolite dykes.

1000-1600 m from the base. The middle 600 m of the Adge-go Formation are characterized by bedded to laminated tuffaceous sediments with local conglomerate-breccia units. The sequence is cut by dykes of high magnesium tholeiitic basalt and komatiitic basalt. A granite dyke complex associated with a stock to the south cuts well layered, massive, greenish metasandstones. Greyish green, fine grained dykes are emplaced along the layering and/or foliation. Near the top of this interval a flattened volcaniclastic unit featuring light coloured, quartzose, ellipsoidal clasts (one is 12 x 6 x 3 cm), is set in a biotite-rich matrix interbedded with biotite-bearing, meta-sandstones and thin, locally crosscutting, amphibolite layers. The section here is composed mainly of massive to indistinctly fragmental, fine grained, 10-15 cm thick beds of recrystallized tuff. One epidotized layer shows regularly disposed quartz veins normal to the layering, giving the appearance of a ladder. This boudinage-like feature suggests that the epidote-rich layer was more brittle than the surrounding biotite-bearing rocks. Epidote veins crosscut the layering at low angles, and a poorly defined schistosity in the micaceous units is also at low angles to the layering.

1600-2100 m from the base. The next 500 m consist of a wedge of coarse grained, clastics including volcanic breccias, flows and intercalated sediments. Mafic dykes, 10 cm to 1 m thick, of high magnesium tholeiitic basalt cut the section; one divides into three, like a fork, cutting through volcaniclastic breccia and intercalated, irregularly and discontinuously layered, tan weathering, grey, fine grained tuff units. Lower in this interval, locally epidotized intermediate volcanic breccias and massive andesite flows are abundant.

2100-2200 m from the base. The top 100 m of the Adge-go Formation consist of an iron-formation which changes facies along strike from thin, carbonate-rich, oxide assemblages in the north (see Fig. 3) to magnetite and hematite-rich assemblages near the pluton and thicker, silicate-rich assemblages, with sporadic iron sulphides layers, nearer Richards Bay in the south. Along the shore, regressive-weathering ultramafic dykes, a few metres thick, cut the iron-formations at acute angles. Interbedded with the iron-formation are komatiitic basaltic tuffs and, to the north, on strike with the iron-formation and in part displacing it, a dacite flow.

Richards Bay Formation conformably overlies the Adge-go Formation.

rapport à la stratification et que recoupent des dykes de granite rouge. Près du sommet de cette partie de la coupe, des unités mésocrates (métatuf felsique?) massives et épaisses sont interstratifiées avec des amphibolites plus sombres de basalte calco-alcalin (métatuf?) et recoupées par des dykes d'amphibolite subparallèles mais croisées par endroits.

De 1 000 à 1 600 m de la base. Les 600 m intermédiaires de la Formation d'Adge-go se caractérisent par la présence de sédiments tufacés lités ou laminaires qui contiennent par endroits des unités de brèche-conglomérat. Des dykes de basalte komatiitique et de basalte tholéiitique magnésien coupent la séquence. Un complexe de dykes granitiques associé à un petit massif intrusif au sud recoupe des grès métamorphisés verdâtres, bien stratifiés et massifs. Des dykes à grain fin de couleur vert grisâtre ont été mis en place parallèlement à la stratification, à la foliation ou aux deux. Près du sommet de l'intervalle, une unité volcanoclastique aplatie contient des clastes quartzeux ellipsoïdaux de couleur claire (un des clastes mesure 12 x 6 x 3 cm) dans une matrice riche en biotite; elle est interstratifiée avec des grès à biotite métamorphisés et de minces couches amphiboliques qui se recoupent localement. À cet endroit, la coupe se compose principalement de lits épais (de 10 à 15 cm) de tuf recristallisé à grain fin, massif à imperceptiblement clastique. Une des couches épidotisées contient des filons de quartz disposés régulièrement, perpendiculairement à la stratification, ce qui leur donne l'apparence d'une échelle. Cette forme de boudinage donne à penser que la couche épidotisée était plus cassante que les roches à biotite environnantes. Des filons d'épidote recoupent la stratification à angle faible, et les unités micacées présentent une schistosité mal définie, qui est légèrement oblique par rapport à la stratification.

De 1 600 à 2 100 m de la base. Les 500 m suivants comportent un biseau de roches clastiques à grain grossier composé de brèches et de coulées volcaniques et de sédiments intercalés. Des dykes mafiques de basalte tholéiitique hautement magnésien, dont l'épaisseur varie de 10 cm à 1 m, traversent la coupe; un de ces dykes se divise en trois, comme une fourchette, et recoupe les brèches volcanoclastiques et les unités intercalées à stratification irrégulière et discontinue de tuf gris à grain fin dont la couleur d'altération est havane. Des coulées andésitiques massives et des brèches volcaniques intermédiaires, épidotisées par endroits, abondent plus bas dans cet intervalle.

De 2 100 à 2 200 m de la base. Les 100 m supérieurs de la Formation d'Adge-go se composent d'une formation ferrifère qui change de faciès en suivant la direction, passant d'assemblages oxydés minces, riches en carbonates, au nord (fig. 3), à des assemblages riches en magnétite et en hématite près du pluton et à des assemblages plus épais, riches en silicates, qui contiennent des couches sporadiques de sulfures de fer, près de la baie Richards, au sud. Sur la côte, des dykes ultramafiques de quelques mètres d'épaisseur, à altération régressive, recoupent la formation ferrifère à des angles aigus. Des tufs basaltiques komatiitiques sont interstratifiés avec la formation ferrifère; au nord, une coulée dacitique parallèle à la direction de la formation ferrifère déplace en partie cette dernière.

La Formation de Richards Bay repose en concordance sur la Formation d'Adge-go.

2200-2400 m from the base. A basal, grey to white weathering quartzite thickens from a few metres at Fury and Hecla Strait to about 200 m, 9 km to the south. It is overlain by southward thickening oligomictic to polymictic breccia or conglomerate which in turn, is overlain by immature siltstones and sandstones.

2400-2700 m from the base. 300 m of calc-alkaline basalt including decametre thick, locally pillowed and amygdaloidal, basaltic flows interbedded with decametre thick breccias and epiclastic arenites. Prominent interbeds are quartzose and a few centimetres thick; others are calcareous and up to 10 cm thick.

2700-3200 m from the base. The upper 500 m of Richards Bay Formation is dominated by tuff and tuffaceous sediments with local breccias. The top of the sequence is oxide iron-formations interbedded with basic volcanic breccias. Some laminated oxide iron-formation units are cut by metre thick ultramafic dykes that are folded with the host rocks.

The Mount Sabine Formation conformably overlies the Richards Bay Formation.

3200-3600 m from the base. The basal 400 m consist of a lower, basaltic, volcanic member, characterized by high magnesium tholeiitic basalt and komatiitic basalt pillows and pillow breccias units with calcareous interpillow cement, interbedded with beds of reworked basaltic debris. Some pillows and clasts are feldspar-phyric. Lower, pillow basalt units, several metres thick, are interbedded with progressively fewer, massive, metre thick, tholeiitic basalt flows and a larger proportion of basic volcaniclastic breccias nearer the base of this member. Pillows are small in the lower units. A 20 m thick meta-agglomerate, with decimetre sized clasts, occurs in the upper third of this interval. A small gabbro sill intrudes volcanic rocks near the middle of the unit and widens considerably along strike to the south. The upper part of this interval is mainly massive basalt units, up to 20 m thick, interbedded with thin tuff beds near the top.

3600-3800 m from the base. This 200 m thick volcanic wedge contains many different breccia beds of diverse origin and composition. Up section the proportion of coarse grained volcanogenic fragmental rock decreases. Lower in the section, metre thick beds of coarse grained volcanogenic breccias are intercalated with 20 cm thick beds of finer grained breccia with clasts less than 3 cm across, whereas nearer the top, a few tuffaceous beds, 10 cm-1 m thick, occur in decametre thick sets of thinly bedded, fine grained, clastic sediments. A thin, ultramafic, schistose dyke crosscuts layers in the basal part of the breccia and is itself cut by a small granite stock.

De 2 200 à 2 400 m de la base. Un quartzite basal gris à couleur d'altération blanc a une épaisseur qui passe de quelques mètres au détroit de Fury and Hecla à environ 200 m à 9 km au sud. Il est sous-jacent à une brèche ou à un conglomérat polygénique à oligogénique qui s'épaissit vers le sud et que recouvrent des siltstones et des grès peu évolués.

De 2 400 à 2 700 m de la base. Cette partie de la coupe comporte 300 m de basalte calco-alcalin, y compris des coulées basaltiques localement en coussins et amygdalaires, d'épaisseur décamétrique, interstratifiées avec des brèches et des arénites épiclastiques d'épaisseur décamétrique. Les interstrates principales sont quartzeuses et ont quelques centimètres d'épaisseur; d'autres sont calcareuses et ont jusqu'à 10 cm d'épaisseur.

De 2 700 à 3 200 m de la base. Les 500 m supérieurs de la Formation de Richards Bay se composent principalement de tufs et de sédiments tufacés avec par endroits des brèches. Le sommet de la séquence comporte des formations ferrifères de faciès oxydé interstratifiées avec des brèches volcaniques basiques. Certaines unités laminaires de formation ferrifère oxydée sont recoupées par des dykes ultramafiques d'épaisseur métrique qui ont été plissés avec les roches encaissantes.

La Formation de Mount Sabine repose en concordance sur la Formation de Richards Bay.

De 3 200 à 3 600 m de la base. Les 400 m inférieurs comportent un membre inférieur volcanique basaltique, caractérisé par des unités de brèches en coussins et de basaltes tholéiitiques hautement magnésiens et de basaltes komatiitiques en coussins avec un ciment calcareux entre les coussins, interstratifiées avec des lits de débris basaltiques remaniés. Certains coussins et certains clastes contiennent des phénocristaux de feldspath. Plus bas, des unités de basalte en coussins de plusieurs mètres d'épaisseur sont interstratifiées avec des coulées de moins en moins nombreux de basalte tholéiitique, d'épaisseur métrique, et une proportion plus élevée de brèches volcanoclastiques basiques plus près de la base du membre. Les coussins sont petits dans les unités inférieures. Un agglomérat métamorphisé de 20 m d'épaisseur, qui contient des clastes décimétriques, se rencontre dans le tiers supérieur de l'intervalle. Un petit filon-couche de gabbro qui recoupe les volcanites près du milieu de l'unité s'élargit considérablement au sud, parallèlement à la direction. La partie supérieure de cet intervalle se compose surtout d'unités basaltiques massives qui ont jusqu'à 20 m d'épaisseur, interstratifiées avec des lits de tuf peu épais près du sommet.

De 3 600 à 3 800 m de la base. Ce biseau de volcanites de 200 m d'épaisseur contient de nombreux lits de brèches d'origine et de composition diverses. Vers le haut de la coupe, la proportion de roches détritiques volcanogéniques à grain grossier diminue. Plus bas dans la coupe, des lits d'épaisseur métrique de brèches volcanogéniques à grain grossier sont intercalés avec des lits de 20 cm d'épaisseur de brèche à grain plus fin contenant des clastes dont le diamètre est inférieur à 3 cm; plus près du sommet, quelques lits tufacés dont l'épaisseur varie de 10 cm à 1 m se rencontrent dans des faisceaux d'épaisseur décamétrique de sédiments clastiques à grain fin, finement lités. Un dyke schisteux ultramafique peu épais recoupe les couches dans la partie basale de la brèche et est lui-même recoupé par un petit massif intrusif de granite.

3800-4500 m from the base. This 700 m clastic sequence contains siltstone near the bottom and coarse grained sandstone near the top, and includes a differentiated basalt flow. The crossbedded arenite, between the volcanic members in the Mount Sabine Formation, is variable in texture and structure. Individual sets are commonly 5 cm thick but may be much thicker. Rocks near the bottom and near the top are coarsely crossbedded, by trough crossbeds with metre thick sets and a northwesterly directed current direction, whereas in the middle and at the top of the unit beds are planar with alternating fine and coarse 5-10 cm thick sand layers. A lenticular volcanic body, in crossbedded sediments in the middle of this member, is bounded by fine grained pillows and pillow breccias of magnesium tholeiite basalt, and cored by a massive, medium grained calc-alkaline basalt, which contains a lenticular carbonate-talc-chlorite schist layer near the base. Along strike this 100 m thick unit pinches to a metre thick, widespread, mafic pyroclastic basaltic komatiite. The chemical variation shown by this isolated basaltic flow is the same as that spanned by the overlying volcanic member and is almost as large as that shown by all three formations.

De 3 800 à 4 500 m de la base. Cette séquence clastique de 700 m d'épaisseur comprend du siltstone près de la base, du grès grossier près du sommet et une coulée basaltique différenciée. L'arénite à stratification oblique qui se trouve entre les membres volcaniques dans la Formation de Mount Sabine a une texture et une structure variables. Chaque faisceau a généralement 5 cm d'épaisseur mais peut en avoir beaucoup plus. Près de la base et du sommet de l'unité, les roches ont une stratification oblique grossière produite par des strates obliques en auge caractérisés par des faisceaux d'épaisseur décamétrique et une direction de courant vers le nord-ouest. En revanche, au milieu et au sommet de l'unité les lits sont plans et contiennent une succession de couches de sable fin et de sable grossier de 5 à 10 cm d'épaisseur. Un massif volcanique lenticulaire contenu dans des sédiments à stratification oblique au milieu du membre est limité par des coussins à grain fin et des brèches en coussins de basalte tholéiitique magnésien; il a pour noyau une couche lenticulaire de schiste à carbonate-talc-chlorite près de la base. Cette unité de 100 m d'épaisseur s'amincit progressivement en biseau suivant la direction pour passer à une komatiite basaltique, pyroclastique, mafique, répandue, d'une épaisseur de 1 m. La variation chimique de cette coulée basaltique isolée est la même que celle du membre volcanique sus-jacent et est presque aussi importante que celle qui est observée dans les trois formations.

4500-4800 m from the base. This 300 m thick upper basaltic volcanic member consists of several decametres thick sequences of mafic to ultramafic flows separated by thin regressive layers of volcanic breccia and detrital sediments. Each sequence has a lower, generally carbonated, ultramafic, lenticular layer with a fragmental structure and composed of serpentinite, talc, chlorite and/or actinolite. Locally the ultramafic layers show relict pillow like structures and vary in thickness along strike from many decametres to pinchouts in pillow basalts. Above the ultramafic portion of the sequence, and along strike from it, off the section line, is a few decametres thick layer of komatiitic to magnesium tholeiite basalt. The flows are locally variolitic and show layers of various sized pillow and mattress structures. Pillow rims are up to 5 cm thick and more chloritic. Interpillow filling is cherty and/or tuffaceous. At one location the vertical transition from ultramafic to basic is gradational and homogeneous and foliated talc schist grades upwards into small variolitic pillows, about 5-6 cm across, which are set in a talcose matrix. The base of the unit is in schistose ultramafic rocks and is probably the site of minor faulting.

De 4 500 à 4 800 m de la base. Ce membre volcanique basaltique supérieur a 300 m d'épaisseur et se compose de plusieurs séquences d'épaisseur décamétrique de coulées mafiques à ultramafiques que séparent de minces couches régressives de brèche volcanique et de sédiments détritiques. Chaque séquence a une couche inférieure lenticulaire, ultramafique et généralement carbonatée, qui possède une structure détritique et se compose de serpentinite, de talc, de chlorite ou d'actinote. Les couches ultramafiques présentent par endroits des structures résiduelles en coussins et, suivant la direction, leur épaisseur va de plusieurs décamètres jusqu'à disparaître progressivement en biseau dans les basaltes en coussins. Au-dessus de la partie ultramafique de la séquence et parallèlement à sa direction mais à l'extérieur de la coupe, il y a une couche de quelques décamètres d'épaisseur de basalte komatiitique à tholéiitique magnésien. Les coulées sont localement variolitiques et présentent des couches à structures en coussins et en matelas de diverses dimensions. Les bordures des coussins ont jusqu'à 5 cm d'épaisseur et sont plus chloriteuses. Le remplissage entre les coussins est cherteux, tufacé ou les deux. À un endroit, le passage vertical des roches ultramafiques aux roches basiques est progressif, et un talcschiste homogène et feuilleté passe vers le haut à de petits coussins variolitiques d'environ 5 à 6 cm de diamètre qui sont fixés dans une matrice talqueuse. La base de l'unité se trouve dans des roches schisteuses ultramafiques et représente probablement le site d'une fracturation mineure.

4800-5000 m from the base. This 200 m unit consists of a thin basaltic pebble conglomerate and basic wackes interlayered with a thin carbonate layer overlain by a thin sequence of distinctly planar bedded alternating coarse and fine grained units of sandstone and in turn overlain by locally crossbedded, microfaulted, tourmaline veined, and slumped, laminated arkosic grits, with rare quartzofeldspathic pebbles.

De 4 800 à 5 000 m de la base. Cette unité de 200 m comporte un mince conglomérat à cailloux basaltiques et des wackes basiques interstratifiés avec une mince couche carbonatée, que recouvre une séquence peu épaisse d'unités de grès à grain successivement fin et grossier et à stratification nettement plane. Cette séquence est sous-jacente à des grès grossiers arkosiques laminaires, microfaillés et affaissés, à filons de tourmaline et, localement, à stratification oblique, qui contiennent de rares cailloux quartzofeldspathiques.

5000 m from the base. The top of section is at the shore of Richards Bay.

The subsequent deformation of the Prince Albert Group was compressive and is postulated to have cast the rocks into a large antiformal syncline imposing a foliation with a flatter dip on the shallow southeast dipping beds north of Richards Bay. A shallow southeast elongation of pebbles, pillows, and metamorphic mineral lineations and minor folds are in rough parallelism with the intersection of bedding and cleavage. A later flexural fold has bent the somewhat higher grade (garnet zone) rocks, near the western granite pluton at the west edge of the map area, into a steeply dipping western limb, whereas the eastern limb shows the shallow dip mentioned above. Z-type minor folds occur on both limbs and little development of an axial plane cleavage indicates that ductile deformation predated the second folds which are concentric. On the two Coxe Islands south of the bay the rocks are considered to be a facies equivalent of the Adge-go Formation. This correlation is uncertain because of possible offset by faulting in Richards Bay, extensive recrystallization and alteration, a steeply dipping, refolded, structural pattern, and the higher grade of metamorphism shown by the rocks on the Coxe Islands which are intruded by three closely spaced granite plutons.

The Richards Bay map area lies athwart faults of the Ossory fault zone (Heywood and Schau, 1978). This fault zone projects southeast toward Frobisher Bay or Cumberland Sound and northwest towards northern Boothia Peninsula. It is in part late Proterozoic, although south of the area movements on parallel faults are known to be as old as mid-Proterozoic and to have been reactivated in, or after, mid-Paleozoic time. Some movement on the fault is tranverse, although some slickensides suggest a normal component.

The environment of deposition of the group was largely subaqueous, chiefly in shallow water. Parts were above sea level, however, as is shown by conglomerates containing clasts of the group, agglomerate units with bombs, and sequences of massive basalt overlying pillowed basalts, a feature commonly associated with basalts deposited at sea level. The quartzite and medium grained quartzofeldspathic pebbles in several beds suggest a continental source for some of the sediments.

The volcanic sequence presented in the section is "inverted" compared to normal Archean sequences. The inversion, which consists of more mafic volcanic rocks overlying less mafic units, is considered a depositional phenomenon and follows from the interpretation of the regional structure as an antiformal syncline. An alternate theory, that the inversion is structural due to a now obliterated premetamorphic thrust or slide episode affecting a normal mafic to felsic volcanic sequence is thought less likely. Basic dykes with an elevated magnesium content, which is the composition of extrusive rocks in the uppermost Mount Sabine Formation cut the intermediate volcanic units of the lowermost Adge-Go Formation.

À 5 000 m de la base. Le sommet de la coupe se trouve sur le rivage de la baie Richards.

La déformation subséquente du Groupe de Prince Albert s'est faite par compression et aurait créé un vaste synclinal antiforme et produit une foliation à pendage moins raide dans les lits peu profonds à pendage sud-est au nord de la baie Richards. Les cailloux, les coussins et les linéations minérales métamorphiques allongés vers le sud-est sur une faible profondeur de même que les plis mineurs sont grossièrement parallèles à l'intersection de la stratification et de la schistosité. Près du pluton granitique occidental sur la bordure ouest de la région cartographique, un pli par flexion plus récent a déformé les roches légèrement plus métamorphisées (zone à grenats), de sorte que le flanc ouest de la synforme a un pendage raide tandis que le flanc est conserve le pendage doux mentionné ci-dessus. Des plis mineurs de type Z se rencontrent sur les deux flancs, et la présence d'une schistosité de plan axial peu développée indique que la déformation ductile a été antérieure aux plis concentriques secondaires. Dans les deux îles Coxe au sud de la baie, les roches sont considérées comme un faciès équivalent à la Formation d'Adge-go. Cette corrélation est incertaine pour les raisons suivantes : décalage possible par suite de la formation de failles dans la baie Richards, recristallisation et altération poussées, motif structural replissé et fortement incliné, et métamorphisme plus poussé des roches des îles Coxe que recoupent trois plutons granitiques très rapprochés les uns des autres.

La région cartographique de la baie Richards s'étend en travers les failles de la zone de failles d'Ossory (Heywood et Schau, 1978). Cette zone de failles se prolonge au sud-est vers la baie Frobisher ou la baie Cumberland et au nord-ouest vers le nord de la presqu'île de Boothia. Elle date en partie du Protérozoïque tardif, bien qu'au sud de la région, les mouvements le long de failles parallèles remontent jusqu'au Paléozoïque moyen et que certaines de ces failles aient été remobilisées au Paléozoïque moyen ou après. Le mouvement le long de la faille a été en partie transversal, bien que la présence de miroirs de faille laisse entendre qu'il existe aussi une composante normale.

Le groupe s'est accumulé dans un milieu principalement subaquatique, surtout en eau peu profonde. Or, certaines parties du milieu se trouvaient au-dessus du niveau de la mer, à en juger par la présence de conglomérats contenant des fragments du groupe, d'unités d'agglomérats contenant des bombes et de séquences de basalte massif sus-jacent à des basaltes en coussins, caractéristique fréquemment associée à des basaltes mis en place au niveau de la mer. La présence de quartzite et de cailloux quartzofeldspathiques à grain moyen dans plusieurs lits donne à penser que certains sédiments ont une source continentale.

La séquence volcanique présentée dans la coupe est «inversée» par rapport aux séquences archéennes habituelles. L'inversion, dans laquelle des volcanites plus mafiques reposent sur des unités moins mafiques, est considérée comme un phénomène de dépôt, et l'on explique son existence en interprétant la structure régionale comme un synclinal antiforme. Une autre hypothèse moins vraisemblable attribue une origine structurale à l'inversion; selon cette hypothèse, l'inversion résulterait d'un épisode prémétamorphique de glissement ou de chevauchement dont il ne reste aucune trace et qui aurait touché une séquence volcanique mafique à felsique normale. Des dykes basiques très riches en magnésium, soit la composition même des roches extrusives dans la partie sommitale de la Formation de Mount Sabine, recoupent les unités volcaniques intermédiaires de la partie basale de la Formation d'Adge-go.

Inverted volcanic sequences are found in modern marginal seas such as the Sea of Japan or the Sea of Okhotsk and in other extensional rift environments such as those in continental part of the Woodlark Basin east of Papua New Guinea. Perhaps the unstable tectonic environment of the continental crust north of Australia or at the east of Asia may be a possible tectonic analogue for some late Archean crust. The conjunction of locally exposed continental crust yielding clastic sediments with small, local, deep extensional basins and filled by succeedingly more mafic volcanic rocks fits many of the features seen in the Richards Bay area, and is consistent with the regional lithological and thickness variations within the Prince Albert Group. A major difference is that extrusive and hypabyssal ultramaficunits are not present in the modern examples.

The preferred environment of deposition of the Prince Albert Group is a tensional and ensialic setting which is similar to modern settings near active edges of cratons. A major difference is that a subcrustal "ultramafic" magma chamber interacting with a lower continental crust provided contaminated intermediate to basic lavas, as well as less contaminated ultramafic lavas, at the surface and producing a structural instability at the surface, is postulated.

A consequent compressive episode generated the postulated antiformal syncline north of Richards Bay and was followed by the emplacement of granitic plutons in the late Archean. This shift from a local extensional environment to formation of subhorizontal structures, followed by emplacement of granite batholiths over a relatively short period of time, followed by upright deformation, and emplacement of large plutons during the later part of the Archean, is similarly expressed over most of Melville Peninsula. The same effects probably extended at least as far west as Laughland Lake or Baker Lake in the District of Keewatin. Le Pichon et al. (1982) suggested that gravitational failure leading to compressive stresses is the expected phenomenon when extension ceases over a thinning region of crust. Such a process is postulated to have occurred in the late Archean.

Subsequent geological history includes several episodes of faulting. The rocks were exposed to erosion prior to late Proterozoic time and act as basement to the Phanerozoic deposits to the south on the peninsula.

The rocks in Richards Bay area remained relatively near the surface throughout their history, in contrast to the Prince Albert Group elsewhere on Melville Peninsula.

Whatever the tectonic significance of the deposition of the group in a shallow unstable tensional environment, it was one in which banded iron-formations formed readily. The prospect for massive sulphide deposits is judged to be low since the deposits are shallow water and there is only minor indications of intense hydrothermal alteration, but the possibility of small noble metal vein deposits is not discounted, although assays on vein materials have been discouraging.

Des séquences volcaniques inversées se rencontrent dans des mers bordières modernes comme la mer du Japon ou la mer d'Okhotsk, et dans d'autres milieux de rift en extension comme ceux qui se trouvent sur la partie continentale du bassin de Woodlark à l'est de la PapouasieNouvelle-Guinée. Le milieu tectonique instable de la croûte continentale au nord de l'Australie ou à l'est de l'Asie pourrait être l'analogue tectonique d'une partie de la croûte de l'Archéen tardif. L'existence de croûte continentale qui affleure localement et contient des sédiments clastiques, de concert avec de petits bassins d'extension profonds et locaux remplis de volcanites de plus en plus mafiques, concorde avec de nombreux éléments observés dans la région de la baie Richards et avec les variations régionales de la lithologie et de l'épaisseur que l'on observe dans le Groupe de Prince Albert. Toutefois, il existe une différence majeure, soit l'absence d'unités ultramafiques hypabyssales et extrusives dans les exemples modernes.

Le milieu le plus propice à l'accumulation du Groupe de Prince Albert est un milieu ensialique d'extension, semblable aux milieux que l'on trouve de nos jours près des marges actives de cratons. Or, il y avait probablement une différence majeure, soit la présence d'une chambre magmatique «ultramafique» subcrustale en interaction avec la croûte continentale inférieure qui aurait fourni des laves contaminées intermédiaires à basiques ainsi que des laves ultramafiques moins contaminées et provoqué une instabilité structurale en surface.

Un épisode subséquent de compression a produit le synclinal antiforme hypothétique au nord de la baie Richards et a été suivi par la mise en place de plutons granitiques à l'Archéen tardif. Ce passage d'un milieu d'extension local à la formation de structures subhorizontales, suivi par la mise en place de batholites granitiques sur une période de temps relativement courte, puis par la déformation verticale et par la mise en place de grands plutons vers la fin de l'Archéen, se rencontre sur la plus grande partie de la presqu'île Melville. Les mêmes effets se sont probablement fait sentir vers l'ouest jusqu'au lac Laughland ou au lac Baker dans le District de Keewatin. Selon Le Pichon et al. (1982), lorsque l'extension prend fin dans une région où la croûte s'amincit, il se produit probablement une rupture gravitaire qui donne lieu à des contraintes de compression. Un tel processus a dû se produire à l'Archéen tardif.

Par la suite, il y a eu plusieurs épisodes de formation de failles. Les roches ont été exposées à l'érosion avant le Protérozoïque tardif et servent de socle pour les dépôts phanérozoïques dans le sud de la presqu'île.

Les roches de la région de la baie Richards sont demeurées relativement proches de la surface tout au long de leur histoire, contrairement au Groupe de Prince Albert ailleurs dans la presqu'île de Melville.

Quel que soit la signification tectonique de l'accumulation du groupe dans un milieu en extension instable et peu profond, les formations ferrifères rubanées s'y sont formées facilement. Il est peu probable que l'on y découvre des gisements de sulfures massifs, car les dépôts se sont accumulés en eau peu profonde et il n'existe que très peu d'indices d'une altération hydrothermale intense; toutefois, on pourrait y retrouver de petits gisements filoniens de métaux nobles, bien que l'analyse des caisses filoniennes ait donné des résultats décourageants.

INTRODUCTION

Location

This report deals with the geology of the Prince Albert Group on the Bouverie Islands and Coxe Islands in Richards Bay which is centred on 64°37′N and 82°15′W. The area is 30 km northwest of Igloolik and 90 km north-northwest of Hall Beach. The geology is presented on the east half of the Richards Bay map sheet (NTS 47D/11E) at a scale of 1:50 000 (see Fig. 17, in pocket).

Present and previous investigations

This critical area was selected specifically in consultation with W.W. Heywood (pers. comm., 1974) as one containing a particularly well preserved stratigraphic section of the Prince Albert Group. This report includes the results of mapping during 2 weeks in the 1974 field season and follow-up visits in 1984 and 1986, augmented with petrographic and chemical analysis of 71 samples collected at appropriate intervals across a section of the group.

The region has had a long history of human habitation (Meldgaard, 1962). Many relicts of old habitation sites are seen on the raised beaches on the south shores of the Bouverie Islands, areas that are still popular camping grounds.

Parry (1824) was the first to report on the nature of the rocks as well as to note a large magnetic anomaly underneath his iced-in ships in Fury and Hecla Strait. Blackadar (1963) provided the first geological map of the region as well as a summary of previous work. Heywood completed the 1 inch:8 mile helicopter reconnaissance survey on Melville Peninsula in 1973 (Heywood, 1974; Schau and Heywood, 1984).

Accessibility and physical setting

The mapped area lies northwest of Igloolik and is within small boat range of this village. Richards Bay ice cover typically opens up during mid July but may be delayed several weeks as in 1986. The passage of icefloes to and fro in the reversing tidal currents in Fury and Hecla Strait after breakup in early to mid July is potentially dangerous to the small boat travel of the uninformed.

The area is one of the colder spots in Canada (Fremlin, 1974). Average temperature is -35°C in winter but reaches an average mean of 12°C during August. Snow typically falls near the end of September and has an average maximum depth of 40 cm in April and May but is usually gone by the end of July. The islands are hilly with steep-sided valleys and rugged relief of up to 273 m. Small ponds dot the poorly drained landscape.

General Geology

The area is underlain by the Prince Albert Group which has been locally metamorphosed and intruded by granitic plutons of possibly Archean age (Blackadar, 1963). The units are summarized in the Table of Formations.

The Richards Bay map area lies athwart the Ossory Fault Zone (Heywood and Schau, 1978) which projects beyond the area southeast toward Frobisher Bay or Cumberland Sound

Table of Formations

	Unit	Nature of Contacts	Lithology
	Fresh diabase		
	--- Intrusive contacts ---		
	Fury and Hecla Group		quartzite
	--- Fault contact ---		
	--- Episode of deformation ---		
	Granite	Intrusive contacts	biotite granite
	--- Period of deformation ---		
	Gabbro	Intrusive contacts	metagabbro
Prince Albert Group		Top not known	
	Mount Sabine Formation		1.8 km basic-ultrabasic metavolcanics, metasediments, basic metavolcanics
	--- Conformable ---		
	Richards Bay Formation		1.0 km iron-formation metasediments, basic metavolcanics, polymictic breccia, quartzite
	--- Conformable---		
	Adge-go Formation		2.2 km iron-formation, intermediate metavolcanic metasediments, intermediate metavolcanics
		Intrusive contact with granite	

and northwest towards northern Boothia Peninsula. On northern Melville Peninsula and nearby Baffin Island the fault system has a south-side-up vertical component which postdates the late Proterozoic Fury and Hecla Group. The fault traces that cross the map area delineate the northern coast of the Bouverie Islands, and parallel traces probably traverse Richards Bay, partly explaining the difficulty in correlating Prince Albert Group formations between the Coxe and Bouverie Islands.

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PRINCE ALBERT GROUP

General statement

One of the best sections of the Prince Albert Group (where one can determine original textures and structures of a large proportion of the rocks) is exposed in the Richards Bay region. Although strained and incomplete, it is at least 5 km thick on the largest of the Bouverie Islands north of the bay. There the Prince Albert Group is divided into three formations which are, from oldest to youngest, Adge-go, Richards Bay, and Mount Sabine formations. On the two Coxe Islands south of the bay the rocks are considered to be a facies equivalent of the Adge-go Formation, although this assignment is tentative because of possible offset by faulting, folding, extensive alteration, and higher grade of metamorphism on those islands.

The names of analyzed volcanic rocks (see Appendix 1, Tables 1, 2, 3) used in the text follow the conventions of the Jensen cation plot (1976), for reasons outlined in Appendix 3, and are tabulated along with location data in Appendix 4.

Adge-go Formation

The Adge-go Formation is named after the Inuktitut name for Fury and Hecla Strait along whose southern shores the formation is well exposed. The type area of the formation is on the western portion of the westernmost Bouverie Islands. The formation is also well exposed and south of Richards Bay on Coxe Islands. The thickness, calculated from air photographs, using control points located by ground traverses, is about 2.2 km.

The Adge-go Formation is composed of recrystallized felsic volcanic rocks, volcanogenic sedimentary rocks, rare carbonate beds, mafic sills and dykes, and is topped by iron-formation. Chemical analyses of a representative suite, arranged in stratigraphic order, are presented in Appendix 1 of this report (Table 1).

Lithology

Metavolcanic rocks comprise up to 80% of the formation. They are recrystallized pyroclastic deposits and flows. Breccias retain their fragmental textures (Fig. 1) but tuffs are thoroughly recrystallized into nearly massive or layered rocks. Because of the recrystallization, felsic and epidote-bearing flows are not readily distinguishable from massive felsic tuffs. Massive felsic units are several to tens of metres thick and are featureless in contrast to bordering layered rocks. Layering is represented by compositional and textural

Figure 1.

Volcanic breccia in Adge-go Formation. Note the variation in size of clasts of which define original layering, and the small angle this makes with the plane of apparent flattening. GSC 204738-B

changes in homogeneous fine- to medium-grained felsic rocks. Variably micaceous elements form centimetre and metre thick layers. Hornblende-rich layers are common, and with epidote, accentuate a secondary layering along shear surfaces. Some hornblende-rich layers probably represent primary mafic tuffs, and locally, flows. Sills of amphibolite, up to 50 m thick, commonly accompanied by amphibolite dykes that pervade the sequence, may be feeders to the mafic volcanic rocks that overlie the formation. Some dykes branch into two or three, suggesting that host rocks of Adge-go Formation were brittle when dykes were emplaced.

The volcanic metasedimentary rocks comprise a large proportion of the section. They contain well defined bedding, locally graded, rare crossbedding, channel fills, slump structures, and rounded volcanic and sedimentary fragments. They are micaceous, locally studded with concretions now composed of epidote, or interlayered with thin layers of limestone and metamorphosed siliceous limestone (Fig. 2).

The upper unit is iron-formation. Which ranges in thickness from 1 to 100 m. Magnetite iron-formation thins and dies out laterally in acid volcanic tuffs to the north, whereas to the south the iron-formation is interbedded with, and passes into, iron-rich volcaniclastic sediments.

Under the microscope the volcanic rocks are extensively recrystallized. Quartz forms a medium- to fine-grained granoblastic texture in intimate intergrowth with feldspar. Relict plagioclase grains are speckled with white mica and are spongy with new, small quartz and feldspar crystals replacing them. Epidote, especially clinozoisite, is pervasively distributed throughout the rocks. Mafic minerals include brownish-green hornblende and actinolite as well as brownish-red and sometimes greenish biotite and chlorite. In the volcanic rocks zircon, apatite, and sphene or "leucoxene" after "ilmenite", pyrite, as well as very scattered chalcopyrite and greenish pleochroic tourmaline are accessories. Near the western contact, rare garnet porphyroblasts are veined by chlorite.

The rocks on Coxe Islands and neighbouring archipelago are mainly grey weathering, massive, locally calcareous and micaceous, quartz arenite, bounded on the east by limy arenites and carbonates, local metamorphosed ultramafic units, and a thick section of iron-formation.

The arenites are generally fine- to medium-grained and are composed of quartz, plagioclase, potassium feldspar, chlorite, muscovite and variable amounts of brown pleochroic hornblende. Rare layers about 2 m thick and local layers up to 25 m thick, are greyish green because they contain more hornblende and epidote than the grey rocks.

Layers of actinolite and biotite-rich rocks are present next to laminated magnetite-quartz iron-formation. Thin layers of quartz-magnetite-hornblende-biotite-muscovite garnet schist and quartz-magnetite-biotite-muscovite-chlorite-tourmaline garnet schist are interlayered with magnetite iron-formation and grunerite-magnetite-quartz silicate iron-formation. Calc-silicate gneiss layers with quartz-plagioclase-tremolite-clinopyroxene-epidote-calcite (± muscovite or biotite) are also present near the iron-formation. To the west of the iron-formation calcite-tremolite marble units are interbedded with calcite-epidote-plagioclase-hornblende-sphene schist (with minor amounts of potassium feldspar, chlorite, and muscovite) and occur near the shore and on the thin isthmus connecting the two large islands.

Figure 2. *Light coloured metacarbonate layer interbedded with darker metagreywackes of the Adge-go Formation. GSC 204738-E*

Calcareous breccias up to 5 m thick contain irregular calc-silicate fragments. Some calcareous breccias are tectonic in origin, the fragments being composed of detached S and M fold noses. Calcareous layers contain rounded, sand size, quartz grains and local subrounded granules of potassium feldspar set in medium grained marble.

Green and chocolate-brown weathering, metamorphosed ultramafic lenticular pods, tens of metres in length and metres thick, are subparallel to layering in the vicinity of the iron-formation. Some highly altered ultramafic rocks cut across structures but the majority are sill- or flow-like. In thin section the rocks are composed of chlorite, tremolite and magnetite with talc, talc-carbonate, or carbonate. These magnesian schists may be altered and deformed ultramafic dykes. Near the contact with intrusive granite the ultramafic unit is composed of phlogopite-tremolite-magnetite-cummingtonite(?).

Dyke rocks of basic composition and less abundant, felsic, feldspar porphyry dykes traverse the region.

Section

North of Richards Bay an incomplete but considerable stratigraphic section of the Adge-go Formation is present. The thickness estimates are derived from calculations using control points recorded on air photographs and estimated dips, as well as from local compass and pace traverses. Lateral variations are known to occur and hence thickness is only locally applicable. Sample descriptions in the section below are of the analyzed samples (see Appendix 1, Table 1) and the localities of samples are shown in Appendix 4.

2200 m. conformably overlain by quartzite of Richards Bay Formation.

2100 to 2200 m. An iron-formation shows a shift of mineral facies along strike from thin carbonate-rich oxide assemblages in the north (see Fig. 2) to magnetite- and hematite-rich assemblages near the pluton, and thicker silicate-rich assemblages with sporadic iron sulphides in beds nearer Richards Bay in the south. Along the shore preferentially weathered ultramafic dykes a few metres thick cut the iron-formations at acute angles. Interbedded with the iron-formation are komatiitic basaltic tuffs (sample 299 B). To the north, on strike with the iron-formation, is a dacite flow (sample 300).

Sample 299 B is hydrated, basaltic komatiitic tuff consisting of plagioclase, biotite, hornblende, and sphene with accessory opaques. Sample 300 is a dacitic flow consisting of bluish weathering quartz phenocrysts set in a beige weathering matrix of quartz, an exceptional amount of potassium feldspar (including minor microcline), clay, brown biotite, white mica, epidote, and carbonate, with accessory zircon, apatite and tourmaline.

1600 to 2100 m. A wedge of coarse grained volcanic rocks, including breccias, flows and intercalated sediments forms this interval. Mafic dykes, 10 cm to 1 m thick, cut the section in this vicinity. One divides into three, like a fork, cutting through a volcaniclastic breccia and intercalated irregularly and discontinously layered tan weathering grey fine grained siltstone unit. This siltstone (sample 280) is composed of abundant quartz, potassium feldspar, blue chlorite, green biotite, white mica, epidote, and carbonate porphyroblasts. Another sample from the top of this section (sample 270 A) is a fragmental rock which preserves three generations of metamorphic minerals. The earliest assemblage appears in a fragment of feldspar porphyry which is composed of quartz, feldspar, and amphibole set in a matrix of apparently later developed biotite-chlorite 1-quartz-pyrite-sphene-epidote-calcite, over which poikilitic chlorite 2 and poikiloblastic carbonate have grown. This probably represents a tuffaceous siltstone with andesite fragments. This part of the section is cut by a slightly boudinaged, massive, high magnesiam, tholeiitic basaltic dyke (sample 270 B(1)) consisting of plagioclase, brown biotite, chlorite, actinolite, sphene, epidote, quartz, potassium feldspar and carbonate with accessory zircon, opaques, and hematite. A thin brecciated dacite dyke (sample 270 B(2)) consisting of quartz, plagioclase, potassium feldspar, brown biotite, and accessory zircon, apatite and hematite also cuts the sequence here.

Lower in the section locally epidotized volcanic breccias and massive flows are more abundant. Sample 279 is a fine grained andesitic tuff composed of rare fragments of andesite in a matrix of quartz, plagioclase, several chlorites, brown biotite, actinolite, epidote, sphene and opaques. Flows are exemplified by sample 278 C, a hydrated, indistinctly heterogeneous to massive andesite flow or autobreccia composed of quartz, plagioclase, several chlorites, green biotite, hornblende, epidote, minor potassium feldspar, opaques and accessory apatite, and sample 278 B, a hydrated, massive to locally feldsparphyric, fine grained andesite composed of quartz, plagioclase, several chlorites, green biotite, hornblende, epidote, opaques and accessory apatite. Sample 278 A is a hydrated, epidotized, massive andesite flow which consists of quartz, plagioclase, white mica, hornblende, epidote, sphene, opaques and accessory apatite cut by minor quartz and epidote veins.

1000 to 1600 m. This interval is sedimentary and characterized by bedded to laminated tuff with local conglomero-breccia units, all cut by basic dykes.

Near the top of this interval a flattened volcaniclastic rock unit featuring light coloured, quartzose, ellipsoidal clasts (one has dimensions 12 by 6 by 3 cm), is set in a biotite-rich matrix interbedded with biotite-bearing meta-sandstones and thin, locally crosscutting, amphibolite layers. Sample 277 B is a massive and locally sheared, medium grained, high magnesiam tholeiite basalt dyke which consists of hornblende, biotite, quartz, feldspar, and sphene with accessory oxides, pyrite, and apatite. Sample 277 A is a hydrated, flattened conglomero-breccia of andesitic composition, composed of quartz and calc-silicate lenticles, and biotite-rich layers interleaved on a fine scale with clasts of quartzite and felsite. Mineralogically it consists of quartz, plagioclase, tan biotite, hornblende, clinozoisite, sphene, opaques and accessory zircon, apatite, and hematite. The section here is composed mainly of massive, fine grained, 10-15 cm thick beds of tuff with indistinct fragments. One epidotized layer shows regularly disposed quartz veins normal to the surface of the layer giving the appearance of a ladder. This boudinage-like feature suggests that the epidote-rich layer was more brittle than the surrounding biotite-bearing rocks. Epidote veins crosscut the layering at low angles and a poorly defined schistosity in the micaceous units is also at low angles to the layering. Sample 275 is an andesitic tuffaceous arenite with clasts of felsite (some vesicular) and greenstone, which is composed of quartz, plagioclase, hornblende, biotite with minor sphene, zoisite and opaques and accessory apatite.

A granite dyke complex associated with a stock to the south is emplaced at this level. Near the dykes, well layered, massive, greenish metasandstones are preponderant. Greyish-green, fine grained dykes are emplaced along the layering and/or foliation. Sample 276 B is a vesicular, opaque studded, hydrated, massive komatiitic basalt dyke composed of quartz, altered feldspar, hornblende, brown biotite, brown chlorite and intergrown sphene and opaques. Sample 276 A is a flattened, hydrated, andesitic, tuffaceous arenite with swallow-tailed felsite and "chlorite-biotite" clasts set in a fine matrix

composed of quartz, plagioclase, grey chlorite, and brown biotite with minor opaques, sphene, clinozoisite and accessory zircon, apatite and hematite.

0 to 1000 m. This basal sequence consists of recrystallized andesite flows and breccias cut by basic dykes. Layering and clast outlines are difficult to distinguish but locally relics are preserved. Small granite dykes from the pluton to the west cut the section. Localities 272, 273, and 274 are equispaced through this interval, 272 being at the bottom.

Near the top of this part of the section, massive thick units with moderate colour index are interbedded with darker amphibolites (metatuffs?) and cut by subparallel but locally crosscutting amphibolite dykes. Sample 274 B is a recrystallized, massive calc-alkaline basalt flow composed of quartz, plagioclase, several varieties of chlorite, green biotite, a retrograded amphibole and accessory opaques, apatite and hematite. Sample 274 A is indistinctly layered, hydrated, recrystallized, locally brecciated, andesite tuff (?) composed of quartz, plagioclase, hornblende, brown biotite and brown chlorite with accessory opaques, sphene, carbonate, apatite, hematite and allanite(?). Near the centre of the section, several sets of 40-50 m thick units of alternating darker and lighter gneisses with intercalations of darker and lighter sequences of flattened brecciated metavolcaniclastic units with a foliation at a small angle to the layering and cut by red granite dykes are abundant. At station 273 the rocks are mainly layered heterogeneous volcaniclastic units with lighter coloured fragments set in a darker matrix interspersed with intermediate and felsic flows up to 5 m thick and thin locally crosscutting amphibolite layers. Sample 273 C is a discontinously layered, homogeneous fine grained andesitic rock composed of quartz, plagioclase, hornblende and actinolite, various opaques, and minor green biotite, and carbonate matrix with accessory zircon, apatite, and hematite. This rock may be part of a recrystallized andesite flow, sill, or dyke. Sample 273 B is a fine grained homogeneous amphibolite derived from a calc-alkaline basalt dyke recrystallized to plagioclase, twinned cummingtonite, hornblende, sphene, clinozoisite, quartz, various opaques and minor green biotite. Sample 273 A is a recrystallized and brecciated rhyolitic flow rock consisting of quartz, altered feldspars, green biotite, with minor amounts of actinolite rosettes, clinozoisite, evenly distributed leucoxene rimmed sphene, and carbonate. Lower in the section and nearer the granite contact the rocks are gneissose. Alternating amphibole-rich and quartzofeldspathic layers show variation in grain size and some layers are mixtures of large, commonly felsic, clasts set in finer grained chiefly mafic matrix. In some beds a subparallel metamorphic amphibole layering crosscuts compositional layering. Small quartz veins are folded and if the folding is due to compression the beds containing the veins have been shortened by 25%. Sample 272 B is a hydrated, recrystallized, porphyroblastic, mafic tuffaceous silicate iron-formation with vague relict fabric, now largely masked by its constituent poikiloblastic amphibole, garnet, quartz, opaque oxides and pyrite. Sample 272 A is a hydrated, recrystallized felsic (lapilli?) tuff with fine grained andesite and biotite-chlorite clasts set in an andesitic matrix of quartz, plagioclase, blue chlorite, brownish biotite with minor amounts white mica, garnet and clinozoisite as well as accessory zircon, hematite and tourmaline. Near the base the rocks are well layered on a 1-5 cm scale, and are biotite-rich, locally epidotized gneisses cut by 15 cm thick biotite-amphibolite dykes containing a biotite foliation at a small angle to the layering, that in turn is cut by thin granite dykes and sills.

0 m. The base of the section is taken at the western edge of the island, at the narrow isthmus, which is below water at high tide. On the mainland, a locally agmatitic granite pluton carries fragments of the Prince Albert Group, indicating that the depositional base of the group is not available for study there.

The structural and metamorphic history and speculations regarding mode of origin and correlations of the Adge-go Formation are presented later in this report.

Richards Bay Formation

The formation is named after Richards Bay along whose northern shore it is well exposed. The type area is on the central south-trending peninsula of the main Bouverie Islands. The formation is approximately 1 km thick. Both bottom and top are conformable with the bounding formations.

The Richards Bay Formation is composed chiefly of intermediate volcanic rocks and sedimentary breccia, with a lower quartzite member and an upper iron-formation member. The distribution of the basal quartzite member on Bouverie Islands is modified by Z-folds.

Lithology

Quartzite is grey, less commonly white, pink or red weathering, 1 to 5 cm thick, or locally thicker, with irregular beds showing rare channel fills and crossbeds. The quartzite is variably sorted; some rocks contain abundant muscovite while others are essentially pure quartz with hematite stain. Many quartz veins cut the unit and locally the quartzite is recrystallized to a massive texture. An associated and overlying sedimentary breccia contains coarse fragments: 60% of underlying quartzite, 10% intermediate volcanic fragments, and 20% felsic porphyritic volcanic rocks. The remaining 10% of the fragments are more mafic, amphibole-bearing and, only in part, coarse grained. In cross-section, the fragments, which are generally 6 to 25 cm in diameter, are seemingly undeformed and show angular to subrounded outlines. Down plunge the fragments are elongated to many times their previous dimension. The matrix consists of varying proportions of amphiboles, biotite and calcite (Fig. 3a, b).

Intermediate metavolcanic rocks include finely laminated, green tuffs, volcanic breccias, and vesicular to massive or, locally, pillowed, rocks. Epidotized intermediate greenstones with abundant feldspar phenocrysts up to 3 cm across are common. Metasedimentary rocks near the top of the formation are volcanic wackes. The iron-formation is a laminated magnetite-quartz variety which is intricately folded, presumably in part as a result of soft-sediment deformation. It has alternating 1 to 5 cm thick lamellae or irregular lenticles of quartz and magnetite. Iron-formation and, less commonly,

Figure 3.

Richards Bay Formation metasedimentary conglomero-breccia. In ***(a)*** *fragments on cross-section are roughly equidimensional. (GSC 204738-C); whereas in* ***(b)*** *which is parallel to the lineation, the cobbles are stretched. (GSC 204738-D).*

other rock types, are cut by metre thick amphibolite metadiabase and talc-chlorite dykes. Rare pegmatitic dykes and quartz or epidote veins are present.

Section

A stratigraphic section of Richards Bay Formation north of Richards Bay is presented below. It is subject to the same limitations as those outlined for the Adge-go Formation. Sample descriptions are of the analyzed samples (see Appendix 1, Table 2) with localities shown in Appendix 4.

1000 m. Conformably overlain by Mount Sabine Formation.

500 to 1000 m. This section is dominated by tuff and tuffaceous sediments with locally developed breccias. The top of the sequence is iron-rich and is topped by oxide iron-formations interbedded with basic volcanic breccias. Some units of laminated oxide iron-formation are cut at low angles by metre-thick ultramafic dykes that have been folded along with the host rocks. Examples of the iron-rich units located at the top are sample 332 C and 332 B. Sample 332 C is a crinkled, hydrated, tuffaceous, silty iron-formation with vaguely outlined fragments of quartz, chlorite, green biotite, and iron oxides and pyrite with accessory zircon. Sample 332 B, which is a hydrated, sheared, tuffaceous iron-formation with vaguely outlined fragments, consists of quartz and iron oxides with minor plagioclase, chlorite, biotite and carbonate, with an extremely small, high-relief, unknown accessory mineral. Interbedded units, such as sample 332 A, consist of foliated, hydrated, carbonated breccias of komatiitic basaltic composition consisting of fragments of biotite and chlorite, which resemble pyroclastic shards, set in a quartz-carbonate matrix. Typical of the volcanic sediments is sample 285, a greywacke consisting of clastic quartz grains, plagioclase grains, brown chlorite, several types of biotites, white mica, opaques, carbonate matrix, and accessory apatite. Another example lower in section (sample 286) is a hydrated, fragmental rock with clastic quartz grains set among fragments of, and a matrix of, quartz, plagioclase, potassium feldspar, several chlorites, biotite, iron oxides, hornblende and carbonate.

200 to 500 m. Basaltic volcanic rocks including decametre thick, locally pillowed and locally amygdaloidal basaltic flows interbedded with decametre thick breccias and epiclastic arenites. Prominent interbeds are quartzose but a few centimetre to 10 cm thick calcareous horizons are present. Sample 287, a flow rock, is a hydrated, schistose calc-alkaline basalt composed of intergrown quartz, plagioclase, chlorite, biotite, hornblende, opaques, sphene, epidote and accessory zircon, and overprinted by actinolite rosettes (garbenschiefer texture). Sample 284 is typical of the breccia. It is a porphyritic calc-alkaline basaltic breccia, whose clasts and matrix are composed of plagioclase, chlorite, biotite, hornblende, epidote, quartz, carbonate and opaques. Sample 283 C is a calcareous sandstone with thin layers of clastic quartz grains set in a calcite matrix with minor amounts of potassium feldspar, biotite, and tourmaline and accessory opaques. Sample 283 B is a hydrated, locally vesicular, calc-alkaline basalt consisting of quartz-filled amygdules set in a matrix of several types of chlorite, green biotite, epidote, and minor quartz, potassium feldspar, carbonate and opaques cut by quartz and carbonate veins. Near the bottom a transitional sediment is exemplified by sample 283 A which is a tuffaceous sandstone with clasts of quartzite, calcareous quartzite and chlorite-talc clasts set in quartz-carbonate matrix. Sample 288 collected near the base of this interval, is a hydrated calc-alkaline basaltic tuff consisting of brown chlorite, brown biotite, hornblende, opaques, sphene, epidote, quartz, plagioclase, and accessory pyrite and hematite. Sample 302 is the first calc-alkaline basalt encountered above the quartzite. It is a hydrated, amygdaloidal, sheared to massive calc-alkaline basalt consisting of brown chlorite, oriented brown biotite, hornblende and minor quartz, plagioclase, and opaques set with chlorite and quartz amygdules.

0 to 200 m. Grey to white weathering quartzite that thickens southward from a few metres by Fury and Hecla Strait to 200 m about 9 km to the south. It is overlain by southward thickening oligomictic, quartz pebble conglomero-breccia grading, near the top, to polymictic, breccia or conglomerate. In turn, this is overlain by a sequence of volcanic siltstone and sandstone and the next basalt member. Just below the flows, are sandy siltstones. Sample 301 is a hydrated metasiltstone of intermediate

Figure 4. Agglomerate in the lower volcanic member of the Mount Sabine Formation. Note irregular shapes representing cross-sections of eared bombs, a feature which is taken to indicate a subaerial flight path for those fragments. GSC 204739-A

composition composed of quartz, indeterminate clay and altered feldspar, chlorite, several types of biotite, actinolite and opaques with accessory zircon and apatite cut by a carbonate vein. Sample 282 exemplifies the polymictic breccia (Fig. 3a and b). It consists of well-rounded pebbles of fine grained quartzite dotted with scattered opaques and angular fragments of felsic volcanics, as well as smaller granules of fine grained quartzite, sodic plagioclase, medium grained quartzite with rare potassium feldspar and carbonate cement and grains of monocrystalline quartz set in a matrix of medium grained actinolitic amphibole, fine grained quartz and minor fine grained biotite. Sample 296 B is an orthoquartzite composed of grains of quartz set in a matrix of fine grained quartz and minor white mica with accessory opaques, apatite and hematite. This quartzite layer of variable thickness forms the base of the Richards Bay Formation.

0 m. Conformably overlies Adge-go Formation.

Mount Sabine Formation

The formation is named for Mount Sabine which is the highest point in the type area. The unit is found along the eastern side of the main Bouverie Islands and on the islands to the east and south. The thickness is at least 1.8 km. Similar rocks tentatively assigned to the formation occur on the outer Bouverie Islands which have been only briefly visited by helicopter. Thick lenses of conglomerate set in metre-thick beds of volcaniclastic rock occur on the small low islands near the eastern edge of the map north of Richards Bay. Massive medium grained amphibolite, possibly recrystallized gabbro, is present near granite dykes and stocks on the southeasternmost islands north of the bay.

On the larger islands the formation is divided into a lower mainly volcanic member, a central mainly sedimentary member, and an upper volcanic member. The lower boundary is conformable upon the underlying formation and the upper part is exposed along the southern shore of the bay and thus has no known upper contact.

Lithology

The lower volcanic member consists mainly of a thick pile of basaltic rocks. Decimetre-thick basaltic breccias, commonly with pillow fragments, are interbedded with metre thick, locally feldspar-phyric massive flows, tuffaceous, well laminated interflow sediments and, locally, calcareous decimetre thick layers. One 15 m thick agglomerate unit is present (Fig. 4). Pillowed basalts, interbedded or intercalated with calcareous interflow sediments, are crudely interbedded with the volcanic breccias. Rare, phyllitic to schistose, locally pebbly, sedimentary units up to 50 m thick are recessive and contribute to a serrated topography. Thin gabbroic sills and finer grained dykes, mainly of basic but rarely of felsic composition, cut across units. The rocks are irregularly sheared and are generally green reflecting their chloritic and epidotic compositions. Veins and shear zones contain carbonate, quartz, chlorite and locally, red weathering potassium-feldspar. Rarely these contain iron or copper sulphides.

The central member constitutes the bulk of the formation and is of sedimentary or volcaniclastic origin. Breccia with quartzose fragments as well as a highly varying amount of very poorly sorted felsic volcanic fragments of unlikely shapes, which reach quite large sizes, form a distinctive unit above the lower volcanic member. This spectacular unit shows layers crowded with many sized and elongate quartzose and felsic fragments (Fig. 5). Coarse wackes, less than a metre thick, are interbedded in this unit. Overlying this unit are wackes with thin pebble layers (Fig. 6). Crossbedded, matrix-bearing, sandstones also form an important element of this formation. The rock weathers so that the rock clasts and quartz grains protrude on the surface. The sandstones locally contain by trough-like crossbeds, up to several metres across, (Fig. 7) which dip to the south and open to the northwest. These are overlain by planar beds of alternating medium grained to medium- to fine-grained sandstone layers. Thinner, well laminated, clearly feldspathic, rarely pebbly sandstones with clasts of felsic volcanic and quartzose rocks are more common near the top. Slump folds are locally present. Interbedded metre-thick calcareous and amphibolitic units

Figure 5.

Interbedded metavolcanic breccia and meta-volcanic wacke, from acid wedge near base of central member, Mount Sabine Formation. Note the low intersection angle between foliation, as shown by flattened fragments and original layering. Note minor warp and fault in corner. GSC 204740-B

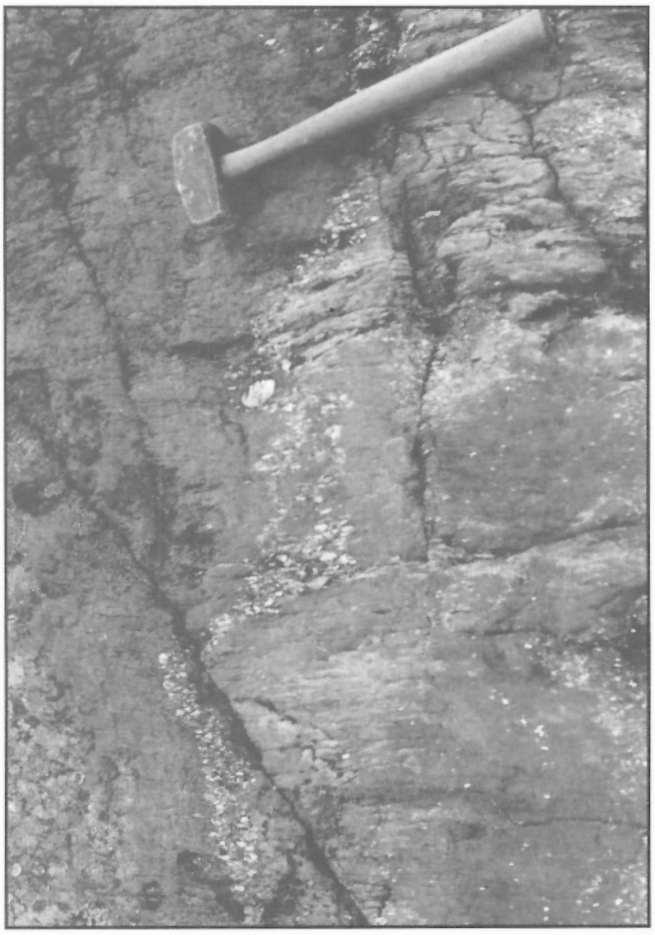


Figure 6. Metaconglomerate lense in metagreywacke of the central member, Mount Sabine Formation, showing a later, probably fault related, fracture cleavage at large angles to bedding. GSC 204741-A

contain scattered pyrite. Along strike these thin amphibolitic units swell to thick lenticles of a basaltic differentiated flow complex. The complex is composed mainly of pseudo-pillowed, medium grained basalt with a basal layer of talc schist encased by a thin skin of packed pillow and pillow breccias. Siltstones or black argillites are dark, poorly bedded and tough, and constitute only a small portion of the section.

The upper member, composed mainly of pillowed basalts, is commonly variolitic, locally amygdaloidal, and sits on the upper portion of the sedimentary part of the Mount Sabine Formation. Many pillow or mattress-shaped basalt units, which are up to 3 m across, have relatively coarse grained epidotized centres. Lenses of carbonated talc-chlorite and/or tremolite rocks occur within the sequence. Because these magnesian lenses contain layers and fragments of pillow breccia, and apparently grade laterally into pillow basalts and upward into pillow lavas or breccias, it is thought that some of these units are ultramafic rocks akin to the komatiites found elsewhere in the Prince Albert Group (Schau, 1975, 1977; Frisch, 1982). They are layered, with tremolite layers alternating with talc or chlorite layers, and are intensely sheared and cut by carbonate veins as well as speckled by dolomite porphyroblasts. In the upper volcanic member, chlorite and calcareous chlorite schists, very rarely with relict volcanic breccia fragments, form units up to 40 m thick, overlying, in particular, the variolitic units. Metre thick beds of basaltic tuffs are much less abundant in the upper member than in the lower member. Interpillow fragments are locally set in a cherty matrix, in contrast to the carbonate matrix of the lower volcanic member.

Section

A 1.8 km thick stratigraphic section of the Mount Sabine Formation, replete with way up indicators, occurs north of Richards Bay. Analyses of the described samples are presented in Appendix 1, Table 3 and the localities are shown in Appendix 4.

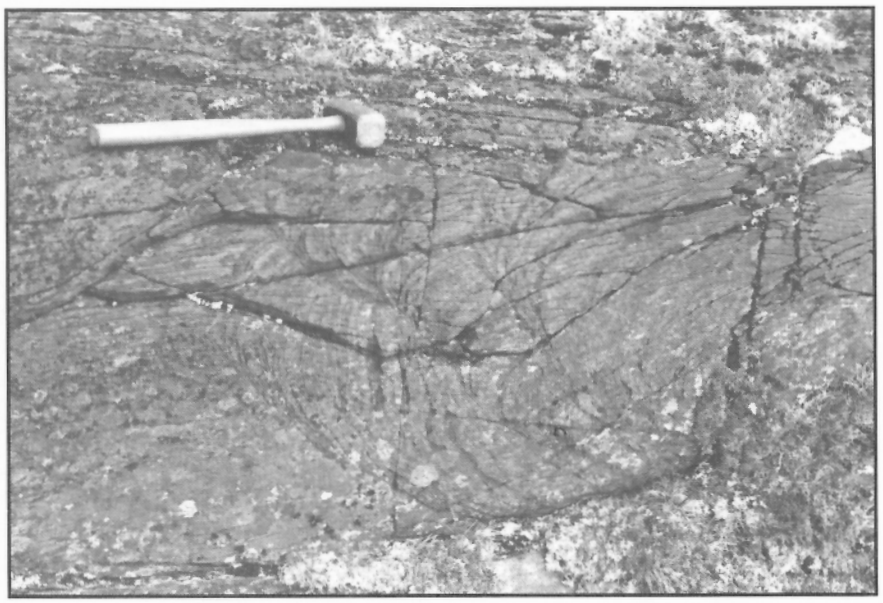


Figure 7.

Trough crossbeds in arenite, central member, Mount Sabine Formation. These crossbeds indicate a shallow water, possibly fluviatile, environment of deposition. Note widely spaced fracture cleavage which characterizes this part of the section. GSC 204740-A

1800 m. Top of section: shore at Richards Bay.

1600 to 1800 m. Locally crossbedded, microfaulted, tourmaline veined, and slumped, laminated arkosic grits, with rare quartzofeldspathic pebbles, overlie a thin sequence of distinctly planar bedded, alternating coarse- and fine-grained units of sandstone resting in turn upon basaltic pebble conglomerate and basic wackes with thin carbonate layers. Sample 259 is near the top of the section. Two specimens are both hydrated meta-arenite with grains and granules consisting of medium grained quartzofeldspathic rock, mica-bearing opaque-dotted quartzite, felsite, and plutonic and volcanic quartz. The matrix consists of quartz, plagioclase, potassium feldspar and clay alteration, with minor chlorite, green biotite, white mica, opaques, apatite and hematite. Sample 258 C is from near the base of the arkosic grits. It is a hydrated and carbonated, foliated, meta-arenite composed of quartz grains and plagioclase set in a recrystallized matrix of quartz, plagioclase, potassium feldspar, clay, chlorite, green biotite, epidote and carbonate with accessory opaques and tourmaline.

1300 to 1600 m. Upper basaltic volcanic member consists of several sequences many decametres thick of mafic to ultramafic flows separated by thin regressive layers of volcanic breccia and detrital sediments. Perhaps each of these sequences represent a differentiated flow as described in the underlying member. Each sequence has a lower, generally carbonated, ultramafic layer with a fragmental structure and is composed of serpentinite, talc, chlorite, and/or actinolite. The ultramafic layers locally show relict pillow-like structures, and range in thickness along strike from many decametres to pinchouts in pillow basalts. Above the ultramafic portion of the sequence, and alongside it, off the section line, is a layer a few decametres thick composed of basalt. The flows are locally variolitic and show layers of various sized pillow and mattress structures. Pillow rims are up to 5 cm thick. Interpillow filling is cherty and/or tuffaceous. At one location the vertical transition from ultramafic to basic was observed to be gradational. There, small variolitic pillows, about 5 to 6 cm across, of basalt sit on, and, in part, in, a talcose matrix which becomes more homogeneous and foliated talc schist down section. Sample 260 is from the pillows described immediately above in the youngest volcanic lenticle. The sample is hydrated, variolitic, magnesiam tholeiite basalt composed of intergrown quartz, plagioclase, chlorite, biotite, hornblende, opaques, sphene, epidote and carbonate porphyroblasts. Sample 258 B is from interflow sediments and consists of sheared, microfolded, phyllitic, metasiltstone composed of fine grains of quartz and plagioclase in a very fine grained matrix of quartz, recrystallized plagioclase, potassium feldspar, chlorite, brown biotite, hornblende, sphene, mantled ilmenite(?), and pyrite with accessory zircon, apatite, calcite, and tourmaline. Sample 258 A is hydrated komatiitic peridotitic schist with carbonate porphyroblasts in a chlorite and serpentine matrix dotted by iron oxides. Two samples of 257 were taken from the same variolitic basalt flow near the centre of the volcanic member. They consist of (a) sheared variolitic magnesiam tholeiite basalt composed of quartz, plagioclase, chlorite, biotite, hornblende, opaques, sphene and accessory hematite; and (b) sheared variolitic magnesiam tholeiite basalt composed of quartz, plagioclase, chloritized biotite, hornblende, opaques, epidote, and carbonate. Sample 256 is a coarse tuff from the top of one of the sequences. It is a hydrated, komatiitic basaltic, tuffaceous schist composed of intergrown quartz, plagioclase, chlorite, green biotite, tremolite, epidote, opaques with a carbonate matrix. Sample 255 D is a finer grained and better bedded tuff than the above sample, and is a hydrated, komatiitic basaltic, tuff with mafic fragments and matrix composed of quartz, chlorite, biotite, talc, opaques, sphene, epidote and carbonate. Sample 255 C is from upper part of a 40 m thick unit which consists of hydrated, porphyroblastic komatiitic peridotitic schist with serpentine (after olivine?) porphyroblasts in a tremolite, chlorite matrix with scattered opaques, carbonate, and talc. Sample 255 B is a tectonically disrupted and foliated metadacite porphyry dyke composed of quartz and plagioclase phenocrysts in a recrystallized matrix of quartz, plagioclase, clay, chlorite, green biotite, white mica, sphene, leucoxene coated opaques, carbonate, and accessory apatite. It cuts the ultramafic rocks near the base of the sequence. The base of the ultramafic rocks is sheared and foliated and is probably the site of minor faulting.

600 to 1300 m. A clastic sequence with coarser grained sandstone grits near the top and siltstone near the bottom. It includes an oblique section of a differentiated basalt flow. The crossbedded arenite, between the volcanic members in the Mount Sabine Formation, is quite variable in texture and structure. Individual sets are commonly 5 cm thick but may be much thicker. Rocks near the bottom and near the top are coarsely crossbedded, by trough crossbeds with metre-thick sets and a northwesterly directed current direction, whereas in the middle and at the top of the unit beds are planar with alternating fine and coarse sand layers 5 to 10 cm thick. Sample 265 is representative of the top part of the grits. These are thinly bedded and consist of hydrated, quartz-rich, meta-arenite composed of granules and pebbles of quartz, albite, felsite, calcite and quartz-feldspar intergrowths set in a matrix of quartz, chlorite, green biotite, carbonate, with minor amounts of potassium feldspar, indeterminate clay, white mica, sphene, leucoxene mantled ilmenite, and accessory zircon, cut by carbonate veinlets. Sample 254 is representative of the upper crossbedded part of the sandstones which contain more matrix at this horizon than lower in the section. This sample consists of hydrated, quartz-rich meta-arenite composed of sand-sized grains and pebbles of quartz, albite, felsite, calcite and quartz-feldspar aggregate in a matrix of quartz, chlorite, green biotite, carbonate, with minor potassium feldspar, indeterminate clay, white mica, sphene-rimmed opaques and accessory zircon cut by carbonate veins. These sandstones are along strike from that basalt flow mentioned below. Sample 253 is from a thin tuff layer interbedded with the grits. It consists of hydrated, komatiitic, basaltic tuff consisting of relict and neomorphic plagioclase, biotite, amphibole, opaques, sphene, epidote, quartz, and carbonate with accessory zircon. Along strike from the tuff is a lenticular volcanic body up to 100 m thick emplaced in crossbedded sediments in the middle of the Mount Sabine Formation. It is bounded above and below by fine grained pillows and pillow breccias. The core of the unit is massive and coarse grained, and near the base is a widespread layer of talc-chlorite-schist. The edges of the 100 m thick unit pinch together to grade into

a metre thick widespread mafic pyroclastic unit. Samples 321, 319 A and 319 B are from this differentiated basalt flow. The bulk of the body (321) is hydrated, massive, magnesiam tholeiitic basalt representing the main flow from which 319 A and B are variants. It is composed of plagioclase, chlorite, biotite, amphibole and hornblende,quartz, opaques and carbonate. Sample 319 A is a hydrated feldspar-phyric phase of 321 which is classified as calc-alkaline basalt, and consists of plagioclase in a quartz, plagioclase, potassium feldspar, chlorite, biotite matrix with accessory opaques. Sample 319 B, a mafic phase of 321, is a hydrated, carbonated, magnesian schist which is classified as peridotitic komatiite and is composed of intergrown chlorites, talc, carbonate, and opaques with sparse carbonate porphyroblasts and minor amounts of quartz and carbonate veining. The chemical variation shown by this basaltic flow is the same as that spanned by the three formations, and in particular that of the overlying volcanic member. It serves as an isolated example of the overlying volcanic flows. Sample 252 B is representative of the siltstones that occur near the base. It is a hydrated siltstone with carbonate porphyroblasts in a matrix of opaques, chlorite, brown biotite, carbonate, granoblastic quartz, and plagioclase with accessory apatite, and is cut by calcite veins. Sample 252 A is taken from the base of the sediments. It is a hydrated, foliated, poorly sorted, micaceous meta-arenite with oligoclase and quartz grains in a matrix of recrystallized quartz, potassium feldspar, plagioclase, chlorite, green biotite, white mica, and carbonate, with accessory zircon.

400 to 600 m. A volcanic wedge with many different breccia beds of diverse origin and composition. Down section the proportions of coarse volcanogenic fragmental rock increases. Near the top, few tuffaceous beds from 10 cm to 1 m in thickness are set in decametre thick sets of finely bedded, fine grained clastic sediments, whereas lower in the section, metre-thick beds of coarse volcanogenic breccias are intercalated with 20 cm thick beds of breccias with maximum clast size no more than 3 cm. Sample 235 is a hydrated, foliated, pyroclastic conglomero-breccia with clasts of quartzite (with chlorite or carbonate), quartz porphyry, quartz-mica schist, chloritic basalt, andesite, and aggregates of potassium feldspar and indeterminate clay in a matrix of chlorites, brown biotite, opaques (including pyrite), sphene, and carbonate, with accessory apatite. Sample 234 B is an autobrecciated feldspar porphyry sill of calc-alkaline basaltic composition in finely layered tuffs and, is cut by quartz-carbonate veins with minor chalcopyrite. The sample consists of quartz, relict and neomorphic plagioclase, chlorite, opaques (including pyrite), sphene, and carbonate. Sample 232 taken near the middle of the section, is a metaconglomerate with pebbles of quartzite, oxide-, sulphide-, silicate-, and carbonate-iron-formation, carbonated feldspar and quartz clasts, chert clasts, porphyry clasts with volcanic quartz phenocrysts in a matrix of biotite, poikiloblastic chlorite, carbonate and opaques, with accessory zircon. This conglomerate is cut by calcite-quartz and chlorite-calcite-quartz-epidote veins. The next two samples are from near the base of the interval. Sample 231 B is a metaconglomerate with quartzite, chert, greenstone, felsite and bull quartz clasts as well as clasts made of intergrown chlorite and biotite in a matrix of quartz, chlorite, biotite, and carbonate with local development of white mica, biotite degraded to epidote and chlorite, and pyrite. Clasts are more rounded than in sample 231 A, a breccia consisting of flattened dacitic clasts composed of quartz (some as phenocrysts), plagioclase, potassium feldspar, chlorite, biotite, white mica, opaques, carbonate and apatite in a mineralogically similar but finer grained intraclast matrix. A thin ultramafic schist crosscuts layers in the basal part of the breccia and is itself cut by a small granite stock. It (sample 229 D) is a hydrated komatiitic basalt schist with carbonate porphyroblasts in chlorite, green chrome mica, tremolite, quartz, plagioclase, opaques and carbonate matrix. An associated schist (sample 229 C), possibly a metatuff or breccia, is a hydrated, carbonated, chlorite schist with vaguely outlined fragments replaced by chlorite, carbonate, and opaques in a chlorite, carbonate, and minor quartz and plagioclase matrix which is classified as a peridotitic komatiite. Sample 229 B and A are from near the base of the felsic volcanic wedge. Sample 229 B is a cobble metaconglomerate with clasts of fine- and medium-grained quartzites, feldspar-phyric and quartz-phyric felsites set in a more basic matrix of plagioclase, potassium feldspar, chlorite, brown biotite, white mica, opaques, and carbonate with accessory pyrite and tourmaline. Sample 229 A is a hydrated dark grey argillite which overlies the volcanics described below. It is of intermediate composition with clastic quartz grains in a fine grained matrix of quartz, plagioclase, potassium feldspar, several types of chlorite, biotite, white mica and accessory sphene, zircon and tourmaline.

0 to 400 m. The lower basaltic volcanic member is characterized by pillows and pillow breccias with calcareous interpillow cement interbedded with reworked basaltic debris. Some pillows and clasts are feldspar-phyric. This interval is mainly massive basalt units up to 20 m thick interbedded with thin tuff beds near the top. Below, pillow basalt units several metres thick are interbedded with progressively fewer, massive, metre-thick, basalt flows, and a larger proportion of basic volcaniclastic breccias nearer the base of the member. The pillows are smaller in the lower units. A 20 m thick unit of meta-agglomerate with decimetre-sized clasts occurs in the upper third of this interval. A small gabbro sill intrudes basalts near the middle of the unit and widens considerably along strike to the south. Samples taken from the top (228 B), middle (227) and bottom (239 A) of this member document some of its chemical variability. Sample 228 B is from a hydrated meta-agglomerate of calc-alkaline basaltic composition, consisting of scoria and bomb fragments in a finer grained fragmental matrix. Both fragments and matrix are composed of intergrown plagioclase, brown chlorite, hornblende, opaques, epidote, quartz, and carbonate. Sample 227 is a hydrated, carbonated, pillow breccia with fragments of altered glassy material in an interlayered matrix of quartz-chlorite, epidote-calcite, and hornblende-chlorite-epidote layers. Sample 239 A is a hydrated, pillow breccia with clasts of altered glassy material and chlorite-serpentine-magnetite-pyrite-carbonate rock in a quartz, plagioclase, carbonate matrix.

0 m. Conformably overlies Richards Bay Formation.

Structural geology and metamorphic grade of the Prince Albert Group

Faulting

The map area consists of slices of country rock between faults of the east-southeast-trending Ossory Fault Zone. Their apparent regional displacement of about 6 km is south-side-up as measured by offset of the Fury and Hecla Group which outcrops mainly northwest of the map region described here. The presence of a small island of quartzite of the Fury and Hecla Group in the northeast part of the map area shows there may have been transverse movement, and hence the vertical component would be smaller. Within the map area there are many prominent linears and minor faults with similar orientations to the Ossory Fault Zone. The south-east dipping beds of the Mount Sabine Formation at the east end of the Bouverie Islands are offset on a small steeply dipping fault with apparent separation of about 1 km consistent with south-side-up movement. Adjacent associated minor fault surfaces have steep southerly dips with dip-slip slickensides, suggesting that steep reverse faulting is locally important. Although the offset of faults that lie beneath Richards Bay is unknown, it is clear that on Coxe Islands the metamorphic grade of the rocks is greater and the structural style more complex than on the Bouverie Islands, favouring a regional south-side-up movement.

Earlier deformational events

The Bouverie Islands display a large asymmetric southerly plunging synform that is superposed on previously strained rocks, possibly representing a large, southeast-facing limb of an anticline-syncline pair or a flat south east dipping ductile shear zone. On Coxe Islands large folds plunge northeast and southeast.

Structural geology north of Richards Bay.

Planar fabrics

Primary planar fabrics include bedding planes and flow contacts. Bedding is parallel or crossbedded. Interflow sediments, tuffaceous units, breccias, conglomerates, wackes, arenites and black slates, all show bedding with varying clarity. Crossbeds are common in the Mount Sabine Formation and each set may be metres thick and show a variability in strike of over 50°. Bedding in volcanic terranes with a subaerial history is commonly inclined. Well bedded tuffs can be deposited by air fall on extreme slopes as is well shown in many present-day volcanic islands such as Lipari or Vulcano. The net result is to give bedding attitudes a considerable scatter. This may partly explain the large scatter on the stereogram showing the distribution of poles to bedding of units in the Bouverie Islands (Fig. 8a). Flow boundaries and internal flow structures, such as vesicule or phenocryst layers, form original planar, though not necessarily horizontal, marker horizons.

Secondary planar fabrics include gneissosity, schistosity, and fracture cleavage. Gneissosity is due to two processes. It is moderately displayed in the Adge-go Formation where the succession of lithologies on small scale, combined with recrystallization of grains to fine- and medium-size give the rocks a gneissic aspect. The local presence of pegmatite and aplite dykes near the "base" of Adge-go Formation enhances this fabric assignment. The tendency to recrystallize decreases away from the western granite pluton as does the occurrence of gneissic fabrics. In the lowest grade rocks, closely spaced veins of tourmaline cut bedding at large angles in units at the top of the Mount Sabine Formation resulting in a layered aspect easily confused with gneissosity.

Layers of the Adge-go Formation dip steeply, whereas orientation of layers in the Richards Bay Formation are more variable but chiefly have moderate southeasterly dips. In the Mount Sabine Formation the dips are gentle to the south. Perusal of the lower hemisphere equal area projection (Fig. 8a) indicates that poles to bedding of all the formations defines a girdle with a southeast plunging axis.

Schistosity is not everywhere well developed in the group, but a fissility is generally present and petrographic study shows that the phyllosilicates are aligned in one or two directions. There is a spatial variation in the style of secondary planar features. Mica-rich rocks in the Adge-go Formation show a schistosity. Greenschists formed in basaltic tuffs and tuffaceous breccias are common in the Richards Bay Formation. A fracture cleavage, defined by well spaced joint-like features along which mica is concentrated, is common in Mount Sabine Formation arenites (Fig. 7). Ultramafic dykes, sills, and/or flows are deformed into talc schists in Richards Bay and lower Mount Sabine formations, but are massive, only locally sheared, talc-chlorite-dolomite rocks in the upper Mount Sabine Formation.

Inspection of the lower hemisphere equal area projection of the foliation shows a complex pattern (Fig. 8b). The majority of the foliations dip with medium inclination southeastward, but the steep to vertical dipping foliations strike more southerly. Based on the similarities in distribution of poles to planar surfaces among lower hemisphere equal area projections of poles to bedding and poles to foliations, it seems that the foliation is folded as well. In detail, the angle between measurements of foliation and layering at the same site is generally less than 25°. The foliation has a shallower dip than layering, and this in conjunction with the southeast facing of the layering suggests that the section is (hypothesis 1) deformed into an antiformal syncline or (hypothesis 2) that the section is assembled from tectonic fragments by either thrusting from the northwest to the southeast (compression) or by gravity induced sliding with the same sense of movement (extension).

An example of a later warping is seen around the eastern small stock where foliations referred to above are warped about a steep east-striking axial plane. Later foliations are generally east-southeast striking and steep (Fig. 8c, 6). They are at high angles to, but not necessarily normal to, previous foliation, and they are subparallel to faults of the Ossory Fault Zone.

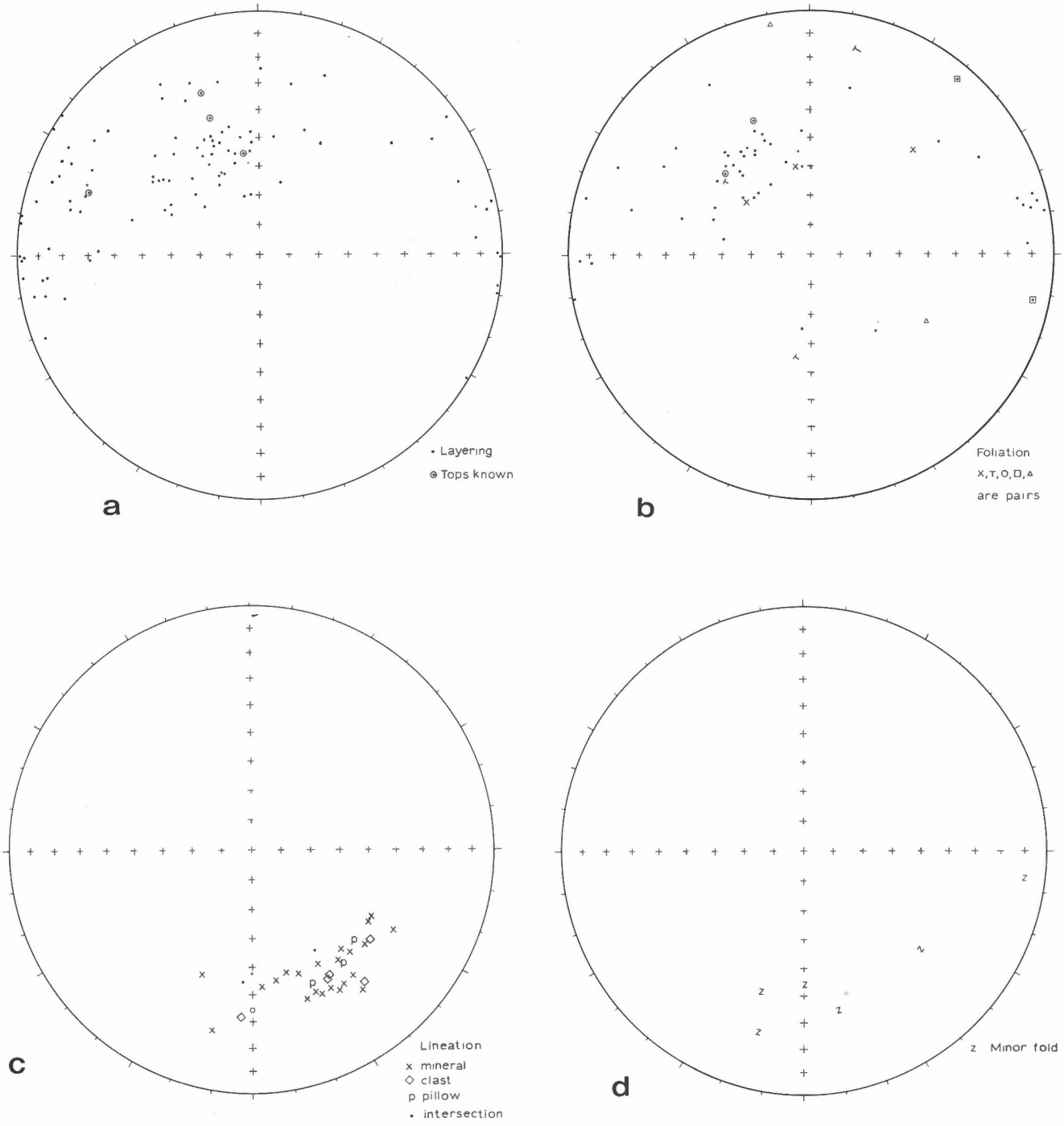


Figure 8. *Lower hemisphere equal area projections of structural elements, north of Richards Bay.* ***(a)*** *poles to bedding (N=86),* ***(b)*** *poles to foliation (N=57),* ***(c)*** *stretched pillows (N=3), clasts (N=5), intersection lineation (N=3) and mineral lineation (N=21),* ***(d)*** *axes of minor folds (N=6).*

Linear structures

Linear elements are all secondary and include stretched pebbles, elongate pillows, intersections of S planes, and crenulations as well as minor fold axes and metamorphic mineral lineations.

Stretched fragments are present in all breccias. An example of the dimensions of a strained quartzose fragment is 30 by 15 by 7 cm from the Adge-go Formation. Perusal of Figures 1, 3a, 3b, 4, and 5 shows qualitatively the variation in strain of clastic rocks. Cross-sections (normal to plunge) of quartzose fragments from the Mount Sabine Formation show flattening ratios of 1:2 to 1:4. Quartzite clasts are less than half as deformed as surrounding volcanic fragments. In Figure 8c note the relatively constant plunge but large azimuth variation. Pillows are elongate downdip and show large azimuth variation as well (Fig. 8c). A pillow from the Mount Sabine Formation was excavated and shows the following dimensions: 200 by 50 by 20 cm. Most of this cigar-shaped elongation of metamorphosed objects is probably associated with the first episode of structural deformation since it needs an environment that is conducive to recrystallization.

Mineral lineations and intersections of bedding and foliation (pencil cleavage) are similar in orientation to adjacent features noted above.

The minor folds are all southeast-plunging Z folds as shown on Figure 8d. The presence of Z folds on either side of the axis of the late open syncline suggests that the Z folds are not associated with this episode of folding but are the product of the earlier structural event.

The linear elements represent generally down-dip southeast plunging elements, but the variation in azimuth of up to 60° must be incorporated into a model. The similar spatial variation of deformed primary fabrics, such as elongated fragments and pillows, and obviously secondary fabrics, such as minor Z folds and some mineral lineations, suggests that they are related and due to the same event.

Where bedding and foliation are recorded in the same outcrop they are at small angles to each other, and commonly the foliation has the shallower dip. Minor folds, the intersection of bedding and foliation, mineral lineation and crenulations are commonly parallel to each other. Elongate pillows and clasts though nearly parallel, lie at various angles to the intersection lineation when viewed in the plane of foliation. At one locality quartz veins in extension fractures are oriented normal to a lineation which parallels a minor fold axis.

Structural history of the Bouverie Islands

Primary and secondary planar fabrics are nearly parallel. Both are folded about a southeast plunging axis which is approximately parallel to the mean concentration of mineral lineations. The spread in the linear elements, combined with the deformed, subparallel-to-bedding, secondary planar fabric suggests a prior period of deformation characterized by an L-S fabric and low angles between bedding and axial planes to early folds; in short an episode of high strain probably associated with a tight antiformal syncline or ductile shear. The uniform way-up determinations and the occurrences only of Z-style minor folds suggest that only the lower limb of this possible antiformal syncline, or part of a shear zone, occurs on the portion of the Bouverie Islands mapped. For the sake of further discussion the episodes are divided into two separate events. The first event includes the formation of secondary planar structures at low angles to the original layering and the resultant strain. The later event is the casting of rocks into the southeast plunging synform that dominates the geology north of Richards Bay.

Later fold event. The rocks of the Prince Albert Group on the Bouverie Islands are folded into a large asymmetric syncline whose western side is northerly striking with steep dips and whose eastern limb is northeast striking with gentle southerly dips. The net result is a steep southwest dipping axial plane and a moderate southeast plunge. The hinge region is rounded and absence of an axial plane cleavage makes it difficult to precisely locate the axial trace of the fold.

Earlier deformational event. Evidence of the earlier strain event is preserved mainly in mesoscopic structures. The presence of secondary foliation at low angles to the bedding, the folded foliations, and the presence of southerly plunging Z-type minor folds on either side of the synformal core constitute good evidence for this earlier strain event. If folding is the cause of the mesoscopic structures then the fold would appear to be larger than the area under consideration. The persistence of south and east facing beds combined with the observation that foliation is shallower than layering indicate that the measured section of the Prince Albert Group is possibly on a southeast facing lower limb of a large antiformal syncline.

The near coincidence of extension lineation with intersection lineation and fold axes poses a room problem (Hobbs et al., 1976). In this area the problem can be addressed by invoking one of two models. One notes that extension parallel to fold hinges occurs in such areas as culminations of doubly plunging folds or in the outer arcs of arcuate fold belts (Hobbs et al., 1976). The presence of an angle between layering and foliation would suggest proximity to a fold nose. The facing and the flatter foliation suggest that the area north of the bay is on the lower limb of an inclined antiformal syncline. The persistence of Z folds similarly suggests appropriate movement out of a synclinal core.

Alternately, rotation of linear fabrics into a new tectonic transport direction by a subsequent shearing event is possible (Johnson, 1965; Williams et al., 1971). Under this hypothesis the small angle between layers and foliation indicates that strain has not been extreme. This is confirmed by the moderate stretching of the pillows and fragments and by the angles between the extension lineation and intersection lineation. Hence, if a ductile shear zone is the causative agent for the regional structure then this area is distant to the most intense shearing. Figure 9 represents, in schematic form, the two choices outlined above. Whether the section described above is stratigraphically coherent or tectonically inverted is a critical consequence of the choice of structural hypothesis.

I prefer the antiformal syncline hypothesis but subhorizontal shear zones formed in compressive or extensional regimes are not entirely ruled out. Two additional observations favour the fold hypothesis: (1) dykes of mafic and ultramafic compositions, similar to those of extrusive flows in Richards Bay Formation and Mount Sabine Formation, cut the Adge-go Formation suggesting that no tectonic inversion took place, or at the very least that ultramafic magmatic fluids were available to form dykes after the deposition of the less mafic Adge-Go Formation (thus removing the advantage of the shear hypothesis which would make the ultramafic rocks the oldest); and (2) no sections of obviously rotated clasts were noted on surfaces normal to bedding in the plane of lineation in the coarse clastic unit overlying the quartzite in the Richards Bay Formation despite a specific search for them (on a return visit) in this potentially favourable location (see Fig. 3a, b for examples of the shapes of these clasts).

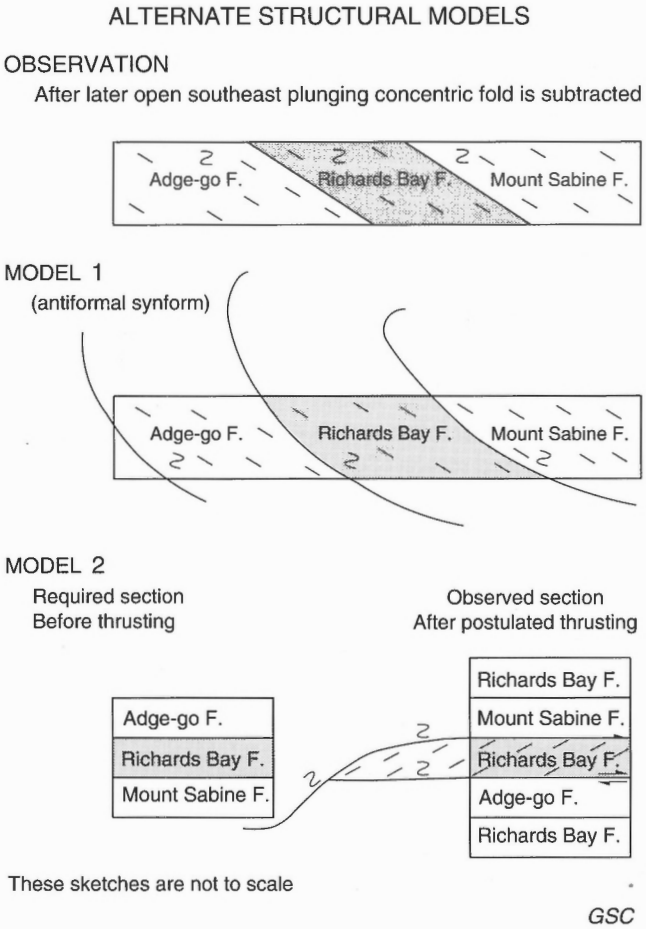


Figure 9. *Schematic sketch of two alternate structural models which satisfy structural data. Model 1 is an antiformal synclinal model which is favoured in this report from considerations of stratigraphy and relative ages of dykes. This model leads to the conclusion that the observed "inverted" volcanic stratigraphy is depositional. Model 2 is a shear model which best explains the near proximity of stretching lineations and minor fold axes. This model can be used to structurally invert a "normal" volcanic pile. Both models requires extensive horizontal movements and in this way depart markedly from traditional Archean vertical tectonic models.*

Environments of folding. The second fold event is a high level phenomenon since the synform shows no axial plane cleavage and although asymmetric, with one steep arm, is an open, concentric style fold. Locally, slip took place along conical surfaces delineated by prior foliation planes or divergent bedding.

The earlier strain event is a deeper level phenomenon. Elongate pebbles and pillows, secondary schistose surfaces, and low foliation-bedding angles all indicate that strain was considerable. The style of deformation involved a certain amount of flowage and reorganization of fabrics. The thickness of the sections presented above have been modified by this heterogeneous strain to an unknown degree. The stratigraphic integrity of the section is preserved under the fold hypothesis, whereas the section as presented would be constituted of randomly assembled tectonic slivers should the shear zone hypothesis apply.

Timing of strain events. The second fold event occurred during or after the emplacement of the granitoid stocks. The stocks are retrograded and some of the contact zones are marked by local slip surfaces. The earlier strain event predates these stocks. The complex intermingling of pegmatites and aplites along the western border of the Prince Albert Group, where low foliation-bedding angles are locally crosscut, suggests that the western pluton *was emplaced after the strain event.*

Structural geology south of Richards Bay

Planar elements

Inspection of airphotographs and aerial observation of the region south of Richards Bay show that it encompasses large complex fold patterns. The impression is that a northeast-trending fold has been buckled by a crossfold on Coxe Island. Neither distribution of rock types nor observations of rather scarce attitudes of layering at outcrop scale were sufficient to confirm these folds on the ground. Layering is obscure and foliation poorly developed; these are shown on a lower hemisphere equal area projection in Figure 10. The orientations of planar structures south of Richards Bay differ from those north of it. No linear elements were recorded in this area.

Structural history

The paucity of planar and linear elements preclude a detailed history, but the presence of interference folds on a kilometre scale is undoubted. An aeromagnetic anomaly (GSC aeromagnetic map 8273 G) over the centre of Richards Bay is puzzling in that two anomalies caused by iron-formations in each of the Adge-go and Richards Bay formations north of the bay and one iron-formation from the Adge-go Formation south of the bay coalesce in the vicinity of a postulated fault trace through the bay.

It is argued that the two island groups north and south of the bay are part of different, albeit related, fault slices. The different levels and styles of deformation of the same rocks are probably due in part to the throw on these east-striking faults and in part due to the earlier structures discussed above.

Metamorphic grade north of Richards Bay

Primary structures are easily recognized in the Mount Sabine and Richards Bay formations, but are obscured in the Adge-go Formation especially near the large granite pluton. Metamorphic textures and lack of easily recognized primary structures suggest that the Adge-go Formation is more recrystallized than the other two formations. Quartz in the Adge-go Formation is commonly medium grained and granoblastic, whereas in the other two formations irregular grains of volcanic heritage or rounded grains of sedimentary origin are present. In the lower half of Richards Bay Formation and throughout the Adge-go Formation, plagioclase is poikiloblastic, whereas primary shapes are preserved in the upper half of the group.

The Prince Albert Group in the map area is in the biotite zone except for a thin zone near granitic plutons where garnet and/or hornblende are present with quartz, muscovite, and biotite. A number of representative analyzed rocks are plotted on ACF (Winkler, 1965) and AFM (Thompson, 1957) diagrams (Fig. 11a, b). 2θ (131)-2θ (131) varies from 1.0 to 2.0, but is chiefly less than 1.4, which is typical for low-temperature albite and oligoclase (Deer et al., 1963). The chlorites show variation in birefringence (related to iron and silica contents) and basal spacing (related to aluminum contents). For example, chlorites from ultramafic rocks in this area contain a small amount of aluminum and are quite magnesian (i.e. they have basal spacing of 14.25 and are nearly isotropic). The most common chlorite in the area has anomalous brown birefringence and a basal spacing of 1.416 to 1.415 nm as determined by X-ray diffraction. According to Deer et al. (1962, p. 137 and 151) the chlorite is a pycnochlorite but variations as aluminous as ripidolite are present. These mineral compositions are typical of greenschist grades.

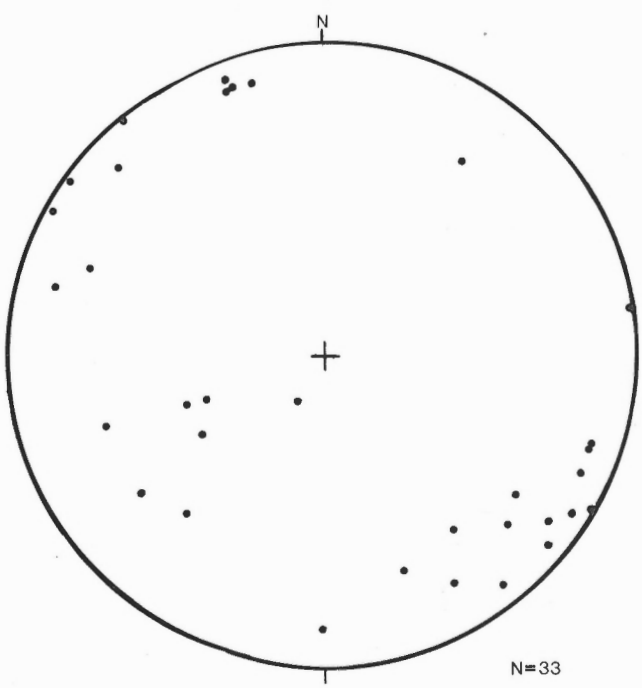


Figure 10. Lower hemisphere equal area projection of poles to planar structures, south of Richards Bay. Note different distribution compared to Figure 9a and b.

The replacement textures seen in thin sections suggest that chloritization is widespread. Biotite is altered to biotite-epidote-chlorite and chlorite. Chlorites of many different compositions occur in the same thin section. Potassium feldspar, which co-exists in patches and veins along with chlorite is indicative of the greenschist facies that has formed at a late stage. The granite plutons are retrograded and also contain co-existing potassium feldspar and chlorite. Since host and granite plutons both carry potassium feldspar and chlorite, it is concluded that the area has been pervasively metamorphosed to greenschist facies subsequent to emplacement of the granite stock. The grade of the majority of the Prince Albert Group north of the bay away from the plutons has never been as high as medium grade, because primary structures and textures in the eastern portion are preserved, and there is a total lack of textural evidence of prior existence of higher grade minerals. The metamorphic grade increases towards the western pluton and some metamorphism was probably associated with emplacement of granite. Textures near the plutons are polygenetic and indicate rocks may have locally reached amphibolite grade, and that since then the whole region has been subsequently retrograded to, or maintained at, low grade.

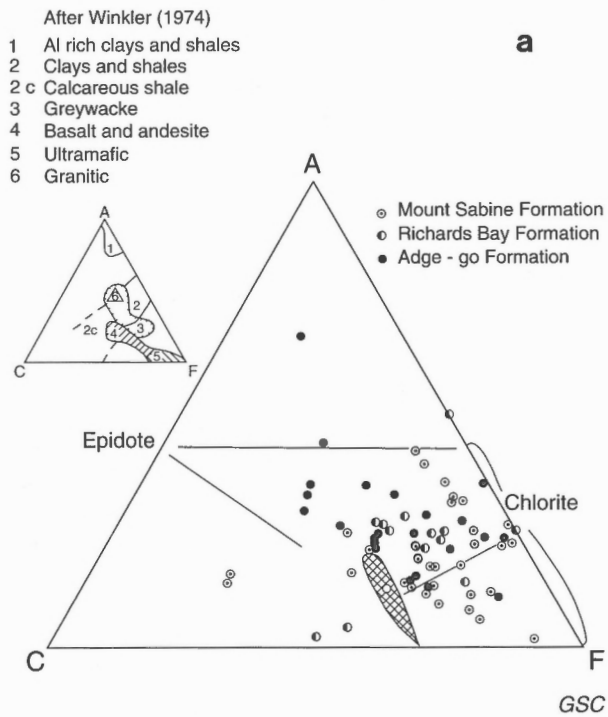
The rocks were probably exposed to erosion by late Proterozoic time although obvious clasts of Prince Albert Group have not been reported in the Proterozoic Fury and Hecla Group nor in the later Paleozoic cratonic sequence.

Metamorphic grade south of Richards Bay

South of Richards Bay and the postulated fault that traverses it, rocks of the Prince Albert Group are at amphibolite grade rather than the greenschist grade found north of the bay.

The bulk of the rocks are calcareous arenites at amphibolite grade. Metamorphic assemblages cluster near the epidote-biotite-quartz-potassium feldspar-tremolite-carbonate invariant point (Fig. 12, point r). In Table 4, Appendix 1, the chemical analysis of a quartz-rich, green-spotted, grey, fine grained, calcareous rock which may have been a limy subgreywacke is presented. It consists of intergrown quartz-potassium feldspar and several textural varieties of chlorite, biotite, white mica, tremolite, sphene and leucoxene, epidote, and carbonate with accessory apatite and hematite. Another typical calcareous assemblage consists of quartz-plagioclase-potassium feldspar-chlorite-white mica-tremolite-epidote, and carbonate with sphene, hematite, and opaques.

The grade of the limy subgreywackes is somewhat higher nearer plutons. At one locality (69°32′N; 82°22′W) on the island with the large southeastern pluton, centred on calcareous



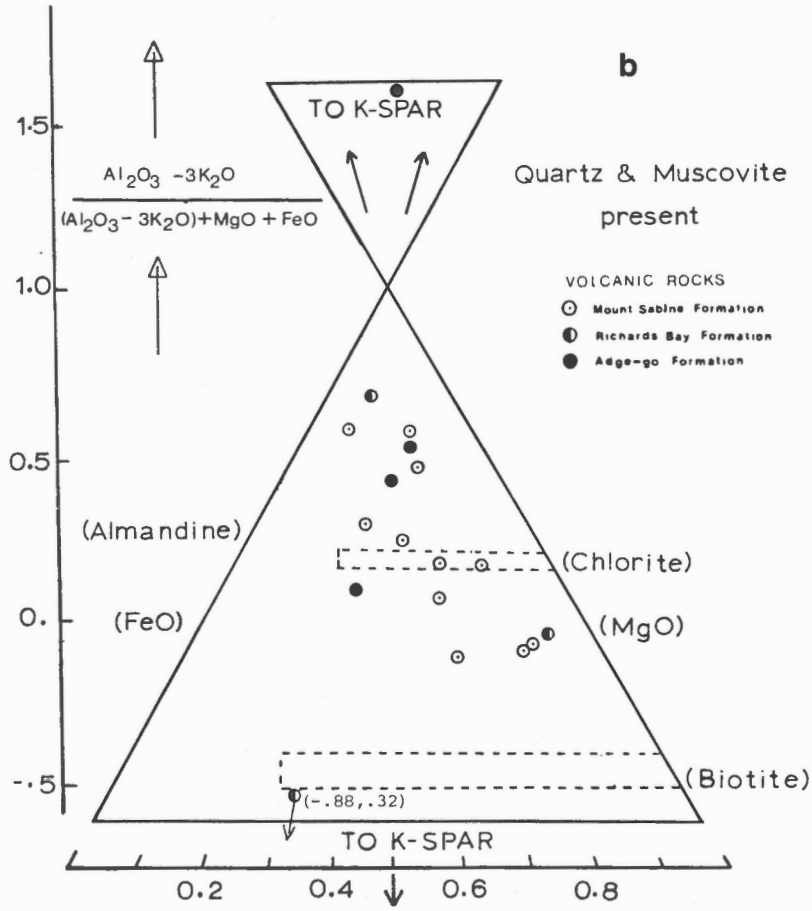


Figure 11.

(a) ACF (Winkler, 1965) and (b) AFM (Thompson, 1957) diagrams showing distribution of bulk compositions of analyzed Prince Albert Group rocks in Tables 2, 3, and 4.

assemblages include interlayered carbonate-phlogopite-chlorite-opaques, carbonate-tremolite-phlogophite-opaques, and quartz-plagioclase-potassium feldspar-white mica-clinopyroxene-epidote with accessory sphene and opaque minerals, suggesting local buffering of fluid compositions. To the south, at another location on the same island, quartz-plagioclase-white mica-hornblende-clinopyroxene-carbonate-sphene is interlayered with plagioclase-microcline-chlorite- white mica-hornblende-epidote-carbonate-sphene, and thin layers of quartz-plagioclase-white mica-tremolite-clinopyroxene-epidote-carbonate skarn. These assemblages straddle a higher temperature invariant point (see Fig. 12, point c) than the bulk of the rocks on the more westerly island, suggesting that the nearby pluton is associated with the elevation in grade. Both

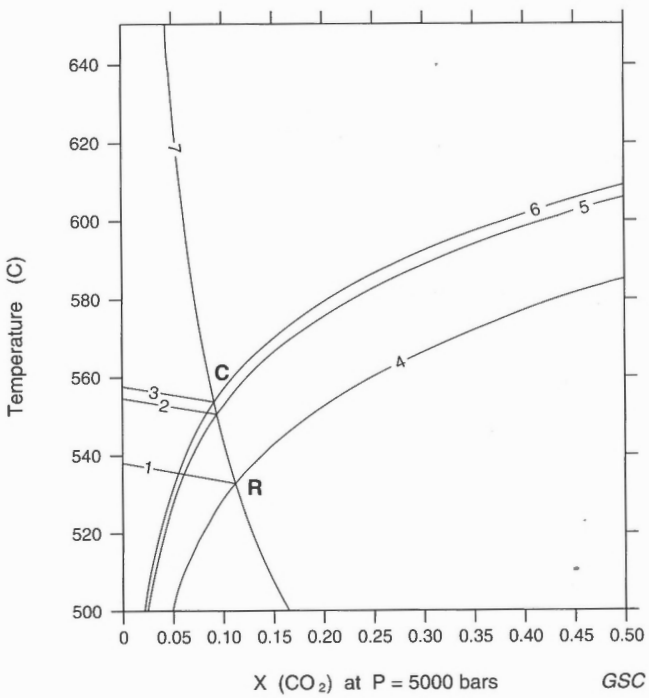


Figure 12. *PT diagram showing three invariant points in the system (K-Ca-Mg-Al-Si-O-H-C) and the regional grade (r) as well as the grade near plutons (c) of carbonate rocks south of Richards Bay. Diagram is modified from Mazurski (1980); the calculations were performed using GEOCALC (Berman et al., 1985; Perkins et al., 1986, and Berman et al., 1986). Assemblages on the left in the table below are stable on the high temperature side.*

1): 3 Tr + 5 Kfs + 18 An + 8 H_2O = 5 Phl + 24 aQz + 12 Zo
2): 5 Di + 9 An + 4 H_2O = 2 aQz + Tr + 6 Zo
3): Phl + 12 Di + 18 An + 8 H2O = Kfs + 3 Tr + 12 Zo
4): 3 Tr + 5 Kfs + 2 H_2O + 6 CO_2 = 6 Cc + 5 Phl + 24 aQz
5): 5 Di + H_2O + 3 CO_2 = 3 Cc + 2 aQz + Tr
6): Phl + 12 Di + 2 H_2O + 6 CO_2 = 6 Cc + Kfs + 3 Tr
7): Cc + 3 An + H_2O = 2 Zo + CO_2

these invariant assemblages are indicative of amphibolite grade. Buffering of rock assemblages by locally derived metamorphic fluids as well as differing compositions give rise to the mineralogical diversity noted. Rare ultramafic rocks are composed of chlorite, tremolite, opaques with sporadic carbonate or talc, and/or phlogopite. Near the plutons ultramafic rocks are composed of phlogopite, anthophyllite(?), tremolite and opaques indicative of higher grades there. Oxide iron-formation contains amphibole and quartz and is locally interbedded with biotite and garnet bearing schist.

Local schists consist of chlorite-biotite-white mica-quartz with accessory tourmaline and apatite, and one pelitic schist sample consists of staurolite porphyroblasts set in quartz-white mica-biotite matrix. Pelites are not common near the plutons in this area.

On Coxe Island bedding is rare, few primary features have survived, and as a result, the protolith is more difficult to ascertain. In this way they contrast sharply with the greenschist grade rocks to the north where primary features are well preserved and protolith easily deduced.

Summary of the structural and metamorphic history of Prince Albert Group in Richards Bay area

An east-striking fault separates the lower grade rocks in the north on the Bouverie Islands from moderate grade rocks in the south on Coxe Islands. This fault is part of the Ossory Fault Zone (Heywood and Schau, 1978) that bounds a graben located north of the map area in which the late Proterozoic Fury and Hecla Group, is preserved (Blackadar, 1967). Apparent movement in Richards Bay is south-side-up based on the higher metamorphic grade of the rocks to the south. On the mainland to the west the same units occur on both sides of the fault indicating that the throw is not large. It is possible that earlier structures are responsible for the differences in metamorphic grade and the later faulting is accentuating an earlier disparity. The age of the faulting in the bay is probably middle to late Proterozoic. Movement along the fault possibly also occurred in mid-Paleozoic times during formation of the Melville Peninsula horst (Sanford, 1977).

Prior to the faulting, granitic plutons were emplaced in the Prince Albert Group both north and south of the fault. The grade of metamorphism increases towards the larger plutons. Both areas contain evidence of at least two episodes of deformation. Earlier shallow dipping structures in the Prince Albert Group are cut by, and deformed near, the larger granite bodies in the north; south of the fault, pluton contacts are generally concordant with the strike of the supracrustal rocks. The earlier structures are probably due to Archean subhorizontal compression whether as fold or thrust or, less likely, due to extensional tectonics.

The regional metamorphism north of the fault, and probably south of the fault as well, accompanied the earlier structures. There is no evidence of a cessation of metamorphism prior to emplacement of plutons. Both deformational episodes possibly occurred during the same metamorphic event. Much later retrogression, which affects plutons as well as the Prince Albert Group, accompanied the later faulting.

Mode of Origin of the Prince Albert Group.

This discussion assumes that the section, as presented, is coherent and in stratigraphic order with the Adge-go Formation the oldest, and the Mount Sabine Formation the youngest, as indicated by way up indicators.

Depositional environment

A model for the origin of the Prince Albert Group includes many different volcanic and sedimentary processes.

The environment of deposition of the Prince Albert Group was mainly shallow water. The presence of pillowed flows, and pillow breccias, along with massive flows, suggests some volcanic flows were subaqueous. Abundantly amygdaloidal flows are common in the Mount Sabine Formation, suggesting extensive degassing which occurs most frequently in shallow water. Pillow basalts overlain by massive flows are often taken as indicators of deposition near or at sea level (Carlisle and Suzuki, 1974). The lenticular differentiated basalt flow whose outer parts are much finer grained than the core in the crossbedded arenites in the middle of the Mount Sabine Formation probably represents a transverse section across a lava tube. Large crossbedded units in the Mount Sabine Formation, with northwest oriented troughs, also suggest shallow water environment, probably near (or in?) a river. Above the upper volcanic member in the Mount Sabine Formation is a conglomerate unit with rounded fragments of immediately underlying pillow basalts, overlain by graded wackes, coarsely crossbedded arenites, which in turn are overlain by very finely laminated arenites tens of metres thick. These indicate deposition in water with considerable variation in current velocity. Lithologically variable breccias and conglomerates imply several source areas. The presence of agglomerate in the basal volcanic member of Mount Sabine Formation indicates that the vent which generated this unit was subaerial.

The presence of facies changes from clastic sediments and iron-formation into volcanogenic rocks at the top of the Adge-go Formation indicates that a volcano was surrounded and overlain by an apron of clastic and chemical sediments. The variable thickness of quartzites and breccias of Richards Bay Formation that covers the edifice suggests that the source was continental. Scattered pebbles of quartz-feldspar aggregates and plutonic cobbles in conglomerates throughout the section imply the presence of a plutonic hinterland. The occurrence of older Prince Albert Group fragments in younger clastic rocks of the group suggests that the depositional environment was unstable and that parts of the group were eroded and redeposited in adjacent shallow waters (Fig. 13).

The choice of the iron-formations as the marker horizons indicating tops of formations is based on the commonly found relation that iron-formations accumulate while volcanism is waning (Eriksson, 1982). He also intimated that the greenstone belts he studied were deposited in shallow-water graben-related environments which were inundated by continentally derived sediments (ibid).

Volcanic regimes

Hand specimens of volcanic rocks were analyzed and the results are presented in Tables 1, 2 and 3 of Appendix 1 and in Figure 14, and the specimens are described in the lithology section of each formation. The range of chemical variation of the rock types is comparable to that reported from near McKar Inlet on the western coast of Melville Peninsula (Fryer and Jenner, 1978; Frisch, 1982).

Reference to Figure 14 shows that the Adge-go Formation contains metamorphosed volcanic rocks which plot along a calc-alkaline trend ranging from rhyolite to basaltic komatiite. The overlying metavolcanics of the Richards Bay Formation are calc-alkaline basalt or basaltic komatiite, and metavolcanics of the youngest Mount Sabine Formation are calc-alkaline basalt, high magnesiam tholeiitic basalt and basaltic and ultramafic komatiites. Dykes in the Adge-go Formation are dacite, high magnesiam tholeiite basalt, and basaltic komatiite, the latter two types being possibly offshoots of feeders to the younger Mount Sabine Formation.

The sequence shown here is inverted compared to normal Archean volcanic assemblages (Goodwin, 1968).

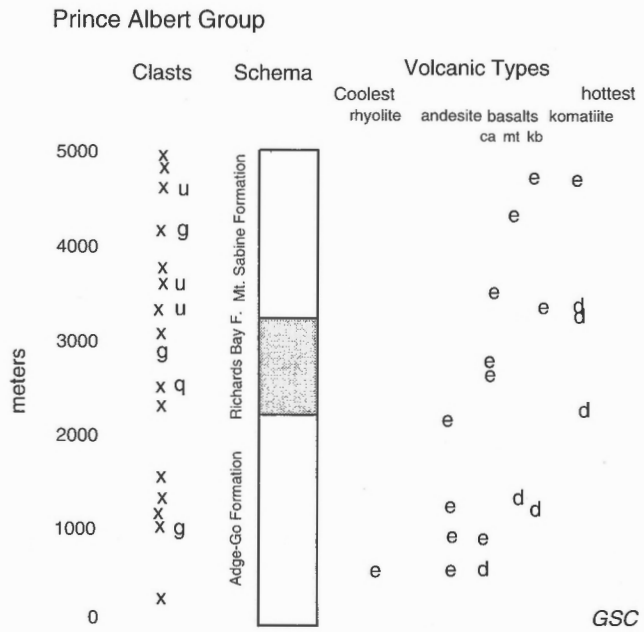


Figure 13. Schematic section showing vertical variation of clast types and volcanic eruptives in Prince Albert Group. On the left hand side, clastic horizons with clasts of Prince Albert Group lithologies (x = volcanic debris, u = ultramafic debris, q = quartzite, g = granitoid materials); and on the right hand side the relative liquidus temperature of hypabbysal (d) and extruded (e) volcanogenic rocks are shown.

ca = calc-alkaline
mt = magnesian tholeiite
and kb = komatiitic basalt

Since a continuum is defined on the diagram (Fig. 14), it is possible that these rocks define an inverted komatiitic trend from peridotitic komatiite through basaltic komatiite, high magnesiam tholeiite, calc-alkaline basalt, andesite, dacite and rhyolite. Although Arndt has suggested such a trend, he now is less certain of its existence (Arndt and Nisbet, 1982) and more theoretical work is needed to determine whether the apparent continuous trend shown in Figure 14 is a remarkable coincidence or a genetic necessity occasioned perhaps by mixing melted crust with komatiite (Sparks, 1986).

The assignment of some of the volcanic rocks to a komatiitic series precludes an interpretation of the andesites of the Prince Albert Group as compression related volcanics. Frisch (1982), for example, recently related the volcanic suites of the Prince Albert Group on western Melville Peninsula to a "...continental margin "Andean"...[regime]" (ibid p. 30) or a "...rifted totally ensialic environment..." (ibid p. 29). Until more definite criteria are developed to distinguish between various volcanic regimes, and some assurance is available that all possible volcanic regimes, including those extant in Archean time, have been modelled, one prefers to withhold judgment on the tectonic significance of the komatiitic rocks of the Prince Albert Group. The possibility of contamination of komatiite by addition of adjacent melted crust, and thus the generation of a smooth series of rocks from komatiite to rhyolite entirely due to mixing, remains an attractive hypothesis and would largely nullify the assignment of tectonic regime from volcanic composition (Sparks, 1986).

Suffice it to say that the Prince Albert Group at Richards Bay consists of a local pile of volcanics deposited near sea level throughout its history. The melting temperature of extruded material appears to have increased from that of felsic calc-alkaline rocks to that of komatiite as the volcanic pile got younger (Fig. 13). Simple thermal cooling subsidence models are ruled out by this inverse relationship i.e. an apparent heating of the source region. On the other hand, the emptying of a crustally contaminated ultramafic magma chamber from the top, would yield the same sequence of melts at the surface.

Models which incorporate the continued exposure of the Prince Albert Group to erosion by faulting are necessary. From a regional perspective, the section at Richards Bay is thicker and more volcanogenic than the Prince Albert Group elsewhere.

The subsequent regionally extensive tectonic activity, gneissification and plutonism that followed the widespread deposition of the Prince Albert Group, indicates that a regional thermal anomaly persisted for some time.

Tectonic environment of deposition

The tectonic environment at the time of deposition was unstable, as inferred above. It was one in which subsidence continued apace with deposition. A possible model involves rifting above a subcrustal thermal anomaly. In the Bouverie Islands region, volcanism continued in pulses that were increasingly hotter. In an extensional regime, local isostatic adjustment to a sediment load may provide a mechanism for continued subsidence. The maximum thickness of sediment that can be accommodated by isostatic depression is a factor proportional to the initial water depth. Although deposition of greenstone belts has been associated with passive margins (Eriksson, 1982) the continuance of volcanism and the inverted nature of the volcanic sequence suggest a more complex tectonic environment. Since most of the group was deposited at a sea-air interface, passive isostasy did not play a large part in the formation of the site of deposition. Instead, an active mechanism was operational. Figure 13 shows a sketch section and the levels from which clasts of rocks attributed to the Prince Albert Group are located. It is clear that the group was available for local erosion throughout its

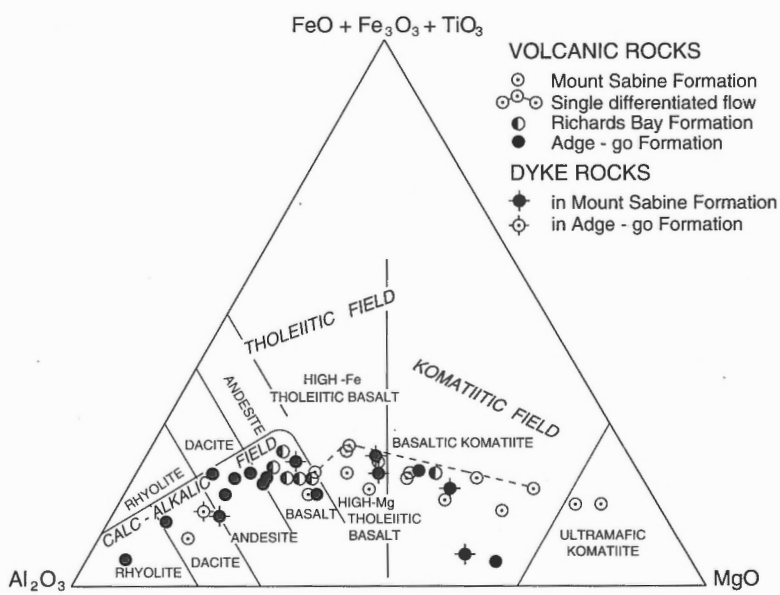


Figure 14.

Jensen (1976) cation plot of chemically analyzed metavolcanic rocks described in the lithology section and presented in Tables 1, 2, and 3 of Appendix 1. This diagram was used to name the volcanic rocks in this study. See Appendix 3 for details. Note that the samples are connected by a broken line which follows the trend shown by all samples collectively; these three points are from a single differentiated flow.

history. Since the Prince Albert Group contains ensialic clastics, it follows that continental crust was nearby, if not underneath, the group at time of deposition. Unfortunately the oldest Prince Albert Group rocks in this area are in contact with an intrusive granite, so that the nature of the depositional basement remains unknown. A possible modern analogue is outlined below.

Modern analogues and caveats

Extensional regimes. The continental crust north of Australia is in a complicated tectonic region. In the area off the eastern end of Papua-New Guinea, in the Woodlark Basin, a possible partial analogue of the Prince Albert Group as manifested in the Richards Bay area, is currently under study (S. Scott, pers. comm., 1986). He noted that in the Woodlark Basin from 151°50′E westward to the d'Entrecasteau Islands, rifting is extending continental crust. Tectonism is manifested topographically by short en echelon troughs, up to 3200 m deep, separated by intervening horsts which approach within 80 m of sea level. Troughs are variably filled by lava. The composition of the lavas change progressively from mid-oceanic ridge basalt at 151°40′E to andesites and dacitic andesites between 151° and 151°45′E (Scott, ibid). Since the rifting is progressing in a westward direction, simple application of Walther's Law indicates that in a vertical section, the most felsic volcanic rocks would be overlain by more basic rocks at any given site of accumulation. This is the feature in which the Papua- New Guinea region resembles the Prince Albert Group at Richards Bay.

It is noted, however, that the most mafic rocks in the Woodlark Basin are tholeiitic basalts, whereas in the Prince Albert Group they are ultramafic lavas. This difference indicates that mantle conditions were different in the Archean compared to the present. (The Archean may have been drier as suggested by Warren (1984), and hence caution is in order in drawing a direct analogy (Sparks, 1986).

Similarly, Karig (1971) noted the continuous transition from a typical continental volcano-tectonic graben system to an inter-arc basin north of New Zealand, and suggested they are formed by a geographically continuous extensional process. When the extension attains sufficient magnitude, new oceanic crust is produced. The first volcanic effluents there are also silicic, followed by more basic volcanism.

A zone stretching from the Arctic Sea in the north, west of the sea of Okhotsk, through Sikhote-Alin, northeast China, Korea and into Southern China is characterized by Mesozoic to Pliocene andesitic to rhyolitic volcanic activity which has, with time, become less silicic so that now, the most common volcanoes in this region are basaltic (Whitford-Stark, 1987). This general inversion of the volcanic sequence is repeated in detail at several localities offshore. Konovalov (in Perchuk, 1987) reported that an inverse volcanic section (in that more basic rocks rest upon less basic volcanic rocks) rests upon the continental basement of the marginal Sea of Japan. Gnibidenko and Khvedchuk (1984) similarly reported that the Sea of Okhotsk basement is also overlain by inverted volcanic sequences. These examples indicate that intermediate rocks are geographically associated with tensional environments such as marginal seas.

The tectonic significance of the marginal seas of eastern Asia is still controversial two decades after their existence was highlighted by Menard (1967). Gnibidenko and coworkers (see Gnibidenko and Khvedchuk, 1984, Gnibidenko, 1979 for reviews) have reported on the geological setting of the surrounding submerged continental seafloor as well as the oceanic crust in the Sea of Okhotsk and the Sea of Japan. They document a long very complex set of events extending from Precambrian time to the present. Recent attention has focussed on the small areas in each of these seas and others like them, underlain by Cenozoic oceanic crust and tectonic models for generating them. Proposals of frictional heating leading to hot diapiric upwelling of the asthenosphere (Karig, 1971); induced asthenospheric upwelling by hydrodynamic forces generated by the sinking of a slab (Sleep and Toksoz, 1971); and kinematic models based on consequences of divergent movements of overriding plates and trench hinge lines occasioned by either retreat of a back-arc plate or oceanward rollback of the trench hinge line or both (see review in Kimura and Tamaki, 1986) indicate continuing puzzlement over the presence of extensional features in what is currently considered to be an essentially convergent environment. Several interpretations of the seas of Japan and Okhotsk agree on the need to fragment and horizontally rotate continental fragments of Japan, but the timing of this is in dispute (Jurdy, 1979; Kimura and Tamaki, 1986; Faure et Lalavee, 1987; Celaya and McCabe, 1987; Chough and Barg, 1987). With this uncertainty in interpretation of young marginal seas where an abundance of interdisciplinary data exist, a prudent course in assigning a tectonic milieu for the Archean, deformed, and metamorphosed Prince Albert Group, with only a small data base, is to note similarities to the modern milieu without embracing any particular type of model.

As a special warning in this context, note the similarity in sections of volcanogenic rock from the Sea of Okhotsk and the Prince Albert Group, and the dissimilarity with the sections recorded by Chough and Barg (1987) from a similar setting along the margin of the Ulleung (also known as Tsushima) Basin in the East Sea (also known as Sea of Japan).

Intermediate rocks in continental settings are not easily explained either. The association of intermediate rocks, such as those on Michipicotin Island in the continental Keweenawan rifting environments, is often explained by mixing crustal contaminants with mantle magma (Annells, 1974). Alternately, Cretaceous intermediate rocks of the Absaroka-Gallatin volcanic province of northwestern Wyoming and southwestern Montana post-date normal faulting and are thought to be generated as a direct response to the melting of old (pre-3.8 Ga) mantle source regions (Meen and Eggler, 1987).

Sugimura (1968) proposed an empirical relation between chemistry and depth of genesis of basic magma called the theta index:

$$\text{theta} = SiO_2{*}(\text{wt\%})-(47{*}(Na_2O(\text{mol.prop.})+K_2O(\text{m.p.}))/Al_2O_3(\text{m.p.})).$$

Theta values are less than 36 in modern volcanics erupted through crust thicker than 30 km, and greater for volcanics erupted through modern (thinner) oceanic crust. Theta values calculated for the basic (feeder?) dykes that cut the Adge-go Formation are less than 36 (theta for sample 273B = 31.1; 277B = 33.0; 270B1 = 33.1) suggesting that continental crust underlay the Prince Albert Group at the time of their emplacement.

On the other hand, Warren (1984) suggested that crustal contamination was more important in Archean times than today, and that Archean intermediate rocks intimately associated with komatiites are derived from crustal contamination of the ultramafic parent (see also Sparks, 1986). Either of these hypotheses requires that continental crust be present below the Prince Albert Group at the time of deposition to be acceptable.

Compressional regimes. According to Le Pichon et al. (1982) where a hot and thin lithosphere, pervasively cut by new faults, is no longer subject to extensional forces, it will tend to be subjected to gravitationally induced compressive forces of several hundred bars as the stresses due to the mass distribution associated with the previous thinning, relax. These tendencies would be accentuated by any additional horizontal compressional stresses. This mechanism would seem sufficient to explain the onset of compression soon after deposition, as is seen in the Richards Bay area. There is insufficient evidence to estimate whether the above mechanism in fact occurred, let alone the value of the additional stresses, if any.

Summary of mode of origin

The unstable extensional tectonic environment of the continental crust north of Australia, or in east Asia, may be a tectonic analogue for some late Archean crust. The conjunction of locally exposed continental crust, yielding clastic sediments with small local deep extensional basins and filled by volcanic rocks, fits many of the features seen in the Richards Bay area, and is consistent with the regional lithological and thickness variations within the Prince Albert Group. A subcrustal ultramafic magma chamber interacting with the lower crust to provide contaminated lavas at the surface and structural instability at the surface is postulated.

The immediately consequent tectonic history includes formation of subhorizontal structures (large folds) which were followed by emplacement of granite batholiths over a relatively short period of time. This shift from a local extensional environment, possibly caused by a thermal anomaly, to a later regional, possibly compressional regime due to gravitational collapse of the subcrustal thermal anomaly and followed by emplacement of large plutons, is typical of late Archean history in the northeastern Canadian Arctic (Schau, 1982).

The rocks in the Richards Bay area remained relatively near the surface throughout their history in contrast to the fate of the Prince Albert Group elsewhere on Melville Peninsula.

Age and correlation

The Prince Albert Group in the Richards Bay region was first recognized by Heywood (1974), although Blackadar (1963) had previously recognized these supracrustal rocks as Archean.

There are no radiometric data available in the map area. Frisch (1982), in a related study 100 km to the southwest on Melville Peninsula, reported an Archean U-Pb age of 2879 Ma on zircons recovered from acid volcanic rocks of the Prince Albert Group.

The correlation is based on lithological similarities to the Prince Albert Group in its type area (Frisch, 1982; Schau, 1982). Other nearby supracrustal rocks on Baffin Island, notably those immediately north of Fury and Hecla Strait (Ciesielski, 1983), are also correlated, on the basis of lithological similarity, to be part of the Prince Albert Group. Likewise, the Mary River Group of Baffin Island has been correlated with the Prince Albert Group by several investigators (Jackson and Taylor, 1972; Jackson and Morgan, 1978).

METAGABBRO

A several hundred metre thick gabbro sill(?) forms a north striking ridge on the largest of Coxe Islands. The rock is a greenish black, medium grained, plagioclase-phyric gabbro grading to a greenish grey, fine grained schist with local thin layers, up to 65%, of flattened plagioclase in similar matrix. In thin section the plagioclase is seen to be retrograded to quartz, new sodic plagioclase, epidote and white mica. The chief mafic mineral is a chloritized, green, actinolitic hornblende with local sphene inclusions. The gabbro is emplaced into the Prince Albert Group at the stratigraphic level of the iron-formation of the Adge-go Formation. Xenoliths of ultramafic and quartz-magnetite rocks are locally abundant. The gabbro has been variably deformed and is cut by pegmatite and a granite pluton on the east. Locally a fault zone marks the contact between gabbro and granite.

Other small decametre-thick metagabbro sills or stocks are found on the islands north of the bay cutting the Richards Bay Formation. They, too, are cut by granite dykes.

The metagabbro is correlated with the Tasijuaq gabbro suite which is best exposed near Hall Lake.

GRANITE

The granite stocks in the map area are part of a widespread plutonic suite.

One stock of about 40 km^2 and centred on 69°32′N and 82°20′W consists of an orange to pink weathering, porphyritic granite with potassium feldspar phenocrysts in a medium grained matrix of biotite, quartz and feldspar. In thin section, the granite is seen to consist of more than half microcline, about a third quartz with the remainder being approximately equal proportions of minor sodic plagioclase and biotite with scattered flakes of muscovite.

This granite and associated pegmatite cut the Prince Albert Group and the gabbro and contains xenoliths of the country rock on Coxe Islands. Several metre-long blocks of iron-formation are present near the contact which is chiefly sharp but, locally, consists of a metre-wide zone of sheared granite, pegmatite and country rock. The granite is similar to, and correlated with, the Hall Lake Plutonic Complex.

Irregular dykes up to 500 m wide of massive light pink biotite granite, possibly related to the above-mentioned stock, cut the peninsula in the southern part of the map area.

Granite on the northwest shore of Richards Bay is part of a larger plutonic complex which contains many phases. In the map area both massive and porphyritic varieties are present. The medium grained, massive variety consists of about equal amounts of quartz, oligoclase, and microcline, and up to 10% biotite. Locally, muscovite, magnetite and/or fluorite occur in trace amounts. The porphyritic variety contains 10 to 15% phenocrysts of microcline in a matrix similar to the massive variety. This granite is probably the source of the abundant granitic dykes at the base of the Adge-go Formation. It contains large blocks of Prince Albert Group, including quartzite and mafic volcanic fragments.

Small stocks of medium grained biotite granite occur on the Bouverie Islands. One cuts both the top of the Adge-go Formation and the base of the Richards Bay Formation. An iron-formation projects into this stock and has contributed numerous stoped blocks to the pluton. In thin section this stock is seen to consist of fine to medium, inequigranular grains of crushed and sutured quartz, annealed microcline, and cloudy, albitized oligoclase in equal amounts, with minor biotite and a trace of muscovite, epidote and apatite. A chemical analysis is given in Table 5, Appendix 1.

Granite on the northeasternmost islands is grey to pink and hornblende-biotite-bearing. In thin section it is seen to consist of about equal amounts of altered plagioclase, altered microcline, and crushed quartz, along with minor biotite and hornblende. Other alteration products include muscovite, saussurite and actinolite. This granite is emplaced in gabbroic and basaltic country rock. Local assimilation of basic country rock may have resulted in the formation of hornblende which distinguishes this granite pluton from others.

These granites are probably coeval with the Hall Lake Plutonic Suite which occurs to the south. Frisch (1982) has described similar granites, of Archean age, on the west side of Melville Peninsula, and they are also similar to the Archean, post-tectonic, granite which occurs on the north side of Fury and Hecla Strait (Ciesielski, 1983).

FURY AND HECLA GROUP

Cataclastically brecciated quartzite of the Fury and Hecla Group outcrop on one small island in the strait. The rocks have a moderate dip to the west and have been intensely shattered. Subaqueous outcroppings of easily weathered shales is suspected since beaches on nearby islands are covered by purple siltstones very similar to the siltstone units elsewhere in the Fury and Hecla Group (Chandler et al., 1980).

This quartzite is probably part of a fault sliver set in the Ossory Fault Zone, and the neighbouring islands underlain by Prince Albert Group are on an adjacent fault block.

DIABASE

Thin, brown weathering,fresh, fine grained to aphanitic, diabase dykes cut granite on small islands in the bay and on the mainland in the central western part of the map area. Their age relations are shown in the region to the west and north of the map area where dykes and sills cut the Late Proterozoic Fury and Hecla Group (Heywood, 1974 and pers. comm.; Chandler et al., 1980). They are possibly coeval with the Franklin diabase swarm.

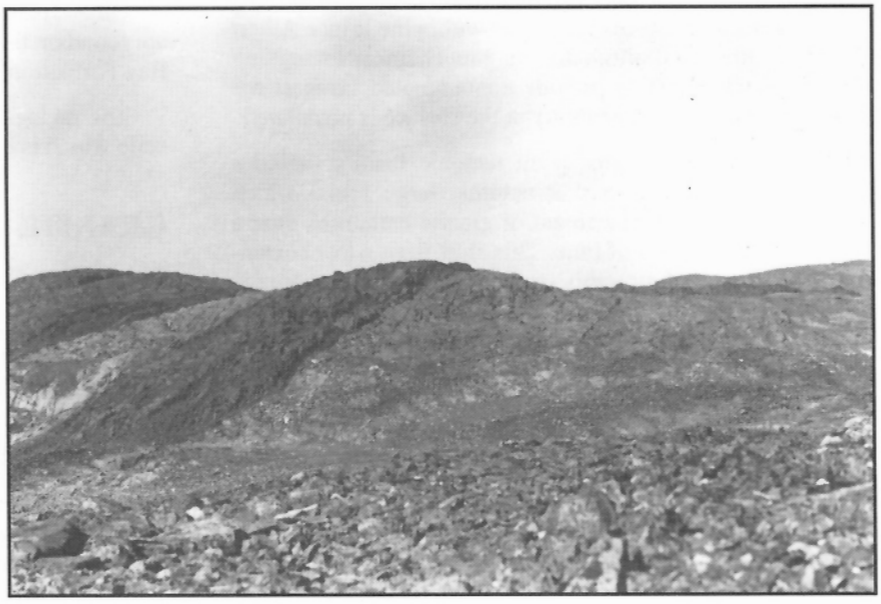


Figure 15.

Photograph of oxide facies iron-formation septa of the Adge-go Formation in a granite stock. GSC 204738-A

MINERAL OCCURRENCES AND PRELIMINARY RESOURCE EVALUATION OF THE AREA

Mineral occurrences

Iron-formations occur north and south of Richards Bay (see Fig. 15, 16, 17). Large positive aeromagnetic anomalies are associated with these deposits (see GSC Map 8273 G). An iron-formation along the west side of a small bay at the contact between Adge-go and Richards Bay formations is oxide-rich in the vicinity of the crosscutting granite stock (Fig. 15). Sporadic sulphides are present in that iron-formation.

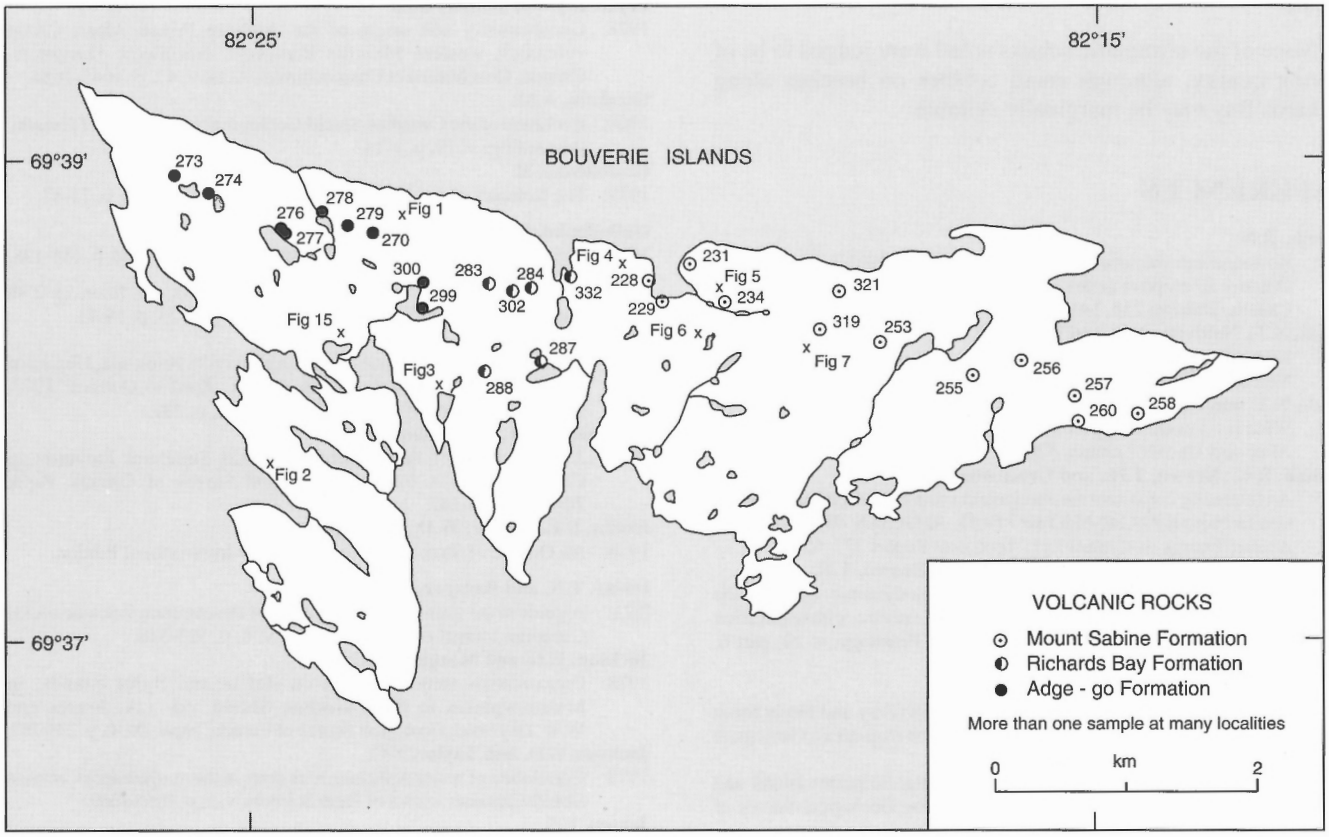
Chalcopyrite occurs along with pyrite as sporadic sulphides in schistose mafic volcanics and metagabbro (see Fig. 17). Quartz veins and chloritized wallrock associated with faults carry minor sulphides and calcite (see Table 6, Appendix 1). Disseminated chalcopyrite and galena occur in grey calcareous meta-arenites on the Coxe Islands near the extension of an east-southeast-striking fault zone which outcrops on the mainland to the west. This association is rarely of Archean age. Lead isotope analyses of the galena indicate that it is similar to Proterozoic galenas present elsewhere in the Churchill Province (R.I. Thorpe, pers. comm., 1984). Therefore it is concluded that the dissemination is not primary, but rather is a secondary epithermal occurrence probably emplaced along a subsidiary fault of the Ossory Fault Zone.

A small yellow stained showing in the granite on the Coxe Islands is several times background in total count as measured on a scintillometer. It is probably derived from allanite or a similar accessory mineral.

Preliminary resource evaluation

If iron deposits near Hall Lake (Wilson and Underhill, 1971) are exploited, then the iron deposits in this area may very well become economically interesting after the transportation problems are solved. The iron-formations around Richards Bay are well exposed, near water, and locally rich in magnetite. Amphibole is locally abundant requiring physical separation of some ores.

The conclusion that the Prince Albert Group is a shallow water deposit leads to the conjecture that it is not favourable to massive sulphide deposits of the deep water type (Sangster, 1972). The zinc tenor in the metavolcanics is not anomalously high, in the sense of Wolfe (1975), and supports the above opinion.



GSC

Figure 16. Localities of analyzed samples and photographs mentioned in text.

The geological setting of the Prince Albert Group for volcanogenic massive sulphide deposits of the Kuroko type is more favourable, since the thickness of the volcanic members locally exceeds 500 m, the group contains both mafic and intermediate to felsic layers indicating that the pile is composed of differentiated volcanics, and pyroclastics are present locally. The existence of banded iron-formation, chert and pillow basalts indicate that the sequence is in part subaqueous. Strong leaching or hydrothermally altered rocks are not abundant and gahnite, spessartine, barite, usually considered indicator minerals, have not been located. On the other hand, magnetite in banded iron-formations and tourmaline in vein fillings at the top of the Mount Sabine Formation do indicate that hydrothermal activity was ongoing during deposition and/or diagenesis of the group. Accordingly the potential for a sulphide deposit of the Kuroko type is rated as possible to speculative (McCammon, 1986).

The combined occurrence of ultramafics, iron-formation, and quartz veining and faulting has provided an environment suitable for noble metal vein deposits elsewhere. However, the only gold assays done on vein material from the area returned discouraging results (see Table 6, Appendix 1).

The prospect for massive sulphides is not optimistic, but the presence of epithermal sulphide deposits suggests the possibility of small local sulphide or noble-metal-bearing vein deposits. Local pods of sulphide may also occur in the granite.

None of the ultramafic schists noted were judged to be of carving quality, although small cobbles on beaches along Richards Bay may be marginally suitable.

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APPENDIX 1

Tables of chemical analyses

Table 1. Chemical analyses, Adge-go Formation.

Major elements														
	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	CO_2	H_2O	S
272A	60.7	1.25	13.6	1.1	9.4	.19	3.41	2.04	.8	3.5	.29	.0	2.7	.0
272B	56.9	.29	9.37	6.1	13.9	.32	2.19	7.74	.2	.39	.16	.0	2.2	.28
273A	76.2	.28	13.8	.6	.2	.01	.71	1.51	.3	3.90	.06	.0	1.4	.0
273B	46.8	1.26	15.4	3.3	10.6	.38	5.56	9.71	2.5	1.34	.43	.0	1.6	.0
273C	55.6	.83	16.9	1.9	6.1	.14	5.39	7.15	3.8	1.10	.14	.0	1.7	.0
274A	62.5	.79	14.6	1.9	3.9	.11	4.16	4.93	4.1	1.37	.17	.3	1.3	.0
274B	57.5	1.14	16.1	1.4	5.0	.03	7.27	.90	3.8	2.65	.23	.0	4.4	.0
****1000 metres														
275	58.6	.63	15.8	1.0	5.5	.16	4.68	8.62	1.8	1.28	.16	.0	1.3	.0
276A	54.6	.81	16.9	.9	7.4	.11	7.54	3.70	2.7	3.02	.19	.1	2.8	.03
276B	52.1	.73	10.4	1.1	6.8	.16	13.3	9.58	1.4	.21	.84	.0	3.3	.0
277A	58.1	.87	15.4	1.1	6.3	.10	5.26	4.51	1.9	2.84	.21	.0	2.1	.0
277B	54.3	.80	12.4	2.1	6.5	.14	9.08	7.57	2.1	2.26	.71	.0	2.0	.1
****1600 metres														
278A	63.7	.77	15.6	1.6	3.3	.07	2.92	7.51	3.2	.88	.25	.0	.9	.0
278B	58.4	.83	16.8	1.7	5.9	.09	4.58	3.57	3.7	2.14	.25	.0	2.8	.0
278C	62.8	.94	15.8	2.5	3.8	.07	3.25	3.23	3.4	2.46	.28	.0	2.1	.0
279	55.2	.77	17.3	1.9	5.2	.14	2.52	8.05	1.4	1.87	.15	.0	1.9	.06
270A	61.8	.50	20.2	1.2	2.0	.07	1.63	3.92	7.1	1.34	.04	.0	.7	.0
270B1	54.1	.59	12.6	1.6	7.6	.21	8.95	8.50	2.5	1.57	.51	.0	1.8	.0
270B2	63.2	.62	16.6	.8	4.0	.08	3.13	4.99	3.1	2.35	.17	.2	1.3	.0
280	69.3	.43	15.9	1.0	2.8	.09	1.11	3.43	2.1	2.76	.14	.0	1.7	.0
****2100 metres														
299B	49.0	1.09	12.9	1.7	8.0	.08	12.7	3.95	.8	6.35	.56	.0	3.1	.0
300	69.6	.28	14.5	.2	2.6	.02	1.23	.21	.0	10.1	.10	.0	1.2	.0
****2200 metres														

Minor elements											
	Cu	Pb	Zn	Sc	V	Ni	Cr	Rb	Sr	Ba	Zr
272A	.0015	.0004	.012	.0021	.011	.004	.0011	.014	.007	.055	.009
272B	.010	.0036	.017	.0007	.0034	.001	ND	.000	.002	.004	.012
273A	.0011	.0013	.000	.0007	.0018	.001	ND	.010	.006	.028	.023
273B	.0064	.0007	.017	.0022	.016	.011	.025	.005	.021	.043	.007
273C	.0011	.0007	.006	.0016	.015	.012	.020	.003	.025	.018	.002
274A	.0022	.0003	.003	.0018	.011	.009	.014	.001	.019	.016	.002
274B	.0015	.0002	.003	.0019	.010	.007	.012	.002	.009	.024	.008
****1000 metres											
275	.0037	.0005	.006	.0017	.013	.014	.026	.004	.019	.020	.003
276A	.0042	.0009	.008	.0019	.015	.010	.020	.012	.020	.038	.004
276B	.0011	.0006	.009	.0016	.012	.053	.1	.00	.011	.005	.007
277A	.0053	.0015	.009	.0016	.013	.008	.011	.011	.054	.072	.004
277B	.0043	.0026	.008	.0021	.012	.018	.042	.010	.059	.11	.01
****1600 metres											
278A	.0014	.0006	.003	.0013	.0094	.008	.0080	.000	.017	.008	.009
278B	.0018	.0009	.007	.0015	.0083	.007	.010	.006	.033	.032	.009
278C	.0017	.0006	.006	.0012	.0085	.006	.0078	.008	.020	.050	.012
279	.0041	.0006	.007	.0018	.011	.007	.0070	.005	.020	.039	.007
270A	.0007	.0009	.003	.0012	.0060	.003	.0026	.001	.020	.023	.007
270B1	.0011	.0007	.010	.0021	.013	.011	.0073	.003	.015	.024	.0
270B2	.0026	ND	.005	.0015	.0087	.006	.0066	.006	.026	.065	.006
280	.0026	.0005	.003	.0007	.0053	.005	.0018	.006	.023	.052	.003
****2100 metres											
299B	.0035	.0002	.009	.0016	.013	.031	.043	.036	.019	.098	.008
300	.0024	.0008	.003	.0007	.0030	.003	.0017	.025	.015	.063	.006
****2200 metres											

APPENDIX 1 (cont.)

Table 2. Chemical analyses, Richards Bay Formation.

Major elements														
	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	CO_2	H_2O	S
**** 0 metres (2200 from base)														
296B	93.5	.10	3.29	.1	.79	.02	.21	.08	.20	1.25	.08	.01	.00	.00
282	68.1	.36	9.8	1.3	8.1	.10	3.78	3.99	1.4	.72	.08	.15	2.1	.08
301	61.3	.44	13.6	1.2	12.1	.07	2.76	1.31	2.3	2.17	.15	.0	3.2	.0
**** 200 metres (2400 from base)														
288	52.1	1.56	18.1	2.4	8.4	.12	5.61	5.51	3.1	1.00	.38	.0	3.1	.15
302	56.2	.78	16.6	1.2	6.7	.12	6.16	6.37	2.5	.98	.13	.0	2.8	.0
283A	75.1	.04	2.0	0.0	1.1	.10	4.83	5.96	0.0	.78	.07	9.9	.7	.0
283B	59.7	.77	14.5	.8	6.3	.07	6.28	3.22	1.9	1.81	.19	.3	3.5	.0
283C	51.3	.20	2.7	.7	.8	.17	9.11	12.8	0.0	1.35	.12	21.2	.5	.0
284	57.6	.84	16.4	1.3	6.8	.12	4.77	6.14	2.7	1.17	.20	.1	2.2	.0
287	53.1	.83	18.3	.1	8.2	.09	6.25	4.3	3.2	2.10	.14	.0	2.9	.0
**** 500 metres (2700 from base)														
286	55.7	.98	16.5	.6	7.5	.09	6.7	3.92	2.9	1.61	.25	1.0	3.7	.0
285	63.0	.49	15.8	.8	3.1	.07	3.45	3.87	3.7	2.67	.19	2.0	1.6	.0
332A	40.3	.59	12.0	.4	10.5	.17	14.0	5.98	.0	1.85	.07	8.4	6.1	.01
332B	48.2	.60	13.6	3.5	20.6	.04	5.82	.40	.0	.09	.28	.0	7.1	.0
332C	61.9	.38	9.9	2.3	17.2	.09	3.06	.13	.0	.58	.12	.0	5.1	.17
**** 1000 metres (3200 from base)														

Minor elements											
	Cu	Pb	Zn	Sc	V	Ni	Cr	Rb	Sr	Ba	Zr
**** 0 metres (2200 from base)											
296B	.0000	.0000	.003	.0000	.0073	.0025	.2800	.003	.000	.007	.000
282	.006	.0001	.005	.0015	.018	.006	.016	.001	.020	.018	.000
301	.0012	.0009	.004	.0008	.0076	.004	.0061	.008	.027	.046	.00
**** 200 metres (2400 from base)											
288	.011	.0003	.010	.0024	.017	.009	.019	.001	.025	.018	.10
302	.0036	.0004	.005	.0021	.015	.012	.116	.000	.020	.016	.004
283A	.0010	.0007	.0	ND	.0017	.005	.0053	.0	.0	.007	.0
283B	.0052	.0002	.005	.0021	.012	.008	.013	.002	.013	.014	.003
283C	.0044	tr	.00	.0009	.0041	.003	.0033	.00	.002	.007	.0
284	.0082	.0007	.008	.0016	.013	.011	.012	.003	.023	.022	.005
287	.0067	.0005	.009	.0022	.017	.013	.016	.006	.016	.055	.003
**** 500 metres (2700 from base)											
286	.0047	.0002	.006	.0020	.012	.010	.0150	.000	.019	.038	.007
285	.0073	.0030	.005	.0012	.0068	.006	.011	.009	.038	.062	.003
332A	.0091	.0003	.006	.0037	.017	.037	.14	.007	.009	.035	.00
332B	tr	tr	.005	.0016	.011	.008	.035	.00	.00	.003	.003
332C	.0048	.0004	.004	.0008	.0050	.003	.0024	.002	.00	.027	.001
**** 1000 metres (3200 from base)											

APPENDIX 1 (cont.)

Table 3. Chemical analyses, Mount Sabine Formation.

Major elements														
	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	CO_2	H_2O	S
**** 0 metres (3200 from base)														
239A	60.0	.80	18.5	.0	6.8	.07	2.81	.57	8.0	.10	.14	.22	.2	.8
227	44.0	.46	9.1	1.0	5.2	.21	3.56	20.6	.3	.20	.09	13.52	.2	.08
228B	48.0	.94	14.8	2.5	8.9	.18	8.23	11.0	1.2	.18	.09	2.2	2.4	.00
**** 400 metres (3600 from base)														
229A	61.5	.62	17.4	.3	6.5	.08	4.02	1.7	2.1	3.51	.20	.0	2.7	.09
229B	61.3	.74	14.0	.8	6.1	.07	6.44	1.91	.5	5.12	.24	.1	2.8	.11
229C	40.2	.16	9.77	.1	7.7	.25	18.9	7.10	.8	.17	.05	9.4	5.7	.0
229D	46.2	.30	12.8	.4	8.1	.17	15.6	3.79	2.3	1.23	.06	4.2	5.2	.0
231A	68.0	.27	15.1	.1	2.3	.06	2.08	2.57	5.9	1.37	.19	1.2	1.0	.0
231B	62.9	.63	12.4	.8	8.0	.14	3.03	3.48	1.5	1.50	.15	1.3	2.7	.17
232	52.4	.62	11.0	3.0	13.1	.26	3.74	5.6	.3	1.6	.1	5.2	3.5	.48
234B	55.1	.48	13.0	.0	5.4	.12	5.56	5.82	4.4	.66	.43	5.1	2.9	.81
235	63.7	.64	12.2	.3	9.9	.14	4.02	1.86	.4	2.15	.14	.9	3.7	.39
**** 600 metres (3800 from base)														
252A	74.0	.36	12.7	.4	2.1	.03	2.00	1.05	1.1	3.75	.17	.7	2.2	.0
252B	48.2	.86	15.4	.3	9.8	.11	7.75	4.16	2.2	1.09	.09	5.9	4.8	0.0
321	48.4	1.27	15.8	.7	11.3	.16	9.06	4.06	3.4	.72	.14	.0	4.3	.0
319A	55.1	1.94	17.3	.1	8.2	.08	7.42	.39	4.8	.27	.12	.0	4.6	.0
319B	37.6	.29	6.9	0.0	9.2	.27	19.0	7.5	0.0	.06	.06	14.5	5.4	0.0
253	50.9	.80	11.7	2.5	6.6	.14	11.2	8.10	1.7	2.96	.64	.5	2.6	.0
254	56.5	.44	12.5	.5	4.4	.12	4.6	7.18	2.3	2.82	.20	6.0	2.6	.0
265	66.7	.29	13.0	.3	2.9	.07	2.18	3.97	2.7	3.09	.11	3.4	1.1	.11
**** 1300 metres (4500 from base)														
255B	67.5	.50	15.5	1.4	2.4	.02	2.32	1.25	3.4	3.40	.23	.2	1.7	.0
255C	49.3	.32	5.3	.5	7.6	.16	23.1	7.6	.0	.06	.03	.4	5.6	.01
255D	50.8	.55	13.1	1.8	7.7	.18	12.1	8.04	.3	.75	.08	.5	4.4	.0
256	52.7	.45	8.6	.5	8.7	.21	14.1	8.5	1.2	.33	.06	.9	4.1	.0
2571	56.9	.63	13.6	.5	6.9	.15	9.09	7.33	3.9	.34	.09	.00	2.2	.0
257	59.3	.59	12.5	1.0	6.3	.14	7.11	7.67	3.8	.42	.08	.1	1.9	.02
260	47.9	.76	14.1	.8	9.7	.19	10.5	6.79	2.1	.80	.13	1.3	4.2	.0
258A	48.1	.22	4.3	4.2	5.8	.05	28.3	.96	0.0	.05	.04	1.3	6.5	0.0
258B	67.5	.58	15.5	.5	3.5	.04	2.81	1.02	5.9	1.34	.23	.0	1.4	.34
**** 1600 metres (4800 from base)														
258C	55.9	.58	11.7	3.4	5.0	.15	7.18	4.45	2.1	3.24	.21	3.5	3.0	.0
2591	62.1	.57	15.3	2.4	4.3	.09	5.26	1.80	.9	5.10	.53	.0	2.0	.0
259	60.8	.59	14.8	2.7	3.8	.09	5.08	2.17	.9	5.03	.75	.0	2.2	.0
**** 1800 metres (5000 from base)														

APPENDIX 1 (cont.)

Table 3. (cont.)

Minor elements											
	Cu	Pb	Zn	Sc	V	Ni	Cr	Rb	Sr	Ba	Zr
**** 0 metres (3200 from base)											
239A	.0033	.0003	.005	.0017	.0011	.012	.034	.00	.010	.003	.007
227	.0092	.0001	.005	.0025	.014	.007	.024	.00	.011	.007	.0
228B	.0120	tr	.007	.0041	.023	.015	.036	.00	.012	.005	.0
**** 400 metres (3600 from base)											
229A	.0047	.0030	.006	.0015	.010	.014	.026	.011	.013	.090	.004
229B	.0046	.0014	.006	.0014	.0095	.016	.023	.021	.009	.084	.006
229C	.0038	.0003	.003	.0022	.0093	.079	.18	.000	.014	.001	.0
229D	.0018	.0001	.006	.0027	.013	.045	.12	.005	.004	.026	.0
231A	.0012	.0055	.003	.0007	.0049	.005	.0063	.004	.033	.050	.005
231B	.0045	.0013	.005	.0015	.0091	.013	.028	.003	.016	.035	.001
232	.0093	.0008	.010	.0014	.011	.008	.0093	.004	.009	.039	.0
234B	.0024	.0052	.005	.0012	.0083	.019	.040	.000	.012	.005	.010
235	.0059	.0007	.005	.0014	.0085	.012	.017	.004	.008	.027	.00
**** 600 metres (3800 from base)											
252A	.0049	.0011	.001	.0004	.0050	.003	.0028	.016	.008	.086	.004
252B	.0098	.0001	.009	.0032	.021	.015	.040	.002	.008	.009	.00
321	.0036	tr	.006	.0033	.020	.021	.025	.000	.010	.021	.00
319A	.0010	.0005	.007	.0013	.014	.012	.0025	.000	.044	.018	.023
319B	.0220	.0001	.004	.0021	.0099	.15	.23	.000	.0028	.001	.00
253	.0061	.0011	.010	.0017	.014	.046	.059	.008	.056	.10	.002
254	.0014	.0009	.006	.0020	.0084	.008	.023	.011	.057	.062	.002
265	.0028	.0016	.003	.0008	.0051	.004	.0063	.015	.034	.068	.000
**** 1300 metres (4500 from base)											
255B	.0017	.0017	.004	.0007	.0065	.002	.0013	.010	.014	.14	.008
255C	.0010	tr	.005	.0028	.0089	.089	.18	.00	.00	.002	.00
255D	.0016	.0002	.006	.0029	.018	.024	.074	.001	.012	.024	.00
256	.0027	tr	.006	.0024	.017	.025	.055	.000	.003	.045	.00
2571	.0071	.0003	.006	.0032	.015	.017	.042	.000	.007	.006	.0
257	.0150	.0001	.004	.0029	.0150	.011	.049	.000	.009	.009	.0
260	.0008	.0002	.006	.0033	.020	.022	.058	.001	.022	.033	.0
258A	.0036	.0001	.005	.0017	.0082	.19	.220	.0	.0	.001	.0
258B	.0019	.0010	.003	.0010	.010	.006	.014	.004	.032	.055	.005
**** 1600 metres (4800 from base)											
258C	.0014	.0002	.009	.0025	.015	.010	.038	.004	.008	.066	.002
2591	.0011	.0010	.006	.0020	.0075	.007	.020	.013	.021	.12	.004
259	.0008	.0010	.008	.0019	.078	.009	.021	.010	.021	.12	.004
**** 1800 metres (5000 from base)											

APPENDIX 1 (cont.)

Table 4. Analyses of Prince Albert Group rocks from south of Richards Bay.

in %	3241-5	3248	3293
SiO_2	47.5	76.1	50.3
TiO_2	.01	.27	.24
Al_2O_3	.76	6.93	2.97
Fe_2O_3	47.0	.20	.2
FeO	nd	1.60	7.8
MnO	.05	.06	.15
MgO	1.25	2.69	29.0
CaO	.61	4.77	3.29
Na_2O	.12	2.10	.1
K_2O	.04	1.67	.1
P_2O_5	.13	.13	.06
H_2Ot	.0	.7	4.9
CO_2t	.0	3.20	.0
S	3.31	.07	.15
in ppm			
Cr	0	262	2470
Ni	52	10	1730
Cu	28	8	35
Pb	78	nf	nf
Zn	110	nd	40
As	6	nd	nd
Ag	.7ppm	nd	nd
Au	3ppb	nd	nd

SMA 74-3241-5,(UTMN 7714600, UTME 444250, Zone 17W), Laminated iron-formation with graded quartz-rich layers which, near the top of lamellae, are biotite and chlorite bearing, interlayered with magnetite and several types of amphibole (including blue amphibole.)

SMA 74-3248,(UTMN 7715750, UTME 443790, Zone 17W), Garbenschiefer; tremolite rosettes set in quartz-rich greywacke. In thin section chlorite, muscovite, and leucoxene pseudomorph a previous mineral, the tremolite rosettes are locally chloritized and opaques are rimmed by leucoxene and chlorite. In the matrix, quartz is the dominant mineral with minor accessory apatite and sphene.

SMA 74-3293-1,(UTMN 7712500, UTME 443750, Zone 17W), Ultramafic sill? Emplaced in iron-formation; felted textured rock composed of talc, chlorite,tremolite and minor opaques.

Table 5. Chemical analyses of granite.

	276 C	298 B
SiO_2	75.7	71.0
TiO_2	.13	.22
Al_2O_3	13.9	13.2
Fe_2O_3	.4	.7
FeO	.4	2.2
MnO	.05	.01
MgO	.43	1.16
CaO	.88	.60
Na_2O	4.20	3.10
K_2O	3.63	5.52
P_2O_5	.07	.08
H_2Ot	.8	.7
CO_2t	.2	.4
S	nf	.3

SMA 74-0276C, (UTMN 7726900, UTME 445100, Zone 17W) Altered granite. Quartz is medium grained and shows strain lamellae and sutured edges, microcline is medium grained and plagioclase is locally altered to white mica, zoisite, and albite. Biotite is locally degraded to chlorite and contains minor unevenly distributed patches of carbonate.

SMA 74-0298B, (UTMN 7714600, UTME 444250, Zone 17W) Granite sampled near an iron formation inclusion. The sample contains quartz with strain lamellae, degraded plagioclase with white mica, relatively fresh microcline, and chloritized biotite which show small pleochroic halos. (This sample also contains .09% Ba, 2 ppm Be, 6 ppm Co, 16 ppm Cu, 17ppm Pb, 180 ppm Zn, 26 ppm V, 50 ppm La, and 1.2 ppm Yb; it contains less than 1 ppb Au, .1 ppm Ag and 2 ppm As.)

Table 6. Assay result (in %) of vein materials.

in %	Wall rock	Quartz vein
SiO_2	82.6	93.1
TiO_2	.03	.03
Al_2O_3	.83	.6
Fe_2O_3	11.3	4.78
FeO	3.0	nf
MnO	.07	.04
MgO	.49	.18
CaO	.10	.15
Na_2O	.09	.11
K_2O	.07	.07
P_2O_5	.05	.04
H_2Ot	.8	1.3
CO_2t	nf	.2
S	.55	1.22
in ppm		
Cu	96	67
Pb	4	5
Zn	21	21
As	4	11
Ag	<.1ppm	.1ppm
Au	<1ppb	2ppb

Samples are from a quartz vein in a metavolcanic host, along a fault zone located at UTMN 7726250, UTME 448125, Zone 17 W. Wall rock is a grab sample of rusty silicified and chloritized mafic metavolcanic host. Quartz vein contains minor sulphides, chlorite, and carbonate. Oxidation state of iron could not be determined due to interference of sulphur.

APPENDIX 2

Analytical precision, accuracy and sample variability

The samples submitted for chemical analyses are hand specimens from which a thin section was made, usually a slice saved, and the remaining material was trimmed of weathered material by sawing or grinding. This sample was then crushed to -250 mesh and the material analyzed.

The major elements were analyzed by a highly automated x-ray fluorescence method developed in the Geological Survey of Canada (XRF-S30). CO_2 was determined by acid evolution and titration, H_2O by fusion in a Penfield tube and a Karl Fisher titration, FeO by cold acid decomposition and back titration, with $K2Cr_2O_7$, and F and Cl by carbonate fusion and determination by selective ion electrodes. Schau (1982) reported on reliability of similar samples.

Trace elements were determined mainly by a semi-automatic optical spectroscopic method (the 12B-DR system) and precision is quoted at ±15%. Some of the minor elements were analyzed by XRF and precision quoted was ±10%. Elements run by both methods yield the same values within cited limits. The spectroscopic results have been cited in this report. Volatile elements were determined by a special spectroscopic technique with a precision of ±30% or by screw rod on atomic absorption with a precision of ±10%.

The author has not monitored any shifts in variability,but the laboratories are continually upgrading and revising their methods so that samples from each batch are not necessarily analyzed the same way, and analytical variability is said to be decreasing with time.

The following are the batches reported: 73-47, 74-21, 43-75, 66-76, 72-76.

APPENDIX 3

Chemical petrology and nomenclature of metavolcanic rocks

Names of volcanic rocks are derived from their chemical analyses (Zanettin, 1984) and based on a location within a grid drawn on a plot of silica vs total alkalis. This system applies only to fresh volcanic rocks. A similar classification scheme (Irvine and Baragar, 1971) based on values of calculated colour index and normative plagioclase composition has been widely used for metavolcanic rocks with varied success. Since the basis for classification is different, and if the rocks have been altered, it is to be expected that names derived using each method are different (see Table 1 below). Since alkalis are mobile in low grade metavolcanic rocks, it would seem prudent to adopt a scheme which avoids utilizing alkalis as a primary basis of subdivision. In this report a plot based on less mobile and more abundant oxides of aluminum, iron and titanium, and magnesium (Fig. 14, Jensen, 1976) gives useful names. Frisch (1982) also used this classification scheme for rocks of the Prince Albert Group.

The localities of samples north of Richards Bay are shown in Figure 16.

Names, based on three distinct ways of processing chemical analyses of the volcanic rocks, are displayed below for Tables 1, 2, and 3 in Appendix 1. The samples are ordered by formation and are in numerical order. For stratigraphic order, see the text and for locations, see Appendix 4. The names used in the text are based on the cation ratio.

Table 1. Nomenclature of metavolcanic rocks by formation.

Sample number	Jensen cation name	Irvine-Baragar name	IUGS name
ADGE-GO FORMATION			
273 A	rhyolite	tholeiitic basalt	rhyolite
273 B	calc-alkaline basalt	tholeiitic basalt	basalt
273 C	andesite	tholeiitic basalt	basaltic andesite
274 A	andesite	tholeiitic andesite	andesite
274 B	calc-alkaline basalt	calc-alkaline andesite	trachy andesite
******1000 metres			
276 B	komatiitic basalt	tholeiitic andesite	basaltic andesite
277 B	high magnesiam tholeiitic basalt	tholeiitic basalt	basaltic andesite
******1600 metres			
278 A	andesite	tholeiitic andesite	dacite
278 B	calc-alkaline basalt	tholeiitic andesite	andesite
278 C	andesite	tholeiitic andesite	andesite
279	andesite	calc-alkaline basalt	basaltic
270B1	high magnesiam tholeiitic basalt	tholeiitic basalt	basaltic andesite
270B2	dacite	calc-alkaline dacite	dacite
*******2000 metres			
299 B	komatiitic basalt	tholeiitic picrite basalt	trachybasalt
300	dacite	tholeiitic basalt	rhyolite
******2200 metres			

APPENDIX 3 (cont.)

Table 1. (cont.)

Sample number	Jensen cation name	Irvine Baragar name	IUGS name
RICHARDS BAY FORMATION			
******0 metres (2200 from base)			
N/A			
******200 metres (2400 from base)			
283 B	calc-alkaline basalt	tholeiitic basalt	andesite
302	calc-alkaline basalt	calc-alkaline basalt	basaltic andesite
288	calc-alkaline basalt	calc-alkaline basalt	basaltic andesite
284	calc-alkaline basalt	calc-alkaline basalt	andesite
287	calc-alkaline basalt	tholeiitic basalt	trachy-andesite
******500 metres (2700 from base)			
332 A	komatiitic basalt	calc-alkaline andesite	n.a.
******1000 metres (3200 from base)			
MOUNT SABINE FORMATION			
******0 metres (3200 from base)			
227	basaltic komatiite	tholeiitic basalt	picro-basalt
228 B	high magnesiam tholeiitic basalt	tholeiitic basalt	basalt
******400 metres (3600 from base)			
229 B	high magnesiam tholeiitic basalt	tholeiitic basalt	basalt
229 C	ultramafic komatiite	calc-alkaline andesite	n.a.
229 D	komatiitic basalt	calc-alkaline andesite	basalt
231 A	dacite	calc-alkaline dacite	dacite
234 B	calc-alkaline basalt	calc-alkaline rhyolite	basaltic andesite
****** 600 metres (3800 from base)			
319 A	calc-alkaline basalt	tholeiitic andesite	basaltic andesite
319 B	ultramafic komatiite	calc-alkaline andesite	n.d.
321	high magnesiam tholeiitic basalt	tholeiitic basalt	basalt
253	komatiitic basalt	tholeiitic basalt	basalt
****** 1300 metres (4500 from base)			
255 B	dacite	calc-alkaline dacite	dacite
255 C	ultramafic komatiite	ultramafic	basalt
255 D	komatiitic basalt	tholeiitic basalt	basalt
256	komatiitic basalt	tholeiitic basalt	basalt
257 A	high magnesiam tholeiitic basalt	calc-alkaline basalt	basaltic andesite
257 B	high magnesiam tholeiitic basalt	tholeiitic andesite	andesite
260	high magnesiam tholeiitic basalt	tholeiitic basalt	basalt
258 A	ultramafic komatiite	ultramafic	basalt
******1600 metres (4800 from base)			
******1800 metres (5000 from base)			

APPENDIX 4

Table 1. Sample locations (Fig. 16), (stratigraphic succession-oldest to youngest),short rock names of analyzed specimens,* of volcanic origin and fully named in Appendix 3. All samples are fully named and described in main text.

ADGE-GO FORMATION				
****** 0 metres				
SMA-74-0272	444145	7727311	Zone 17	B/iron-formation; A/tuff
SMA-74-0273	444480	7727225	Zone 17	C/*andesite; B/*basalt dyke; A/*rhyolite
SMA-74-0274	444718	7727065	Zone 17	B/*basalt; A/*andesite
****** 1000m				
SMA-74-0275	445017	7726826	Zone 17	arenite
SMA-74-0276	445266	7726765	Zone 17	B/*basalt dyke; A/arenite
SMA-74-0277	445310	7726733	Zone 17	B/*basalt dyke; A/conglomerate
****** 1600m				
SMA-74-0278	445576	7726911	Zone 17	C/*andesite flow; B/*andesite; A/*andesite
SMA-74-0279	445695	7726972	Zone 17	* andesite tuff
SMA-74-0270	445986	7726781	Zone 17	A/siltstone; B1/*basalt dyke; B2/*dacite dyke
SMA-74-0280	446059	7726859	Zone 17	siltstone
****** 2100m				
SMA-74-0299	446241	7726117	Zone 17	B/* basic tuff
SMA-74-0300	446316	7726335	Zone 17	* dacite flow
****** 2200m (=2200 m cumulate thickness of group)				
RICHARDS BAY FORMATION				
****** 0 (=2200 m from base)				
SMA-74-0296	446240	7725425	Zone 17	B/quartzite
SMA-74-0282	446588	7726598	Zone 17	polymictic breccia
SMA-74-0301	446444	7726459	Zone 17	siltstone
****** 200 m				
SMA-74-0283	446750	7726530	Zone 17	B/*breccia
SMA-74-0302	446706	7726409	Zone 17	* basalt
SMA-74-0288	446559	7725760	Zone 17	C/arenite; B/* basalt; A/arenite
SMA-74-0284	447006	7726422	Zone 17	* breccia
SMA-74-0287	447013	7725886	Zone 17	* basalt flow
****** 500m				
SMA-74-0286	447200	7725900	Zone 17	quartz-rudite
SMA-74-0285	447490	7725910	Zone 17	greywacke
SMA-74-0332	447250	7726500	Zone 17	C/iron-formation; B/iron-formation; A/*breccia
****** 1000m (=3200 m cumulate thickness of group)				
MOUNT SABINE FORMATION				
****** 0 (=3200 m from base of group)				
SMA-74-0239	447600	7726480	Zone 17	flow breccia
SMA-74-0227	447953	7726343	Zone 17	*pillow basalt
SMA-74-0228	448071	7726239	Zone 17	B/*agglomerate
****** 400m				
SMA-74-0229	448228	7726147	Zone 17	D/*basalt; C/*breccia; B/*breccia; A/siltstone

APPENDIX 4 (cont.)

SMA-74-0231	448399	7726412	Zone 17	B/conglomerate; *A/dacite breccia
SMA-74-0232	448490	7726212	Zone 17	conglomerate
SMA-74-0234	448695	7726197	Zone 17	B/*basalt;
SMA-74-0235	448845	7726178	Zone 17	andesite breccia
****** 600m				
SMA-74-0252	449317	7725990	Zone 17	B/siltstones; A/arenite
SMA-74-0319	449500	7725820	Zone 17	A/*and B/* differentiated flow
SMA-74-0321	449495	7726003	Zone 17	* differentiated flow
SMA-74-0253	449805	7725780	Zone 17	* tuff
SMA-74-0254	450100	7725470	Zone 17	arenite
SMA-74-0265	449890	7724837	Zone 17	arenite
****** 1300m				
SMA-74-0255	450585	7725595	Zone 17	D/*tuff; C/*komatiitic schist; B/*dacite dyke;
SMA-74-0256	451005	7725465	Zone 17	* tuff
SMA-74-0257	451242	7725500	Zone 17	** basalt (2specs)
SMA-74-0260	451200	7725100	Zone 17	* basalt
SMA-74-0258	451685	7725200	Zone 17	B/siltstone; A/*komatiitic schist
****** 1600m				
SMA-74-0258	451685	7725200	Zone 17	C/arkose
SMA-74-0259	451828	7725077	Zone 17	arenite (2 specs)
****** 1800 m. (=5000 m total thickness of group)				